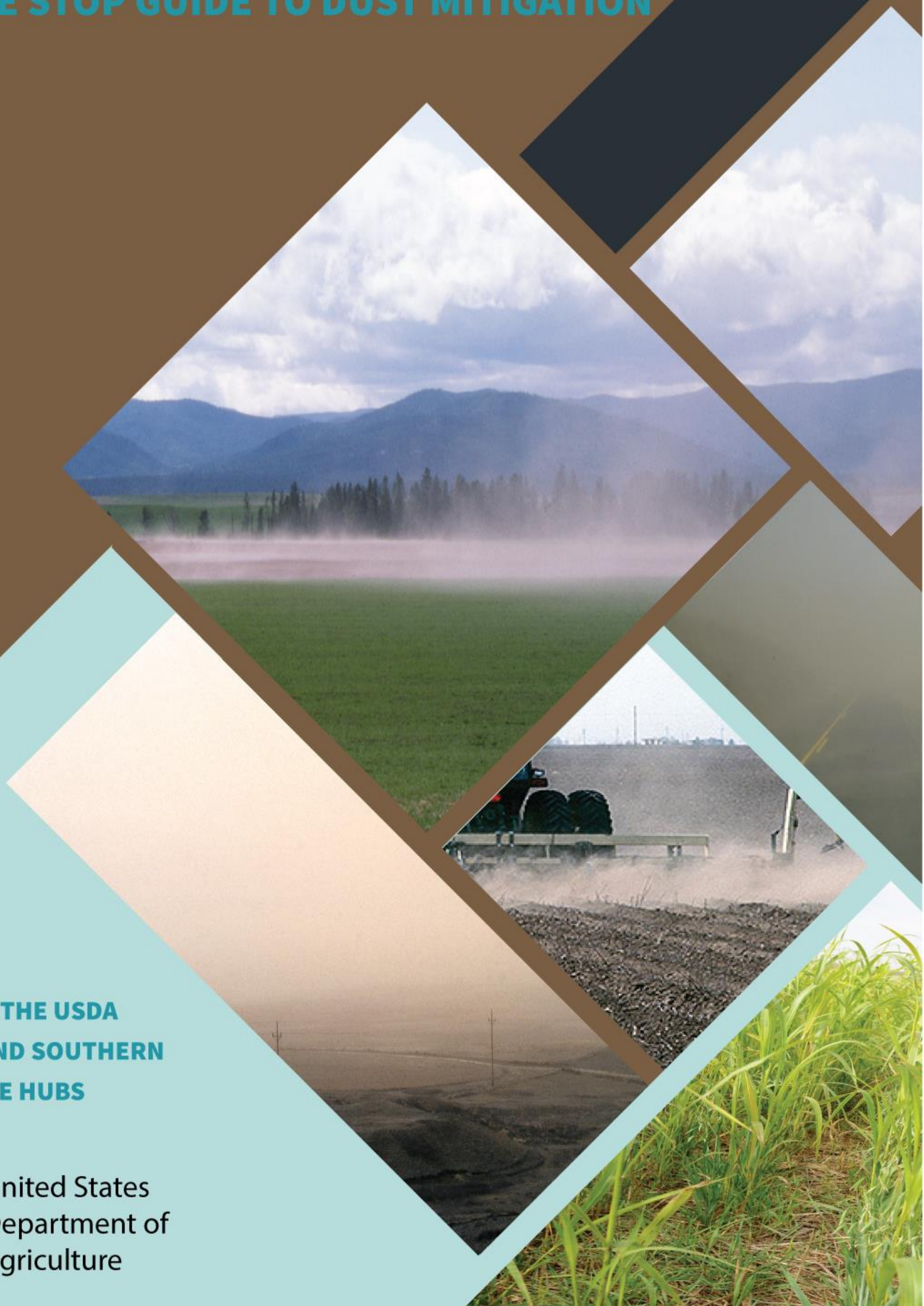
DUST MITIGATION HANDBOOK

ONE STOP GUIDE TO DUST MITIGATION



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Throughout this handbook, supplemental information and weblinks to helpful guides, manuals, and websites and are provided. For the benefit of the offline user, the underlying web address of all hyperlinks not spelled out in the text is provided in the References section by the corresponding reference number (e.g., hyperlink[1] would appear in the references section as: 1. *Webpage name*. http://www.examplewebURL.com).

The concepts and suggestions in this handbook come from many sources and are based on the field experiences and research of practitioners, NRCS agents and scientists, as well as published technical guides, program-specific literature, and scholarly literature. For simplicity, all references from all chapters are listed together in Appendix A.

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An electronic version of this handbook is available online at:

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Acronyms used in this handbook

Acronym	Definition
°C	Degrees Celsius
°F	Degrees Fahrenheit
ACEP	Agricultural Conservation Easement Program
AED	Aerodynamic equivalent diameter
AERO	Aeolian Erosion (model)
AIM	Assessment, Inventory and Monitoring
AOD	Aerosol optical depth
APEX	Agricultural Policy / Environmental eXtender
ARS	Unites States Department of Agriculture Agricultural Research Service
BLM	Bureau of Land Management
CCA	Critical Conservation Area
CEAP	Conservation Effects Assessment Project
CMIP5	Coupled Model Intercomparison Project
CO_2	Carbon dioxide
CPC	Conservation Program Contract
CPPE	Conservation Practice Physical Effects
CPS	Conservation Practice Standard
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
CTSG	Conservation Tree and Shrub Groups
dS	Decisiemens
ECP	Emergency Conservation Program
EFRP	Emergency Forest Restoration Program
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESD	Ecological Site Description
FOTG	Field Office Technical Guide
FSA	USDA Farm Service Agency
HFRP	Healthy Forest Reserve Program
IET	Integrated Erosion Tool
IMPROVE	Interagency Monitoring of Protected Visual Environments
MLRA	Major Land Resource Area
MP	Marianas Islands
NARR	North American Regional Reanalysis
NCEP	National Centers for Environmental Prediction
NIPF	Non-Industrial Private Forest
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service

NRI	National Resources Inventory
PL-566	Public Law 83-566 Watershed Authorities
PM	particulate matter
PM_{10}	particles with an aerodynamic equivalent diameter (AED) less than or equal to 10 µm
$PM_{2.5}$	particles that have an aerodynamic equivalent diameter (AED) less than or equal to 2.5 micrometers (µm)
PR	Puerto Rico
PSFP	Prairie States Forestry Project
RCP8.5	Representative Concentration Pathway 8.5
RCPP	Regional Conservation Partnership Program
RHEM	Rangeland Hydrology and Erosion Model
RMA	USDA Risk Management Agency
RMS	Resource Management Systems
RUSLE2	Revised Universal Soil Loss Equation -2
SCI	Soil Conditioning Index
STIR	Soil Tillage Intensity Rating
SWEEP	Single Wind Erosion Event Program
USDA	Unites States Department of Agriculture
USDA-ARS	Unites States Department of Agriculture Agricultural Research Service
WEG	Wind Erodibility Group
WEI	Wind Erodibility Index
WEPP	Water Erosion Prediction Project
WEPS	Wind Erosion Prediction System
WEQ	Wind Erosion Equation
WSG	Windbreak Suitability Groups

Table of Contents

Chapter 1 : Hazards and Concerns of Airborne Particulates

Particulate Matter

Particulate matter (PM) in the atmosphere is a mixture of solid particles and liquid droplets, many of which are not visible to the naked eye. PM can be directly emitted or formed by chemical reactions in the atmosphere. PM is a concern because it can 1) cause health impacts to humans, plants and animals, 2) degrade visibility, causing accidents on roadways or impairing the view of scenic vistas, and 3) deposit out of the atmosphere causing a variety of impacts including influencing nutrient cycles. Farming, ranching, and forestry operations can all be sources of particulate matter. This chapter is designed to give a brief introduction to PM characteristics and the impacts of PM.

Particulate Matter Size and Shape

PM in the atmosphere exists in a wide range of shapes and sizes and is made up of a variety of chemical species (for example, carbon, sulfates, heavy metals). PM is classified by its size, where fine particles are the small particles that can be inhaled deep into the lungs. These fine particles are known as $PM_{2.5}$, which are particles that have an aerodynamic equivalent diameter (AED) less than or equal to 2.5 micrometers (µm). The next size class of PM are inhalable larger particles, known as PM_{10}, which are particles with an AED less than or equal to 10 µm. Note that $PM_{2.5}$ is actually a subset of PM_{10}. Particles are typically not perfectly spherical and instead come in a variety of shapes. The AED is defined as the diameter of a spherical particle with a density of 1 g/cm^3 that would have the same settling velocity as the particle in question.[1] Particles with the same AED presumably perform alike when suspended in the air. Particles larger than 10 µm in AED can also be suspended and transported in the atmosphere, however these particles usually settle out rather quickly in comparison to smaller particles. Figure 1-1 shows the relative size of $PM_{2.5}$ and PM_{10} compared to a human hair and beach sand. $PM_{2.5}$ is approximately 30 times smaller than human hair while PM_{10} is approximately 7 times smaller. PM concentration is typically measured on a mass per volume basis (µg/m^3) but it can also be discussed in terms of particle number. While small diameter particles can have a low mass concentration in the atmosphere, on a particle number basis there can be orders of magnitude more fine particles than larger, more coarse particles.

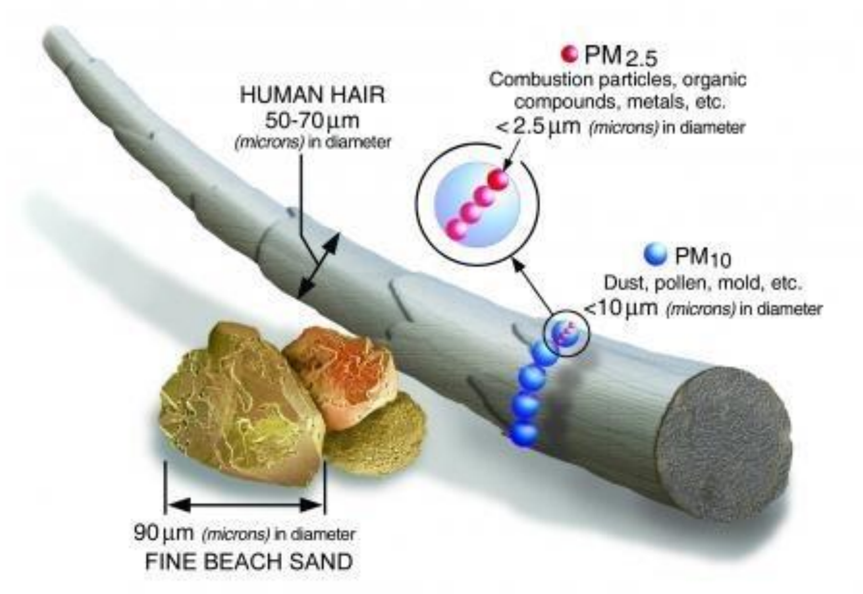

Figure 1-1. Size of $PM_{2.5}$ and PM_{10} relative to a human hair and beach sand.[2]

Fine PM concentrations in the atmosphere can be generated from a variety of natural and man-made sources, and can be comprised of carbonaceous compounds, soil (geologic material) and inorganic species of sulfate, nitrates and ammonium. Coarse PM typically is comprised of geologic dust or soil and often is directly emitted to the atmosphere. Fine PM can be directly emitted or created by physical and chemical processes in the atmosphere (secondary PM). Figure 1-2 shows examples of various types of particles and their typical size distributions. Dust tends to be 1-10 µm while combustion processes mostly produce smaller particles in the 0.01-1 µm range.

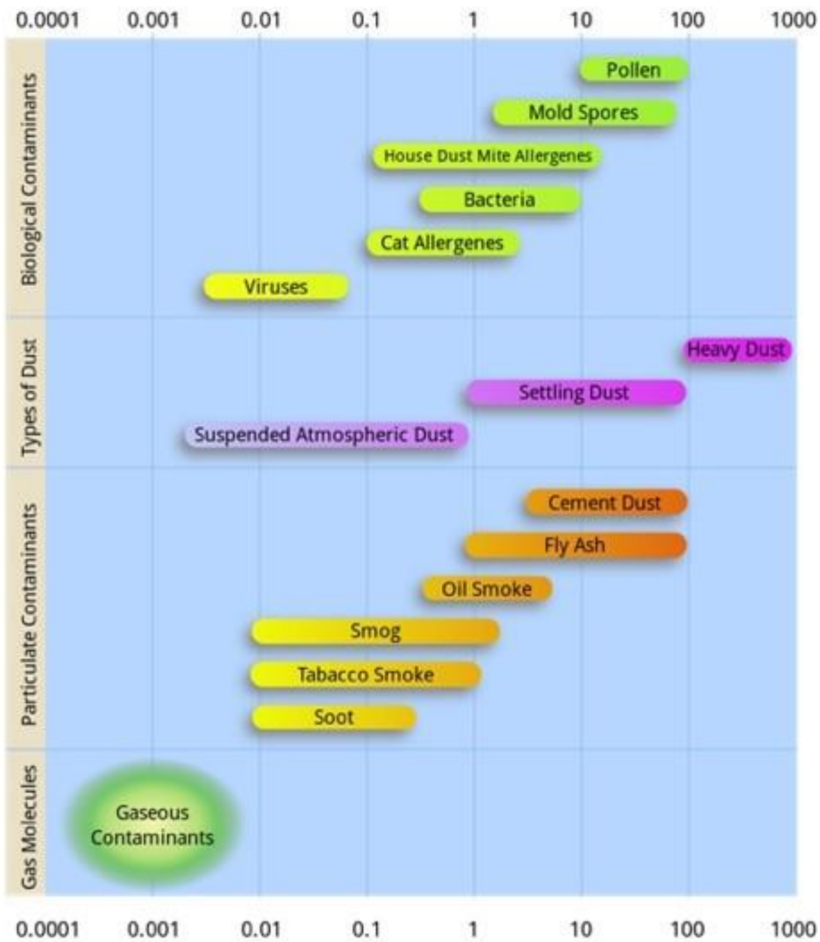

Figure 1-2. Examples of the size distribution of particles emitted from various sources in micrometers (µm).[3]

Impacts of Particulate Matter

Particulate matter (PM) can cause impacts on local, regional, and even global scales. Larger particulates tend to deposit quickly out of the atmosphere, but can remain suspended long enough to create local visibility reductions and transportation issues (such as on roadways or at airports) and other local impacts. Smaller particles that are either directly emitted or formed by atmospheric chemical processes can stay suspended in the atmosphere for longer periods of time and can therefore be transported greater distances, creating regional, and sometimes even global, health, visibility and deposition impacts.

Health Impacts

Figure 1-3 illustrates where and how particulates can be removed from or deposited in the human body. While the human body is efficient at filtering out the larger particles (> 10 µm) in the nasal passages, smaller particles on the scale of 5 µm get filtered out in the trachea. Fine particles can progress past the natural defenses into the bronchioles (< 2 µm) and some alveoli (< 1 µm) of the lungs. Once particles enter the lungs, the immune system sends white blood cells, called lymphocytes, to surround the particulates, protecting the body from the foreign objects. The lymphocytes settle on the alveoli walls, causing inflammation and scarring. The built-up scar tissue slows oxygen flow, making transfer of air to capillaries more difficult. This can be of particular concern to sensitive populations such as the elderly and asthmatics.

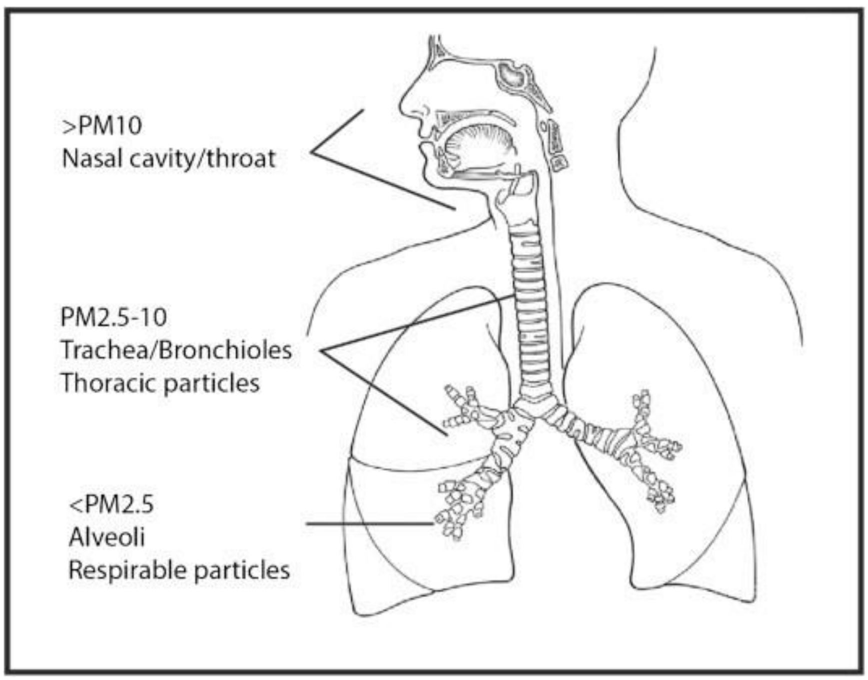

Figure 1-3. Deposition of airborne particulate matter in the human respiratory system.[4]

Visibility Impacts

PM in the atmosphere can absorb and scatter light, thereby reducing visibility. Episodes of impaired visibility can range in scale from local plumes (e.g., road dust) to widespread regional haze. Increased haze in the atmosphere causes objects to appear "flattened," whitens the background, and degrades the aesthetic value of scenic vistas. For example, the view visibility along Interstate 10 in Cochise County led to road closures in 2016 (Figure 1-4). Visibility can also be a local issue because dust or smoke can decrease the visible range to distances that can be dangerous on roadways, along with other localized impacts.

Figure 1-4. Dust storms in April 2016 in Cochise County forced interstate closures. Courtesy Arizona Department of Public Safety.[5]

Deposition and Impacts

Deposition is the removal of PM via precipitation, gravitational settling, or inertial impaction and/or absorption due to changes in airflows. Deposition as a result of precipitation is known as wet deposition and occurs through scavenging of the particle by rain, snow, clouds, or fog. Deposition via gravitational settling or inertial impaction is known as dry deposition. Deposition may adversely affect ecosystems by causing nuisance dusting, changing the pH balance, damaging plants or by adding additional nitrogen to the environment, which can result in an increase in eutrophication.

Ecosystems can be sensitive to the effects of deposition. High elevation ecosystems in the Rocky Mountains, Cascades, Sierra Nevada, southern California, and the upland areas of the eastern U.S. are generally the most sensitive to the acidifying effects of deposition due to their poor ability to neutralize acid deposition. Other potentially sensitive areas include the upper Midwest and New England. Acid deposition can also impact agricultural systems by changing the chemical properties of soil, although management of these systems with fertilizers and other soil treatments mitigate this. However, acid deposition can also damage waxy coating on leaves. In addition, many ecosystems are sensitive to the enrichment effects of nitrogen deposition, including those with short growing seasons (i.e., a limited capacity to use available nitrogen) and those that have evolved under low nutrient conditions. Nitrogen sensitive areas include high-elevation ecosystems, arid ecosystems, grasslands, and shallow bays and estuaries along the Atlantic and Gulf Coasts. The transport and deposition of dust and black carbon to the snowmelt dominated basins worldwide are of concern, especially in the springtime where the deposition increases snowpack albedo thereby enhancing snowmelt. Dust can have a physical effect on plants, coating the plant and blocking sunlight necessary for photosynthesis, causing abrasion, and blocking the stomata. Also, a dust coating can affect the intended action of pesticides and other chemicals. Depending on the chemical composition of the dust, its deposition can also alter soil chemistry.

Chapter 2 : Understanding Wind Erosion

Soil Disturbance and Wind Erosion Processes – From the Natural Resources Conservation Service (NRCS) National Agronomy Manual[6]

Wind is an erosive agent. It detaches and transports soil particles, sorts the finer from the coarser particles, and deposits them unevenly. Loss of the fertile topsoil in eroded areas reduces the rooting depth and, in many places, reduces crop yield. Abrasion by airborne soil particles damages plants and structures. Drifting soil causes extensive damage to adjacent land, roads, and drainage features. Sand and dust in the air can harm animals, humans, and equipment. Wind erosion events have caused major highway accidents.

Some wind erosion has always occurred as a natural land-forming process, but it has become detrimental as a result of human activities. This accelerated erosion is primarily caused by improper use and management of the land.

Few regions are entirely safe from wind erosion. Wherever the soil surface is loose and dry, vegetation is sparse or absent, and the wind sufficiently strong, erosion will occur unless control measures are applied. Soil erosion by wind in North America is generally most severe in the Great Plains. The NRCS annual report of wind erosion conditions in the Great Plains shows that wind erosion damages from 1 million to more than 15 million acres annually. Other major regions subject to damaging wind erosion are the Columbia River plains; some parts of the Southwest and the Colorado Basin, the muck and sandy areas of the Great Lakes region, and the sands of the Gulf, Pacific, and Atlantic seaboards. In some areas, the primary problem caused by wind erosion is crop damage. Some crops are tolerant enough to withstand or recover from erosion damage.

Other crops, including many vegetables and specialty crops, are especially vulnerable to wind erosion damage. Wind erosion may cause significant short-term economic loss in areas where erosion rates are below the soil loss tolerance (T) when the crops grown in that area are easily damaged by blowing soil. Figure 2-1 displays the relative crop tolerance to blowing soil.

Tolerant T	Moderate tolerance 2 ton/a	Low tolerance 1 ton/a	Very low tolerance 0 to 0.5 ton/a
Barley Buckwheat Flax Grain sorghum Millet Oats Rye Wheat	Alfalfa (mature) Corn Onions (>30 days) Orchard crops Soybeans Sunflowers Sweet corn	Broccoli Cabbage Cotton Cucumbers Garlic Green/snap beans Lima beans Peanuts Peas Potatoes Sweet potatoes Tobacco	Alfalfa seedlings Asparagus Cantaloupe Carrots Celery Eggplant Flowers Kiwi fruit Lettuce Muskmelons Onion seedlings (<30 days) Peppers Spinach Squash Strawberries Sugar beets Table beets Tomatoes Watermelons

Figure 2-1. Crop tolerance to blowing soil.

The wind erosion process is complex. It involves detaching, transporting, sorting, abrading, avalanching, and depositing of soil particles. Turbulent winds blowing over erodible soils cause wind erosion. Field conditions conducive to erosion include:

- loose, dry, and finely granulated soil
- smooth soil surface that has little or no vegetation present
- sufficiently large area susceptible to erosion
- sufficient wind velocity to move soil

Winds are considered erosive when they reach 13 miles per hour at 1 foot above the ground or about 18 miles per hour at a 30 foot height. This is commonly referred to as the threshold wind velocity.

The wind transports single grain particles or stable aggregates, or both, in three ways (Figure 2-2):

Saltation — Individual particles/aggregates ranging from 0.1 to 0.5 millimeter in diameter lift off the surface at a 50- to 90-degree angle and follow distinct trajectories under the influence of air resistance and gravity. The particles/aggregates return to the surface at impact angles of 6 to 14 degrees from the horizontal. Whether they rebound or embed themselves, they initiate movement of other particles/aggregates to create the avalanching effect. Saltating particles are the abrading bullets that remove the protective soil crusts and clods. Most saltation occurs within 12 inches above the soil surface and typically, the length of a saltating particle trajectory is about 10 times the height. From 50 to 80 percent of total transport is by saltation.

Surface creep — Sand-sized particles/aggregates are set in motion by the impact of saltating particles. Under high winds, the whole soil surface appears to be creeping slowly forward as particles are pushed and rolled by the saltation flow. Surface creep may account for 7 to 25 percent of total transport.[7,8]

Suspension — The finer particles, less than 0.1 millimeter in diameter, are dislodged from an eroding area by saltation and remain in the air mass for an extended period. Some suspension-sized particles or aggregates are present in the soil, but many are created by abrasion of larger aggregates during erosion. From 20 percent to more than 60 percent of an eroding soil may be carried in suspension, depending on soil texture. As a general rule, suspension increases downwind, and on long fields can easily exceed the amount of soil moved in saltation and creep.

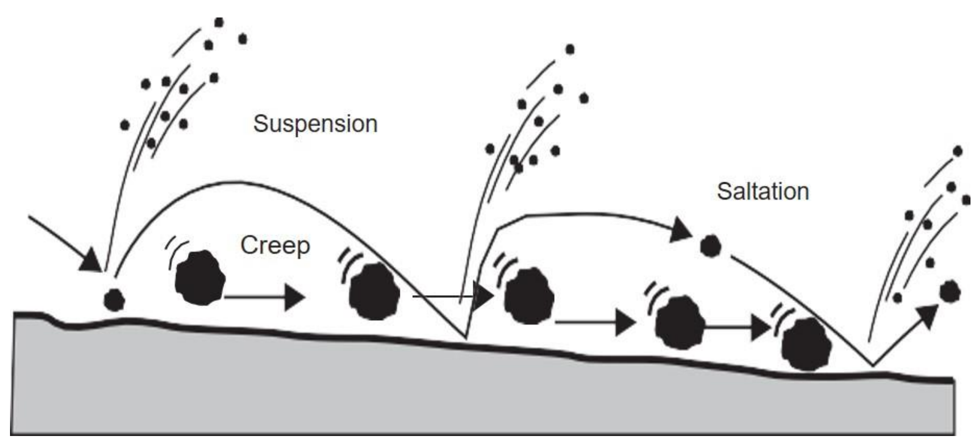

Figure 2-2. The wind erosion process.

Saltation and creep particles are deposited in vegetated strips, ditches, or other areas sheltered from the wind, as long as these areas have the capacity to hold the sediment. Particles in suspension, however, may be carried a great distance. The rate of increase in soil flow along the wind direction varies directly with erodibility of field surfaces.

The increase in erosion downwind (avalanching) is associated with the following processes:

- the increased concentration of saltating particles downwind increases the frequency of impacts and the degree of breakdown of clods and crusts
- the accumulation of erodible particles and breakdown of clods tends to produce a smoother (and more erodible) surface. The distance required for soil flow to reach a maximum for a given soil is the same for any erosive wind. The more erodible the soil surface, the shorter the distance in which maximum flow is reached. Any factor that influences the erodibility of the surface influences the increase in soil flow.

Climate Considerations

Increased aeolian activity and dust emission have important ecological and hazard implications. For example, soil loss and redistribution from aeolian activity affects soil health, nutrient cycles and land potential. Dust emissions impact air quality and long-term health and episodic hazards such as dust storms pose immediate threats to human life. As such, understanding potential climate change impacts to wind erosion and dust emission is critical for applying appropriate management and mitigation practices.

Overall, climate change is expected to increase vulnerability to wind erosion in many landscapes of the Southwest (see Edwards et al.[9] for detailed review). Projected increases in temperature and carbon dioxide (CO_2) concentrations coupled with expected drying and increased precipitation variability are expected to have long-term effects on important limiting controls of erosion, especially vegetation cover and community composition. In addition, the frequency and magnitude of extreme events such as drought, fire and high intensity storms are expected to increase, which could significantly increase vulnerability to wind erosion over multiple scales.

Climate Change Projections

There is very high confidence that CO_2 concentrations and temperatures across much of the West have been increasing over the past century, and that this trend is intensifying.[10] Predictions from the Coupled Model Intercomparison Project (CMIP5) further suggest mean temperatures across the West could increase by ~3.3°C (6°F) by the mid-21st century and ~5°C (9°F) by late-21st century under the Representative Concentration Pathway 8.5 (RCP8.5), which is consistent with recent observations of emissions. Increases in temperature are projected across all seasons but are higher for summer and fall when many plants are already stressed. Projected warming has the potential to impact wind erosion through further increasing evaporative stress and soil moisture deficits, which in part control vegetation cover and plant community structure.

Observed changes in annual precipitation are more variable, but annual drying trends have been observed for much of the Southwest.[11] In general, drying in the Southwest has been observed during spring and summer. Projections for annual precipitation by the mid-21st century under RCP8.5 are more uncertain than for temperature but suggest continued drying,[12] with drier winters and springs but wetter summers.

Surface winds in the US have declined by ~10% over the last 30 years.[13] Patterns of seasonal wind-speed projections for mid-century are consistent with these evaluations but highly uncertain. Despite the projected decrease in mean winds, most projections include an increase in potentially erosive weather events, such as thunderstorms and severe winter storms. Further, warming and drying conditions favor longer term disturbances which increase vulnerability to wind erosion, such as prolonged soil moisture deficits and large fires.

Potential Impacts on Wind Erosion

Projected changes in atmospheric CO_2 concentration, temperature, and precipitation will likely impact vegetation production, cover, and community composition in the Southwest (see Polley et al.[14] and Briske et al.[15] for detailed reviews). Increased CO_2 promotes growth and water use efficiency by plants, but these benefits will likely be limited by water availability. Both Polley et al.[14] and Briske et al.[15] suggest that coupled warming and drying trends in the Southwest will reduce overall net primary production, reducing vegetation cover, and could favor shifts to more woody species. In addition to an overall drying trend, increased variability in precipitation also decreases overall ecosystem productivity and promotes shrub productivity at the expense of grasses.[16] This suggests that prolonged periods of increased variability in precipitation could favor grass-to-shrub transitions, which, once started, are often self-sustaining.

Although lower mean wind speeds are projected across much of the region, any reduction in wind erosion potential could be offset by vegetation responses to climate change. Wind erosion frequency and magnitude depend on the degree of soil exposure to the wind field, which is largely controlled by vegetation cover and community structure. Decreases in overall cover and transitions from high-cover grasses to shrubs with bare interspaces effectively increase long-term vulnerability to wind erosion. In addition, wind erosion and dust emission events are largely driven by frontal passages over much of the region. Dryer winters and springs may further promote increased wind erosion by reducing early season production and thus vulnerability to these events. Local convective winds are also important drivers of dust events in the Southwest. Increased frequency of severe storms would likely increase the frequency of dust-related hazards. Finally, warming and drying could increase the frequency and return interval of wildfires, which would significantly increase wind erosion at local scales during recovery periods.

Given current vulnerability of arid and semi-arid lands to erosion and the uncertainty regarding future trajectories of vegetation cover and community structure, wind erosion should be explicitly considered in management benchmarks and decision support. However, management options to limit wind erosion are largely similar to those already in place to address other disturbances, such as drought, fire, invasive species, and shrub encroachment. As such, implementing active, planned management now that has multiple benefits, including for mitigating erosion, will very likely increase resilience and adaptability in the future.

Weather Events Characterized by High Winds

The majority of dust storms can be classified as convectively driven dust storms, synoptic scale dust storms, and dust channels. Dust storms can occur any time of the year and in some cases appear quickly and disappear quickly. They can be found in practically any location. The basic ingredients for dust storms are high winds exceeding the threshold for wind erosion and dry, erodible soil in the absence of vegetation cover. This section very briefly describes the meteorological drivers creating the winds for various types of commonly encountered dust storms.

The first category are associated with thunderstorms. In the southwest convectively driven dust storms are common during the summer months when we see a seasonal shift in wind direction bringing in moist airmasses. During those times we often see surface dewpoint temperatures rise as shallow airmasses moves toward the region from the south and east. Storms starts out with convection over the higher terrain with smaller storm cells developing over the surrounding smaller mountain ranges. Convective storms grow in size and intensity, steered by upper level winds and pressure gradients. Once these storms reach maturity they then decay, losing energy through falling rain drops. If the lowest level of the atmosphere is dry, the drops eventually evaporate as they fall. Evaporation is a cooling process and as a result we observe cool downdrafts or air falling toward the ground. These descending winds eventually impact the surface and spread out horizontally. The horizontal winds can achieve speeds more than 70 mph over short distances over a time period of a few minutes. Very intense but localized winds include dry microbursts in scale of less than 5-kilometers across. In some cases impacts of evaporation are much larger as in the case of a large thunderstorm or a mesoscale convective complex extending over a hundred kilometers. Winds from these type of storms are called thunderstorm outflow winds and the leading edge of these are called outflow boundaries. In the desert Southwest these outflow boundaries can create dust storms that are often called haboobs. This particular type of dust storm is hazardous due to its quick formation, potential to create very high concentrations of aerosols, and extremely low visibility. Wind directions during these events can come from most any direction and depend on where the convection is located.

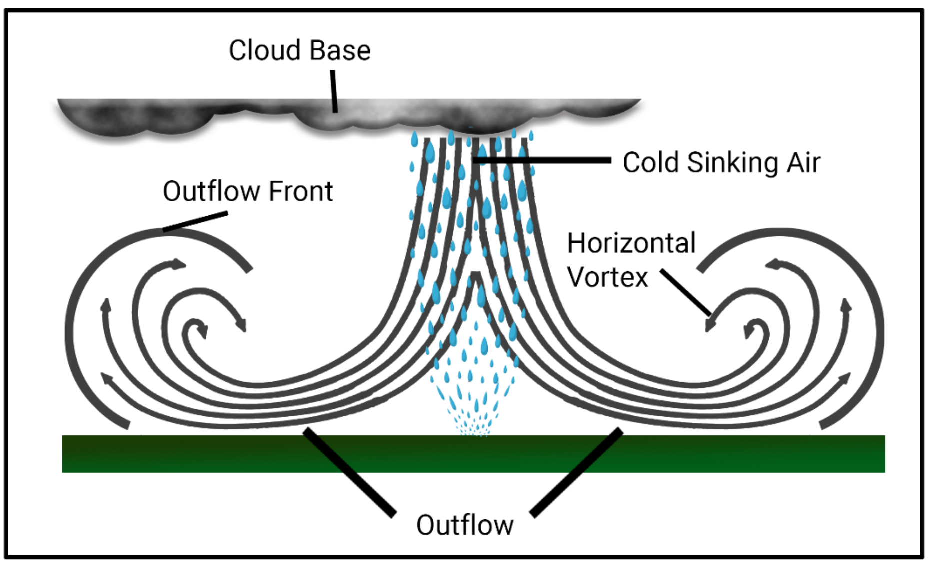

Figure 2-3. Schematic of a thunderstorm outflow event that generates high winds and dust.

The second type of dust storm that occur are from midlatitude cyclones that bring in cold fronts and high winds over the region mainly in the spring. A smaller number of synoptic dust storms occur in the fall and winter. These high winds occur over a much longer period of time compared to the convectively driven ones. In some instances high winds over 30 mph with higher gusts are found in these storms covering more than 12 hours. These systems bring in strong winds from the southwest where winds occasionally reach 50 mph sustained. Winds of this type are straightforward to forecast and local National Weather Service offices provide several days of notice in these cases. Uncertainties in the forecasts of dust storms have been in the timing and location of the high winds, presence of precipitation during the storm, along with the condition of the soils. Synoptic dust storms occur frequently in the afternoon from 3 pm to 5 pm as higher winds aloft mix down toward the ground but can be found throughout the day. The longer duration storms from cold fronts tend to last much longer with some lasting an entire afternoon.

The third type are small in scale on the order of tens to hundreds of meters in size and are called dust channels. Dust channels arise by wind blowing across small erodible areas such as a recently disturbed parking lot, agricultural field or rangeland. Disturbance can be from many activities including building construction, off-road vehicles, and livestock. These type of dust events are particularly hazardous since they are highly localized, hard to predict, can change quickly in response to changes in wind direction and wind speeds. In many instances dust channels tend to be short in duration -less than 5 minutes- but can last longer depending on the meteorological cause of the winds. Another characteristic of these are the dust is often at very high concentrations low to the ground and degrades visibility to passenger vehicles but to lesser amounts for high profile trucks. Meteorological causes for dust channels can vary from thunderstorms to cold fronts.

Other meteorological conditions that are associated with high winds can be from downslope or Fohn winds such as the Santa Ana winds from the Mojave Desert impacting southern California. These winds can be amplified when they flow though valleys or narrow mountain passes. Other causes of dust include dust devils that can create low visibility conditions over small areas.

Chapter 3 : Modeling and Predicting Wind Erosion

Wind Erosion Equation (WEQ) – **From the WEPS 1.5 User Manual**[17]

The Wind Erosion Equation (WEQ) was first published in 1965 by Woodruff and Siddoway. For years, WEQ has represented the most comprehensive and widely used model in the world for estimating soil loss by wind from agricultural fields. WEQ uses five factors to calculate the erodibility of a given soil.

The equation for WEQ is:

$$E = f(I,K,C,L,V)$$

where E is the average soil loss (tons/acre/year), I is the soil erodibility, K is the soil ridge roughness, C is the climatic factor, L is the field length along the prevailing wind erosion direction, and V is the vegetative factor.

WEQ is largely empirical in nature and was derived from nearly 20 years of field and laboratory studies by scientists at the United States Department of Agriculture Agricultural Research Service (ARS) Wind Erosion Research Unit.[18–21] Many improvements were made to WEQ over the next 30 years. The limitations of adapting WEQ to many problems and environments, as well as advancements in wind erosion science and computer technology, led to the USDA Natural Resources Conservation Service (NRCS) requesting that ARS develop a replacement for WEQ.[22]

Wind Erosion Prediction System (WEPS) – **Adapted from the WEPS 1.5 User Manual**[17]

WEPS is a process-based, daily time-step model that simulates weather, field conditions, and erosion. As such, it simulates not only the basic wind erosion processes, but also the field processes that modify a soil's susceptibility to wind erosion. It is designed to provide the user with a simple tool for inputting initial field conditions, calculating soil loss, and displaying either simple or detailed outputs for conservation planning and designing erosion control systems.

Research in the 1980's provided the initial attempt to outline a processed based approach to simulating wind erosion that would replace the Wind Erosion Equation (WEQ). Following this initial work, the modular structure used in the current WEPS model was developed and the experimental research needed to support that structure was outlined. Numerous field and laboratory studies were conducted to develop relationships for surface conditions and erosion.

Experimental data were collected for weather, hydrology, crop growth, residue decomposition, soil, management, and erosion. Experiments were conducted to validate that the erosion routines were producing accurate and precise erosion estimates.

A multi-disciplinary team assembled to develop WEPS included climate modelers, agronomists, agricultural engineers, soil scientists, and crop modelers. In 2005, WEPS was released to the NRCS for testing and further development for field office conservation planning. In 2008 WEPS was released to NRCS for field office implementation.

Early in the WEPS development process, input was requested from potential users on the needed capabilities of a new wind erosion simulation model. Based on these requirements, WEPS was designed to:

Provide more accurate and detailed estimates of soil loss by wind from agricultural fields. Results for WEQ were an annual average soil loss based essentially on average weather and field conditions. Since erosion is often the result of extreme weather events (e.g., high wind or dry soil conditions), an approach that accounts for such extreme conditions was needed to simulate the extreme soil loss for these situations. In addition, WEPS is capable of outputting erosion loss and surface conditions on a relatively fine temporal scale (e.g., hourly). However, for practical purposes, the default time step for WEPS output is two weeks. Such detail allows the user to observe the periods when excessive erosion occurs and the wind or surface conditions which caused the soil loss (e.g., low vegetative cover). These conditions can then be addressed by altering management or other control measures.

Develop more cost-effective erosion control methods. The detail in the soil loss and field conditions provided by WEPS is a valuable tool for testing various management scenarios or control methods through simulation. Each scenario can be evaluated before a change in farming practices is made in the field. Surface conditions and management can be observed during periods of excessive loss and adjusted to minimize erosion.

Simulate the amount of soil loss by direction. With increasing concern about the impacts of wind erosion on soil, water, and air quality, the capability of WEPS to provide the direction of soil loss is useful. For example, creep and saltation loss to a roadside ditch or waterway will impact water quality, so attention can be focused in these scenarios to control loss based upon impacts. Similarly, suspension loss in the direction of highly populated areas and control strategies can be simulated with WEPS.

Separate soil loss into creep/saltation, suspension, and PM_{10} components. Each of these components have specific characteristics and effects. Particles lost through creep/saltation are typically deposited locally where they can affect soil and water quality, bury crops, roads, and irrigation ditches, or be deposited as dunes in fences or windbreaks. Suspension particles, by definition, can be lifted into the air and carried great distances. As such, it can be a detriment to air quality, become a health hazard, and reduce visibility along transportation systems. PM_{10} has been determined by the U.S. Environmental Protection Agency to be a hazard to air quality and a respiratory hazard in particular.[23] Estimating soil loss of each of these components can aid in environmental assessments.

Taking all user requirements into consideration, WEPS is designed to be an aid in: 1) soil conservation planning, 2) environmental assessment and planning; and 3) determining offsite impacts of wind erosion.

WEPS Modeling Approach

To simplify inputs, WEPS is designed with specific geometric constraints when specifying the simulation region or field (Figure 3-1). The simulation area may be rotated to orient the field correctly on the landscape to account for the effects of varying tillage, planting, and wind directions.

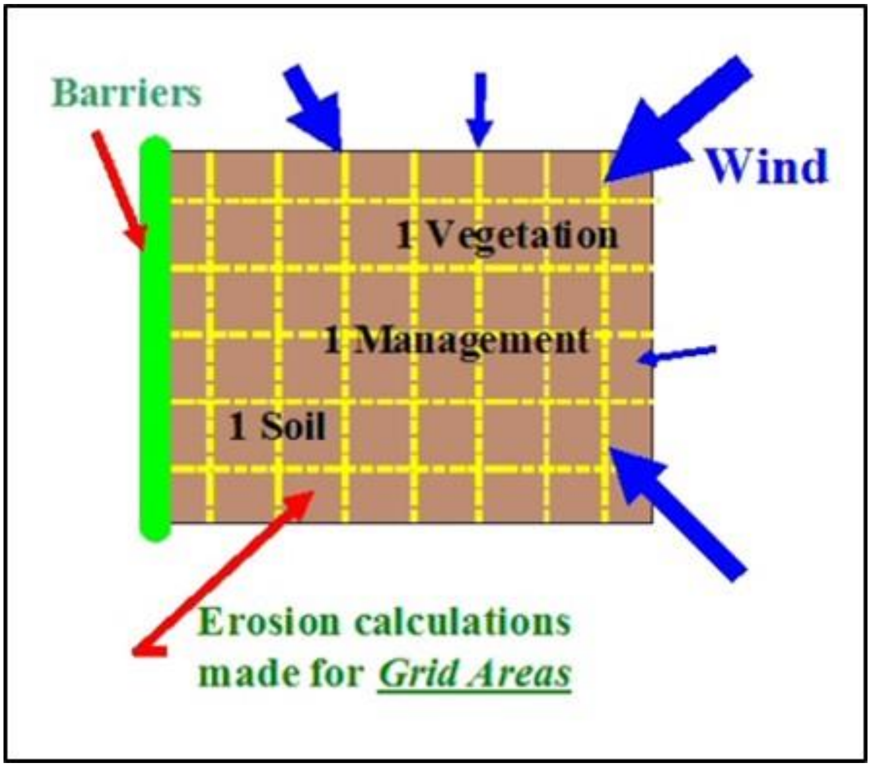

Figure 3-1. WEPS simulation geometries.[17]

A uniform simulation region surface is assumed in that only one soil type (uniform soil properties), crop type (biomass properties), and management are uniformly distributed over the field. In reality, fields are often not uniform so the user may select the dominant-critical (i.e., most erodible) soil or crop condition for a simulation. Barriers may be placed on any or all field boundaries. When barriers are present, the wind speed is reduced in the sheltered area on both the upwind and downwind sides of the barriers.

The erosion submodel determines the threshold friction velocity at which erosion can begin for each surface condition. When wind speeds exceed the threshold, the submodel calculates the loss/deposition over a series of individual grid cells representing the field. The soil loss and deposition is divided into components of saltation/creep and suspension, because each has unique transport modes, as well as off-site impacts. The field surface is periodically updated during erosion events to simulate the surface changes caused by erosion. Surface updating during an erosion event includes changes to aggregate size distribution of the surface as fine particles are removed, smoothing of ridge roughness as ridges are eroded and furrows filled with eroded materials.

Once given user supplied inputs, the interface accesses five databases for climate, soils, management, barriers, and crop growth and residue decomposition for the simulation. These databases provide needed parameters for location and conditions simulated as specified by the user. WEPS also uses 50 years of climate data containing daily precipitation, maximum and minimum temperatures, solar radiation, and dew-point temperature as well as a daily wind direction and sub-daily (e.g., hourly) wind speeds.

These input files for a given simulation are collectively known in WEPS as a "run". The science model reads the input run files and calls the Hydrology, Soil, Crop, and Decomposition submodels daily which account for changes in the soil surface erodibility as influenced by Management and Weather. If surface conditions for a given day are such that erosion can occur for the maximum wind speed for that day, Erosion submodel routines are called to calculate soil loss and deposition. Soil erosion by wind is initiated when the wind speed exceeds the saltation threshold speed for a given soil and biomass condition. After initiation, the duration and severity of an erosion event depend on the wind speeds and the evolution of the surface conditions.

Since WEPS uses 50 years of data to determine the average erosion rates, it is not useful for looking at the effects of single weather events. The SWEEP program (single wind erosion event program) can be used along with the WEPS erosion model to determine the soil losses from individual weather events. This program is not a formal part of the NRCS WEPS package, but is available from the USDA-ARS WEPS website.

Aeolian Erosion (AERO) Model

The Aeolian Erosion (AERO) model was developed by the United States Department of Agriculture Agricultural Research Service (ARS) to address the need for a generalizable, physically-based wind erosion and dust emission model that could be applied to existing standardized monitoring datasets across all land cover types. The need for a generalizable and physically-based model arose from recognition that the strengths of available cropland wind erosion models (e.g., WEPS) for assessing management impacts on soil loss do not currently (2018) extend to rangeland applications. Available cropland wind erosion models and global dust models were also seen as being either too empirically tuned to cropland settings or too insensitive to the subtle, and sometimes not so subtle, effects of rangeland management and vegetation state changes on aeolian sediment transport and dust emission. AERO was developed from a selection of the best-available schemes to represent biophysical controls on sediment transport and dust emission processes. Criteria for scheme selection included a desire for a high level of process fidelity, low model complexity, and the ability to be applied directly to available soil and ecological monitoring data collected by the Natural Resources Conservation Service's (NRCS) National Resources Inventory (NRI) and the Bureau of Land Management's (BLM) Assessment, Inventory and Monitoring (AIM) programs.[24]

The AERO model draws heavily on the structure of the Shao[25] dust model. The threshold wind friction velocity for soil entrainment is estimated using the Iverson and White[26] threshold equation. A minimally dispersed soil particle size distribution, identified by geographic location and surface soil texture class, is used as input to the equation to produce a size-resolved entrainment threshold. The Fécan et al.[27] scheme is used as a threshold modifier to account for the effects of soil moisture on inter-particle cohesion. The Okin[28] drag partition scheme is used to estimate the probability density distribution of wind friction velocity at the soil surface as a function of the freestream wind velocity, mean vegetation canopy height, and the vegetation canopy gap size distribution. A tiered drag partition can be implemented to assess effects of shrubs, grasses and oriented soil roughness (e.g., due to tillage) on surface wind friction velocities and sediment transport. Horizontal sediment mass flux, Q (g m^{-1} s^{-1}) is estimated when the surface wind friction velocity exceeds the entrainment threshold and is computed for each soil particle size class using the Owen[29] sand transport equation. Size-resolved vertical dust flux, F (g m^{-2} s^{-1}) is calculated using the Shao[25] dust emission scheme as a function of saltation bombardment and aggregate disintegration processes. A dispersed soil particle size distribution and surface wind friction velocity are used to estimate the level of soil disaggregation, with F estimated as the volume of fine particles emitted from the soil surface. AERO outputs can be tailored by application and may include total horizontal (saltation) and vertical (dust) mass fluxes, size-resolved dust mass flux, and gross wind erosion.

AERO can be implemented in three modes: (1) a timeseries mode using field measured inputs of meteorological, soil and vegetation properties; (2) a probabilistic mode using a combination of field measured inputs, spatially-explicit soils data and reanalysis wind speed probability densities queried by geographic location; and (3) a spatial mode in which AERO can be run offline or online with a numerical weather model. The primary intended application of AERO is in probabilistic mode using wind speed from the National Centers for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR) dataset and soils and vegetation inputs from the NRI and AIM programs and/or collected following the standardized methods of Herrick et al.[30] In this mode, AERO estimates are produced at the plot scale (typically measured as ≤ 1 ha) and can be scaled to produce spatially-weighted estimates of Q and F. Spatially-weighted AERO estimates can be produced to assess wind erosion and dust emission responses to treatments (e.g., tillage, vegetation clearing, seeding) and disturbances (e.g., fire) and at different administrative and ecogeomorphic scales. For example, AERO has been applied to county, state, ecological site (to inform Ecological Site Descriptions - ESDs), Major Land Resource Area (MLRA), and ecoregion-level assessments. At the time of writing (December 2018), AERO is being calibrated in the Agricultural Policy / Environmental eXtender (APEX) farming systems model to support management scenario-driven assessments of wind erosion and dust emission for croplands and rangelands. AERO model development was funded by and supports the NRCS Conservation Effects Assessment Project (CEAP) and the BLM.

It is anticipated that AERO will serve as a tool for conservation planners to evaluate aeolian sediment transport patterns and trends, and following land treatments and disturbances under different climatic conditions (drought, extreme weather phenomenon). By both enhancing wind erosion monitoring and evaluating management and disturbance scenarios, conservation planners, ranchers and farmers will be better prepared to recognize and react to projected adverse climate conditions, and where risk is deemed too high- avoid or delay the proposed treatment. The capacity to run AERO using standardized monitoring data (NRI, AIM) will enable wind erosion and management options to be assessed along other land health attributes and resource concerns managed on private and federal lands.

Currently, AERO is being validated using data from the National Wind Erosion Research Network[31] cropland and rangeland sites across the Great Plains and Western United States and is expected to be released as a fully functional tool by 2020.

Soil Properties and Interpretations

Understanding a landscape's susceptibility to erode by wind begins with determining the relationships between wind speed, surface cover and vegetation. Web Soil Survey[32] is the USDA's platform to find seamless soil survey data for the entire nation. The site is free to the public and is capable of printing professional reports including scientific soil descriptions, soil properties and qualities, suitabilities and limitations for use, and ecological site assessment- all with accompanying high quality color interpretative maps. This section describes the site's capabilities in understanding the relationships of soils and vegetation in mitigating and preventing soil erosion.

Fundamentally, there is a close correlation between wind erosion and the texture of the surface layer, the size and durability of surface clods, rock fragments, organic matter, and a calcareous reaction. Soil moisture and frozen soil layers also influence wind erosion. Wind

Erodibility Group (WEG) and Wind Erosion Index (WEI) -discussed in a later chapter- can be found on this tab under the Soil Erosion section. WEG and WEI are developed from an algorithm of the above properties.

Materials published through Web Soil Survey include some excellent descriptions and definitions of many of the site and soil properties discussed here, written by experts in the field. In an effort to take advantage of the work that has already been done by others and to avoid re-inventing the wheel, so to speak, relevant portions of these descriptions are provided as part of this section, unmodified from their original source and indicated with quotation marks.

The Ecological Site Assessment

The Ecological Site Assessment tab can be used to map out and determine ecological sites for a selected area of interest. From there, the ecological site name can be cross-referenced to ecological site database called Ecosystem Dynamics Interpretive Tool (EDIT), or alternatively the state FOTG, to obtain a reference site description for that ecological site. This description will provide a listing of structural groups of vegetation (grasses, forbs, shrubs/vines, and trees) and their canopy percentage that can be expected if the site is in its reference state. Other states, man-made or natural alterations to the site, are also described in narrative fashion. The description includes other characteristics of the site that directly affect its potential to erode by wind, including biological crusts, surface fragments, litter, bedrock, and bare ground. With both the vegetative composition and a detailed description of the soil surface, reasonable inferences can be made of the site's potential to erode by wind.

Other interpretations available in Web Soil Survey include:

Organic Matter Depletion

Organic matter content in soils is an indicator of soil health. Organic matter is a soil binder and contributes to keeping soil in place when subjected to wind and rain. This interpretation rates the soil's susceptibility to deplete organic matter on a scale of 0 to 1, where 1 represents a soil feature has the greatest ability to enable organic carbon depletion. Several soil features are evaluated, for example- high oxidation rate, low clay surface percentage, well aerated, low antecedent organic matter content, and others. These ratings are then compiled into a rating class.

“Rating class terms indicate the extent to which the soils enable the depletion of organic matter. ‘Organic matter depletion high’ indicates that the soil and site have features that are very conducive to the depletion of organic matter. Very careful management will be needed to prevent serious organic matter loss when these soils are farmed. ‘Organic matter depletion moderately high’, ‘Organic matter depletion moderate’, and ‘Organic matter depletion moderately low’ are a gradient of the level of management needed to avoid organic matter depletion. ‘Organic matter depletion low’ indicates soils that have features that are favorable for organic matter accumulation. These soils allow more management options while still maintaining favorable organic matter levels.”[33]

Fragile Soils Index

“Soils can be rated based on their susceptibility to degradation in the ‘Fragile Soil Index’ interpretation. Fragile soils are those that are most vulnerable to degradation. In other words, they can be easily degraded—they have a low resistance to degradation processes. They tend to be highly susceptible to erosion and can have a low capacity to recover after degradation has occurred (low resilience). Fragile soils are generally characterized by a low content of organic matter, low aggregate stability, and weak soil structure. They are generally located on sloping ground, have sparse plant cover, and tend to be in arid or semiarid regions. The index can be used for conservation and watershed planning to assist in identifying soils and areas highly vulnerable to degradation.”[34] “Soils are placed into interpretive classes based on their index rating, which ranges from 0 to 1. An index rating of 1 is the most fragile, while a rating of zero is the least fragile.”[34]

These values are accompanied by interpretative classes that provide a more detailed evaluation of the susceptibility to erode and/or degrade.

Soil Surface Sealing

“Surface sealing is the orientation and packing of dispersed soil particles that result from the physical breakup of soil aggregates due to raindrop impact. Rapid soil wetting (in dry soils) and high exchangeable sodium percent can also cause aggregates to disperse. Sealing results when clay and silt particles get detached and/or dispersed and become suspended in the infiltrating water, which is moving downward through surface-connected pores. The pores become clogged with the fine particles, which become closely packed and create a surface seal.

Surface sealing is the initial process in the formation of a mineral crust, which is a broader term for a surface feature that is dense, hard, or restricts infiltration. A seal is a more specific term and refers to a surface layer that inhibits infiltration (Heil, 1993)."[35]

Although surface sealing is an indicator of poor soil health and an undesirable condition, in arid areas where water erosion is not a concern, the propensity of a soil to develop a surface seal may be beneficial when it comes to wind erosion.

Reference cited as part of the above-quoted text:

Heil, J.W. 1993. Soil properties influencing hydraulic sealing of the surface on Alfisols in the Sahel. Doctoral dissertation, Texas A&M University. College Station, Texas.

Unpaved Local Roads and Streets

Web Soil Survey defines unpaved local roads and streets as "those roads and streets that carry traffic year-round but have a graded surface of local soil material or aggregate."[36] This interpretation evaluates soil suitability for building these type roads. Attributes include susceptibility to flooding, bedrock, low strength, shrink-swell, and dusty qualities. Each attribute is rated from 0 to 1, where 1 is most limiting. Additionally, a composite rating is compiled from all attributes that indicate whether the soil would be very limited, somewhat limited, or not limited.

Recreational Development

Similar to Unpaved Local Roads and Streets, several recreational development scenarios are rated, including camp areas, off-road motorcycle trails, paths and trails, picnic areas, and playgrounds, with "dusty" being a primary feature evaluated. The importance of these recreational activities becoming very limited due to dust is underscored by realizing that these disturbed areas can serve as a catalyst to start the saltation process into adjoining areas, contributing to a larger suspension problem.

Soil Habitat for Saprophite Stage of Coccidioides

"Valley fever or coccidioidomycosis is caused by the soil-borne fungi *Coccidioides immitis* and *Coccidioides posadasii* which are endemic to the Southwest United States and a few other places in Central and South America. The symptoms of the disease range from none at all to mild cold or flu-like conditions in most people. However, some people experience the disseminated form of the disease, which can kill.

According to Kolivras et al (2001), the life cycle of fungus consists of a saprophytic and parasitic phases. The saprophytic phase lives in soil as entangled mycelia and hyphae. The hyphae grow and mature to produce generally rectangular arthrospores. The arthrospores are 1.5 to 4.5 microns in width and 5 to 30 microns in length. These spores move easily in air currents. The parasitic phase occurs in nature under dry, dusty conditions when a host mammal inhales airborne arthrospores. The fungus in this phase grows as spherules that mature and burst, releasing endospores that can grow into new spherules in the host lungs, inducing valley fever (Kolivras et al, 2001)."[37]

"Many prior maps of endemic areas are made from testing people for reactivity to coccidioidin and not the soil for presence of the fungi (Edwards and Palmer, 1957). The objective of the current study is to use the soil survey database to identify areas that are potentially habitat for this soil-borne fungus. This approach will allow habitat mapping at far finer spatial resolutions than has even been done in the past. This will allow habitat considerations to be targeted in the planning stage of any soil disturbing activity so as to proactively apply dust control methods when needed. The criteria mapped are as follows. The mean annual precipitation (about 230mm) and air temperature (about 20 degrees C) found in the Lower Sonoran Life Zone are used as the optima for habitat. For xeric areas, the rainfall can be somewhat higher and the temperature somewhat lower. Southerly slope aspect, moderate slope gradient, and low surface albedo are used to better capture extreme soil surface temperature effects. Electrical conductivity of over 4dS/m, soil reaction of at least 8.0, or the presence of gypsum in the upper 30cm of the soil are used to indicate an environment high in soluble salts. Some organic matter and water storage must be present in the soil for the saprophytic phase to grow. Soil components fitting all of those specifications, at least marginally, are considered possible habitat for the fungus. Variation in rainfall and temperature from year to year can increase or decrease the range of *Coccidioides* spp (Kolivras et al, 2001)."[37]

References cited as part of the above-quoted text:

Edwards P.Q., C.E. Palmer. 1957. Prevalence of sensitivity to coccidioidin, with special reference to specific and nonspecific reactions to coccidioidin and to histoplasmin. Chest;31(1):35-60

Kolivras, K. N., P. S. Johnson, A. C. Comrie, S. R. Yool. 2001. Environmental variability and coccidioiomycosis (valley fever). Aerobiologia 17:31-42

Range Production

"Total range production is the amount of vegetation that can be expected to grow annually in a well-managed area that is supporting the potential natural plant community. It includes all vegetation, whether or not it is palatable to grazing animals. It includes the current year's growth of leaves, twigs, and fruits of woody plants. It does not include the increase in stem diameter of trees and shrubs. It is expressed in pounds per acre of air-dry vegetation. In an unfavorable year, growing conditions are well below average, generally because of low available soil moisture. Yields are adjusted to a common percent of air-dry moisture content.

In areas that have similar climate and topography, differences in the kind and amount of vegetation produced on rangeland are closely related to the kind of soil. Effective management is based on the relationship between the soils and vegetation and water."[38]

Although range production cannot be considered as any measurement of wind erosion, it can be somewhat of an indicator of potential to erode, particularly during extended drought. Where production is low, the lack of vegetative growth may lead to increased potential for soil to blow. Of course, there are many other soil characteristics that may negate wind erosion, for instance- desert pavement, fragment percentage, litter, biological crust, etc.

Chapter 4 : Measuring Airborne Particulates

Measuring Airborne Particulates

Monitoring airborne particulates has been the primary approach to collecting data on spatial and temporal patterns of wind erosion for decades.[39] Monitoring in the US is coordinated through meteorological observation networks and aerosol measurement networks. Indicators of airborne particulates used by these networks include: dust event frequencies obtained from visual observations made by the National Weather Service; atmospheric particulate matter (PM) concentrations measured using high volume air samplers, lidar, and light-scattering laser photometers (e.g., Hand et al.[40]); and aerosol optical depth (AOD) obtained from ground-based sun photometers and satellite observations (e.g., Holben et al.;[41] Prospero et al.;[42] Ginoux et al.[43]). Each of these indicators provides different information about airborne particulates. Dust event frequency data by event type (e.g., locally blowing dust, dust storm, dust haze) can be used to understand the timing of wind erosion and dust emission around an observation site and regional dust event patterns and trends. Atmospheric PM concentrations and AOD provide additional information on how much airborne particulates are at a sampling location or through the vertical column of atmosphere over an observation location or area. PM concentrations and AOD directly inform air quality, human health and climate impacts of blowing dust. Spatial patterns and temporal trends of PM and AOD have been used to interpret the very general location of dust sources, and dust emission responses to climate variability, but do not inform which landscapes are eroding and why with enough accuracy to inform land management. Site-specific information about soils and vegetation are needed to identify why particular landscapes are eroding and when they are most susceptible.

Nationally, airborne particulates are monitored by federal, state and county networks, with data accessible online through the US Environmental Protection Agency (EPA) Interactive Map of Air Quality Monitors.[44] This tool provides access to concentration data for PM_{10} and $PM_{2.5}$ in addition to other aerosols and enables users to identify mapped non-attainment areas and Federal Class 1 Areas. Interagency Monitoring of Protected Visual Environments (IMPROVE) Program data that include PM and haze composition can be accessed through the EPA or dedicated IMPROVE Program data portal.[45] The National Wind Erosion Research Network[31] is actively incorporating PM_{10}, PM_4, $PM_{2.5}$ and PM_1 concentration monitoring at sites, including measurements at two levels (2 m and 4 m above ground level) to enable estimates of vertical dust flux across agroecosystems and support calibration of predictive models.

Chapter 5 : Conservation Planning for Wind Erosion Resource Concerns

Introduction to Conservation Planning

Natural Resources Conservation Service (NRCS) has established a process for conservation planning called the "Nine-Step Conservation Planning Process." The process provides a template for conservation planners to follow when working one-on-one with farmers and ranchers, or in a collaborative setting with multiple individuals, units of government and/or other stakeholders. Briefly, the nine steps include:

1. Identify problems and opportunities
2. Determine objectives
3. Inventory the natural resources
4. Analyze the resource data
5. Formulate alternatives to address the resource concerns
6. Evaluate the alternatives
7. Make decisions
8. Implement the plan
9. Evaluate the implemented plan

Further description and discussion of the nine-step process can be found in the NRCS National Planning Procedures Handbook, Subpart C.[46]

These nine steps are further divided into three phases. Steps 1 through 4 are labeled as Phase 1- Collection and Analysis, steps 5 through 7 as Phase 2- Decision Support, and steps 8 and 9 as Phase III- Application and Evaluation. In the Collection and Analysis phase, NRCS has adopted the phrase "natural resource concerns" or simply "resource concerns" to embody the suite of natural resource issues and problems which the agency will address technically and/or financially. The resource concerns are categorized as effects to soil, water, air, plants, animals and energy. Although NRCS will use general terms like "watershed health" in describing broad issues on the landscape, conservation planners are required to narrow their investigations down to these six resource categories. The complete set of defined resource concerns that NRCS addresses can be found in the NRCS's National and State Resource Concerns and Planning Criteria (Appendix B, Exhibit 5-1), including how the concerns are analyzed, a description of the tools used to assess the problems, and any thresholds that clarify the extent of the problem. This list of resource concerns is modified from time to time to capture new national priorities or to take advantage of new conservation technologies. Ideally, NRCS prefers to assess all resource concerns on a land unit before moving to the Decision Support phase of planning. Treating resource concerns independently has some inherent risks, whereby treatment of one resource concern can aggravate or make more complex the treatment of another resource concern in the future. However, oftentimes programmatic timelines/guidelines, producer time constraints, staffing limitations, etc., will dictate a progressive planning approach be made in assessing resource concerns.

Assessing Wind Erosion and Particulate Emissions

NRCS's National and State Resource Concerns and Planning Criteria document (Appendix B, Exhibit 5-1) displays all the resource concerns that NRCS currently addresses, and wind erosion is categorized as a Soil Erosion resource concern. However, particulate emissions of dust can originate from agricultural sources other than from wind blowing across fields and pastures. In these cases, dust is recognized as an air quality problem, and can be found in the Resource Concern guide under Air Quality Impacts. Emission sources causing air quality concerns include tillage, prescribed burns, combustion engines, feed lots, unpaved traffic areas, and manure transfer. These kinds of air quality issues are typically measured/categorized as particulate matter $(PM)_{10}$ and $PM_{2.5}$. PM_{10} consist mostly of dust, pollen, and other organics such as mold spores, while $PM_{2.5}$ generally concerns particulates produced by combustion sources or formed via chemical reactions of precursor gases in the atmosphere.

As noted in Exhibit 5-1, wind erosion can be screened from assessment during conservation planning activities for cropland if permanent ground cover exceeds 90%. For practicality's sake, most perennial cropping/pasture systems are considered "permanent," even though they may be renovated or replanted every three to five years. In essence, this means NRCS conservation planners need not spend time assessing the extent of wind erosion on these systems because the overwhelming likelihood is that a wind erosion problem does not exist. For forestland, the screening criteria is greater than 80% organic residue cover. For rangeland, each state has the prerogative to establish its own screening criteria; this is due to the variability of range conditions across the country, including vegetation types and ecological sites being grazed, canopy cover, grazing management systems, etc.

Inventory the Resources

The first step in assessing the possibility of a wind erosion resource concern is to consult the appropriate Soil Survey for the area of interest. All NRCS soil survey data can be found online using the Web Soil Survey tool.[32] In Web Soil Survey, after selecting the Area of Interest, select the Soil Data Explorer tab, and then the Soil Properties and Qualities tab, and finally Soil Erosion Factors. The wind erosion factors are made up of the Wind Erodibility Group (WEG) and the Wind Erodibility Index (WEI). Although these factors were originally intended to serve as indices for the Wind Erosion Equation (WEQ) on cultivated land, which NRCS has abandoned for use as a wind erosion model, the values can still be used to gauge the soils' susceptibility to wind erosion for the selected area. WEGs range from 1 through 8, where group 1 is very highly erodible and group 8 is not susceptible to wind erosion. WEG is further explained in the National Soil Survey Handbook,[47] Part 618 (see Appendix B, Exhibit 5-2).

The WEI is the base variable in the WEQ and represents the potential erodibility of a soil, expressed in tons/ac/year before any other variables are applied through the equation. Keep in mind that the WEG and the WEI were intended to be used only on cultivated lands. However, these values can also serve as an indicator where there may be resource concerns on rangeland or other associated agricultural lands. Likewise, the Ecological Site Description (ESD) might provide some insight to the susceptibility of the site to wind erosion in various states. States are currently developing ESDs to a new standard; as ESDs become more robust in their interpretations, they will have increasing value for the inventory stage of conservation planning.

On cropland, identifying a wind erosion resource concern can be as simple looking for field clues. Wind-blown soil will deposit in field ditches, crop furrows, along fencerows, in low areas, and at the windward base of any wind barrier, including walls or even a sign post. Even the crops themselves or in adjacent fields might show evidence of sandblasting. Oftentimes, sandblasted seedlings will quickly desiccate, wither, and die.

As discussed in Chapter 3, the tool used to evaluate and estimate soil erosion on cropland is the Wind Erosion Prediction System (WEPS), now integrated into the NRCS Integrated Erosion Tool. The tool, developed by USDA Agricultural Research Service, is the model NRCS has determined provides the best estimation of erosion (expressed as tons/ac/year) over the wide range of soil and climatic conditions, agronomic systems, erosion control methods, and tillage equipment used across the Nation. It is important to note that the system provides an estimation of erosion, and it is not an absolute value. By accounting for local climatic conditions, on-site soil conditions, exact crops grown and their planting and harvesting dates, irrigation or lack thereof, and the tillage and harvesting equipment used, the model is very good at evaluating alternative cropping systems. This allows the planner to easily adjust planting and harvesting dates, alter irrigation scheduling, reorganize tillage patterns, and select different crops to offer the farmer alternatives that would make the least impact on the soil resource.

Formulating and Evaluating Alternatives

Phase II of the NRCS conservation planning process involves the development of alternatives to address the identified resource concerns. The alternatives are typically made up of one or more conservation practices; currently, there are 166 NRCS-recognized conservation practices, and the complete description for each practice is known as the Conservation Practice Standard (CPS). The CPS specifies the definition, purpose, the conditions where the practice applies, the criteria for installation, other considerations in planning, and minimum requirements for plans and specifications.

The complete list of conservation practice standards can be found on the NRCS national website under Conservation Practices.[48] Each state can customize the CPSs used in that state, and those can be found in Section IV of the Field Office Technical Guide (FOTG).[49]

An experienced conservation planner typically will know which conservation practices will best address the wind erosion and air quality resource concerns in a given area. However, reviewing the long list of conservation practices may not be suitable for novice planners or farmers not familiar with the practices or terminology. Additionally, some practices may indirectly benefit wind erosion; such practices are called facilitating practices. For instance, most fences do not directly benefit wind erosion, but they can indirectly benefit wind erosion by providing a means to control grazing needed for a prescribed grazing plan that does directly benefit wind erosion. For this reason, NRCS has developed tools to assist in understanding which practices address which resource concerns. Resource concern planning guides for wind erosion and particulate matter air quality impacts (Appendix B, Exhibit 5-3 and Exhibit 5-4), found in the Arizona FOTG, Section III, under the Resource Concerns Guides folder, display the conservation practices that can be utilized to address these resource concerns.

Analyzing Effects of Conservation Practices and Alternatives

As mentioned previously, NRCS planners typically assess multiple resource concerns during the planning process. Once the assessment is completed, alternatives are developed to address the resource concerns discovered.

A high-order review of analyzing effects can be completed using the Conservation Practice Physical Effects (CPPE) matrix and associated Resource Management Systems (RMS) tool. Both the CPPE matrix and the RMS tool can generally be found in each state's FOTG. The CPPE matrix is a general depiction of all 166 conservation practices' effect on the full list of resource concerns that NRCS evaluates. The CPPE is developed on the national level, but each state has the prerogative to adjust the values in the matrix based on local professional expertise. The rating ranges from -5 to +5 as shown in Figure 5-1. The intent of the CPPE is to enable planners to compare proposed practices effectiveness in treating the resource concern, while considering any potential negative effects.

Effects Quantification	Rating
Substantial Improvement	5
Moderate to Substantial Improvement	4
Moderate Improvement	3
Slight to Moderate Improvement	2
Slight Improvement	1
Not Applicable	0
Neutral	0
Slight Worsening	-1
Slight to Moderate Worsening	-2

Effects Quantification	Rating
Moderate Worsening	-3
Moderate to Substantial Worsening	-4
Substantial Worsening	-5

Figure 5-1. Conservation Practice Physical Effects (CPPE) ratings.[50]

The CPPE is developed by specialists in the fields of agronomy, range science, soil science, wildlife biology, forestry, economics, and engineering, both nationally and at the state level, and is reviewed annually. The complete CPPE matrix, including the tab to examine human considerations, can be downloaded from a locally-stored copy here,[51] or found on the NRCS website[52] as *Conservation Practice Physical Effects on Soil, Water, Air, Plants, Animals, Energy, People (XLSM, 844kb)*. NRCS always welcomes outside review and recommendations from qualified conservationists, natural resource professionals, academics, and researchers in the development of the practice ratings.

Another tool for conservation planners to incorporate into their alternative assessments is the above-mentioned RMS Planning Tool.[50] A current version of this tool can be found on the NRCS website in their Tools[53] section under Technical Resources, Economics.

A final tool that can be used to compare benefits with negative effects is simple T Charts (see Appendix B, Exhibit 5-5).

Chapter 6 : Wind Erosion Abatement on Cropland

Introduction to Wind Erosion Abatement on Cropland

The physical properties associated with wind erosion include: soil moisture, soil aggregate stability, soil crusting, surface rock fragments, vegetative cover, plant residue, soil organic matter, wind barriers, and surface roughness. Conservation practices utilized for wind erosion control favorably alter one or more of these properties. The following practices have been recognized by NRCS as having a positive impact on wind erosion on cropland, included are their respective Conservation Practice Physical Effect (CPPE) value (see Analyzing Effects of Conservation Practices and Alternatives in Chapter 5 of this handbook for an explanation of CPPE values):

NRCS Practice Name and Practice Code	CPPE Value for Wind Erosion
Alley Cropping 311	5
Amending Soil Properties with Gypsum Products 333	1
Conservation Cover 327	4
Conservation Crop Rotation 328	4
Cover Crop 340	4
Critical Area Planting 342	5
Cross Wind Ridges 588	4
Cross Wind Trap Strips 589C	4
Field Border 386	4

NRCS Practice Name and Practice Code	CPPE Value for Wind Erosion
Field Operations Emissions Reduction 376	4
Hedgerow Planting 422	1
Herbaceous Wind Barriers 603	4
Mulching 484	4
Multi-Story Cropping 379	1
Residue and Tillage Management, No-till 329	5
Residue and Tillage Management, Reduced Till 345	4
Stripcropping 585	4
Surface Roughening 609	3
Vegetative Barrier 601	1
Windbreak/Shelterbelt Establishment 380	5

Figure 6-1. Conservation practices that are recognized to address wind erosion on cropland.

A full list of NRCS practice standards can be found on the NRCS national website under Conservation Practices.[48]

Several of these conservation practices are recognized as having a positive effect on wind erosion even though they do not have a stated purpose listed in the practice standard for controlling erosion. For instance, Vegetative Barrier is used primarily for controlling water erosion, as the barriers are planted along the contours of slopes or across concentrated flow areas. However, they can have a positive effect on wind erosion because they interrupt the saltation and creep processes to varying extents. Other practices with similar considerations are

Amending Soil Properties with Gypsum Products, Field Border, and Field Operations Emissions Reduction, where significant ancillary benefits to abating dust emissions can be obtained.

Only five of the above practices are exclusive to the wind erosion resource concern. They include Cross Wind Ridges, Cross Wind Trap Strips, Surface Roughening, Herbaceous Wind Barriers, and Windbreak. The remainder of the practices have multiple purposes. Practices such as Conservation Crop Rotation, Cover Crop, and Residue Management can address soil health issues, plant pests, water erosion, water quality, and soil compaction. These three practices are sometimes considered to be the “holy trinity” of soil and water conservation, as they frequently do more to minimize water and wind erosion, promote soil health and a diverse microbial population, and sustain water quality than the rest of the conservation practices combined. They are the key to building sustainable farming enterprises that are resilient in the face of a changing climate and harsh weather extremes. The key to the success of these practices is soil cover, diversity of crops grown, increased water holding capacity, and increased water infiltration rate.

Below is a graphical summary of conservation practices used to address the wind erosion resource concern within NRCS programs across the country (Figures 6-2 through 6-5). These programs include financial assistance programs and do not include practices installed with NRCS technical assistance only. Figure 6-2 and Figure 6-4 represent total NRCS dollars contributed for each practice for the five-year period between 2013 and 2017. Since dollars spent do not adequately show popularity of practice use, a set of graphs that depict the number of times each practice is used in programmatic contracts has also been provided (Figure 6-3 and Figure 6-5). Because some practices are used far more than others, both in dollars and count, the practices have been grouped for easier comparison.

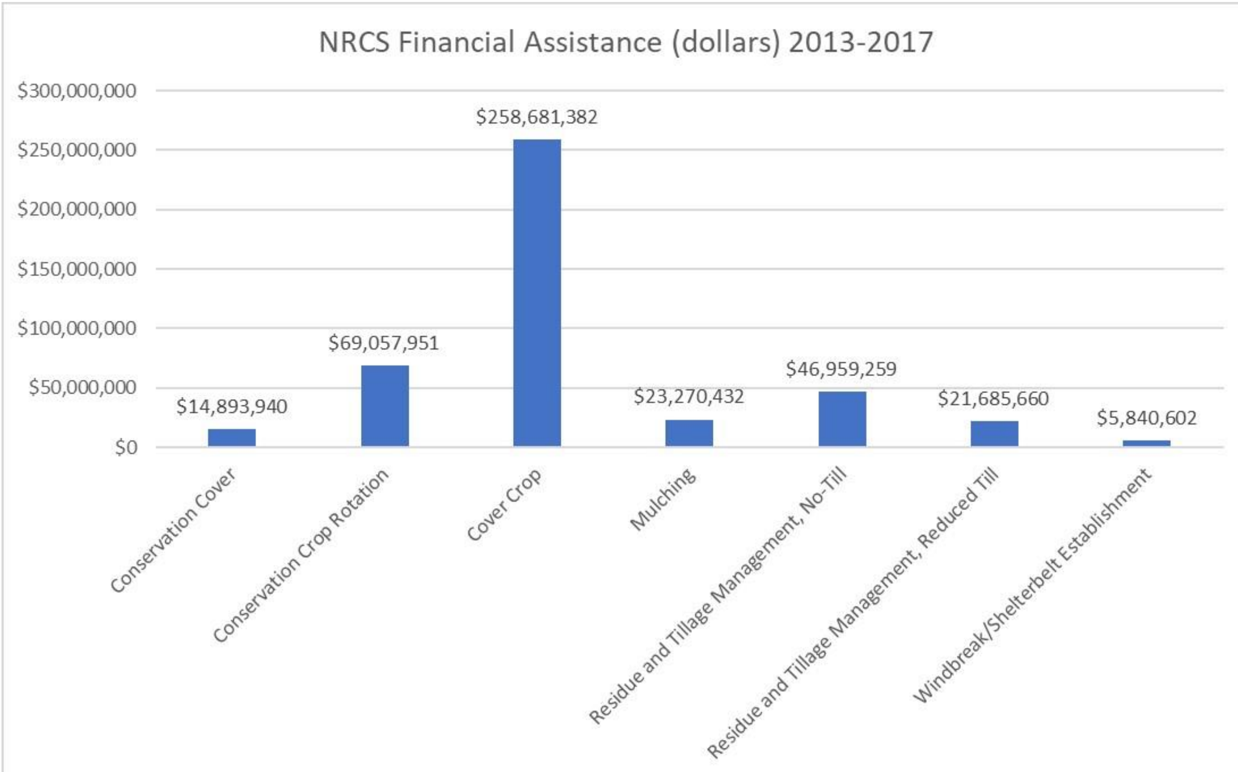

Figure 6-2. NRCS Financial assistance dollars spent on practices used to address wind erosion on cropland.

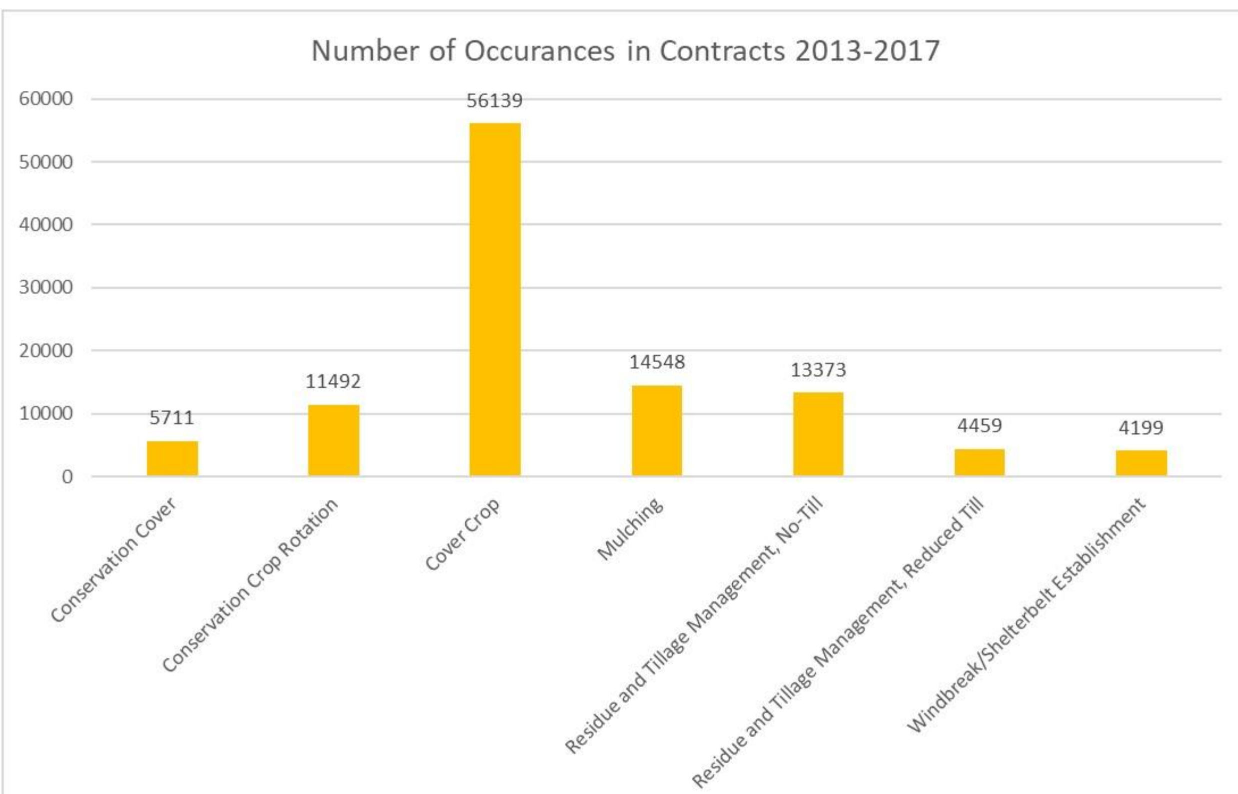

Figure 6-3. Occurrences in NRCS contracts of conservation practices used to address wind erosion on cropland.

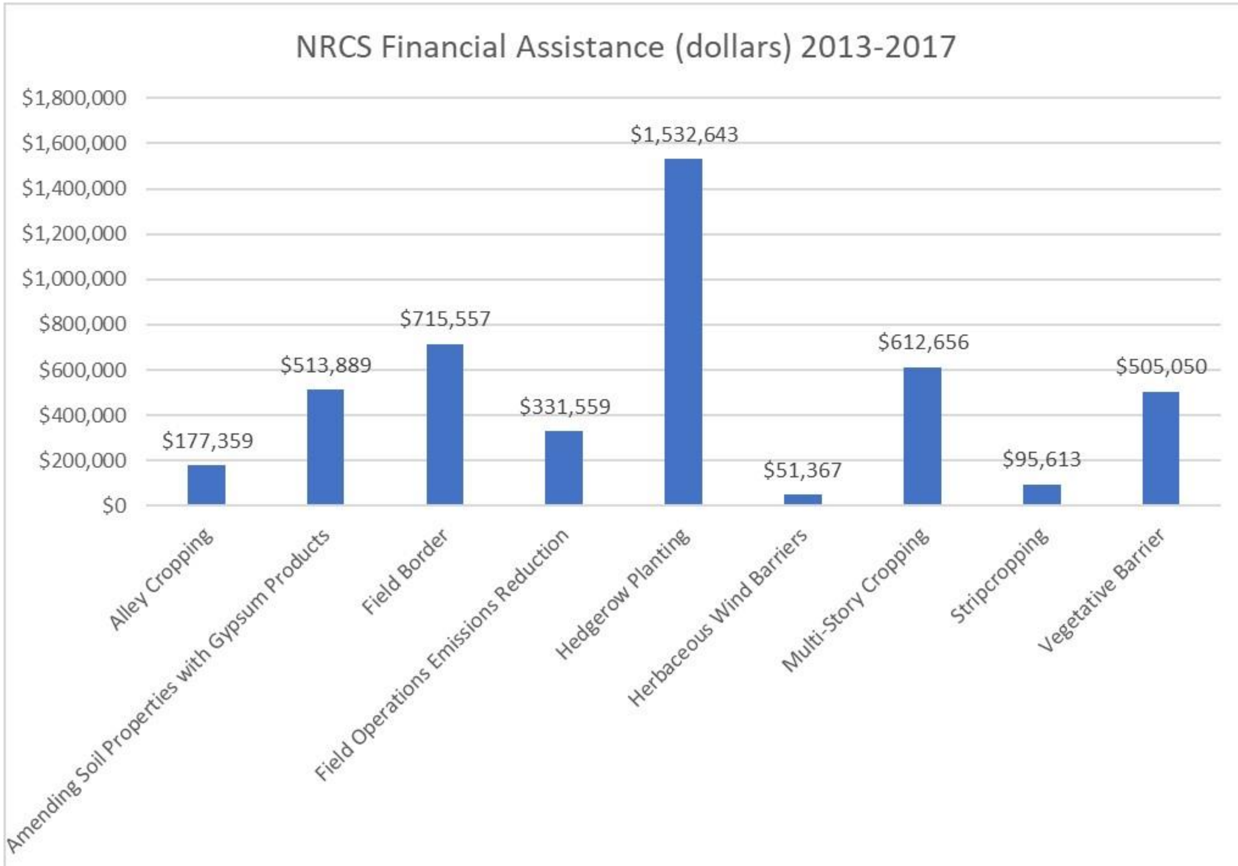

Figure 6-4. NRCS Financial assistance dollars spent on practices used to address wind erosion on cropland.

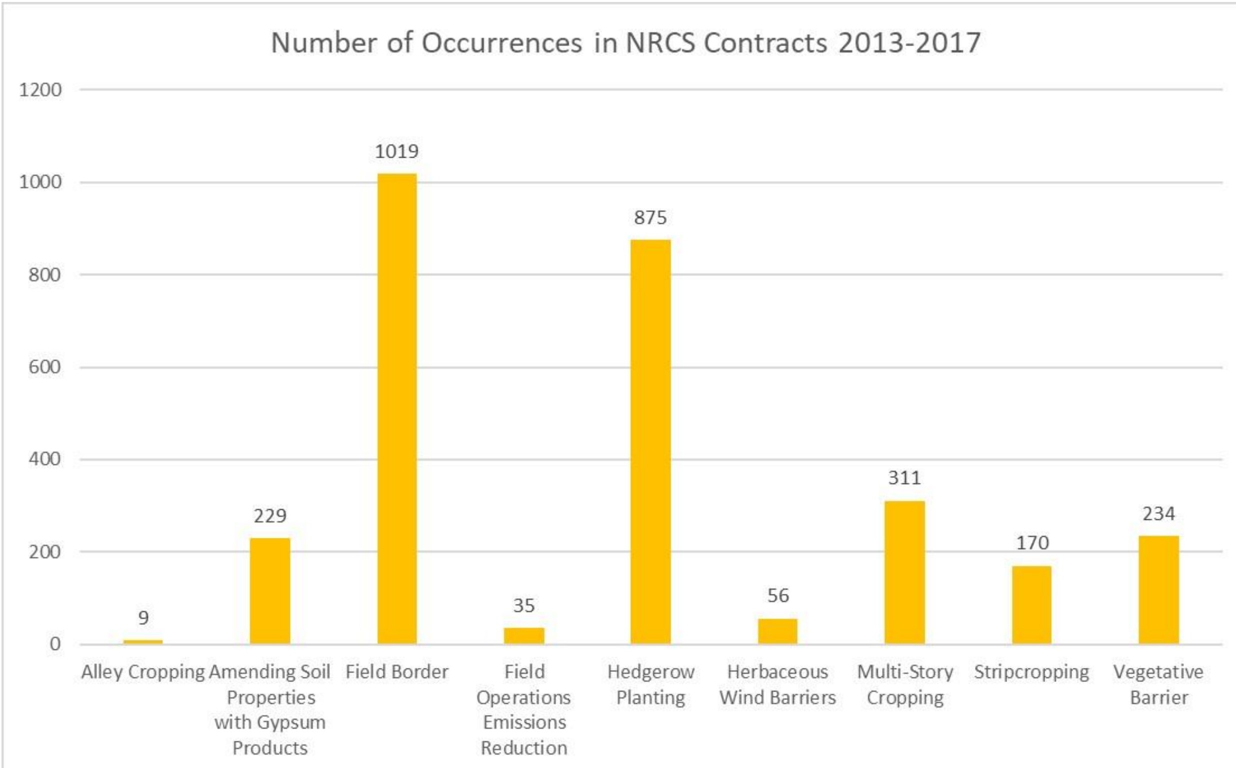

Figure 6-5. Occurrences in NRCS contracts of conservation practices used to address wind erosion on cropland.

Clearly, Cover Crop is by far the most utilized practice for controlling wind erosion, both in dollars spent, as well as number of occurrences in contracts. No-Till Residue Management and Conservation Crop Rotation come next, bearing in mind that these top three practices satisfy solutions to multiple resource concerns. Mulching, though, is more popular, as it occurs in contracts more often than does Conservation Crop Rotation and No-Till Residue Management. Investment in No-Till Residue Management more than doubles that of other Reduced Tillage Residue Management, indicative of NRCS's successful marketing of that practice as well as its acceptance by farmers.

Interestingly, several practices were not implemented through NRCS financial assistance programs throughout the five-year span: Cross Wind Ridges, Cross Wind Trap Strips, and Surface Roughening. Additionally, the diminutive application of Herbaceous Wind Barriers and Stripcropping is worth noting. Farmers may prefer to invest in practices that offer solutions to multiple resource concerns, rather than apply practices that primarily address only wind erosion. However, one might conjecture that farmers that do not practice no-till or cover crops would have an interest in some of these soil saving wind erosion practices.

For graphs of each State's implementation of wind erosion practices on cropland, please see Appendix B, Exhibit 6-1.

Conservation Practices for Wind Erosion Abatement on Cropland

Conservation Crop Rotation – 328

A conservation crop rotation is a planned sequence of at least two different crops grown on the same ground over a period of time. It is a fundamental agronomic practice that reaps a long list of benefits, of which many have been recognized for centuries. Simply put, actively growing crops limit wind erosion because wind velocities at the soil surface are kept below the thresholds that cause creep and saltation. Crop rotation can be considered the umbrella practice that numerous others build from, such as Cover Crops (340), Residue Management (329, 345), Nutrient Management (590), and Integrated Pest Management (595). The chief benefit is marked increase in production, making it relatively acceptable to most farmers. For example, a thirty-year study conducted at Penn State[54] evaluated continuous corn versus short-term and long-term corn rotations. Corn/Soybean outperformed continuous corn, and corn in rotation with two-year and three-year alfalfa cycles outperformed corn/soybeans.

Figure 6-6. Conservation Crop Rotation (328) frequently consists of a row crop, a small grain, and a cover crop rotated over a farm's acres, as seen here with corn, wheat, and oats. Photo: Jeffery Hemenway, USDA NRCS, Beresford, SD.

NRCS utilizes the Soil Conditioning Index (SCI) to evaluate the adequacy of the crop rotation. The SCI is embedded in all NRCS erosion prediction tools, including the Wind Erosion Prediction System (WEPS), Water Erosion Prediction Project (WEPP), Revised Universal Soil Loss Equation -2 (RUSLE2), and the Integrated Erosion Tool (IET). The SCI rates an individual Conservation Cropping Rotation based on the system's effects realized from tillage, residue use, and added mulches. The rating is based on three subfactors - organic matter buildup or depletion, tillage effects to residues and compaction, and predicted erosion rates. A positive rating indicates that the employed system is building organic matter in the soil, sequestering carbon, and is a sustainable long-term cropping system. A negative rating would indicate the system is depleting organic matter and would have some long-term production limitations. For more information on the SCI, see Appendix B, Exhibit 6-2.

However, there are certain areas across the country where mono-cultures are practiced. In arid and semi-arid regions where dryland farming exists, soil moisture is such a critical limiting factor that growing anything but drought tolerant grains is highly risky. If the plant residues are properly managed, this is an acceptable cropping system. In much of the West, development value of land exceeds the farming value of the land. Where this occurs, investor speculation prompt landowners to rent farmland out to the highest bidders on short-term leases, while the investor can maintain the lower agricultural property taxes. Farmers leasing these lands are apt to farm the most profitable cash crop prevalent in the area rather than invest in soil building crops, not knowing when they may lose the lease. In these cases, the same crop may be grown year after year, reducing the profitability of the land and negatively impacting soil health. These lands can be high risk areas for wind erosion.

Nearly all crop rotations will have some value to the soil health, structure, or fertility, and even the simplest two-crop rotations will return fewer greenhouse gases to the atmosphere than monocultures.[55] However, most rotations are designed around either improving soil fertility or organic matter content in the soil, or both. Legumes, such as alfalfa, clover, vetch, peas, and beans, improve soil fertility through their ability to fix nitrogen in the soil to render it readily available for the next crop. This reduces the need to buy nitrogen fertilizer, a key macro-nutrient for all plant growth. High biomass crops, needed to improve organic matter in the soil and general soil health, are typically grasses and grain crops, such as wheat, barley, oats, sorghum, and rye. This organic matter is critical in developing a soil that is resistant to wind erosion. Additionally, high biomass rotations will sequester carbon and reduce greenhouse gas emissions responsible for climate change.

With farmers facing the impacts of climate change nation-wide, it is becoming clear to many growers that, in selecting the right crop rotation, “business as usual” can be fraught with peril. Across the West, many surface water supplies in rivers and reservoirs are diminishing. In the West, water rights often exceed water availability in many areas. Compounding the water shortage problem, some key groundwater aquifers are depleting, causing wells to become less productive. Farmers are making difficult decisions to maintain their production system viability, for example, whether to invest in expensive improvements to their wells, or in higher efficiency irrigation systems. Beyond that, they should be considering changes to their crop rotations that reduce their dependency on water, build more resiliency to wind and water erosion, and improve infiltration rates so that water from high-intensity rainfall can be more readily absorbed into the soil.

Double-cropping, sometimes also called multi-cropping, is a system where two harvested crops are produced during the growing season. This is most easily accomplished in the southern parts of the country where the growing season is long enough to accommodate two crops, and usually involves the growing of a cool season grain crop. Double-cropping is made easier when coupled with a version of reduced tillage to shorten preparation times between both crops. Double-cropping is an excellent way to reduce wind erosion. Fields are covered with a growing crop most of the year, and the time when fields are most vulnerable between crops is shortened because the farmer is pressed to meet planting windows for optimum yields.

Alfalfa is excellent at building soil health and improving infiltration rates and soil fertility, but it also has a high water requirement. In areas where water supplies are not dependable, crop rotation considerations should include warm and cool season crops that fix nitrogen, have high biomass potential per unit of water, and - when water suddenly becomes unavailable - plant residues that are sufficient to keep the soil in place for an extended period of time. Producers should consult agronomic professionals to determine which crops are feasible alternatives for their specific area.

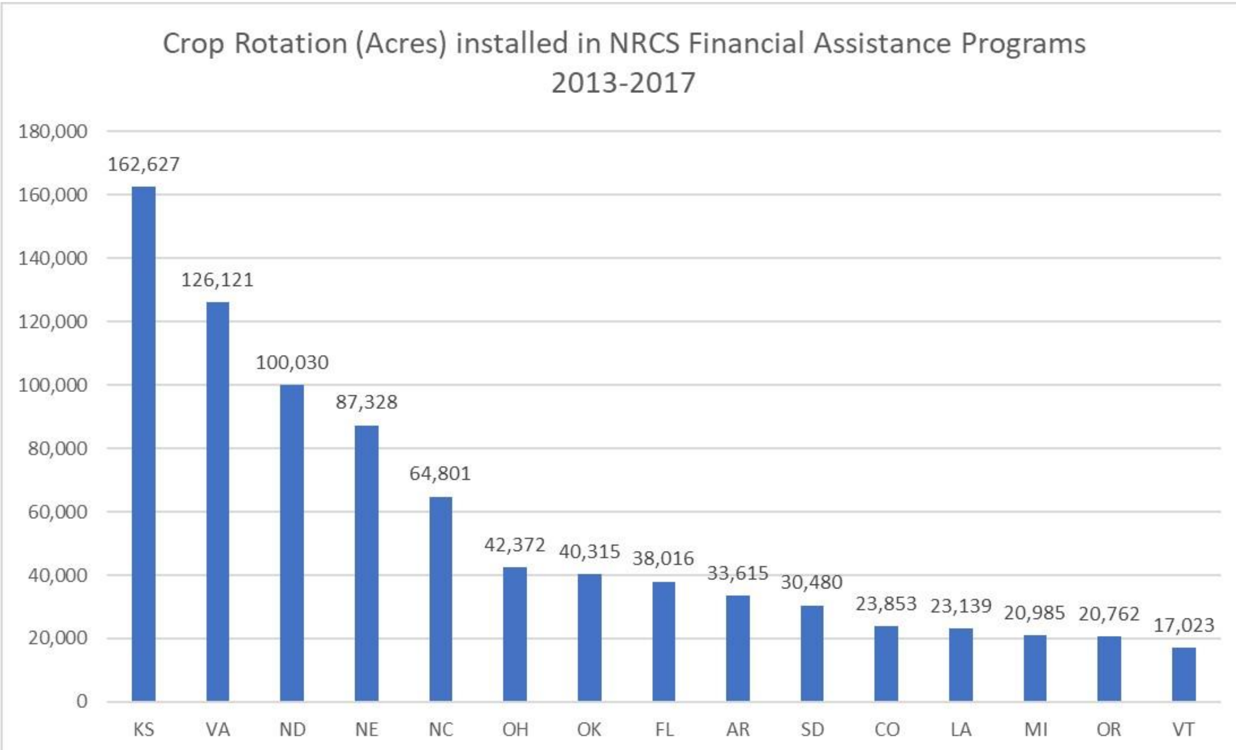

Figure 6-7. NRCS program accomplishments for installing Crop Rotation (328) during 2013-2017 - top 15 states (by acres).

Residue and Tillage Management, No Till – 329, and Residue and Tillage Management, Reduced Till – 345

These practices are highly effective in controlling wind erosion. Where significant crop residues are left on the soil surface, the creep and saltation processes of wind erosion are vastly reduced. Additionally, these residue management systems improve organic matter content in the first six inches of soil. The soil macro and micro-fauna break this organic matter down to humus, which is the "glue" that holds soil particles together in stable aggregates that resist dislodging by the forces of wind. Residues on the surface also moderate soil temperature and conserve soil moisture that contribute to sustainable and resilient farm fields.

Figure 6-8. Residue Management, No-Till (329). Direct seeding into prior crop's residue, with fertilizer application. Photo: Eric Barsness, USDA NRCS South Dakota, June 2013.

Over the last few decades, numerous variations of conservation tillage equipment were developed. Hence, NRCS naming conventions for the various systems had also changed. In the "farm ugly" days of the 1970's and 1980's, no-till systems were being marketed and encouraged as alternatives to the moldboard plow and other conventional tillage systems. Most of the early no-till systems involved direct seeding into the previous crop's residue. As a result, it was typically easy to tell when a farmer was utilizing a no-till system or conventional tillage. Any system that used variations of conventional tillage that left appreciable amounts of residues on the surface was simply referred to as "minimum tillage." As time went on, tillage systems became more complex, with many variants leaving almost as much residues on the surface as no-till. NRCS kept up with these advancements and established practice codes and definitions for mulch till, ridge till, and strip till, while still recognizing no-till and other minimum till systems. Tillage systems have continued to evolve, and differentiating between the systems has become increasingly difficult. Thus, NRCS recently established only two practice codes. No-till (329) accounts for all direct-seeding systems into the previous crop's residues and all strip till systems that have a Soil Tillage Intensity Rating (STIR) no greater than 20. Reduced Till (345) accounts for all systems, including mulch, ridge, and conventional, that reduce traffic in the field and have a STIR no greater than 80. Reduced Till is also sometimes referred to as "conservation tillage."

Figure 6-9. Residue and Tillage Management, No Till (329). Iowa farmer Doug Seltz inspects his Spring strip-till as he prepares for soybean planting into the corn residues. Strip-till is considered no-till since only the seed row is disturbed. Photo: USDA NRCS, Clare Iowa, Spring 2009.

Although amounts of residues are not specifically detailed in the practice criteria, no-till generally leaves about 60 to 70 percent of the soil surface covered by residue, while reduced till leaves no less than 30 percent of the surface covered. By definition, neither No-till nor Reduced Till can utilize residue inversion, such as a plow. The STIR is calculated within the erosion modeling software currently employed by NRCS, including the WEPS and the WEPP. STIR values can also be calculated using the Revised Universal Soil Loss Equation, a system currently being phased out of NRCS.

Figure 6-10. Residue and Tillage Management, Reduced Till (345). This field meets the practice standard since no inversion tillage was used and the STIR value was less than 80. Photo: Beverly Mosely USDA NRCS, Jan. 2014, Cochise County, AZ.

Advantages of no-till and reduced-till systems are profound, especially in the context of variable and changing weather and climate conditions. A major advantage of No-till and Reduced Till is the vastly reduced energy inputs needed to prepare the land from one crop to the next. With slim margins for agricultural commodities and unstable energy prices, it behooves the farmer to consider tillage systems that cost less to implement. The 2017 Census of Agriculture, released by the National Agricultural Statistics Service in April 2019, estimated that 37% of America's tillable cropland were utilizing no-till systems, and another 35% of American farmland is reported to be utilizing some form of reduced tillage.[56] This means that approximately 72% of U.S. farmland is under no-till or reduced-till. This is an increase from the estimated 62% of farmland under no-till or reduced till reported in the 2012 Census of Agriculture.[57] Naturally, adoption is varied by region and crop; Figure 6-11 summarizes the Economic Research Service's study on adoption of no-till by crop.

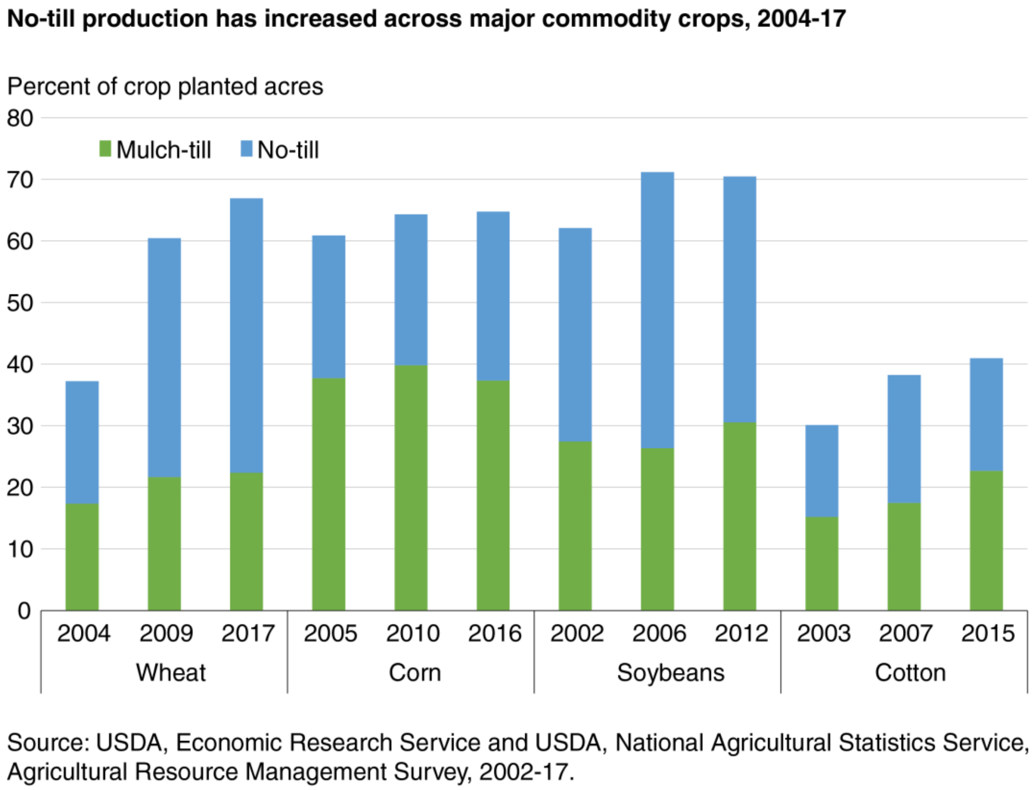

Figure 6-11. Adoption of conservation tillage on four major crops.[58] Mulch till refers to some tillage activity with a Soil Tillage Intensity Rating (STIR) is less than or equal to 80 (for the entire season).[59]

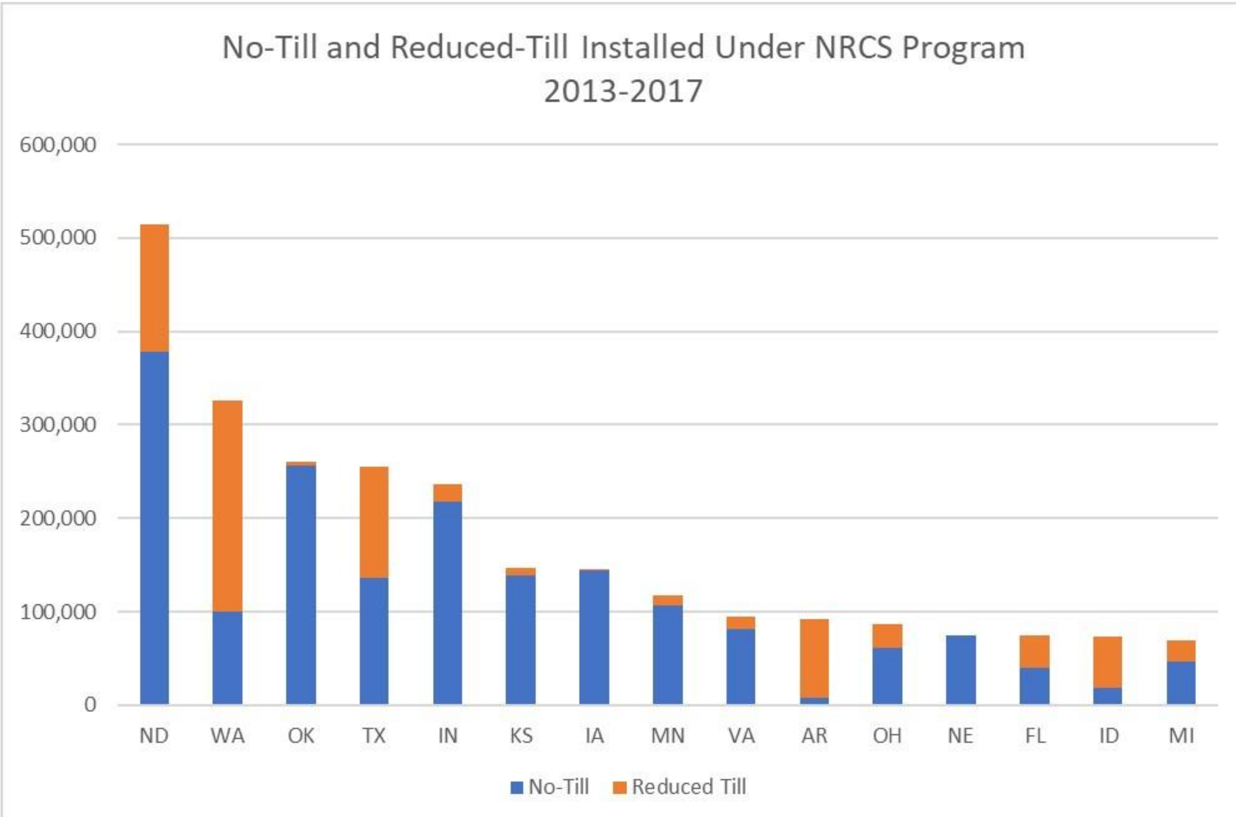

Figure 6-12. Top 15 States (by acres installed) installing Residue Management Practices during 2013-2017.

Adoption of No-till and Reduced Till is hampered in some regions of the country by the production systems used and food safety concerns. In those areas where surface irrigation is prominent, early adopters admit a steep learning curve when dealing with large amounts of crop residue on the soil surface. Furrows tend to clog with debris leading to bed failure and some rows receiving too much water and leaving other rows dry. Additionally, after several years of reduced till, the infiltration rate increases, and irrigators find it difficult to get the water down the complete furrow. Farmers in turn need to adjust set sizes, set times and flow rates to accomplish efficient irrigation. This can take years of tinkering before adequate solutions are discovered. Another option is to convert the irrigation system to level basins and plant on the flat or convert to sprinkler or drip irrigation. Leased land can compound this dilemma, as each field will respond differently based on soils and other conditions. Farmers do not want to spend time or money "figuring it out."

Also, in intense food production systems that include vegetables and fruits, industry standards are calling for clean till systems out of concern for food safety. Where residues are present, wildlife are attracted to the fields, which raises concern for contamination by E. coli and other pathogens. These are high dollar food production systems where contamination of one field can cost the grower millions of dollars.

Cover Crops – 340

Cover Crops are an extremely effective means of controlling wind erosion during otherwise fallow portions of a cropping rotation. In fact, cover crops are gaining popularity as a routine component of the cropping system. Cover crops also play a role in improving organic matter content, managing soil and temperature, suppressing weed growth, providing nutrient enrichment (where leguminous cover crops are used), interrupting plant pest cycles, mitigating soil compaction, and providing cover and food for wildlife. Their value to natural resource conservation cannot be understated.

Figure 6-13. Cover Crop (340). Besides soil health benefits, cover crops can also benefit wildlife, as seen with this cover crop of buckwheat, lentils, sunflower and Canamaize. Photo: USDA NRCS, Fergus County, MT. July 2012.

Figure 6-14. Cover Crop (340). Leguminous cover crops are beneficial for orchard crops as seen here with clover planted between rows of almond trees. Photo: USDA NRCS, California, October 2011.

Figure 6-15. Cover Crop (340). No Till planting into a terminated cover crop. Photo: Lance Cheung, USDA NRCS, Laytonsville, MD, March 2015.

Cover crops are the most popular erosion control practice in NRCS programs, both in number of contract line items as well as dollars expended. Programmatically, implementation of Cover Crops incentivizes the farmer to examine the benefits of the practice with little financial risk. However, the USDA Economic Research Service has estimated that only 2% of the nation's cropland utilizes cover crops. This low number may reflect producer reluctance based on unfamiliarity with the practice, its economics, shortened windows for the cash crop, and lack of equipment to properly handle green manure crops or heavy residues. Also, in semi-arid, dryland farming areas, soil moisture depletion by a cover crop has been shown to be detrimental to the subsequent cash crop's yield.[60] In irrigated areas, the cost of irrigation water to grow a crop that will not be harvested can also be a concern. To assist in determining whether a cover crop can be supported economically, an Excel-based Cover Crop Economics Tool[61] has been developed. The NRCS webpage for the tool[62] also features a video demonstrating the tool's use; a fact sheet explaining the tool is included in Appendix B, Exhibit 6-3 of this handbook.

Figure 6-16. Farmer Levi Lyle of Keokuk County, Iowa demonstrates his crimper implement used to terminate his cover crops. Photo: Jason Johnson, USDA NRCS, March 2017.

Figure 6-17. Here Levi crimps his cereal rye cover crop and plants soybeans directly in the matted cover crop. Photo: Jason Johnson, USDA NRCS, March 2017.

Figure 6-18. Three weeks later the soybeans emerge through the cover crop residue. Photo: Jason Johnson, USDA NRCS, March 2017.

Because growing a cover crop in low rainfall, dryland farming areas can negatively impact yield of the cash crop, the USDA Risk Management Agency (RMA) has established rules for planting cover crops in fallow periods when insuring the cash crop. It is critical to understand these rules in order to not jeopardize crop insurance payouts. General information can be found on the RMA's website under 2020 Cover Crops Insurance and NRCS Cover Crop Termination

Guidelines[63] and also under the topic Cover Crops,[64] but farmers should consult their local NRCS, RMA, or Cooperative Extension agent to understand how best to incorporate cover crops into their crop rotation.

Cover crops are not typically harvested, and where increasing organic matter in the soils is a concern, they are not grazed or baled for hay. Some USDA programs restrict these activities; again, producers should contact their local NRCS, FSA, RMA or Cooperative Extension agent to understand what options are available in a given area.

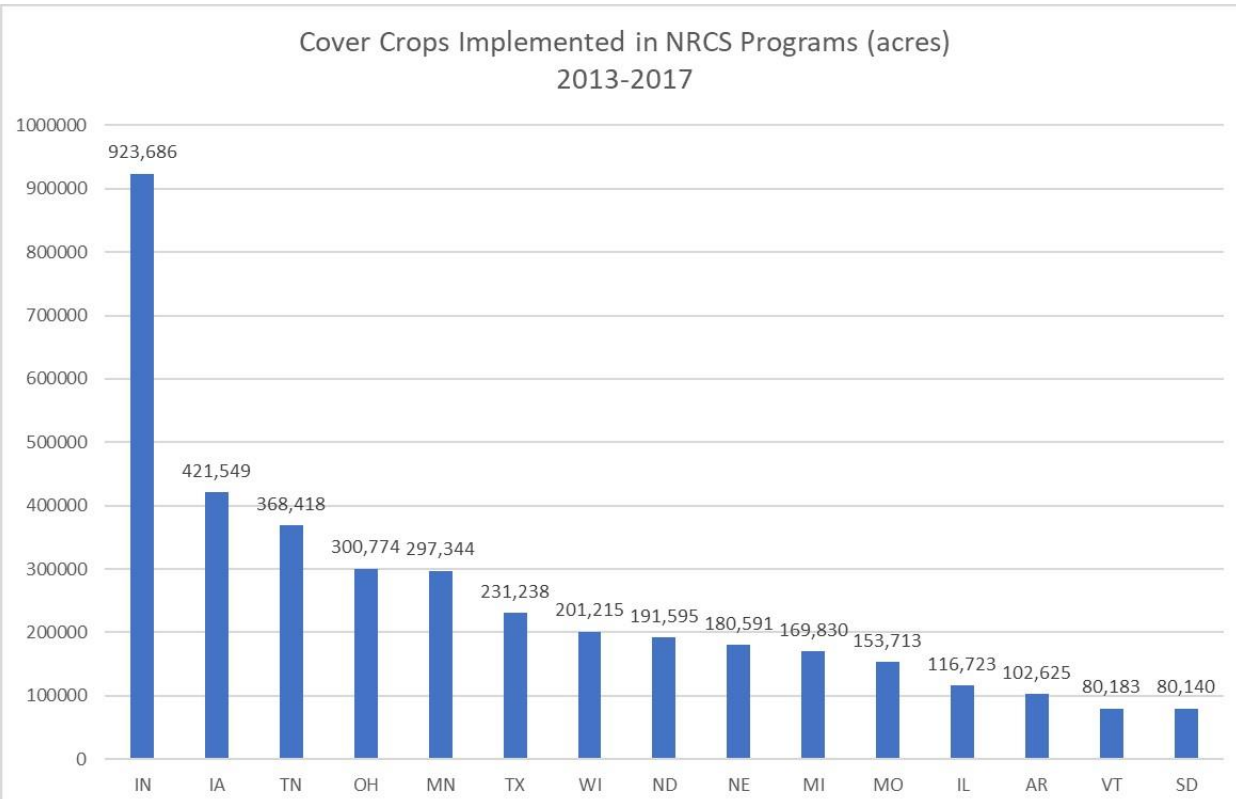

Figure 6-19. NRCS program accomplishments for installing Cover Crops (340) during 2013-2017.

Selecting the right cover crop or cover crop mix for your operation can be confusing, as the choices are many. First one must decide which are the priority resource concerns that need addressed- lack of soil organic matter, soil fertility, compaction, lack of pollinators in area, etc. And then, which fallow period in their crop rotation would be most beneficial to address the specific needs, and appropriately select warm or cool season cover crops. If soil salinity is a concern, select cover crops that are salt tolerant. If soil moisture or irrigation requirement is a concern, select low water users. If broadleaf weeds are a concern, select grasses so that broadleaf herbicides can concurrently be utilized. Many crops can also express an allelopathy to the following crop. For instance- corn, wheat, barley, peas, canola, and many other crops, may not do well when planted into sunflower residue. For all of the above reasons, cover crop specialists have developed tools to assist the farmer in selecting the right cover crop to meet the needs. USDA Agricultural Research Service (ARS) developed the Cover Crop Chart,[65] with internal links for specific cover crop attributes, included here as Appendix B, Exhibit 6-4. The NRCS in the Pacific Northwest developed an Access® database,[66] called the Pacific Northwest Cover Crop Selection Tool,[67] to walk a farmer through the decision-making process. And the NRCS Plant Materials Program developed *A Comprehensive Guide to Cover Crop Species Used in the Northeast United States* (Appendix B, Exhibit 6-5). Although some areas across the country do not have a tool developed expressly for that area, the information contained in these references is still helpful in that many of the crop characteristics described are valid anywhere.

In the Southwest, where water costs are relatively high, low water use winter grains are oftentimes planted as cover crops, such as one-irrigation barley and drought tolerant sorghum. The NRCS Plant Materials Center in Tucson, Arizona established a cultivar of one-irrigation barley called Seco Barley and released it for public use. Farmers will plant and irrigate once to establish the crop; if winter rains are favorable and a healthy stand is realized, they may take the crop to fruition and harvest the grain.

Windbreak/Shelterbelt Establishment – 380 and Windbreak/Shelterbelt Renovation – 650

Windbreaks and shelterbelts consist of trees and shrubs planted in single or multiple linear rows with the purposes of reducing leeward wind speeds, controlling snow drifts, and providing shelter for farmsteads, livestock and wildlife. Historically, shelterbelts were considered to be wide windbreaks with ten to twenty rows of trees and shrubs, while windbreaks were smaller one to three row systems primarily meant to control wind erosion on agricultural lands. Today, some still make that distinction that shelterbelts protect farmsteads, livestock facilities, and wildlife, while windbreaks are primarily for cropland protection. However, NRCS uses the terms interchangeably in most areas of the country.

Figure 6-20. This relatively new windbreak is protecting a stripcropped assortment of flowers. Photo: Lynn Betts, USDA NRCS, Michigan.

Windbreaks have long been considered a benefit to agricultural operations, via their ability to reduce wind speeds and control wind erosion, increase crop yields across protected fields, offer protection from blowing snow, serve as shelter for livestock from weather extremes, offer habitat for wildlife and pollinators, conserve soil moisture on fields by reducing evapotranspiration and sublimation of snowpack, and reduce energy needs around farmsteads. In the early 1900's, President Theodore Roosevelt was convinced by previous work of the USDA's Division of Forestry that tree reserves could be established on the Great Plains to offer timber resources to the developing area. He was also convinced that large-scale tree planting on the west edge of the Great Plains could affect higher precipitation to the eastern plains. By Executive Order in 1902, President Roosevelt subsequently created two forest reserves in the Sand Hills area of Nebraska, which at the time were mostly void of trees. These areas were later renamed the Nebraska National Forest, which to this day has the distinction of being the largest man-made forest in the United States.

The success centering around the Nebraska National Forest effort, and the establishment of several USDA forest nurseries capable of producing hundreds of thousands of tree seedlings annually, spawned President Franklin Roosevelt's idea of creating a 100-mile wide shelterbelt across the Great Plains to address the Dust Bowl of the mid-1930's. Although the 100-mile wide shelterbelt never came to fruition, Congress did enact the Cooperative Farm Forestry Act which paved the way for the Prairie States Forestry Project (PSFP). The PSFP was responsible for installing over 220 million trees between 1937 and 1942 in over 30,000 windbreaks that stretched from Texas to Canada. Many of these windbreaks still exist today, though a large percentage are in various states of disrepair.

Figure 6-21. This photograph shows the extent of field windbreaks in some parts of North Dakota. Photo: Erwin Cole, USDA NRCS.

Windbreaks installed during the PSFP proved their value, and efforts of the Soil Conservation Service brought windbreak technology to other wind erosion problem areas across the western United States during the 1940s and 1950's. However, since irrigation was required to maintain windbreaks in the arid west, these were not as robust as the oftentimes 20-row windbreaks installed under the PSFP. In fact, most irrigated windbreaks installed to this day in the west are single-rows of drought tolerant trees.

By the mid-70's, irrigation was becoming commonplace on the Great Plains and reduced tillage systems were keeping more residues on the surface, thereby feeding the perception that windbreaks were no longer needed. Additionally, windbreaks were not compatible with center pivots and larger farm equipment, and many of the older windbreaks were in dire need of renovation. Consequently, many farmers began removing their decades-old windbreaks and shelterbelts. In 1975, the General Accounting Office and the USDA submitted a report to Congress requesting action to discourage removal of shelterbelts in the Great Plains. The report acknowledged that irrigation and newer conservation tillage systems were very effective at controlling wind erosion, but also stated that during severe drought windbreaks may be the only source of protection against wind erosion. It recommended that a cost-sharing renovation program be created, along with an education program that emphasized all the benefits of windbreaks. Furthermore, the report requested a survey to assess the status of existing windbreaks.

In response to this request, Iowa State University was commissioned to study windbreak removals and installations over a five-year period. This effort, which took place from 1970-1975 and included a five-state sampling area (North Dakota, South Dakota, Nebraska, Kansas, and Oklahoma), revealed that more windbreaks were installed than removed, although South Dakota and Oklahoma saw a net reduction in windbreaks. Also noted was a trend away from wide windbreaks, as the total area under windbreaks decreased by 2 percent.

A more recent analysis[68] shows a nearly 50% decline in both number and feet of windbreaks installed from 2006 to 2012 under the NRCS financial assistance programs. Conversely, during the same period, a nearly 400% increase in the number and feet of windbreak renovations has occurred, again through NRCS financial assistance programs. Figure 6-22 shows the top 14 states in implementing Windbreaks (380) and Windbreak Renovation (650) from 2013 to 2017.

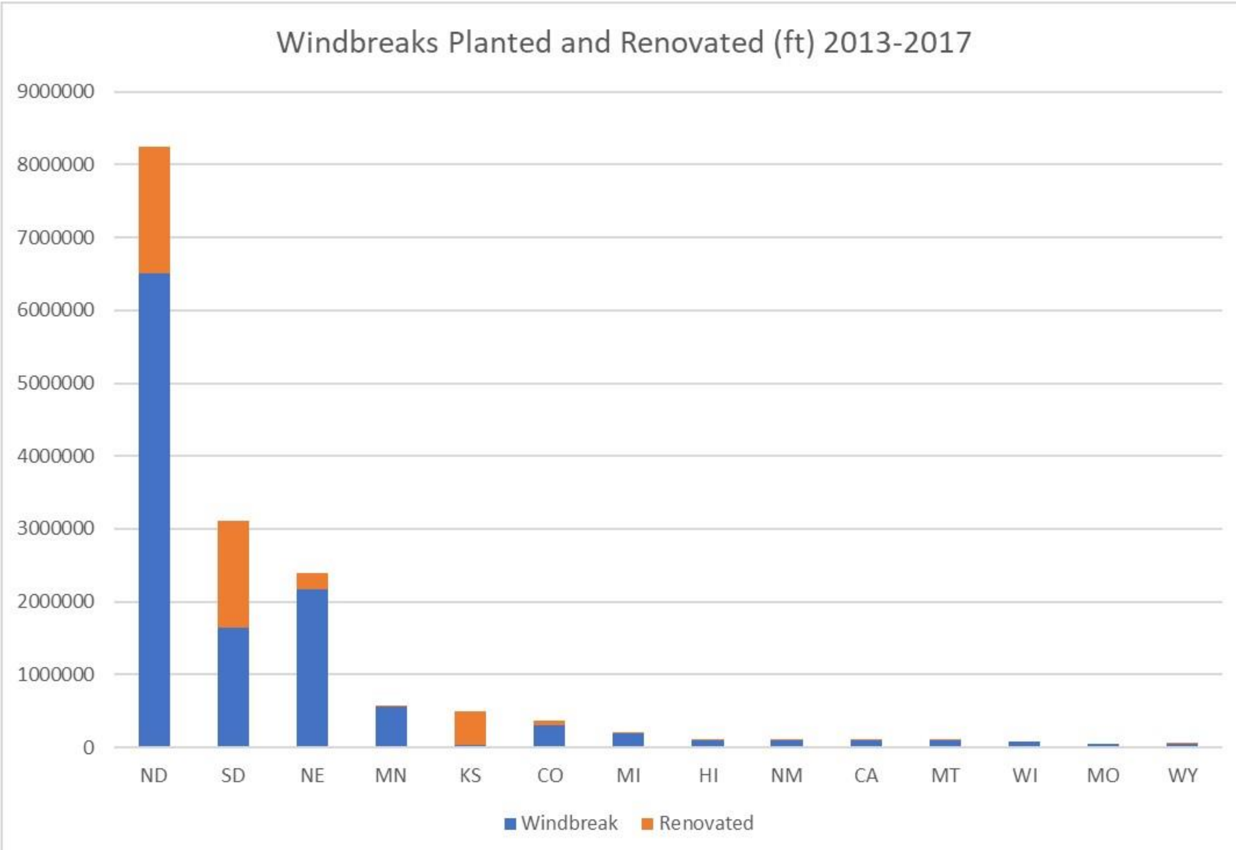

Figure 6-22. Top 14 states (by ft planted or renovated) implementing Windbreaks (380) and Windbreak Renovation (650) during 2013 to 2017.

The design of windbreaks is highly technical, and this may explain why some states, by a wide margin, install more windbreaks than others. A state's historical connection with windbreaks may offer continuing specialized training opportunities to foresters, arborists, and conservationists who develop and maintain the necessary expertise to carry out a robust and persistent windbreak program. The disparity between states could also be attributed to frequency of weather events that drive the need and desire for windbreaks.

Windbreaks will typically have multiple objectives that must be considered when developing the design and layout. The planner must thoroughly examine the landowner's intents and purposes, as these can inform subtle differences in design criteria. For example: are there concerns with crop protection, crop production and yields, wind erosion from a neighboring field, snow management, irrigation efficiency, water erosion, droughty soils, farmstead protection and energy use, protection of livestock loafing areas, aesthetics, screening of unsightly areas, maintenance requirements, noise reduction, wildlife habitat, salinity from salt application on adjacent roads, chemical drift, and/or carbon storage? The answers to these questions will determine tree/shrub selections, the number of rows and height of trees needed, density of plantings, the herbaceous component and management thereof, and orientation of the windbreak. Each state has developed a specification for design of windbreaks; North Dakota's is one of the most comprehensive and is included in this handbook as Appendix B, Exhibit 6-6.

Figure 6-23. Select the right tree for the intended use and consider all environmental conditions, including exposure to livestock and wildlife. Avoid trees that may be subject to herbivory, as seen by the girdling of this entire row of trees by horses. Photo: USDA NRCS, Montana.

Figure 6-24. Where tree planting isn't possible, consider artificial windbreaks. This fabricated windbreak shelters livestock and protects the heavy use area from wind erosion. Photo: USDA NRCS, Gallatin County, Montana, 2007.

Most states where windbreak installation is common have also developed Conservation Tree and Shrub Groups (CTSG, but sometimes referred to as Windbreak Suitability Groups, WSG) that assist in selecting trees that are compatible with varied soil and climate conditions. These references are generally found in each state's Field Office Technical Guide (FOTG).[69] Formats for these reports vary widely from state to state; samples of these tools are included in Appendix B for Kansas (Exhibit 6-7), Nebraska (Exhibit 6-8), and Colorado (Exhibit 6-9). It is imperative to know the soils types for the site to utilize these tools. They can be found online at Web Soil Survey[32] by selecting the area of interest in the online tool. Web Soil Survey typically will have the CTSG available under the "Suitabilities and Limitation for Use" tab listed under the "Land Classifications" section.

As a rule of thumb, windbreaks provide cropland protection from wind and erosion equal to a horizontal distance on the leeward side of the prevailing wind direction that is ten times the height of the tallest row in the windbreak. This can be highly variable, as it is based on the aerodynamics of the windbreak and heavily influenced by the porosity of the windbreak. Denser windbreaks tend to shelter a greater distance; however, excessively dense windbreaks create turbulence as the wind breaks over the top that can cause wind to be drawn down quicker. Regarding snow management, excessively dense windbreaks will cause large drifts leeward of the windbreak. Whereas, somewhat porous windbreaks will drop snow evenly over the field, thereby improving soil moisture management. For these reasons, a multiple-use windbreak will generally be designed with a density of 60 to 80 percent (porosity of 20 to 40 percent).

In the West where single-row windbreaks are commonplace, tree spacing and tree selection can result in a relatively porous windbreak that gives protection at much less than 10 times the height of the trees. Single-row windbreak's greatest disadvantage can be attributed to the dichotomy of aesthetics versus functionality. The tendency is to select drought tolerant trees that grow tall, but as these trees mature, the lower limbs either die off naturally or develop a ragged, sparse appearance. If the objective is to reduce crop damage originating from erosion on an adjacent field, the farmer may be better served by selecting a low-growing tree that maintains its low-level density over its lifetime.

Generally, when looking at whole-field yields, windbreaks do improve average yields, and there have been many site-specific, tree-specific, and crop-specific studies that validate this.[70,71] However, many studies will show decreased yields directly adjacent to the windbreak up to twice the tree height. This is due to shading and competition for water and nutrients. The yields gradually increase up to the protected distance, where yields will begin to diminish. To maintain reasonable yields adjacent to the windbreak, root pruning is generally completed every 5 to 10 years, but may require more frequent intervals depending on tree root growth.

As windbreaks age, normal annual maintenance should be expected to sustain the objectives and preserve aesthetics. This might include mowing the interspaces between rows, eradicating noxious or invasive weeds, reseeding pollinator beneficials, servicing irrigation equipment (if irrigated), and light pruning. However, major renovation of the windbreaks should be expected to be completed on 15-year cycles. The NRCS has developed a practice standard for Windbreak Renovation, and the practice is eligible for financial assistance in most states for NRCS's financial assistance programs. Recognizing the value and legacy of windbreaks, many states have developed their own renovation programs available through their natural resources agencies or conservation districts.

Figure 6-25. Windbreak Renovation (650) includes removal of decadent tree rows and replacing with a new row or simply adding new rows to an existing windbreak. Seen here with irrigation. Photo: USDA NRCS, South Dakota.

Windbreak renovation consists of any single or combination of the following techniques: sod release (disrupting dense sod growth around trees with shallow cultivation), supplemental planting (adding new rows or replacing dead trees), coppicing (cutting shrubs and trees near ground level to encourage new growth), pruning, thinning of woody plants, row removal (generally older rows with many dead or decadent trees), and root pruning. Each state has developed a specification for more detailed guidance on each technique; North Dakota NRCS has developed an excellent example which is included in this handbook as Appendix B, Exhibit 6-10. Windbreak renovation can be very technical, and it is advised to solicit expert instruction from a local NRCS office, Cooperative Extension, Conservation District, or state forestry agency. Renovation of an existing windbreak can easily be more expensive than the original establishment, depending on the techniques needed.

Figure 6-26. Coppicing is a renovation technique whereby shrubs are sheared off near ground level. Photo: Craig Stange, USDA NRCS, Bismarck, ND, 2003.

Figure 6-27. Coppicing encourages vigorous new growth, as seen in these photos with red dogwood before (Figs. 6-26 and 6-27) and after coppicing (Fig. 6-28). Photo: Craig Stange, USDA NRCS, Bismarck, ND, 2003.

Figure 6-28. These dogwood were coppiced in March, and had 6 foot of growth by August in a dry year. Photo: Craig Stange, USDA NRCS, Bismarck, ND, 2003.

Hedgerow Planting – 422

Hedgerows and windbreaks function similarly and have many of the same purposes and benefits. Like windbreaks, hedgerows can intercept airborne particulates, reduce chemical drift and odors, screen and provide barriers to noise and dust, provide food and cover for wildlife, provide pollen, nectar and nesting habitat for pollinators, provide substrate for beneficial invertebrates, and provide boundary delineation. Hedgerows differ from windbreaks in that they are narrower and shorter, and thus do not provide as much lateral protection from erosive winds. However, they can be very effective at intercepting aeolian sediment from adjacent fields. They are typically denser than windbreaks and can serve as a living fence, particularly when thorny shrubs are included in the species mix. They can be effective at excluding livestock and ungulate wildlife from sensitive areas. By NRCS standard, hedgerows must have a minimum mature width of 15 feet. From a historical context, hedgerows were often used a source of fuel wood due to their short stature and relatively rapid regrowth. Conventional heating of rural farmsteads has reduced hedgerow use for this purpose.

Figure 6-29. Hedgerow Planting (422). Golden Currant makes an excellent hedgerow for controlling wind erosion on small fields. The plant is highly adaptable to much of the United States and Canada, attracts wildlife as browse for ungulates and for the berries, and the berries are used to make jams and jellies. Photo: USDA-NRCS PLANTS Database / Herman, D.E., et al. 1996. North Dakota tree handbook. USDA NRCS ND State Soil Conservation Committee; NDSU Extension and Western Area Power Administration, Bismarck.

Figure 6-30. Hedgerow Planting (422). This willow hedgerow suffered heavy damage from browsing elk. Like windbreaks, plant selection is critical to success of the intended purpose. Photo: Gary Kramer, Colorado, July 2001.

Hedgerows are widely utilized across the country. Thirty-three states and U.S. territories reported programmatic use of Hedgerows (422) during the years 2013 to 2017. Figure 6-31 shows the top 15 states and territories in implementing the Hedgerow Planting practice.

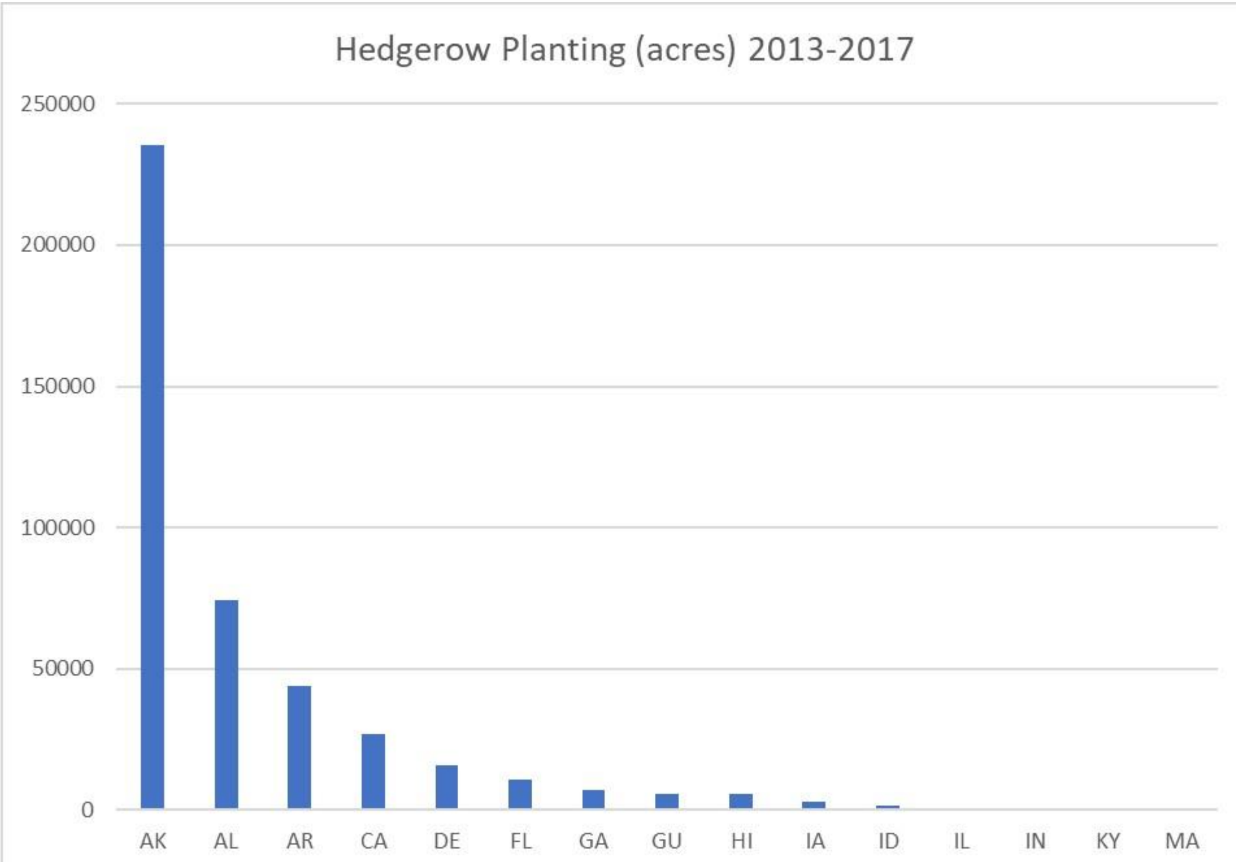

Figure 6-31. Top 15 states and U.S. territories (by acres) implementing Hedgerow Planting (422) during 2013-2017.

Mulching – 484

Mulching is the act of applying plant residues, compost, composted manures, wood chips, and other suitable materials to the land surface. Mulching (484) can be implemented on all land uses, although cropland is the predominant land use. This practice can be applied when associated to Critical Area Planting (342) to stabilize and restore vegetation after catastrophic fire, flooding or extreme erosion activity. More recently, this practice has been evaluated for its efficacy in controlling wind erosion and restoring severely degraded rangeland, as it performs similarly to crop residues left on the field. However, depending on the composition of the mulch, it too can be subject to blowing. Therefore, in non-cropland scenarios, mulches are commonly applied in combination with a tackifier, netting, or some other anchoring mechanism to keep the mulch in place. Hydromulchers and strawblowers are commonly used to distribute mulch in non-cropland land uses. Hydromulchers can distribute seed, fertilizer, mulch, tackifier and water in a single operation. The largest models can discharge the slurry up to 300 feet; strawblowers can distribute straw anywhere between 40 to 120 feet.

In cropland situations, fine fiber mulches are subject to blowing as well, which is why most fine fiber mulches are incorporated into the soil to some degree. This would include organic mulches and composted manure. In these cases, soil health and fertility may be the primary concern, with wind erosion abatement being a secondary benefit. The secret to organic mulches in controlling wind erosion is directly related to the soil-binding capability of decomposed organic matter- called humus. Humus is the glue that holds soil particles together, building soil structure responsible for the macro and micro pores that hold water and nutrients. These aggregated soils are more resistant to saltating soil particles.

Organic mulches can consist of a variety of plant-derived materials, including leaves, grass clippings, straw, tree clippings, bark, sawdust, seaweed, and the like. "Certified" organic mulch is guaranteed not to include products exposed to pesticides, inorganic commercial fertilizers, or other man-made chemicals. Certified organic mulch is highly sought by USDA certified organic producers. Almost all organic mulches generally include some type of animal manure that supplies nitrogen to the mix. The nitrogen is needed to feed the microorganisms that break the plant materials down to humus and useable nutrients. When manure is used as mulch, or as a component of the mulch mix, application rates should be in accordance with a nutrient management plan. The nutrient management plan will ensure nutrient levels do not exceed plant needs and be susceptible to leaching or runoff.

Figure 6-32. Mulching (484). Application of barnyard manure or composted manure is an example of mulching which should be done in conjunction with a nutrient management plan. Photo: USDA NRCS, South Dakota, 2007.

Woody materials have a high carbon to nitrogen ratio (C:N); thus, they break down slowly. An ideal C:N ratio for agricultural mulch or compost is 25 to 30:1. Mulches with higher ratios will take longer to break down, and soil microbes will then consume other plant-available nitrogen. This may cause a slowdown in crop growth due to nitrogen deficiency. Mulches with lower C:N ratios are quickly consumed by microorganisms, resulting in surplus nitrogen that can actually be counterproductive to healthy plant growth or simply be lost through volatilization or leaching beyond the root zone.

Large fiber mulches such as straw and wood chips are often used in orchard and vineyard alleys, as well as livestock loafing and bedding areas. They are effective in controlling wind erosion and keeping dust down when used in this capacity. They are less likely to blow away when left on the surface, but the land owner should be aware that they can float away in heavy rainfall, and should guard against drainages being blocked or plugged. Large fiber materials have a high carbon to nitrogen ratio and, if ever incorporated into the soil, a period of low nitrogen availability for crop growth may be realized.

Inorganic mulches include man-made materials (plastic sheeting, polypropylene sheeting, geotextiles, rubber, rock, gravel), and the conservation practice standard permits the use of inorganic mulches. Sheet mulches are used to control wind erosion and dust emissions when planting/growing specialty crops, human consumables, and windbreak establishment. Sheet mulches conserve soil moisture, protect seedlings from damaging wind erosion events, reduce weed competition, reduce dust deposition on vegetables, warm the soil faster, and provide a longer growing season, among other agronomic benefits. These benefits are particularly realized when planting windbreaks. Woven polypropylene sheeting is becoming the mulch of choice for windbreak planting due to its longevity, permeability and ruggedness.

Figure 6-33. Mulching (484). Woven polypropylene sheeting is becoming the mulch of choice for windbreak establishment due to its permeability, durability and longevity. Photo: Larry McBride, USDA NRCS, North Dakota.

Figure 6-34 below shows the top 15 states in implementing the Mulching practice through the NRCS Environmental Quality Incentives Program (EQIP) program; there appears to be a significant association of this practice with windbreaks, when compared to the windbreak planting and renovation statistics shown in Figure 6-22.

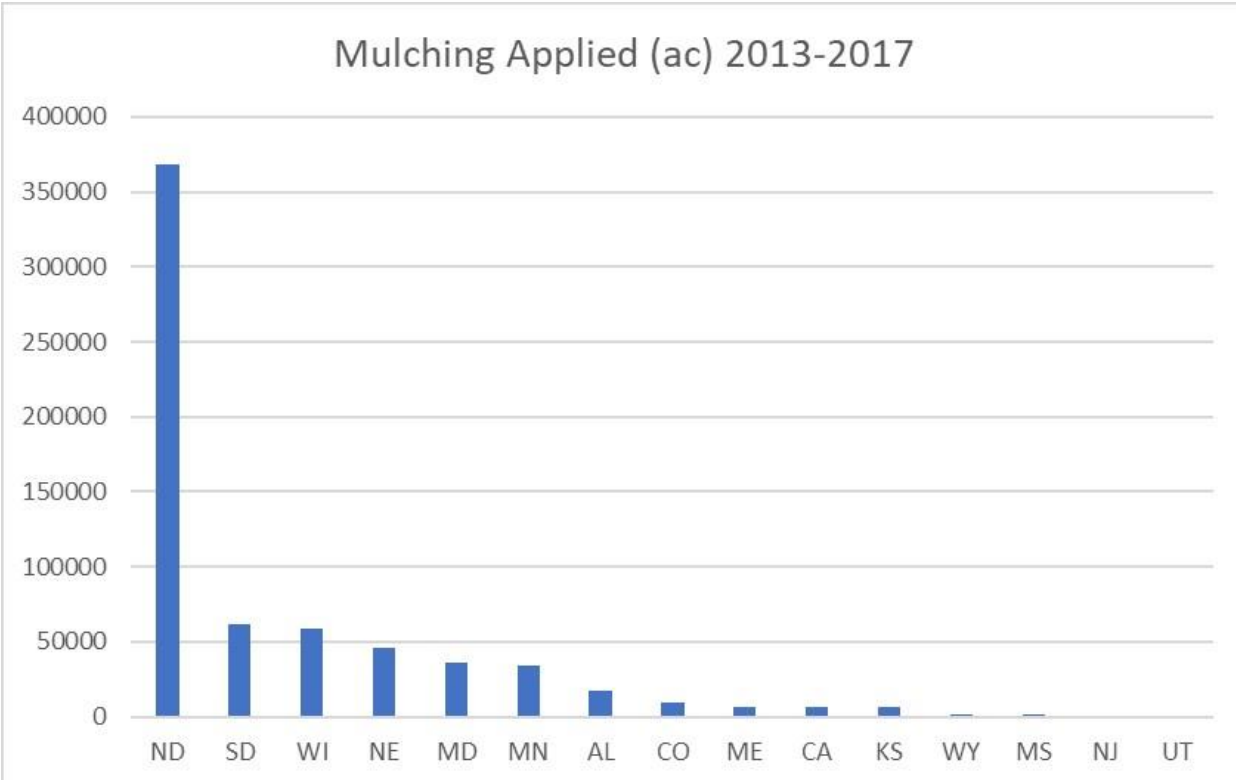

Figure 6-34. Top 15 states (by acres) implementing Mulching (484) during 2013-2017.

Conservation Cover – 327

This practice is used to provide permanent vegetative cover to areas that would otherwise be exposed to erosion. The practice is designed to have a 5-year lifespan, and only minimal harvesting of any vegetative matter is permitted (only to the amount that the purpose is not compromised), unlike Cover Crop which is seasonal and allows harvest for livestock forage. Typically, Conservation Cover (327) is utilized in pivot corners or other associated agricultural areas that are oddly-shaped, small, have production issues, or are otherwise difficult to farm. These areas are commonly planted with vegetation that enhances wildlife habitat, pollinators, or other beneficial organism that facilitates Integrated Pest Management. Although native plants are not required as part of the seeding mix, the practice standard does give strong consideration for the use of native plant materials.

Figure 6-35. Conservation Cover (327). Established Conservation Cover that also functions as pollinator habitat. Photo: Steve Beaulieu, NRCS, Massachusetts.

The USDA Farm Service Agency (FSA) administers the Conservation Reserve Program (CRP). Although FSA does not follow NRCS practice standards for the CRP, the CRP does have definitions for several practices that are consistent with the NRCS Conservation Cover practice standard, including CP-1 - Introduced Grass and Legume Establishment, CP-2 – Native Grass, Forb and Legume Establishment, CP-4D – Permanent Wildlife Habitat. Farm owner Alan Honeyman of North Dakota, a CRP program participant, stated, “Before CRP, we used to have dust storms in the spring, which have now abated." Water quality has also improved. But most of all, Alan noted, "We have created wildlife habitat that has repopulated game birds."[72]

Figure 6-36. Farm Owner Alan Honeyman explains how his CRP cover of mixed grasses and legumes attracts up to 3,000 pheasants. Photo: FSA, North Dakota.

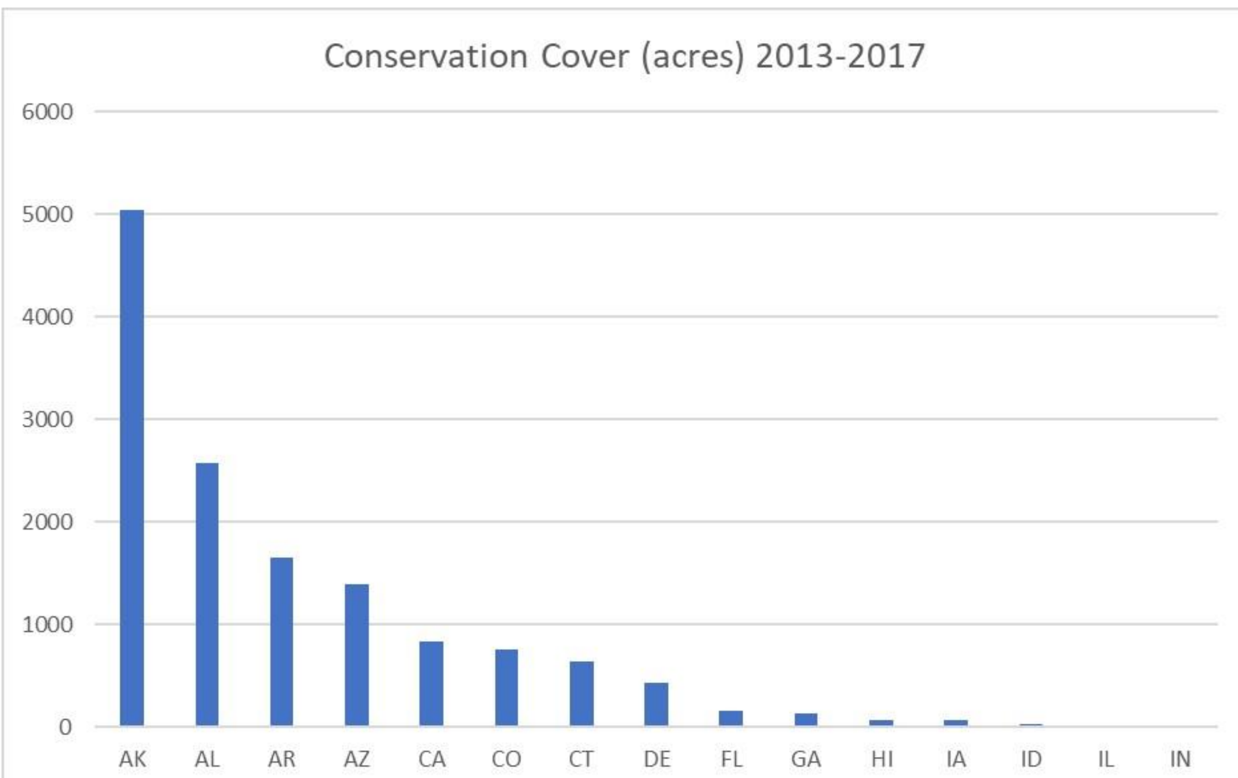

Figure 6-37. Top 15 states (by acres) implementing Conservation Cover (327) during 2013-2017.

Field Border – 386

Like Conservation Cover, Field Borders (386) are designed as permanent perennial vegetation to control soil erosion. However, Field Borders are designed for a life expectancy of 10 years, compared to Conservation Cover's 5-year expectancy. To control wind erosion, field borders are installed on the field edge that would give the most protection from prevailing winds during critical wind erosion periods for the crops grown. They can be planted on a single field edge or along multiple edges. For wind erosion purposes, the vegetation should provide a dense cover, with the minimum height of vegetation being one foot and made up of plant materials with stiff, rigid stems that disrupt creep and saltation and trap airborne sediments. Field Borders are oftentimes installed to address a wind erosion problem originating from an adjacent field or degraded area. Most Field Borders are approximately 30 feet wide, but they should be wide enough to control erosion. Vegetation can be single species or a mix; mixed species field borders are better suited to address multiple purposes, e.g., pollinators, wildlife habitat, etc. Most states have a vegetation planting guide that will identify which vegetative species are best suited for Field Borders specific to soil and site conditions. Field Borders are widely utilized across the country; they have been installed in 44 states and U.S. territories in NRCS financial assistance programs during the period from 2013-2017. This practice has multiple purposes and is more likely to be installed for water erosion and water quality concerns in Eastern and Southeastern states where average annual precipitation exceeds 35 inches.

Figure 6-38. Field Borders are often planted at sloped ends of cropped rows. This provides maximum protection against both wind and water erosion and allows ample space for equipment turns. Photo: Jason Johnson, NRCS, Iowa.

Figure 6-39. This conservation farm in western Iowa features not only field borders, but also grassed waterways, contour buffer strips and grassed terrace slopes. Photo: Lynn Betts, USDA NRCS, Iowa.

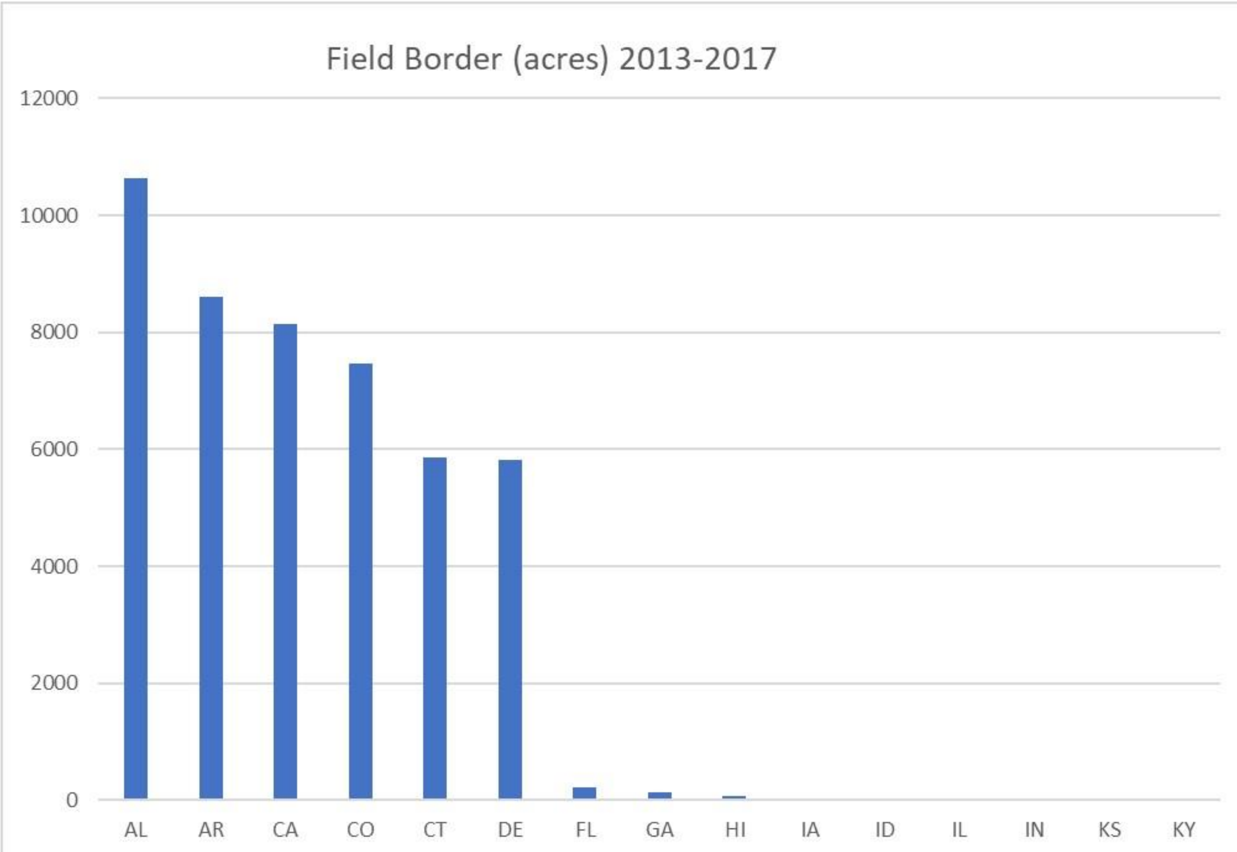

Figure 6-40. Top 15 states (by acres) implementing Field Border (386) during 2013-2017.

Herbaceous Wind Barrier – 603 and Vegetative Barrier – 601

Both Herbaceous Wind Barrier (603) and Vegetative Barrier (601) are composed of stiff, erect vegetation planted in a row (or rows). They can appear similar on the landscape, with the exception that Vegetative Barriers will most likely be placed on steeper slopes. However, these two practices have separate purposes: Herbaceous Wind Barriers are associated to a wind erosion, while Vegetative Barriers are installed to address sheet and rill erosion. This difference leads to dissimilar design and layout considerations. Because of their similar composition, both practices will show a positive effect for wind erosion in the Conservation Practice Physical Effects (CPPE). Nevertheless, Vegetative Barrier is purposed to address sheet and rill erosion, and thus should not be considered to address a wind erosion concern and is not further discussed here.

As noted, Herbaceous Wind Barriers are composed of relatively dense, erect, stiff vegetation that is resistant to lodging and can withstand blowing soil particles and the resultant deposition of soil at the base of the plants. They are intended to be a 5-year practice with perennial vegetation. However, annual plants are permitted by the practice standard, which then would require annual replanting and renovation of the barrier. Since the practice has a 5-year lifespan, financial assistance through NRCS programs would be limited to a 5-year cycle.

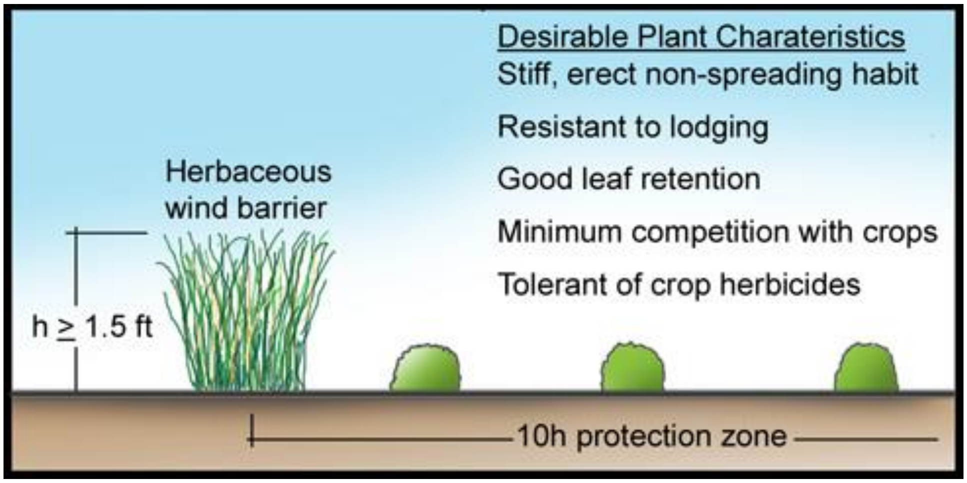

Figure 6-41. Characteristics of quality herbaceous wind barrier.[73]

Like windbreaks, Herbaceous Wind Barriers provide soil protection up to ten times their height when planted perpendicular to the prevailing winds. Therefore, to adequately protect a field with this practice, multiple rows of barriers would be planted across the field at roughly 10 times the expected height of the barrier. Barrier interval spacing must give consideration to the width of farm equipment used in the cropped area.

Figure 6-42. Herbaceous Wind Barriers (603). Photo: USDA NRCS, Montana, 1970.

Herbaceous Wind Barriers are not widely practiced across the country. In fact, only seven states and one U.S. territory reported any activity with this practice during 2013 to 2017. Figure 6-43 shows where this practice is being implemented with NRCS financial assistance programs. It can be suggested that this practice is perhaps best applied in coastal areas where droughty sandy soils are prone to blowing, as indicated by its presence in California, Florida and Hawaii as well as Puerto Rico (PR).

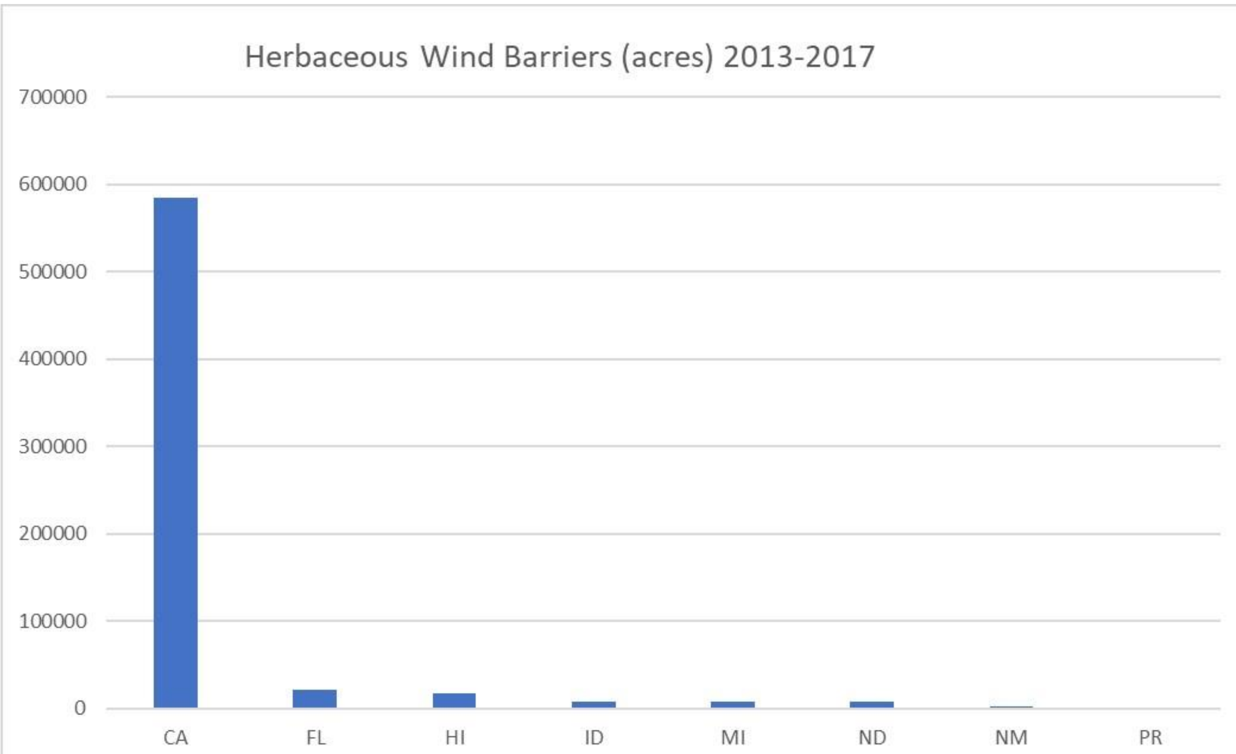

Figure 6-43. States and U.S. territories implementing Herbaceous Wind Barriers (603) during 2013-2017.

Stripcropping – 585

Stripcropping (585) is defined as the growing of planned rotations of erosion-resistant and erosion-susceptible crops or fallow in a systematic arrangement of strips across a field. Erosion-resistant crops are considered to be close-growing crops such as grain or forage. This practice can be used to address wind erosion or water erosion. For wind erosion purposes, at least half of the field in consideration will be planted to the erosion resistant crop in alternating strips. The width of the strips will be designed as such that the WEPS computes an average erosion rate for the field to be less than T (soil loss tolerance for the soils on the field). Historically, Stripcropping was commonly applied across the country, particularly from the 1950's through the 1970's, and picturesque scenarios were commonplace over thousands of contiguous acres. However, as other forms of erosion technology came online in the 1970's, namely reduced tillage systems, Stripcropping began to wane. Only eleven states had reportable activity during the 2013-2017 period through NRCS financial assistance programs (Figure 6-47). Even Colorado, which far exceeded any other state's adoption, installed only slightly less than 4000 acres during this five-year period.

Figure 6-44. Stripcropping (585) is especially beneficial when alternating strips are in different growth stages or where one crop is post-harvest or in bare ground condition. Photo: USDA NRCS, Great Falls Montana, July 1983.

Figure 6-45. Stripcropping (585) can be enhanced with herbaceous wind barriers or hedgerows. Photo: USDA NRCS Montana, August 1962.

Figure 6-46. Stripcropping (585) combined with contour farming enhances water erosion benefits. Photo: USDA NRCS, Montana.

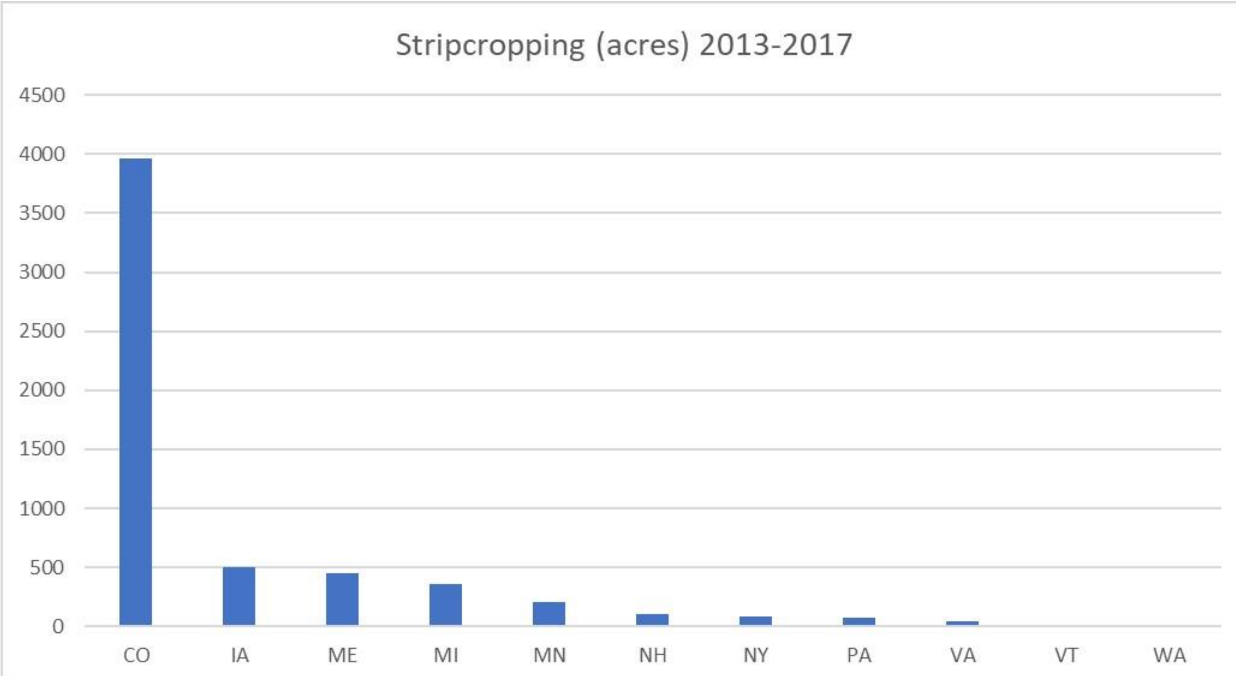

Figure 6-47. States implementing Stripcropping (585) during 2013-2017.

Multi-story Cropping – 379

Multi-story Cropping (379) is defined as existing or planted stands of trees or shrubs that are managed as an overstory, with an understory of woody and/or non-woody plants that are grown for a variety of products.[74] This practice can be compared to windbreaks, as there is a tree component whose effect will reduce wind speeds and provide protection to cropped fields planted on the leeward side of the prevailing wind direction. However, they are different from windbreaks in that there are oftentimes no discernable rows of trees and shrubs, and most often every vegetative component (story) has a harvestable commodity. Also, the trees may be a native stand that is augmented with mid- and understory crops. This practice currently applies only to tropical islands, for example Hawaii, as shown in Figure 6-50, and is commonly used in small farm and/or subsistence farming operations. Because of the intermixed species, harvest is not typically mechanized for any of the crops. Thoughtful planning of the various crops can space harvest labor over an extended period.

Figure 6-48. This Multi-story Cropping system includes betel nut (*Areca catechu*) palms, coffee (*Coffea arabica*) and banana (*Musa* spp.). Photo: Craig Ziegler, USDA NRCS, multi-story cropping in Saipan, Commonwealth of the Northern Mariana Islands.

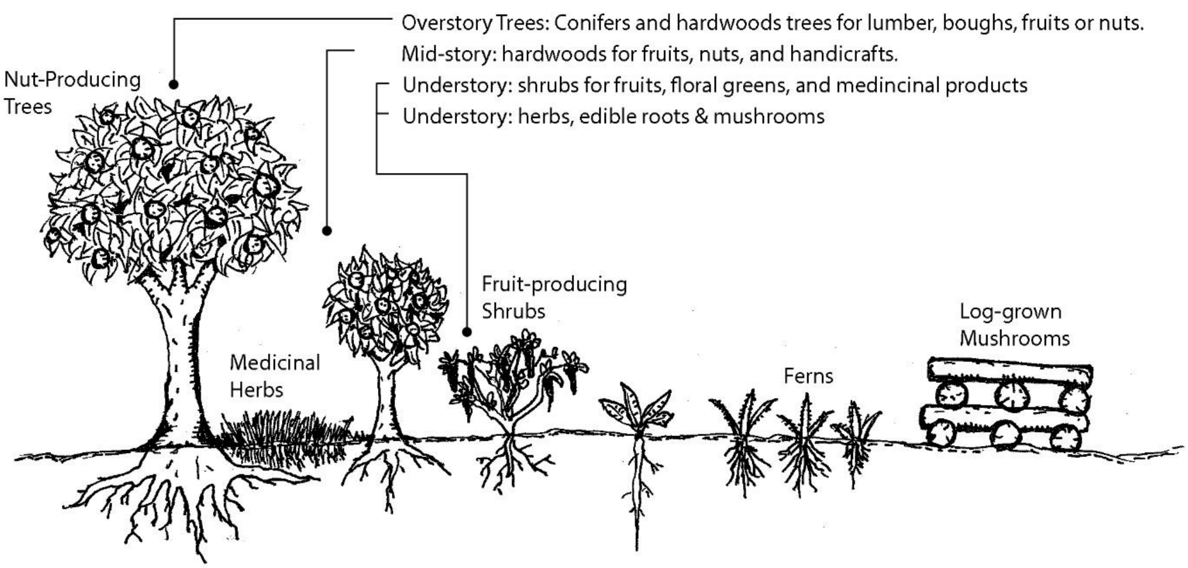

Figure 6-49. Typical orientation of Multi-story Cropping (379).[75]

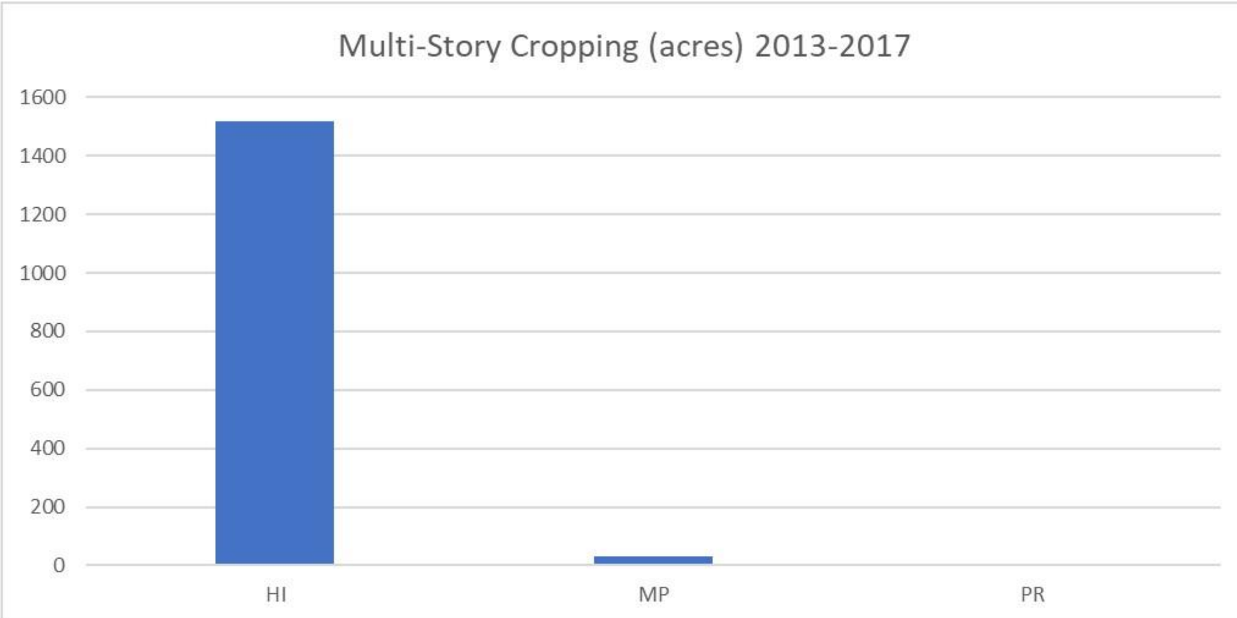

Figure 6-50. States and U.S. territories implementing Multi-Story Cropping (379) during 2013-2017.

Alley Cropping – 311

Alley cropping is the process of growing harvestable crops between rows of trees or shrubs. Typically, the trees are considered the primary crop (nuts, fruit, or wood products), while crop production between the trees is secondary (forage, horticultural, or agricultural products). However, it can be reversed, where the trees are secondary and supply protection from erosion and other environmental elements to the primary crop. In either case, the compatibility of the crops should be explored, particularly with regard to plant pests and disease that could be transferred from one crop to the other.

Figure 6-51. Alley Cropping (311) of soybeans between walnut tree rows in Missouri. Photo: Jim Jones, USDA National Agroforestry Center.

When trees are young, successful implementation of alley cropping is relatively simple. As the trees age and their root systems and canopies expand, competition for light, water, and nutrients will become apparent, thus crop selection decisions should include management implications. In scenarios where the trees are secondary, root pruning and canopy reduction will likely become necessary. Root pruning should be started early while the trees are young to train the roots to grow deep rather than laterally, and continued annually or biennially. If it is known at the time of planting that the trees will be the secondary crop, planting the trees at a wider row spacing can reduce competition while not impairing the protection qualities of the trees. In scenarios where the tree crop is primary, tree canopy will likely eventually shade a significant portion of the interspace, and production of the herbaceous crop must shift to shade tolerant species, of which there are far fewer to choose from.

Alley Cropping (311) has limited use in NRCS financial assistance programs, as evidenced in Figure 6-52 below. Only four states and one U.S. territory reported any activity during 2013-2017, and participation appears limited to small acreage farms, with particular interest in the Pacific Basin (Hawaii and the Marianas Islands [MP]). NRCS considers the lifespan of this practice to be 15 years. Program participants are expected to maintain any cost-shared practice for the expected lifespan. This may underpin the unpopularity of this practice, as growing annual crops between rows of trees is likely an annual operational decision.

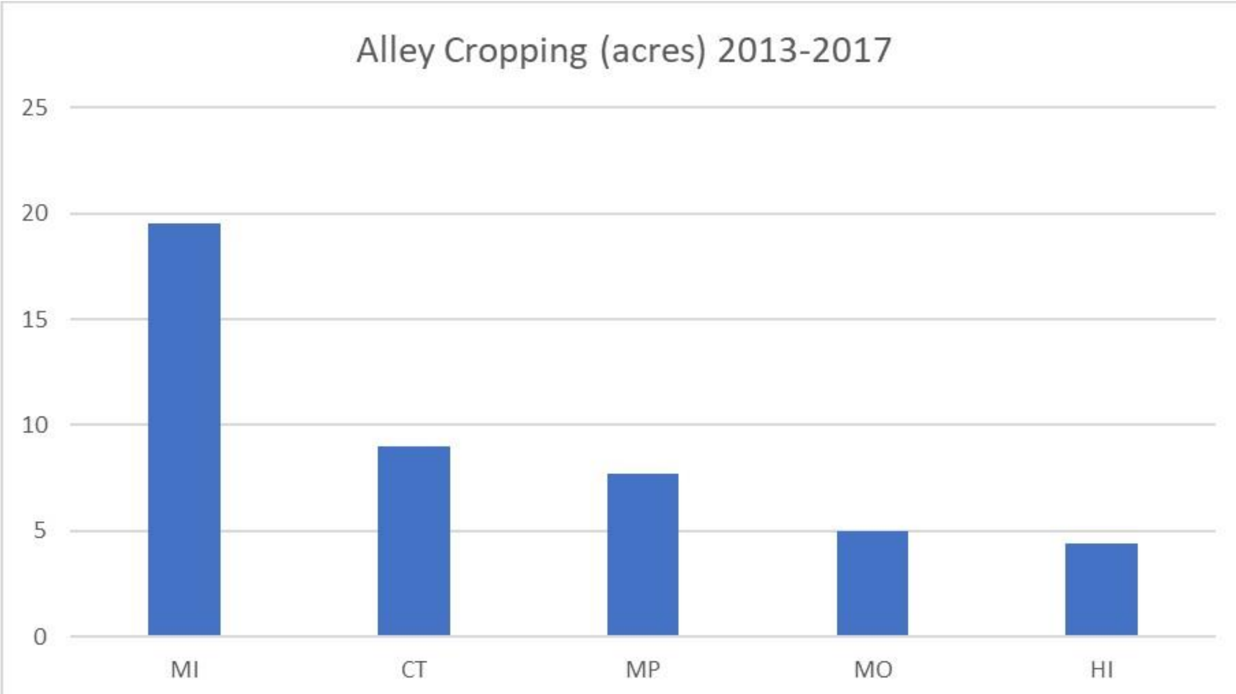

Figure 6-52. States and U.S. territories implementing Alley Cropping (311) during 2013-2017.

Field Operations Emissions Reduction – 376

This practice is designed specifically to reduce particulate matter emissions resulting from routine field operations, which might include planting, harvesting, or tillage. As such, it is principally considered an air quality practice. Although primarily purposed for cropland, this practice also applies to activities on rangeland, pastureland, and forestland. Since excessive trips across a field disturbs the soil, there is an increased likelihood of creep and saltation. Thus, the practice has air quality and wind erosion benefits. Also, the premise of this handbook is to include dust abatement practices.

Dust emissions can be mitigated by combining operations in a single trip across the field, utilizing water or other chemicals designed to keep particulates from getting airborne, using precision agricultural equipment to reduce overlap, increasing equipment size to reduce the number of trips across the field, timing operations to avoid weather conditions that promote emissions, or completing other field operations that limit the opportunity for dust to become entrained in the air column. Where air quality is a concern – such as fields adjacent to residential areas, schools, churches, etc., when PM_{10} exceeds standards, or adjacent to major transportation corridors – this practice should be considered.

During the evaluation period of 2013 to 2017, California was the only state to implement this practice.

Amending Soil Properties with Gypsum Products – 333

This practice has no direct purpose associated to wind erosion; rather, the practice's main purposes are to address soil properties related to fertility, health, productivity, and permeability. There is a possible benefit to wind erosion and dust abatement when soil quality is negatively impacted with excessive salinity and sodium. An imbalance of sodium, and to some degree potassium, ions with calcium and magnesium ions can deflocculate soil aggregates to the point that water penetration into the soil profile is seriously impaired. Over time, the lack of hydraulic conductivity through the soil profile can promote salt accumulation in the upper horizons. This results in an area that has high salinity and sodium content, which tends to raise the pH of the soil. High pH can limit the availability of some key macronutrients. The combined effects of high salinity, low available water, and limited nutrient availability can lead to an area devoid of vegetation. These areas are susceptible to wind erosion and the blowing soil particles can damage and disrupt the development of nearby growing crops.

Application of gypsum (calcium sulphate) can ameliorate the negative effects of excess sodium in the soil, whereby mass exchange of sodium with calcium on the exchange sites of soil colloids allows the sodium to bind with the sulphate anion and leach from the soil profile. Once the sodic condition in the soil is corrected, water can easily infiltrate the soil surface, vegetation can be established, and a reduction in wind erosion will be realized. Sodic and saline-sodic conditions can also be found on rangeland, and treatment of these areas with gypsum products is normally not considered for economic reasons.

Figure 6-53. Application of gypsum to farm field. Photo: USDA NRCS.

Only four states had reportable activity with this practice through NRCS programs in the years 2013 through 2017 (Figure 6-54).

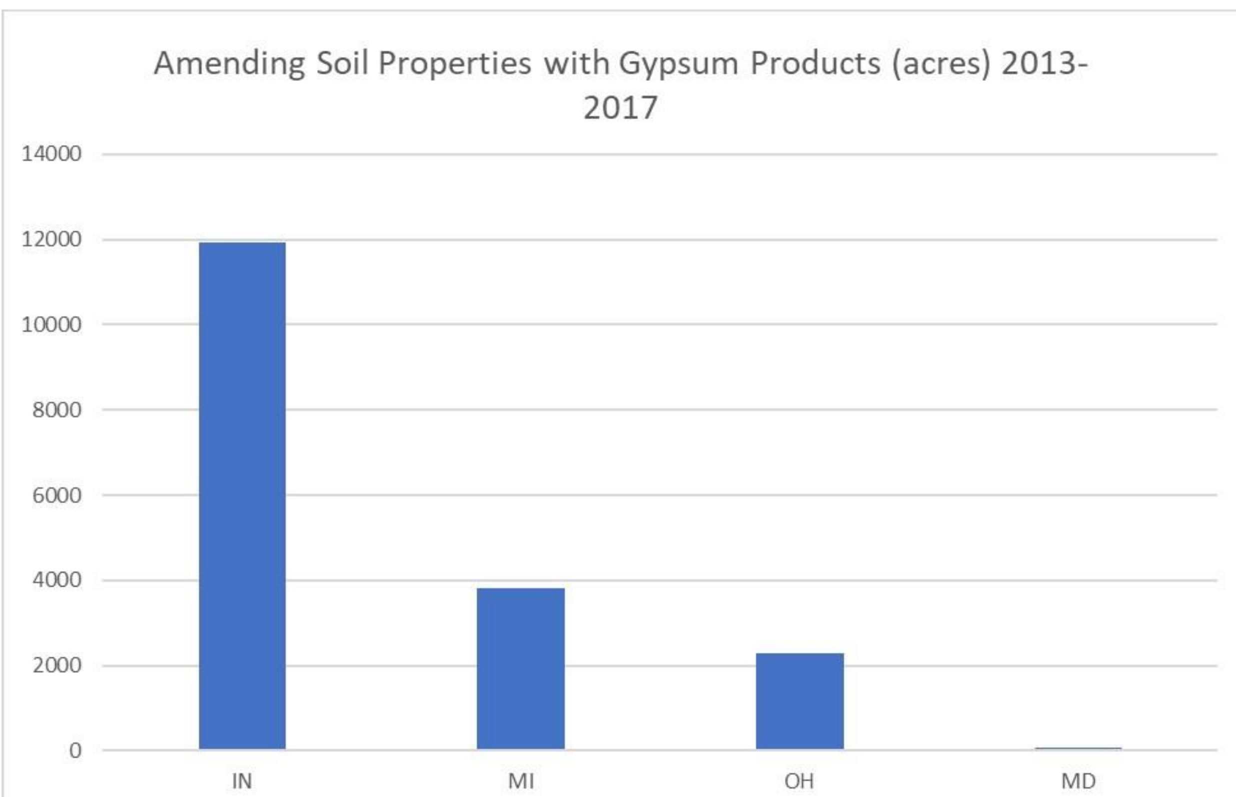

Figure 6-54. States implementing Amending Soil Properties with Gypsum Products (333) during 2013-2017.

Cross-Wind Trap Strips – 589C

Cross-Wind Trap Strips (589C) consist of herbaceous cover established in one or more strips typically perpendicular to the most erosive wind events. The vegetation can consist of annuals or perennials, growing or dead. The width of the strips is dictated by the height of the vegetation. Where the vegetation is less than one-foot tall, minimum strip width must be 25 feet or greater. Where the vegetation exceeds a height of one foot, then the strips must minimally be 15 feet wide.

Figure 6-55. Cross-wind Trap Strips (589C), seen here paired with Cross-wind Ridges (588). Photo: USDA NRCS.

Cross-wind trap strips are most effective when planted perpendicular to the prevailing wind direction during critical wind periods. This practice would typically be implemented on fields with problem soils or when a crop rotation leaves the field vulnerable to wind erosion during critical periods. When implemented, it is common for the selected vegetation to have a wildlife benefit. This practice should be a consideration for temporary water shortages on irrigated lands where whole fields may need to be fallowed for an extended period of time.

This practice was not utilized nationwide in NRCS financial assistance programs during the evaluation period of 2013 to 2017. Presumably, the practice has fallen out of favor because its implementation requires a substantial amount of land to be taken out of crop production.

Cross-Wind Ridges – 588 and Surface Roughening – 609

These practices are typically classified as emergency tillage and employed as a last-ditch effort to control wind erosion on susceptible fields. Both of these practices utilize the same principles: introducing roughness to the soil surface to increase friction, thereby slowing wind speeds down at the ground surface. Also, these practices interrupt the creep and saltation processes. Many states or local governments have dust ordinances that require emergency tillage be practiced when fields are susceptible to blowing dust. These practices can be implemented as it becomes evident a problem exists.

Cross-Wind Ridges (588) are constructed perpendicular to prevailing wind direction with some type of tillage equipment that forms ridges and furrows. Varied types of tillage equipment can serve the purpose, including listing equipment (bedding up), chisel plows, border disks, or seed drills with hoe openers. Cross-wind ridges are best utilized in sandy soils.

Figure 6-56. Cross Wind Ridges (588). Photo: USDA NRCS.

Surface Roughening (609) is designed to introduce large clods to the soil surface. Surface roughening implements can include heavy disks, rippers, chisels, or any equipment that forms large clods on the soil surface. Spacing and depth of the individual rippers, chisels, etc. must be considered to get optimum performance of the treatment. Too narrow of a spacing will tend to pulverize the surface, potentially nullifying its effectiveness, and it must be set deep enough to bring up large clods. This practice is best utilized on fine textured soils capable of establishing stable clods.

Figure 6-57. Surface Roughening (609). To achieve desired effect with stable clods, several chisel points have been removed to prevent the soil from being pulverized into smaller aggregates. Photo: USDA NRCS.

Neither of these practices should be considered as a primary approach to wind erosion control, and preferably they should be applied with other companion wind erosion practices. They are considered temporary practices, as wind and blowing soil particulates eventually wear down the clods and ridges and reduce their effectiveness. Oftentimes, the treatment needs to be reapplied before the wind erosion period is over.

Assembling the Conservation Plan

As noted in Chapter 5, the conservation planner should evaluate the whole farm for natural resource concerns – soil, water, air, plants, animals, energy, and the human environment. The human environment includes farmer/family attitudes and values, farming economics, currently owned farm equipment, social considerations, and the farmer’s commitments to neighbors and neighborhoods. It is important to evaluate the big picture to avoid conflicts in the implementation of conservation practices. Implementation of one conservation practice can restrict or make more complex the installation of future conservation practices. Additionally, the planner does not want to exacerbate an existing resource concern or topographic or hydrologic condition on the land. Therefore, even when addressing a single resource concern, such as wind erosion, one must complete a minimum due diligence during the inventory stage of conservation planning and provide a sufficient set of alternative actions to avoid future complications.

With wind erosion as a resource concern, the planner will inventory soil resources, benchmark cropping system, tillage system, field layout, and – of critical importance – wind speed and direction. The best method of getting a quick snapshot of wind speeds and direction is through the use of wind roses (Figure 6-58). NRCS hosts a wind rose data set[76] for key areas in all States and U.S. Territories. This dataset was developed in 2003 and is based on the 30-year climatic "normals" period of 1961-1990. Additional customized wind roses at more locations and for more recent time periods are available from the National Oceanic and Atmospheric Administration (NOAA).[77] Given considerations of current and projected future climate change, this site may be more flexible and therefore advantageous to use than the NRCS site. You must register and create a login to utilize the site, and its use is free of charge.

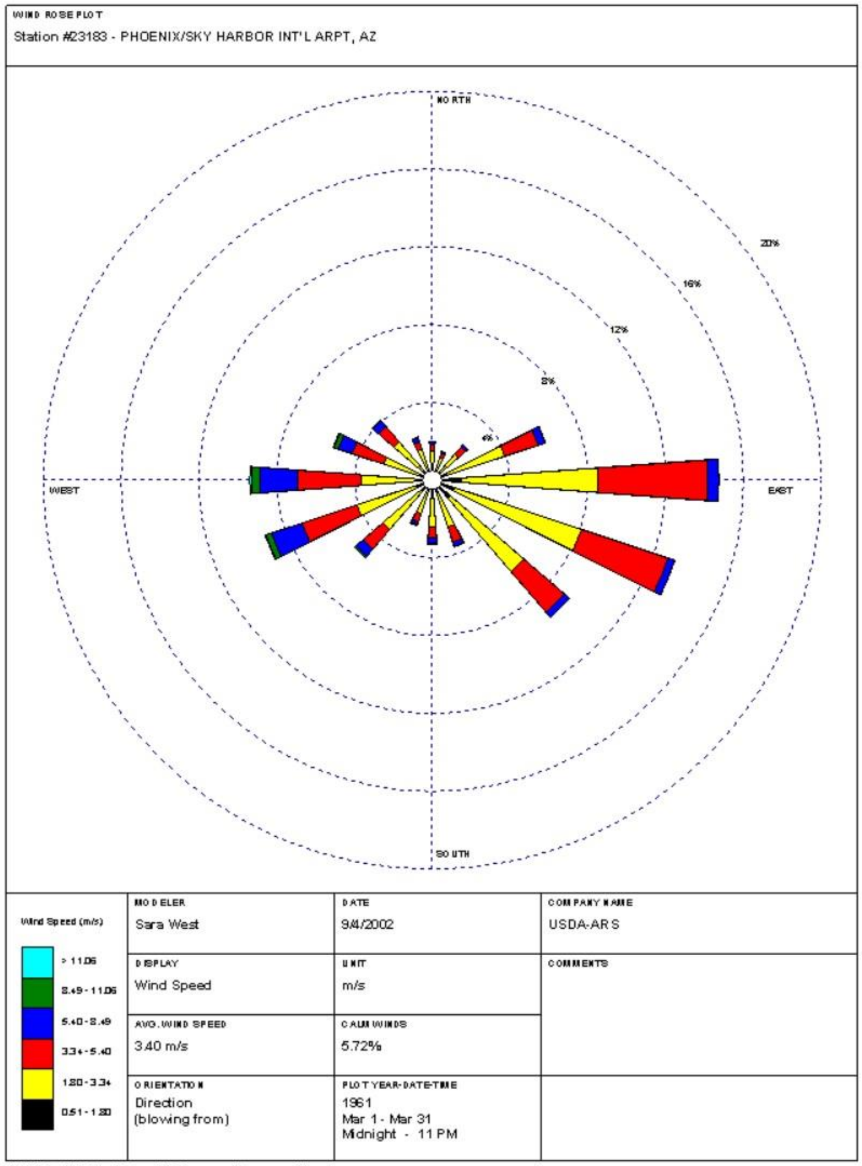

Figure 6-58. Wind rose for Phoenix for the month of March for years 1961-1990.[78]

Figure 6-58 depicts a wind rose generated for Phoenix, AZ for the month of March based on the period from 1961-1990. The spokes represent the direction from which winds blow, separated into 16 directions- the cardinal, ordinal and half winds. The concentric circles represent frequency of winds expressed in percentage of time for the period evaluated. The colors of the spokes are separated into ranges of wind speed as described in the legend. For this wind rose, the concentric circles are labeled as 4, 8, 12, 16 and 20 percent. For example, we can see the highest wind speeds come directly from the west (green), and in total, winds come from the west about 9.5% of the time during March. The highest wind speeds (green) make up about 1% of wind occurrence in March, of which the typical highest wind speed range is 8.49 to 11.09 m/s. Meters per second is commonly used in wind roses, since most wind erosion, air pollution, and other climate-oriented models use these units of measure. If desired, convert to miles per hour by multiplying by 2.237. The NOAA website allows you to select the units you desire.

The wind velocity at which soil particles begin to move across the soil surface is called the threshold friction velocity. For agricultural soils, the threshold friction velocity at which sand particles begin to move is about 5.5 m/s, but it is variable and dependent on soil texture and organic matter content. In-field conditions, like soil moisture and surface roughness (cloddiness), are other key variables that will affect threshold friction velocity. From a conservation planning standpoint, we can consider winds greater than 5.5 m/s as potentially erodible wind speeds. Thus, looking back at the wind rose, the planner would be concerned with speeds indicated with a blue or green color. About 9% of March winds fit this category, ranging from northwest to southwest directions, with the bulk of those strongest winds coming directly from the west. Therefore, the best direction to orient linear wind barriers, including tillage practices, would be in a north-south direction – perpendicular to the prevailing erosive wind direction.

March was the month chosen for this example as it is the month in the Phoenix area that farmers begin preparing their land for planting. In a conventional tillage system, there are multiple field operations conducted during this period, making it the most critical period for wind erosion for these farmers. Key months for wind evaluation will differ across the country, based on the cropping systems and climate. In fact, the period of evaluation may be greater or less than a month; this is another advantage of the NOAA wind rose website, as the period of evaluation can be altered specifically to the days of concern for each farmer.

The conservation planner uses this information to develop alternatives with the aforementioned conservation practices. These alternatives are evaluated with the Wind Erosion Prediction System (WEPS). In fact, the farmer's current benchmark condition, considering his soils, cropping system, and tillage operations, is evaluated first through WEPS. This establishes an annual erosion rate for comparison of management practice options. Ideally, the planner will propose a system that meets long-term production sustainability goals. This is the acceptable soil loss rate ("T") determined in Web Soil Survey for each soil. For most deep agricultural soils, this rate is determined to be 5 tons/acre/year. WEPS takes into account a vast array of climatic, soils, agronomic, irrigation, and wind barrier conditions to evaluate alternatives. Since WEPS is process-based, it evaluates conditions on daily increments, considering tillage operations, crop growth, irrigation, and climatic factors. The planner can assess critical time periods and potentially hazardous tillage operations and make recommendations for simple variations to the farmer's basic crop rotation and tillage operations. Alternatively, the planner can add cover crops or other conservation practices to show the incremental benefits. The selling points of reduced erosion are expected yield gains, improved soil health, improved infiltration (to capture and store water in the soil profile), and improved air quality.

Chapter 7 : Controlling Wind Erosion on Rangeland, Natural Areas and Unpaved Surfaces

Introduction to Controlling Wind Erosion on Rangeland, Natural Areas and Unpaved Surfaces

This chapter will discuss the common practices applied to all grazing lands, natural areas, and unpaved surfaces. It will also include disturbed areas that do not succinctly fit into any land type, like abandoned cropland, as the treatment will closely resemble that of degraded grazing lands. Natural areas include lands reserved for wildlife and associated agricultural lands that are difficult to farm or graze, such as pivot corners and on-farm transportation corridors.

For simplicity's sake, this section will discuss wind erosion control on grazing lands as a collective that includes rangeland, pastureland, woodlands, forestland, and grassland. Where treatments differ depending on the land type, that clarification will be made. Rangeland is considered grazed dryland consisting of native and/or naturalized vegetation that is only rarely renovated or otherwise altered. Pastureland includes grazed land that may or may not be irrigated, is regularly renovated or seeded in a cyclical pattern, and may include native vegetation but also could be entirely composed of introduced forages. Woodlands are generally open-canopied lands that dominated with trees and shrubs. Forestland includes a denser component of tall trees whose makeup is primarily evergreens. Grasslands are a sub-component of rangeland and pastureland where the soils, climate and position on the landscape are especially suited to grasses.

The set of practices that show a positive effect for wind erosion on the land uses above, as assessed in the Conservation Practice Physical Effects (CCPE) database, are listed below with their corresponding CPPE value.

NRCS Practice Name and Practice Code	CPPE Value for Wind Erosion
Access Control 472	1
Anionic Polyacrylamide (PAM) Erosion Control 450	2

NRCS Practice Name and Practice Code	CPPE Value for Wind Erosion
Brush Management 314	1
Critical Area Planting 342	5
Dust Control on Unpaved Roads and Surfaces 373	5
Forage and Biomass Planting 512	1
Grazing Land Mechanical Treatment 548	1
Heavy Use Area Protection 561	2
Herbaceous Weed Control 315	4
Land Reclamation, Landslide Treatment 453	2
Prescribed Burning 338	2
Prescribed Grazing 528	4
Range Planting 550	4
Restoration of Rare or Declining Natural Communities 643	2
Riparian Forest Buffer 391	2
Riparian Herbaceous Cover 390	2
Road/Trail/Landing Closure and Treatment 654	1
Silvopasture Establishment 381	3
Trails and Walkways 575	1

NRCS Practice Name and Practice Code	CPPE Value for Wind Erosion
Tree/Shrub Establishment 612	5
Water Well 642	2
Watering Facility 614	2

Figure 7-1. Conservation practices that are recognized to address wind erosion on rangeland.

Conservation Practices for Controlling Wind Erosion on Rangeland, Natural Areas and Unpaved Surfaces

Access Control – 472

Access Control (472) is defined by the NRCS as the temporary or permanent exclusion of animals, people, vehicles, and/or equipment from an area.[79] The practice applies on all land uses and is used to achieve or maintain desired resource conditions in an area.[79] Controlling access to an area can help prevent use-related damage and degradation, dust generation from vehicular traffic, and excessive removal of vegetative cover by livestock or human activities.[80] Access control might be for an entire management unit or for a specific area needing protection within a larger unit.[81]

Access to an area can be managed through the installation of constructed barriers such as gates and fences, planting vegetative barriers of trees or shrubs (refer to the Conservation Practice Standard (CPS) Hedgerow Planting (422) when using this approach), electronic or sonic devices, signage, patrols, or some combination of these.[82–84] Physical barriers may be constructed from conventional fencing materials or from natural materials such as logs, boulders, or earth-fill.[82–84] Barriers should be adequate to accomplish the intended exclusion or limitation of use by target populations and should not pose a safety hazard.[80] To prevent accidents, any physical barriers that cross roads should be clearly marked with bright reflective paint, signs, or other reflective material.[80,84] Barriers should also not impede emergency preparedness and response activities such as those for fire control – for example fire suppression crews may have need to access pumper truck water sources on or near the area.[79]

When planning to install access control structures, consideration should be given to the impact on non-target species such as local wildlife, and on cultural resources (e.g., soil compaction from fence installation).[85] The operator must also comply with applicable federal, state, and local laws and regulations during the installation, operation, and maintenance of this practice.[80] Potential landowner and user liability should be assessed before installing barriers to control access.[85] Figure 7-3 shows the top 15 states implementing Access Control during 2013-2017.

Figure 7-2. Access Control (472). Gates and fences can selectively control use of an area by people and vehicles. Photo: USDA NRCS.[81]

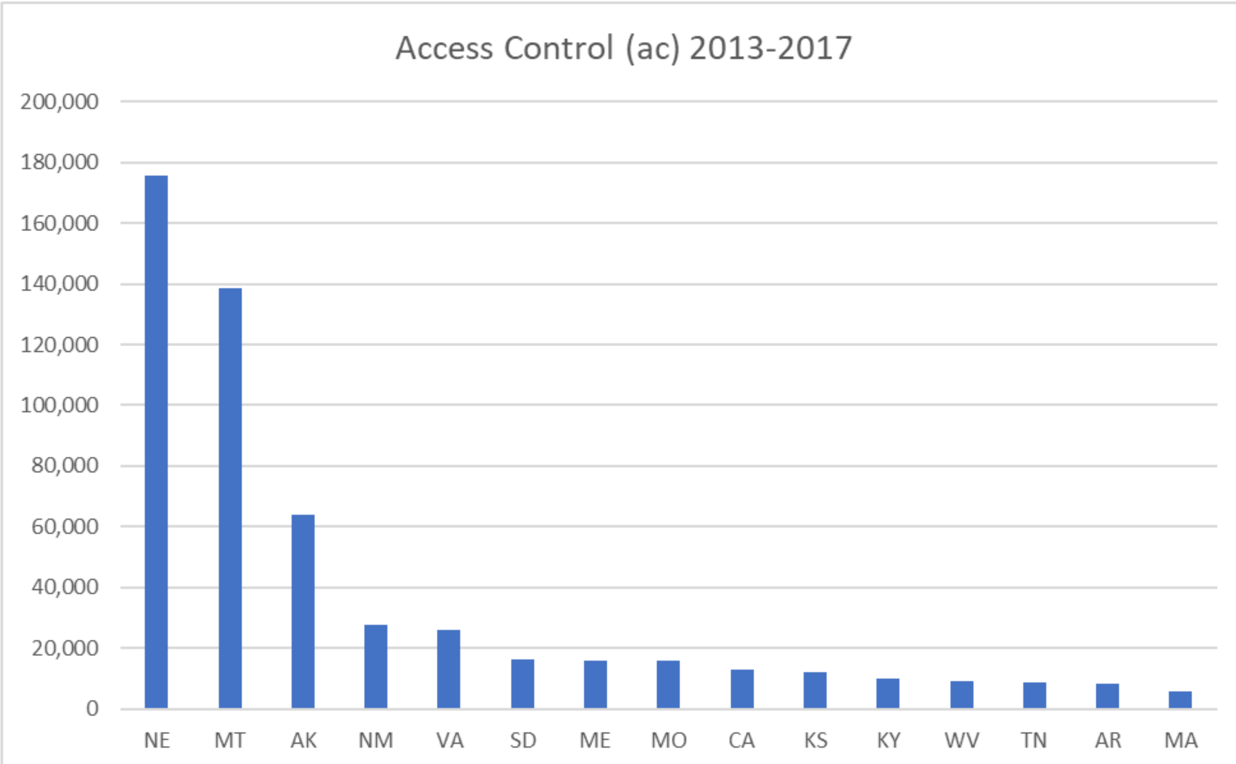

Figure 7-3. Top 15 states (by acres) implementing access control (472) during 2013-2017.

Anionic Polyacrylamide (PAM) Erosion Control – 450

Anionic Polyacrylamide (PAM) is a synthetic water-soluble soil additive used to increase flocculation of soil particles, improve water infiltration, and temporarily stabilize the soil surface to reduce wind and water erosion.

Application of PAM for Erosion Control (450) applies to:

- irrigated lands susceptible to irrigation-induced erosion where the sodium adsorption ratio (SAR) of irrigation water is less than 15;
- critical areas where the timely establishment of vegetation may not be feasible, or where vegetative cover is absent or inadequate;
- areas where plant residues are inadequate to protect the soil surface from wind or water erosion;
- sites where disturbance activities prevent establishment or maintenance of a cover crop.

This practice does not apply to soils with peat or organic matter surface horizons, nor does it apply to the application of PAM to flowing waters that are not being used for irrigation.[86]

Figure 7-4. Anionic Polyacrylamide helps flocculate fine soil particles into more stable aggregates which are less likely to be carried away by water and wind. Photo: USDA NRCS.[87]

PAM works by binding soil particles together and increasing soil stability through enhanced aggregation.[88] Application of PAM can reduce dust emissions and improve water quality.[89] It can also improve soil surface infiltration rate and minimize soil surface crusting, which aids plant growth. Although it can be very helpful in the short term, PAM loses effect relatively quickly and may need reapplication within 6-8 weeks, and potentially sooner in highly exposed areas.[90] For this reason, PAM should be considered a temporary solution to be used in combination with other erosion-control measures. For example, seed can be combined with the PAM mixture to provide longer-term erosion control.[86,90,91] PAM applied to the soil surface and then covered with a layer of mulch may remain effective for several months.[92]

The anionic form of PAM, provided it is free of nonylphenol (NP) and nonylphenol ethoxylates (NPE) which are often used as surfactants,[86] is non-toxic and environmentally benign when used in the recommended amounts.[88] Cationic PAM, on the other hand, is extremely toxic to fish and aquatic life and should never be used.[88,91] Anionic PAM used for Anionic Polyacrylamide (PAM) Erosion Control must meet acrylamide monomer limits of ≤ 0.05 percent, have a charge density of 10 to 55 percent by weight, and have a molecular weight of 6 to 24 mg/mole.[86] PAM can increase downstream or offsite sediment deposition if it mixes with sediment-laden waters downstream of the application site,[86] as it will cause flocculation of the suspended sediments which then fall out of suspension.

PAM comes in emulsion, granular, and brick or log form.[90] PAM requires turbulent mixing with water to fully dissolve the product.[93] Beyond that, it does not require specialized application equipment and can be applied through regular irrigation equipment, hydromulcher, water truck, or similar means. Some special handling may be required to avoid clogging the nozzles of sprinkler systems.[86] Mechanically incorporating PAM into the soil reduces, rather than increases, effectiveness. If an area is disturbed after application, then PAM will usually need to be re-applied.[90,91] Thus, PAM is usually not a consideration, particularly for wind erosion control, in cropping systems that utilize intensive tillage. PAM is not effective when applied over snow-cover.[91]

The correct application rate of PAM depends on the soil properties, slope, and the resource concern being addressed.[86,91] Specifications developed uniquely for the site should be prepared for each unit being treated.[94] PAM works best on fine and medium-textured soils; it typically will reduce, rather than increase, infiltration on coarse-textured soils.[86] PAM is an excellent alternative for controlling irrigation erosion where erosive surface irrigation streams are used to optimize irrigation efficiency, where tailwater recovery systems are used, and/or on graded furrow irrigation systems where concentrated flow may cause erosion. Using more than the recommended amount of PAM will not increase effectiveness[86] and may clog soil pore spaces, decreasing infiltration.[92] The maximum application rate for critical areas is 200 pounds per acre, per year, of pure form polyacrylamide.[86] To be effective, PAM needs a source of divalent cations, such as Ca^{+2} or Mg^{+2}.[95] In many arid climates, Ca^{+2} and Mg^{+2} are already naturally present abundantly within the soil, however soil testing can determine this. A supplemental source of divalent cations, if needed, can be applied to the soil (i.e., gypsum) or mixed with the PAM solution at the time of application.[95] Idaho NRCS has published a number of help sheets that give directions for finding the reports in Web Soil Survey[32] that contain soil and site properties of interest when planning various NRCS conservation practices, including PAM Erosion Control. These help sheets are included in Appendix B, Exhibit 7-1.

PAM does not store well, so it is generally not recommended to bulk-purchase more than will be needed at a given time.[96] PAM must be mixed and applied in accordance with

Occupational Safety and Health Administration (OSHA) Material Safety Data Sheet requirements and the manufacturer's recommendations.[96] Safe handling requires the use of proper personal protective equipment (e.g., gloves, masks, and other health and safety precautions) in accordance with the label, industry, and other Federal, State, and local chemigation rules and guidelines.[96] Inhaled dry PAM can cause choking and difficulty breathing.[86] The operator is responsible for complying with all Federal, state, and local laws, rules, or regulations, including those governing land-applied additives and surface water discharges.[91] PAM solution can make surfaces extremely slippery, so care should be taken not to spread or spill PAM on roads or other paved surfaces.[86,91]

PAM Erosion Control is not a widely used practice across the nation and no nationwide statistics for use of this practice were available to the authors at the time of creating this handbook.

Brush Management – 314 and Herbaceous Weed Treatment – 315

Brush Management (314) and Herbaceous Weed Treatment (315) both pertain to the removal of one or more undesirable vegetation species on a non-cropland area. Unwanted vegetation can be removed using mechanical, chemical, burning, or biological methods, alone or in combination. Brush Management applies to the management or removal of woody (non-herbaceous or succulent) plants including those that are invasive and noxious,[97] while Herbaceous Weed Treatment pertains to the removal of unwanted herbaceous species, including those that are invasive, noxious, or prohibited.[98] The requirements and considerations for Brush Management and Herbaceous Weed Treatment are very similar. The standards for both practices also suggest using Integrated Pest Management (595) in support of brush or herbaceous weed control efforts. When burning is chosen as a brush or weed removal method, then CPS Prescribed Burning (338) also applies (see section on Prescribed Burning).[97,98]

As specified by the NRCS Practice Standards, Brush Management applies on all lands except active cropland where the removal, reduction, or manipulation of woody (non-herbaceous or succulent) plants is desired. Herbaceous Weed Treatment applies on all lands except cultivated cropland and horticultural cropland, including orchards and vineyards, where removal, reduction, or manipulation of herbaceous vegetation is desired. These practices do not apply to removal of woody or herbaceous vegetation by prescribed fire (Prescribed Burning) or removal of woody or herbaceous vegetation to facilitate a land-use change (CPS Land Clearing (460)).[97,98]

Figure 7-5. Juniper invasion of northern Arizona grassland. Foreground and left background was treated by mechanical mastication. Right background is untreated. Photo: USDA NRCS.

Figure 7-6. Pastureland infested with Canada thistle. Photo: USDA NRCS, Montana.

Woody brush in densities sufficient to compete with herbaceous species can reduce the herbaceous ground cover, potentially leaving bare or sparsely vegetated areas which are susceptible to increased wind erosion. Reducing brush can help allow for the restoration of a more desirable plant community that provides improved habitat for wildlife, improved forage, and better erosion control.[99] Sometimes the remaining desirable plants at a site lack the vigor or abundance necessary to provide an adequate seed supply or otherwise re-populate the area naturally.[100] It may be that the brush encroachment has already eliminated most or all of the preferred understory vegetation species at the site.[100] In these instances, the desired vegetation will not come back on its own, and the area will need to be seeded to achieve the desired outcome.[100] Range Planting (550) or Forage and Biomass Planting (512) are recommended follow-up practices where natural revegetation with desired species is unlikely.[97] In areas of low rainfall, however, Range Planting has a low chance of success, so the decision to use this approach must be made judiciously within the context of local site and climatic conditions.[100] Removing brush or weeds when there is little likelihood of the area revegetating with a more desirable species in a reasonable amount of time may only make wind erosion problems worse by removing what little cover currently exists. Where Brush Management/Herbaceous Weed Treatment and any needed follow-up practices are advisable, a period of grazing deferment to allow for desirable plant establishment is usually needed following the brush/weed removal. Length of the grazing deferment may be as short as "until the end of the growing season"[101] or as long as one to two years,[102] depending on local variation in standard requirements; the needed deferment period may be longer in the presence of other complicating factors such as drought.[102] It is not uncommon to need to repeat brush or weed removal over the two to three years following the initial treatment to manage vegetative regrowth or seedling emergence from built-up seed stocks of the undesirable species in the soil.[100]

Developing a plan for brush or weed removal will in almost all cases be done in such a way as to move vegetation cover and composition toward the reference plant community described in the Ecological Site Description[103] (ESD) for that area.[100] Managing for a plant community not typically found under natural conditions can be disruptive to the ecosystem.[100] If the reference plant community includes, for instance, 30% cover by a woody species targeted for removal, then a removal density which supports this composition would normally be selected.[100] Instructions for how to find ESD information in the NRCS Web Soil Survey can be found in Appendix B, Exhibit 7-1. An exception to this general guidance would be in the case of naturalized pasture, which is historically forested land that is deliberately being kept in herbaceous vegetation and managed for pasture.[100] On naturalized pasture, woody plant removal is often conducted as a maintenance to prevent the site from reverting back to its natural wooded state.[100,104] NRCS will usually only assist with the initial clearing of woody brush on such sites, with subsequent maintenance activities being the responsibility of the land owner or manager.[100]

The impact on wildlife should be taken into account when planning brush or weed removal.[97] As a general rule of thumb, it is preferable to create a mosaic of irregular vegetation patches rather than block treatment of an area.[98] However, when creating a plan that leaves some brush standing for wildlife use, the most beneficial pattern (see diagrams below) will depend on the target wildlife species.[100] Ungulates, for example, will often benefit most from patterns that maximize edge effect – the increased diversity found at the interface between two habitat types.[100] Birds may do well with a patchy pattern that leaves clumps of brush standing, while ground-dwelling wildlife may need corridors through which they can travel from one area of habitat to the next.[100] The diagrams below and their accompanying explanations come from the *National Range and Pasture Handbook*, *Chapter 8 - Wildlife Management on Grazing Lands*,[105] and serve to provide a few examples of different configurations that a land manager might want to consider when planning a brush removal pattern for their land. Which pattern is best will depend on the plant community characteristics and the target wildlife species.

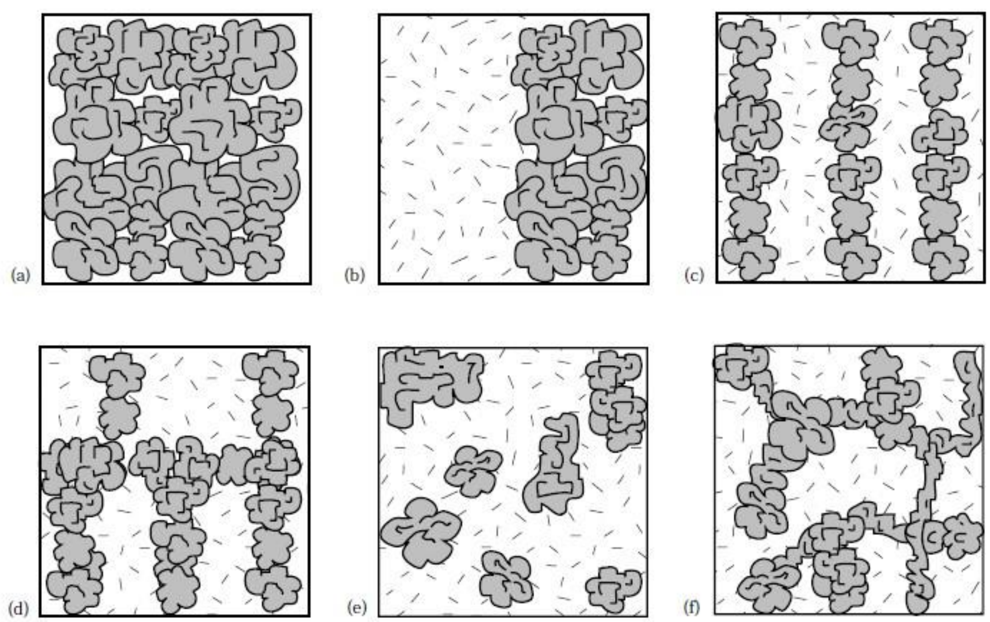

Figure 7-7. Potential brush management configurations.[105]

"A landowner wishes to apply brush management and range seeding on a rangeland pasture dominated by brush species. Many alternative designs can be considered in planning and implementing the practices. The five alternatives shown provide for half of the pasture (a) to be cleared and seeded and half to remain in brush.

- Alternative b is the simplest approach and provides for some edge between the grass and brush halves of the pasture.
- Alternative c provides six times the linear edge effect.
- Alternative d provides even more edge plus wildlife travel corridors between the brush strips.
- Alternative e provides a greater amount of edge and leaves brush motts that provide a natural appearance.

Alternative f provides for the greatest amount of edge and interspersion of habitat types, a natural appearance, and wildlife travel corridors between brush motts."[105]

In areas where a species of special concern, such as the Greater Sage-Grouse, is known to exist and/or make use of the habitat type under consideration for treatment, there may be specific requirements that the local NRCS office can either advise on or suggest appropriate resources for.[102]

Figure 7-8. Male sage grouse gathered at a lek in Central Montana. Photo: USDA NRCS, Montana.

Despite the ultimately positive effects of brush removal, this practice does have the potential to temporarily increase the risk of erosion on the newly cleared area, particularly if mechanical methods which disturb the soil are used. When planning for brush control, it is important to consider methods and timing that will minimize soil disturbance and soil erosion.[97]

The various options for plant removal under Brush Management/Herbaceous Weed Treatment are briefly summarized below.

Mechanical control

There are many forms of mechanical control, including chaining/cabling, railing and dragging, mowing or rotobeating, grubbing, discing, root-plowing, manual pulling/cutting, girdling, shearing, mastication, bulldozing, and other similar methods.[99,106] When selecting a control method, the target species needs to be considered, as not all methods are effective for all species. For example, alligator juniper (*Juniperus deppeana)*, a species common in the Western US, will re-sprout from roots and stumps left in the ground by methods that only destroy the above-ground parts of the plant.[100] Mesquite (*Prosopis* spp.), common to the Southwestern US, will also re-grow from root/crown and in addition has the potential to damage mastication equipment due to the hardness of its wood.[100] Grubbing may be a more appropriate method for controlling species with characteristics such as these.[100] Usually the local NRCS or Cooperative Extension office will have personnel with the expertise needed to identify the best removal method for a given locally-occurring species. Disposal of debris following a mechanical clearing may include things like shredding/chipping of large woody species, piling and burning, stacking and leaving piles of debris to serve as wildlife shelters, or leaving felled large woody species to decompose in place, where advisable.[107,108] In some cases, leaving residue such as downed large woody species in place may provide conditions in which harmful pests can thrive,[109] so care should be taken not use a method that will have unintended negative consequences.

Figure 7-9. Mechanical removal of woody vegetation. Photo: Jason Johnson, NRCS, Iowa.

Mechanical treatment is generally considered a ground disturbing activity and may require a completed cultural resource assessment before proceeding.[102,108,110] The difficulty of reseeding an area should also be given consideration before selecting a treatment which causes soil disturbance.[107] Seasonal use of the area by local and migratory wildlife or pollinators for reproductive and other life cycles (i.e., nesting) may mean that the treatment will have to be planned to take place outside of the usual nesting/fawning/calving/etc. season for the species of concern.[97,98]

Chemical control

There are several options for applying herbicide, which include but are not limited to aerial broadcasting, ground-based sprayers, foliar spot-treatment, soil spot treatment, or painting stumps following mechanical removal. Methods which minimize chemical drift and excessive chemical application are encouraged.[97,98] Consequences to non-target species should also be considered; for example, in situations where broad-scale application of an herbicide to treat an undesirable woody species will also kill desirable forbs that may be needed by wildlife or pollinators, a manually applied spot-treatment to just the target plants may be a better alternative.[100] Herbicides vary by chemical in their effects on non-target species and specific considerations will depend upon which one is selected for treatment of an area.[100] NRCS cannot make recommendations for chemical treatments but may be able to provide appropriate resources for this type of information.[98,99] Cooperative Extension can provide recommendations on herbicide treatment, as can a qualified agricultural consultant.[108] The most appropriate chemical, application rate, and application method will depend on the plant species and abundance, and may also need to account for other factors such as soil type (for example, high amounts of clay and soil organic matter can adsorb to some herbicides making them less effective[111]). Plant growth stage and timing of application can also affect how well the herbicide works.[107] Proximity to organic agricultural operations may be a consideration for some operators.[101] The operator should always read and follow label directions closely and comply with all State and Federal laws, with maintenance of Appropriate Material Safety Data Sheets (MSDS).[97] MSDS and pesticide labels may be accessed on the Internet at: http://www.greenbook.net/. An evaluation and interpretation of herbicide risks associated with the selected treatment(s) using WIN-PST (an environmental risk screening tool for pesticides, available online[112]) or other NRCS-approved tools is required for Brush Management and/or Herbaceous Weed Treatment.[98,99]

Biological control

The most commonly applied type of biological control is targeted grazing, often with browsers such as sheep or goats. Use of grazing animals is the only form of biological control for which NRCS will develop recommendations, although they may be able to suggest appropriate alternative resources.[98,99] When the NRCS does make grazing recommendations for biological control CPS, Prescribed Grazing (528) applies in conjunction with the CPS for Brush Management/Herbaceous Weed Treatment.[98,99] Helpful resources may be also available from other sources such as land grant universities and Cooperative Extension. The University of Idaho offers a number of resources on Targeted Grazing[113] including a Targeted Grazing Handbook[114] online that contains information on the principles and practices of biological control through grazing. Other methods of biological control include the release of insects or diseases which target the undesirable plants. Cornell University hosts a webpage[115] with information about biological control agents of insect, disease, and weed pests in North America.

Figure 7-10. Goats can be an effective form of biological control, targeting woody plants that grazing animals such as cattle normally avoid. Photo: Jason Johnson, NRCS, Iowa.

Figure 7-11. Biological control of leafy spurge. Flea beetle and spurge hawkmoth on leafy spurge; Ravalli County, Montana. Photo: USDA NRCS Montana.

Burning

Burning for brush or weed control should be carried out according to the CPS for Prescribed Burning, which is addressed under its own heading in this handbook.

The most effective control method(s) to implement for brush or weed management is highly dependent on the species of concern and the individual site characteristics. Often the local NRCS Field Office Technical Guide (FOTG)[69] will either have detailed species-specific recommendations or direct the user to resources where such recommendations can be found. Cooperative Extension programs and their associated Land Grant Universities are also an excellent resource for this type of information and may also offer locally applicable publications or online decision tools to assist in determining an appropriate treatment method.

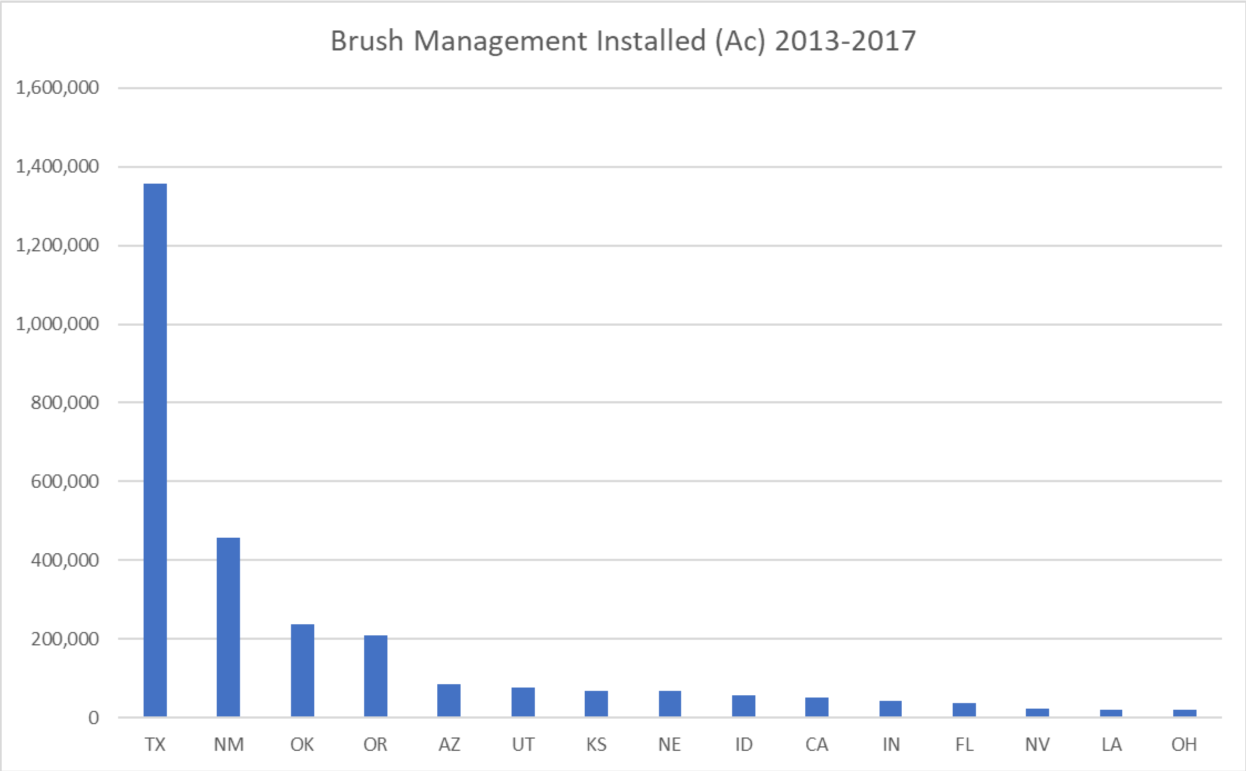

Figure 7-12. Top 15 states (by acres) implementing Brush Management (314) during 2013-2017.

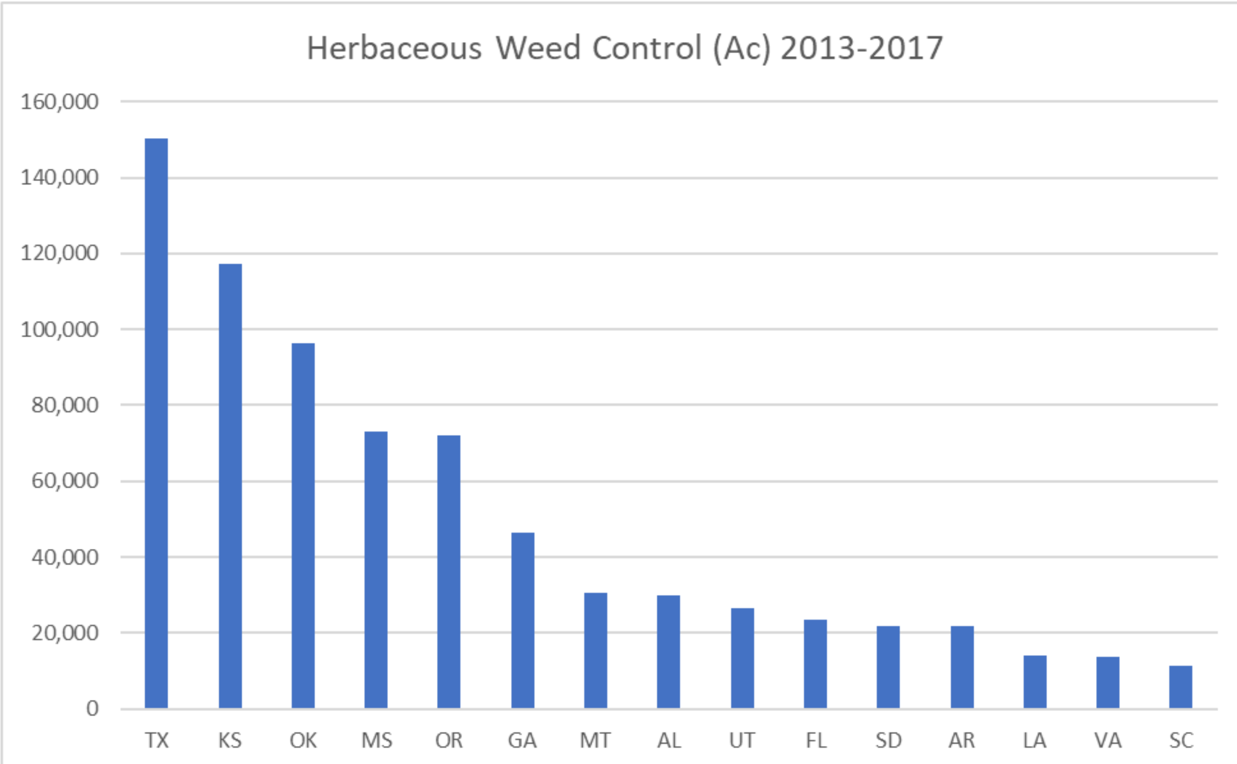

Figure 7-13. Top 15 states (by acres) implementing Herbaceous Weed Treatment (315) during 2013-2017.

Critical Area Planting – 342

Critical Area Planting (342) as defined by the NRCS is the practice of establishing permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical, or biological conditions that prevent the establishment of vegetation with normal practices. The establishment of permanent vegetation serves to stabilize susceptible areas such as:

- sand dunes and riparian areas;
- stream and channel banks, ponds and other shorelines;
- constructed earthen features such as berms;
- highly disturbed areas such as active or abandoned mine sites and construction or urban restoration sites;
- areas affected by natural disasters such as wildfires, floods, hurricanes or tornados;
- other areas degraded by human or natural events that may be prone to high rates of soil erosion by wind or water.[116]

Figure 7-14. Bare area that could benefit from erosion control measures. Photo: USDA NRCS.[117]

Figure 7-15. Establishing vegetation in erosion-prone areas can stabilize the soil and reduce dust emissions. Photo: USDA NRCS.[117]

Critical Area Planting requires a site evaluation to identify any physical, chemical, or biological conditions that could affect the successful establishment of vegetation.[116] Necessary site preparation may include mechanical leveling or shaping of the area, filling in deep gullies and cuts, and seed bed preparation.[118] Depending on local soil conditions, addition of lime, fertilizer, or other amendments may also be needed.[116] A soil test is often recommended, but not always required. The local NRCS FOTG should be consulted for details on the Critical Area Planting requirements specific to state and conservation site type. Mulching (484) is typically indicated as a component of Critical Area Planting in order to facilitate vegetation establishment. Hydromulching is routinely considered, as it offers the ability to apply seed, mulch, tackifier, and fertilizer in one operation. Grazing access to the site must usually be suspended during vegetation establishment, and in some cases permanently, depending on the erodibility of the area.[118,119] The site should also be protected from pests and wildlife damage during establishment, and potentially for maintenance as well; however, care should be taken to minimize harmful impacts to wildlife particularly with regard to maintenance practices.[118,119]

The specifics of the site will determine what additional steps may need to be included in the conservation plan. For instance, in areas where a suitable growth medium for vegetation establishment does not exist at the soil surface, topsoil may need to be brought in and distributed across the site.[120–122] Topsoil, where present prior to mechanical site modification, can be removed and stockpiled for later use but should not be stored any longer than necessary and for no more than two years.[121,122] For sites that are currently being affected detrimentally by water erosion, the flow route of the water may need to be diverted before proceeding.[101] Sites with active dunes and blowout areas present a unique challenge and are generally best addressed by being treated in stages, by stabilizing the upwind contributing area(s) first before addressing the areas associated with deposition accumulation, so that newly planted vegetation on these areas does not immediately become buried by sediment before it can establish.[101]

The vegetation selected for planting a critical area should be locally appropriate, compatible with existing vegetation in the area, and adapted to the conditions found at the site.[116] The selected species should have the capacity to achieve the density and vigor needed to stabilize the site within an appropriate period of time.[116] Planning tools such as the WEPS, Water Erosion Prediction Project (WEPP), RUSLE2, Rangeland Hydrology and Erosion Model (RHEM), or also the Aeolian Erosion (AERO) Model anticipated for release in 2020 (see Aeolian Erosion (AERO) Model in Chapter 3 of this handbook), may be used to determine the amount of established vegetation cover needed to reduce soil erosion to a level that is within management objectives. Reports available from the NRCS Web Soil Survey can supply soil erodibility factors and other soil information helpful for planning purposes; available reports of particular relevance to the concerns stated in the practice standard are noted in a help sheet from Idaho NRCS included here as part of Appendix B, Exhibit 7-1. Other site conditions to consider in selecting appropriate vegetation species include soil chemical and physical properties, climate, slope, and exposure. For example, vegetation used to stabilize sand dunes should be able to tolerate being buried by blowing sand, sand blasting, drought, heat, and low nutrient supply.[116]

Figure 7-16. Herbaceous cover used to stabilize a roadside slope. Photo: USDA NRCS Montana.

A list of approved plants for this practice that are considered appropriate for erosion control in a given state is usually available from the NRCS and should be followed. The CPS for Critical Area Planting usually requires the use of certified seed where available, and no species that are listed on Federal, state, or other locally applicable (e.g., tribal) noxious weeds lists may be used.[118,121–123] Use of native species, where appropriate to the site conditions, is usually preferred. Inclusion of a small quantity of one or more flowering species with strong roots to benefit pollinators is also suggested as a consideration. Since the perennials used to establish permanent vegetation may be slower growing, a faster-growing annual may also need to be planted to provide temporary cover to immediately stabilize the area of concern.[117,124] In some cases, the permanent vegetation can be seeded through the cover crop residue using a no-till or conservation tillage technique; this maximizes protection from wind erosion and eliminates the need for mulching.[124] Guidance on establishing temporary cover or on the use of a nurse crop, however, varies substantially by state, and the local NRCS FOTG should be consulted for details on recommended species as well as when and if this practice is appropriate in a given area. Likewise, appropriate planting dates and methods are best obtained from the local NRCS field office or technical guide. All plans and specifications for each field or management unit should be prepared according to the Criteria and Operation and Maintenance sections of the Critical Area Planting CPS for the state of interest.

Figure 7-17. Volunteers install fiber rolls (also called wattles) on burned area prior to Critical Area Planting (342) to control erosion. Photo: USDA NRCS.

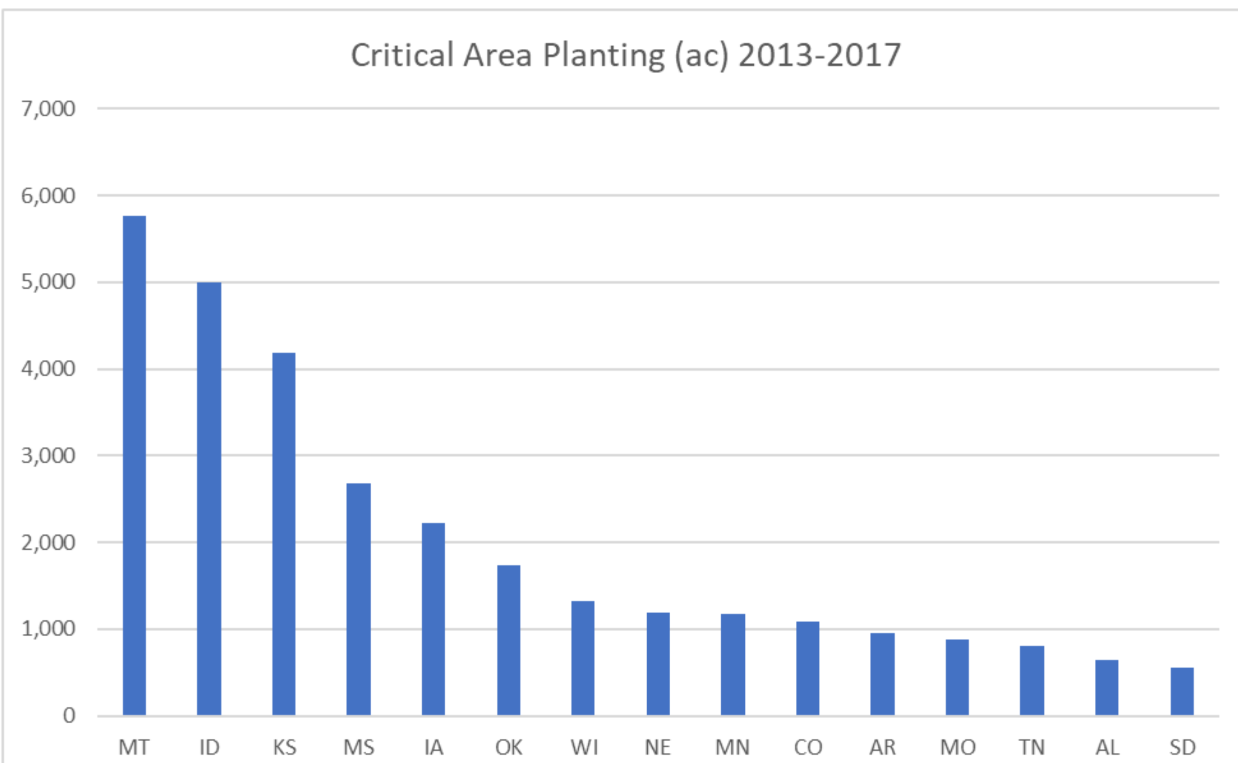

Figure 7-18. Top 15 states (by acres) implementing Critical Area Planting (342) during 2013-2017.

Dust Control on Unpaved Roads and Surfaces – 373

Dust Control on Unpaved Roads and Surfaces (373) consists of applying a dust-suppressing palliative product on unpaved surfaces where vehicle movement or wind action would normally occur. Examples of areas where this conservation practice applies are unpaved roads and parking lots, staging areas, and equipment storage areas. This practice does not apply to rangeland, cropland, vegetated areas, or areas subject to animal activity such as corrals. An assortment of dust-controlling products exists. Acceptable palliative products for use under the CPS for Dust Control on Unpaved Roads and Surfaces are: water; water absorbing suppressant (hygroscopic palliative); adhesive; petroleum emulsion; polymer emulsion; clay additive; and bituminous (petroleum-based road oil).[125]

The type of product chosen will depend on factors such as the length of time that dust suppression is needed, traffic intensity, vehicle types, local climate, and proximity to water bodies. The USDA Forest Service has produced a *Dust Palliative Selection and Application Guide*[126] which contains information about a range of palliatives, including application tips, typical application rates and frequency, product limitations, and environmental impacts. Currently, this is the only USDA publication available to assist in selecting the proper dust control product, and this industry has continued to advance over the last 20 years. Other state and local units of government have released more recent publications that include newer products that have become available, such as the U.S. Department of Transportation, Federal Highway Administration's *Unpaved Road Dust Management, A Successful Practitioner's Handbook*.[127] It is important to select a product that is suitable for the area of concern; for example, calcium chloride and magnesium chloride are both hygroscopic/deliquescent palliatives and require a certain amount of atmospheric moisture to work,[126] so they should not be used in areas where the daily summertime relative humidity averages below 30%.[125] Lignosulfonate, an organic non-petroleum product, should not be used in areas where the runoff could enter fish spawning waters.[128] Some products may require restricting access to the area after application to allow the product to cure – liquid asphalt, for instance, may need 7-10 days to cure before resuming normal traffic.[129] Roads and other surfaces may need to be graded or smoothed in preparation for applying a palliative; refer to the selected product's guidance materials for appropriate site preparation.[128]

Figure 7-19. Water can provide temporary dust control on unpaved roads and surfaces. Photo: USDA NRCS.[130]

Figure 7-20. Commercial polymer being applied to farm road. Photo: Andrew Faison, USDA NRCS, Avondale Arizona.

Where practical, also consider using measures such as speed control, vehicle exclusion, establishment of vegetation, windbreaks, and/or mulching to support dust control on unpaved areas.[131] Where there is concern about an applied palliative entering local water bodies through runoff, it may be helpful to install buffer strips along the sides of the road or unpaved area to minimize transport.[131]

During the 2013-2017 evaluation period, only five states implemented the NRCS practice Dust Control on Unpaved Roads and Surfaces. As shown in Figure 7-21, the practice was implemented much more widely in California than in other states.

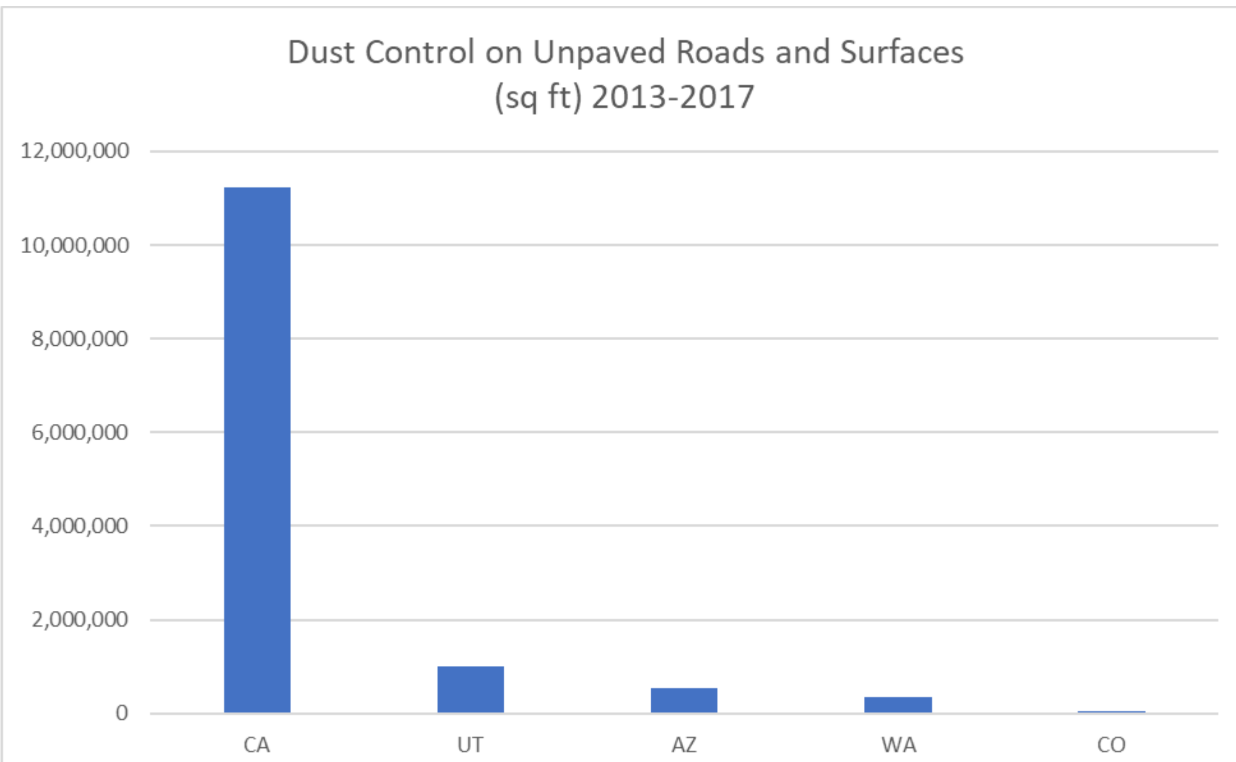

Figure 7-21. States implementing Dust Control on Unpaved Roads and Surfaces (373) during 2013-2017.

Forage and Biomass Planting – 512 and Range Planting – 550

Range Planting (550) and Forage and Biomass Planting (512) are two practices designed to improve vegetative cover and reduce erosion on grazing lands. Both practices call for the establishment of suitable plant species adapted to the site. The practice standards have similar requirements and considerations. However, Range Planting is restricted to native and naturalized plant materials that are consistent with the ecological site description for the area being treated. Whereas, Forage and Biomass Planting can include any species, varieties, and cultivars suitable for pasture, hay or biomass production. Another difference is Range Planting can include grasses, forbs, shrubs or trees and Forage and Biomass Planting is restricted to herbaceous plant materials.

Range Planting is an intervention conservation practice utilized when the current vegetation is degraded to a point that natural reseeding will not occur and grazing management will not likely recover the site. Range Planting is a restoration practice and normally not considered a routine practice. The seed mix consists of native species to the area, as per the ecological site description. The ecological site name can be obtained from Web Soil Survey on the internet, and then cross-referenced to state's FOTG Section II for a complete description of the ecological site. Since range planting consists of native species, the seed mix can be expensive. The conservation planner must develop a seed mix that is economical, has a noted success rate, and consists of seed varieties that are readily available and adapted to the site. Oftentimes, compromises must be made. Most state's FOTG will have a seed/vegetation guide that lists which species are adapted to the Major Land Resource Area (MLRA), Common Resource Area (CRA) and/or Ecological Site. Some guides will give specific recommendations on seeding rates, depth of planting, and when to plant. However, until the planner develops the expertise to make recommendations on his/her own, it is best to consult a plant materials specialist or ecologist.

The risk of an unsuccessful range planting is greater as average annual rainfall diminishes and evapotranspiration increases. For instance, in the arid southwest, range planting is rarely attempted in areas with less than 10" precipitation and a hyperthermic temperature regime. An exception to that rule would be in large, wide, flat watershed drainages that receive moisture from runoff, or in areas of man-made topographic improvements designed to re-route and/or collect runoff. Considering climate change and increased temperatures and increased variability of precipitation, evaluating site suitability for range planting should be closely examined.

Forage and Biomass Planting, on the other hand, may have the benefit of irrigation as an option to establish and support the planted vegetation, such as on irrigated pasture and hayland. If irrigation is not going to be applied, then similar considerations as mentioned above for Rangeland Planting will apply to planting forage in areas of low precipitation; the chances of plant survival and success should be carefully evaluated before beginning. This is particularly true if existing vegetation or ground cover will be removed in the process of site preparation and planting. Although plants established under Forage and Biomass Planting are not limited to native species,[132–134] as is the case in Rangeland Planting, it is still important to select species which are adapted to the region, site conditions, and intended use. Many state FOTGs have plant recommendations or criteria for selecting species appropriate for the area and purpose, as well as locally relevant guidelines for successful planting and establishment. Some relevant soil and site properties that can be obtained from Web Soil Survey are listed in Appendix B, Exhibit 7-1. Consider using site preparation and planting methods that will minimize particulate emission, such as no-till, to protect air quality.[135] For effective wind erosion control, plants should be able to produce good ground cover and have enough root mass to stabilize the soil.[132]

For both Range Planting and Forage and Biomass Planting, appropriate management is needed to sustain the benefits achieved from the treatment. If the area is to be grazed, following a Prescribed Grazing plan can aid in maintaining the forage in a desirable condition.[136]

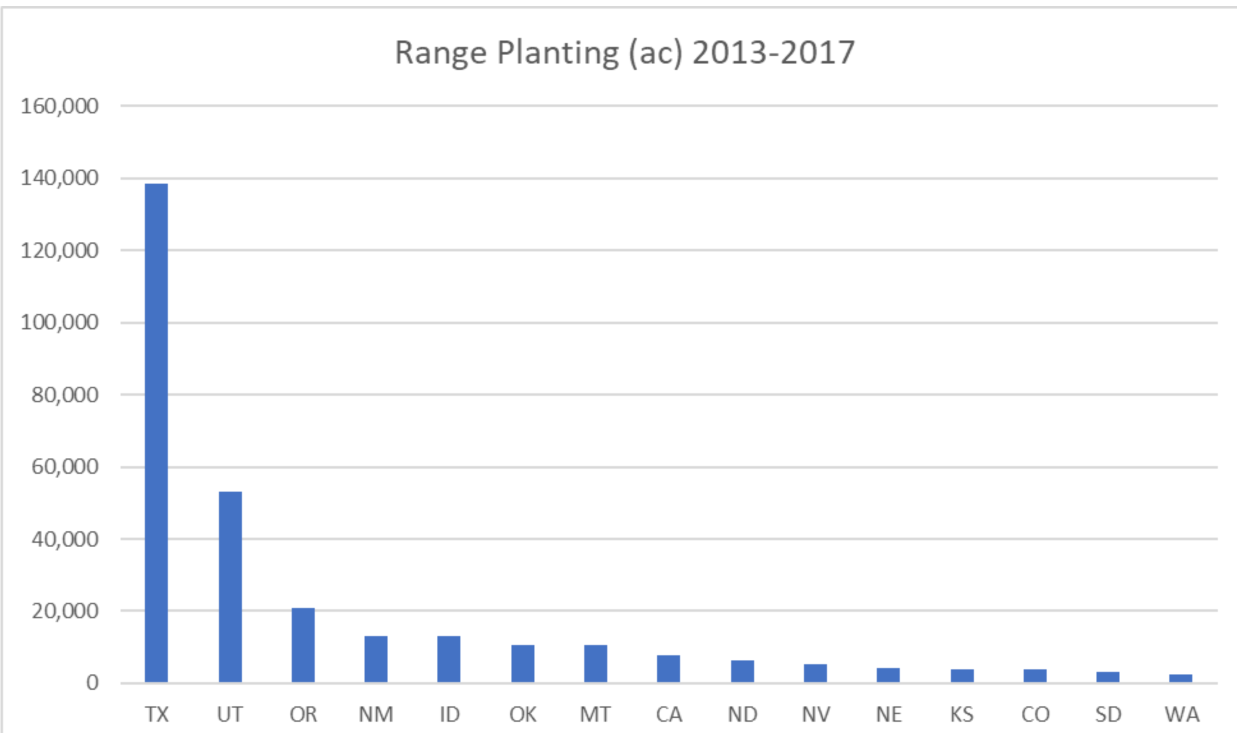

Figure 7-22. Top 15 states (by acres) implementing Range Planting (550) during 2013-2017.

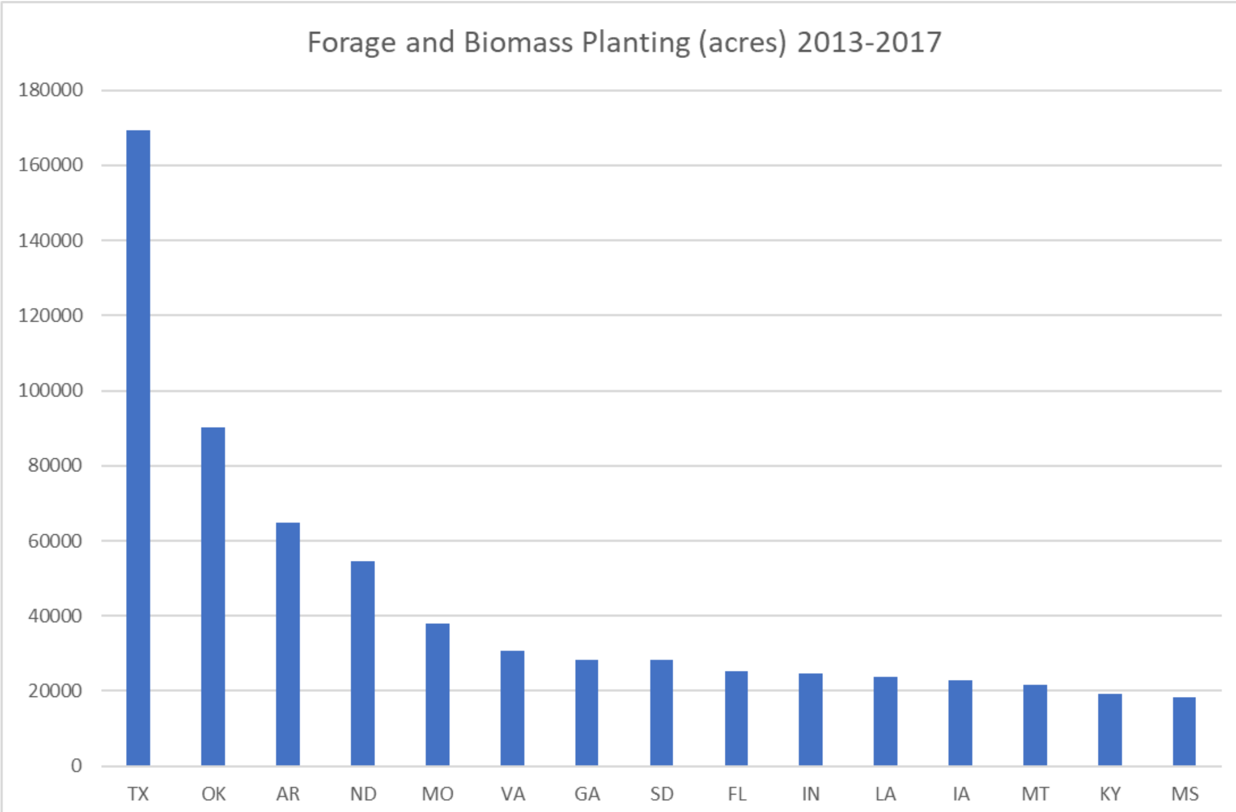

Figure 7-23. Top 15 states (by acres) implementing Forage and Biomass Planting (512) during 2013-2017.

Grazing Land Mechanical Treatment – 548

Grazing Land Mechanical Treatment (548) as defined by the NRCS refers to modifying physical soil and/or plant conditions with mechanical tools by treatments such as pitting, contour furrowing and chiseling, ripping or subsoiling, and aeration or plugging.[137–139] It is usually performed as a treatment to correct conditions such as excessive water runoff from an area, compacted soil with poor permeability, or root-bound conditions and thatch which needs to be broken up.[137] The treatment helps by increasing water infiltration and reducing runoff, increasing plant vigor, and in some cases reducing competition from undesirable plants.[139] Like brush and weed removal, Grazing Land Mechanical Treatment does not directly reduce wind erosion but can positively influence plant production and yield,[139] which in turn increases ground cover and root networks. This helps to hold the soil in place and lessens the potential for wind erosion.

Grazing Land Mechanical Treatment can be used on pastureland, rangeland, grazed forest, and native pastures, but is only suitable where the slopes are less than 30 percent and where disturbance will not result in unacceptably high soil erosion.[137] Commonly associated practices include Range Planting (550), Forage and Biomass Planting (512), Herbaceous Weed

Treatment (315), Prescribed Grazing (528), Integrated Pest Management (595), and Nutrient Management (590).[137,140] Grazing land mechanical treatment should only be done in areas that are relatively free of noxious or undesirable plants, as these may increase after surface disturbance.[137] Prescribed Grazing is a requirement following Grazing Land Mechanical Treatment and is considered essential to the success and long-term maintenance of this practice.[137] The treated area will in most cases need to be rested from grazing for a time following the treatment. Length and timing of requisite grazing deferment varies and is usually specified in the local NRCS FOTG, but in general is one to two years and takes into account the reproductive cycle of the desirable vegetation.[140–142]

Figure 7-24. Chiseling is a form of Grazing Land Mechanical Treatment (548) used to disrupt matted vegetation (like clubmoss) and compaction caused by hoof action to rejuvenate vegetative growth. Photo: USDA NRCS Montana.

Figure 7-25. The range imprinter can be utilized to restore degraded rangeland as a method of Grazing Land Mechanical Treatment (548). The imprinter creates an uneven surface to interrupt sheet flow and encourage additional moisture to enter the soil. The imprinter does not perform well in hard, compacted soils, where thick desert pavement exists or where large rock fragments exist. Photo: USDA-NRCS Gilbert Two Two.

Mechanical treatment should take place when the soil is dry enough that the equipment will not cause compaction, yet still contains enough moisture to facilitate adequate penetration and disturbance of the compacted soil layers.[138,142] Fine textured soils that are too dry may clod excessively.[138] In general, tillage for this practice should be applied when soil moisture is no more than 30% of field capacity.[140,142,143] When ripping to break up compacted soil layers that restrict root growth and limit water infiltration, the depth of compacted layers should be investigated with a probe or other suitable tool prior to ripping to determine the appropriate treatment depth.[137,138]

This practice is not suitable for all soil types and all areas.[138,141,142] Suitable soil textures, percent slope limits, and other site considerations for a given treatment type (e.g., chiseling) are usually described in the locally applicable FOTG. Depending on the level of expected soil disturbance, the maximum acceptable slope may be less than the 30 percent limit specified in the general practice description.[138,142] The ability of livestock to navigate the terrain following treatment should also be considered,[137] as increased surface roughness may hinder usability.

Mechanical treatment which disturbs the soil below depths that have been disturbed by previous activities can potentially pose a risk to buried cultural resources that may exist in the area; therefore it may be necessary to consult with a cultural resource specialist when preparing the plan for this practice.[137,141] One should also be aware of any buried pipelines, tile drains, or other buried structures which need to be avoided so as not to cause damage the equipment or to the structure.[137,142]

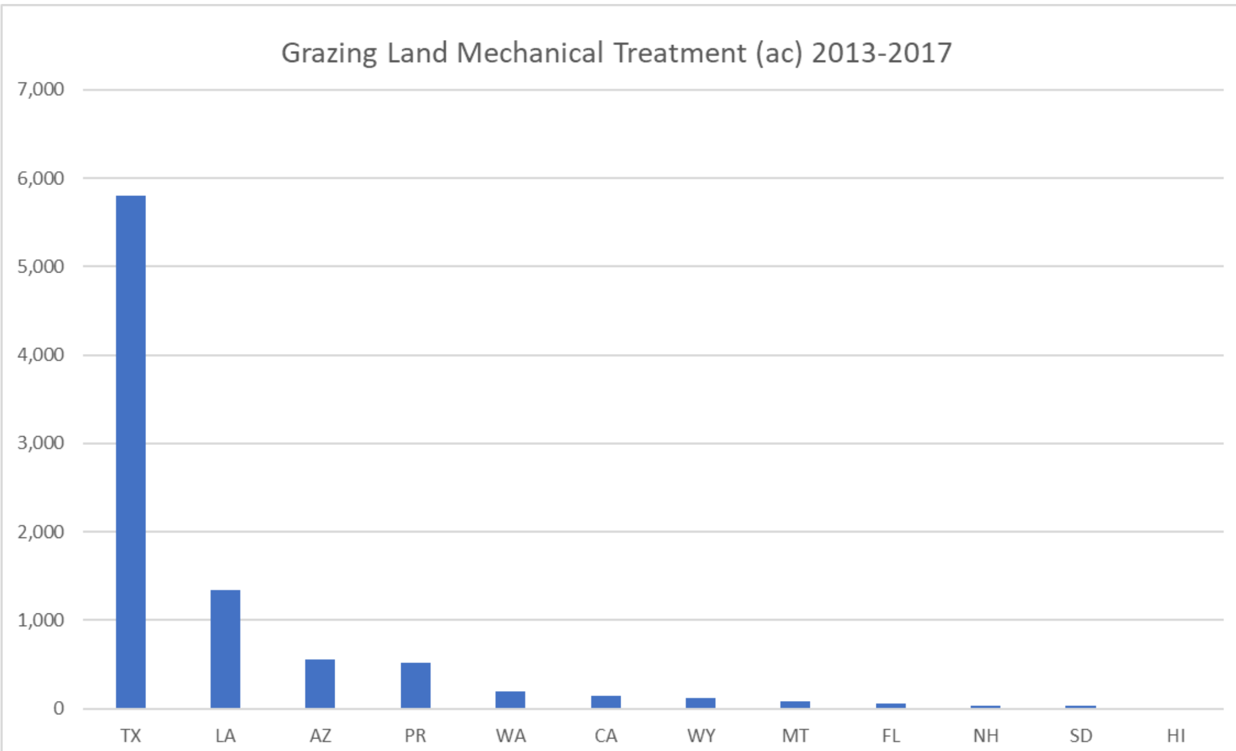

Figure 7-26. Top 12 states and U.S. territories implementing Grazing Land Mechanical Treatment (548) during 2013-2017.

It is not uncommon for grazing land mechanical treatment and several of the other practices described so far to be used in combination to restore the health of an area of rangeland. The following photo series provides an example of this – an area is treated first with Brush Management, then with Grazing Land Mechanical Treatment followed by Range Planting. The final photo (Figure 7-31) shows the resulting range condition post treatment.

Figure 7-27. Brush Management (314) conducted on an invaded grassland. Photo: USDA NRCS, Doug Saunders.

Figure 7-28. Grazing Land Mechanical Treatment (548) practiced post-Brush Management (314) treatment and prior to Range Planting (550). In this case Grazing Land Mechanical Treatment is utilized to break up compaction and surface seal prior to seed planting to improve planting success. Photo: USDA NRCS, Gilbert Two Two.

Figure 7-29. Range Planting (550) utilizing native seed and a broadcast seeder. Photo: USDA-NRCS, Doug Saunders.

Figure 7-30. Range Planting (550) conducted by collecting native purple three-awn seed heads and manually planting. This method of planting is sometimes necessary with native seeds sensitive to seed-cleaning operations, as it increases germination rate. Photo: USDA NRCS, Gilbert Two Two.

Figure 7-31. Post treatment of the series of practices. Photo: USDA NRCS, Doug Saunders.

Heavy Use Area Protection – 561

Areas of heavy use by animals or humans may need extra protection so as not to become a source of dust. The NRCS defines Heavy Use Area Protection (561) as the stabilization of areas frequently and intensively used by animals, people, or vehicles by establishing vegetative cover, surfacing with suitable materials, and/or installing needed structures.[144] Livestock feeding and watering facilities, portable hay rings, mineral boxes, and areas of frequent vehicular traffic are some examples of potential problem areas which may become denuded of vegetation over time and thus prone to wind erosion.[145] Where possible, land managers should consider adjusting management practices to keep the extent of such areas to a minimum.[144,145] In small areas of unavoidable heavy use, however, it may be desirable to pave or otherwise install a stable, non-eroding surface to protect water and air quality.

Figure 7-32. Heavy use area that has been armored with a surface of aggregates, Thibodeaux, Louisiana. Photo: Stephen Kirkpatrick, USDA NRCS.

The best design and type of protective surface to install in a heavy use area will depend on site characteristics and the intended use. The local NRCS CPS (found in the local FOTG) for this practice can offer some general guidance on site preparation and design requirements for various construction materials and in most cases directs users to the appropriate section(s) of applicable engineering documents as well. Commonly used materials for Heavy Use Area Protection include concrete, bituminous concrete, and gravel; other materials such as soil cement, agricultural lime, roller-compacted concrete, and coal combustion by-products (flue gas desulphurization sludge and fly ash), may also be used where appropriate.[146] Artificial mulches, such as cinders, bark mulch, brick chips, or shredded rubber can be used in some situations, but they are not recommended for livestock or vehicular applications.[146] Sometimes a heavy use area can be stabilized by establishing vegetation of a species that can withstand the wear and tear it will receive.[146] Land managers should establish vegetation in accordance with CPS Critical Area Planting and may also need to plan for periods of rest and recovery and/or use reinforcing materials such as geogrids.[146]

Safety of the users should always be a consideration when installing any surface or structure.[146] For example, concrete surfaces may need roughening to avoid creating slippery conditions when wet.[147] Likewise, sharp corners should be avoided, and materials used around livestock should not be of a type or shape that will cause hoof injury or other harm.[146] Practicality is also important; if the area will be cleaned of manure by scraping, then a surface consisting of loose aggregates may not be a good choice.[145] Prior to disturbing the ground for construction of the stable surface, always ensure that no buried utilities or other subsurface structures will be damaged by the activity.

Since reducing the permeability of an area will have an impact on water infiltration and runoff, consideration should be given as to how installing the planned Heavy Use Area Protection will impact the surrounding area in terms of water budget, erosion, and water quality.[144] Provisions for handling runoff without contributing to erosion or water quality impairment should be included in the design.[144] If the current location of a heavy use area poses a risk to nearby surface waters, the area may need to be relocated.[145] Windbreaks or Shelterbelts (380) and Herbaceous Wind Barriers (603) can also help to minimize dust emission from a heavy use area.[146] Access Control or Fence (382) can also be used to modify traffic patterns around the area.[148] Sometimes it is appropriate to install a roof in a heavy use area, and in that case, users should refer to CPS Roofs and Covers (367).[146] Some reports obtainable from Web Soil Survey that relate to Heavy Use Area Protection are listed in the help sheet found in Appendix B, Exhibit 7-1.

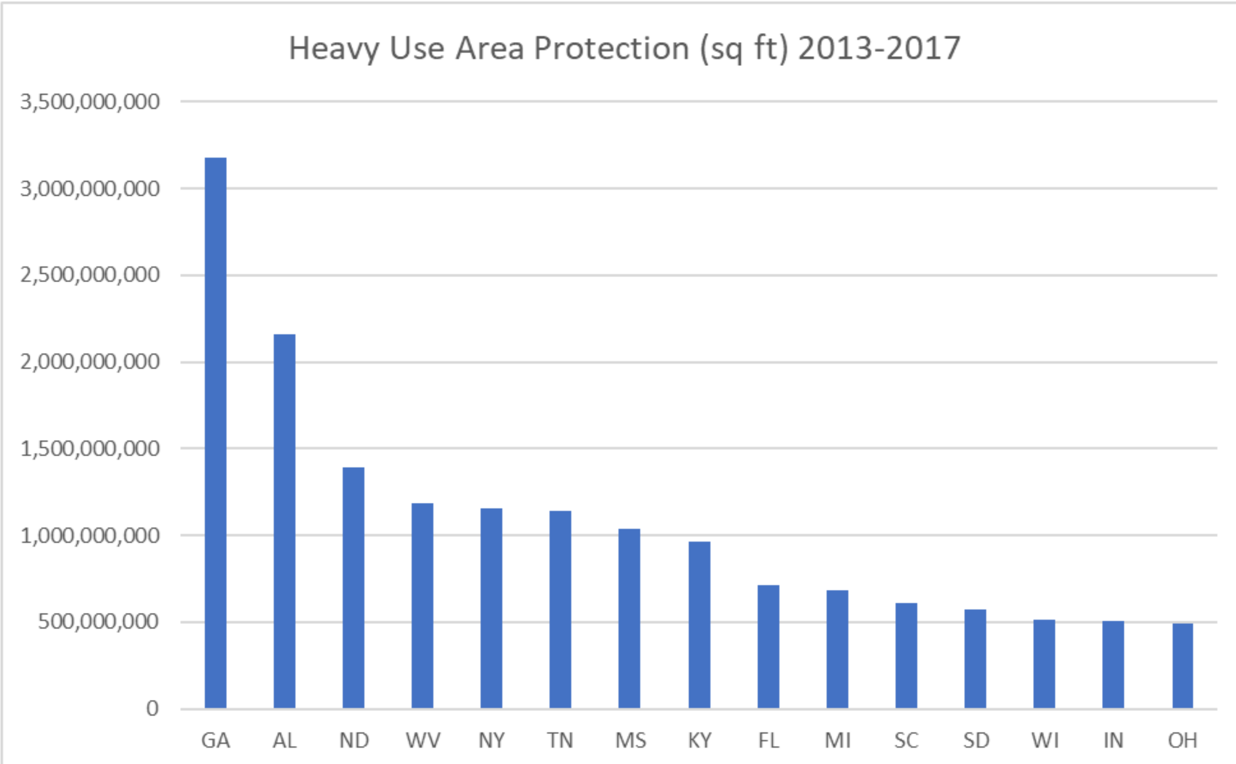

Figure 7-33. Top 15 states (by sq ft) implementing Heavy Use Area Protection (561) during 2013-2017.

Prescribed Burning – 338

The NRCS defines Prescribed Burning (338) as "controlled fire applied to a predetermined area." Prescribed Burning applies on rangeland, forestland, native pasture, pastureland, wildlife land, hayland, and other lands as appropriate.[149]

Figure 7-34. Prescribed burning can help meet management goals. Photo: USDA NRCS.[150]

Prescribed burning does not in itself reduce wind erosion – in fact, it often makes the burned area more prone to erosion and may necessitate implementation of erosion-control measures as a follow-up.[151] When used in concert with other appropriate practices, however, prescribed burning can be an effective tool to help achieve management goals. Prescribed burning may be used as a means of removing undesirable plants as part of Brush Management or Herbaceous Weed Treatment.[97,98] Prescribed burning can also be used to remove accumulated dead residue and brush on previously abandoned pastureland which is to be brought back into forage production.[152] Warm season grasses are more tolerant to burning than cool-season grasses, and it is generally not recommended to burn cool-season grasses unless the goal is to eradicate them.[152] Follow up treatment to prescribed burning may include conservation practices such as Range Planting, Critical Area Planting, and/or Prescribed Grazing.[151,153]

Prior to burning, a burn plan needs to be developed and the landowner must secure all necessary permits;[149] the landowner is responsible for complying with all applicable Federal, state, and local laws, rules and regulations when planning and during application of prescribed burning. Caution should be used in an area where burning may provide the opportunity for one or more undesirable plant species, such as an invasive annual grass, to take over the site post-disturbance. The anticipated response of noxious or invasive species should be addressed in the burn plan.[154] The impact to cultural resources, threatened and endangered species, and use by local wildlife and pollinators should also be considered.[150,155] Some wildlife-related information, such as ecological site information and location of wetlands can be found in Web Soil Survey, and a help sheet on how to find these reports is included in Appendix B, Exhibit 7-1.

Smoke management is an important component in planning and executing a prescribed burn.[149,156,157] The National Wildfire Coordinating Group (NWCG) has published a *Smoke Management Guide for Prescribed Fire*[158] which some may find helpful. The timing and burn intensity should be managed to minimize carbon released into the atmosphere.[149] In some cases, smoke discharge from a controlled burn may be regulated by a state or local department of environmental control, from which approval must be obtained.[154]

The exact site conditions needed for a successful controlled burn are extremely specific and will be addressed in formulating the burn plan before any burn is implemented, however, in general weather and atmospheric conditions, fuel load, and purpose of the burn are all considerations. Additionally, the type and timing of a fire to control one species of woody brush may not be the same as the control of another undesirable plant.[157,159] The best resource for site- and species-specific advice will be the expertise of local professionals consulted in the process of selecting Prescribed Burning as an appropriate treatment and preparing the burn plan. Beyond the physical potential of a site to support and benefit from a prescribed burn, however, there are some other equally important components that influence the practicability of conducting a prescribed burn:

Qualified personnel: Only those who have been properly trained and have the appropriate job approval authority and/or certification level may provide assistance in planning and implementing a prescribed burn.[160] In parts of the country where fire is routinely used as a land management technique, there may be local appropriately qualified staff. In other areas where the application is less common, the required technical capacity may be a thinly stretched resource.[100] Prescribed Burning can, however, be implemented using a burn plan that has been prepared at the landowner's request by a qualified individual from another agency, provided the requirements for the CPS are still met.[100]

Land ownership and jurisdiction: For some, a pasture or range to be burned crosses jurisdictional boundaries. Examples of this would be managers who lease their land from several entities (e.g., State Trust, BLM, USFS) that hold adjoining parcels arrayed in a checkerboard pattern.[100] All parties that hold any portion of the land to be burned must agree to the burn before it can happen, which adds another level of coordination to the effort.[100]

Liability: In the event that inadequate smoke management or an out of control/escaped fire results in damage to structures or property, harm to human health or safety, wildfire ignition, or any other harm, the landowner or cooperator may be liable for the damage.[157,159,161] This may include the cost of fire suppression for an escaped fire.[159,161] Some landowners carry an insurance policy that covers unintended mishaps associated with a prescribed burn, while others may have no such policy and may be understandably reluctant to take such a large risk.[100] It is important that the landowner or cooperator fully understand their liability before making plans for a controlled burn.

Coordination with local entities: Local fire departments, public safety officials, and adjoining landowners need to be notified of the planned burn.[149] It is often necessary to inform residents in the area as well to prevent a nuisance amount of unnecessary reports of the fire to local authorities/emergency personnel.[100] There must be enough fire suppression equipment and personnel available during the burn to adequately respond to the fire's behavior and prevent a wildfire or other safety, health, or liability incident.[149] How much is "enough" depends on a variety of factors including weather conditions, fuel condition and moisture content, and other related effects such as possible obstruction to human or vehicular traffic due to heat or smoke.[156,157,159]

Proximity to urban features: Presence of urban structures nearby can be hazardous should the burn get out of control. There may be a stipulated setback distance of several miles from urban boundaries or subdivisions that must be observed.[154] Near populated areas there is also often a higher likelihood of encountering utilities conveyance structures such as power lines and natural gas pipelines, which need to be avoided. The hazard to vehicular traffic visibility and access may be a problem as well.[149,157] An area that is situated relatively far from most urban features is generally a better candidate for prescribed burning.

The relative ease or difficulty in addressing the necessary components will influence the decision regarding whether or not to apply prescribed burning as a management tool. The extent to which NRCS can participate in the planning and execution of a prescribed burn also varies by state. In many states, policy stipulates that NRCS personnel cannot serve as fire boss and/or cannot ignite or assist with igniting a fire. In some places NRCS personnel cannot in any way participate in a burn implementation plan.[151] There may also be restrictions in place regarding authorship of the burn plan. It is best to check with the local NRCS office to determine the type of assistance they can offer and if other resources are available if needed.

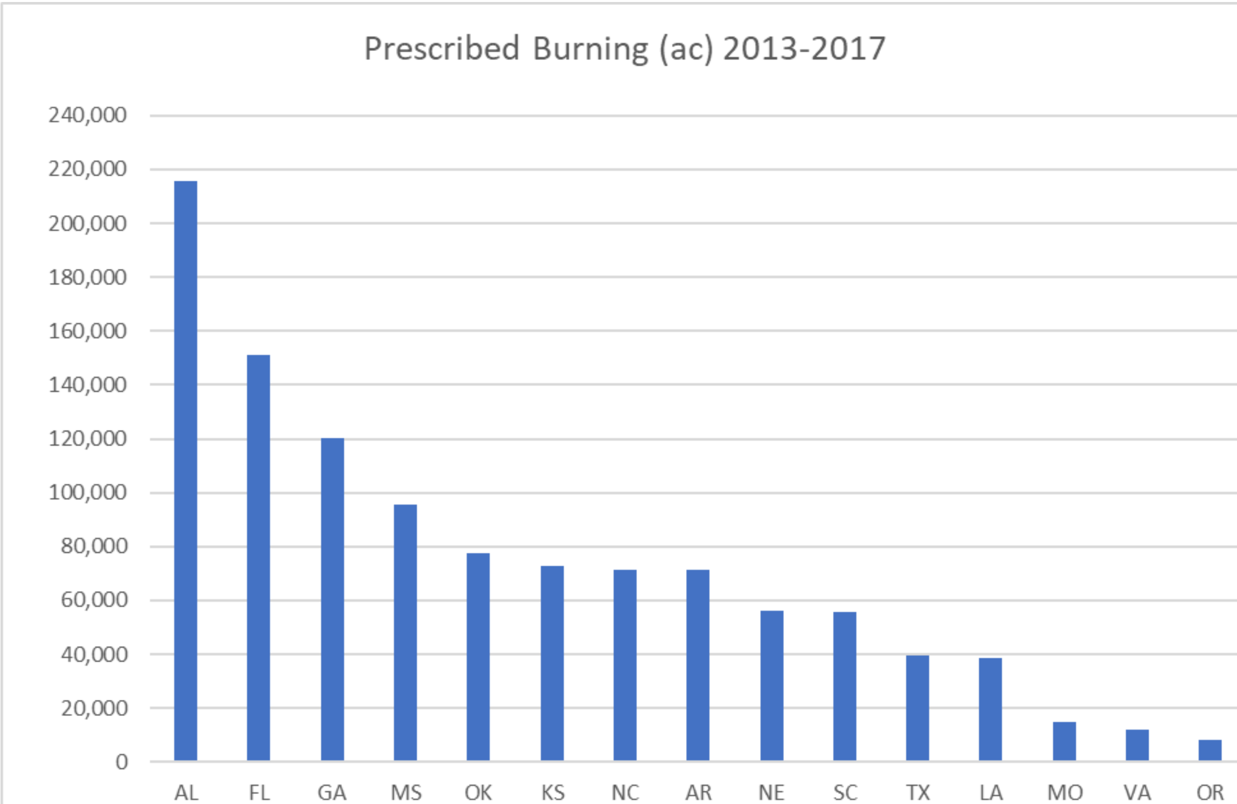

Figure 7-35. Top 15 states (by acres) implementing Prescribed Burning (338) during 2013-2017.

Prescribed Grazing – 528

The NRCS definition for Prescribed Grazing (528) is managing the harvest of vegetation with grazing and/or browsing animals with the intent to achieve specific ecological, economic, and management objectives. Another common name for this practice is a *grazing management plan*. Managing the harvest of vegetation includes adjusting grazing animal numbers (accounting for grazing/browsing wildlife), adjusting the timing of grazing exposure to each pasture, and devising a rotational scheme of moving the livestock from pasture to pasture. A successful grazing plan is dependent on knowing the current condition and the production potential of the ecological sites on the ranch. There are numerous tools available for grazing land professionals and practitioners to utilize in gauging the condition of grazing lands: Range Health Assessment,[162] Pasture Condition Score,[163] and many range and pasture inventory and monitoring tools detailed in the *National Range and Pasture Handbook*.[104]

The practice standard recognizes numerous purposes for implementation:

- Improve or maintain desired species composition, structure and/or vigor of plant communities.

- Improve or maintain quantity and/or quality of forage for grazing and browsing animals' health and productivity.
- Improve or maintain surface and/or subsurface water quality and/or quantity.
- Improve or maintain riparian and/or watershed function.
- Reduce soil erosion, and maintain or improve soil health.
- Improve or maintain the quantity, quality, or connectivity of food and/or cover available for wildlife.
- Manage fine fuel loads to achieve desired conditions

Although any of these purposes can validate the implementation of this practice in NRCS financial assistance program, a good Prescribed Grazing Plan will likely address and ameliorate multiple concerns listed above. The goal of Prescribed Grazing is to sustain productive grazing lands considering the economic viability of the ranching enterprise while balancing the needs of a diverse biotic community and a healthy watershed. Maintaining appropriate and acceptable vegetative cover is critical to controlling wind and water erosion on all forms of dryland grazing lands. This is accomplished with a rotational grazing plan based on a proper inventory of the soils, ecological sites, and forage resources across the entire ranch. The rotational grazing plan may utilize a rest-rotation schedule, where the "rest" cycle is a full-year non-grazing period for each pasture that is rotated annually. Or, the rotational grazing plan might consist of a deferred-rotation schedule, where each pasture is "deferred" from grazing typically during the growing season and the deferral is rotated annually from pasture to pasture. Or lastly, the rotation may consist of a high intensity-short duration schedule (sometimes called mob grazing), where the grazing pattern mimics the nomadic nature of wild grazing animals and the grasses are heavily grazed for a short period but then given ample time to recover. It should also be noted that deferment, apart from being a routine component of a deferred-rotation grazing plan, is a common consideration after a planned vegetative/soil manipulation on range, a range planting, prescribed fire, wildfire, or drought, to allow targeted grasses to develop good root structure and to mature to seed and promote a healthy seed bank in the soil.

Inventorying the forage resources and developing a short and long-term monitoring plan are required components of the Prescribed Grazing standard. Long-term monitoring plans are typically developed to support a goal of improving or maintaining species composition in a sensitive area, or on a specific ecological site(s), or a degraded pasture, or across the whole ranch. A short-term monitoring plan is used to assess effects of grazing, weather events, wildfire, and past land/vegetative treatments to make adjustments to the prescribed grazing plan as needed to protect the resource base. A proper inventory will identify unused, underutilized, and overutilized portions of the pastures or range. This, in turn, helps identify the needs for additional facilitative practices, such as fences, water developments, and soil/vegetative manipulations.

Many facilitative practices do show a benefit in addressing wind erosion according to the Conservation Practice Physical Effects (CPPE). However, this is due to the practice's contribution to the improved distribution of livestock over the grazing unit. For instance, a Water Well (442) does not in itself control erosion on grazing lands, but it does help facilitate improved livestock distribution and more uniform forage utilization. Improved livestock distribution over the whole range reduces areas of degraded range.

Another important requirement of the Prescribed Grazing standard is the development of a drought management plan for the ranch. Drought is commonly described as when annual precipitation drops below 75% of the long-term (normally 30-year) average. During drought, good range managers understand grazing is not business as usual. Adjustments must be made to the grazing plan, including intensity, frequency, timing, duration, and distribution of grazing, and depending on the duration and severity of the drought, these adjustments must be continued for at least a year after the drought has broken. Thresholds must be set that trigger herd movement, pasture rest, supplemental feeding, and even herd culling. For instance, the grazing standard of "take half, leave half" might be adjusted to take 40%, leave 60% to reduce degradation of the plants' root systems, and consequently the range in general. Guidance for drought management plans will vary from state to state due to the vast differences in landscapes and grazing systems. Some states have developed formats for drought management plans and incorporated them into the specification for the practice, such as North Dakota.[164] Many land grant universities have assembled excellent guidance for managing grazing during drought, such as the University of Arizona Cooperative Extension's publication *Rangeland Management Before, During and After Drought*,[165] by Larry D. Howery, and USDA RMA/University of Nebraska/National Drought Mitigation Center partnered publication *Managing Drought Risk on the Ranch - A Planning Guide for Great Plains Ranchers*.[166]

NRCS Environmental Quality Incentives Program (EQIP) payment schedules have practice scenarios based on the level of intensity of the grazing management plan, the complexity of the monitoring plan, wildlife management considerations, and identified needs for deferment. Prescribed Grazing is practiced in every state and territory; Figure 7-36 displays the top 15 states in implementing the practice.

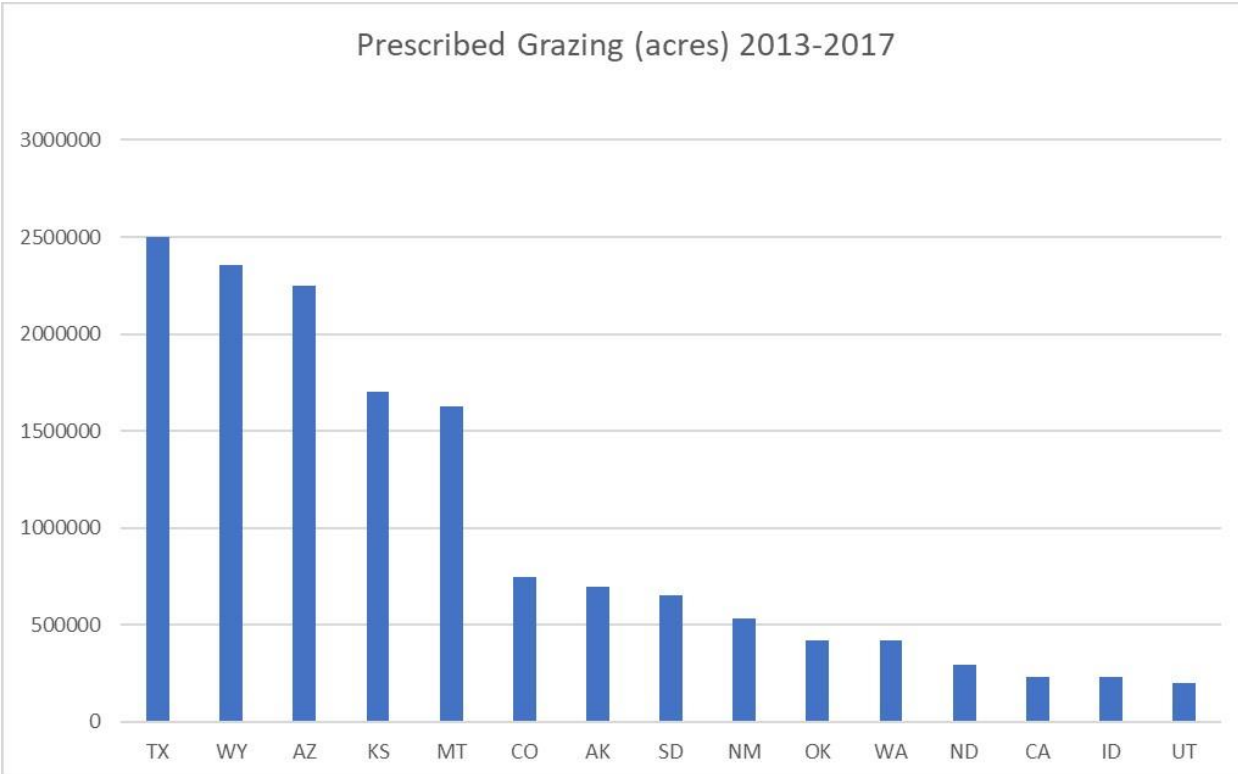

Figure 7-36. Prescribed Grazing installed under NRCS programs from 2013-2017.

Figure 7-37. White Mountain Apache Tribe employees Sisto Hernandez and Ricardo Velasquez estimating utilization. Proper range inventory and monitoring is essential to establish stocking rates, understand forage composition and quality, to establish pasture trends, and to track expansion of invasive species. Photo: Jan Pertruzzi, District Conservationist, USDA NRCS.

Restoration of Rare or Declining Natural Communities – 643

Restoration of Rare or Declining Natural Communities (643) applies where the goal is to restore, conserve, and/or manage unique or diminishing native terrestrial and aquatic ecosystems to return them to their original or usable and functioning condition.[167] It can also apply to restoring a habitat of local cultural importance.[167]

Rejuvenating or restoring a rare or declining natural community on a site that has become degraded will almost always involve creating a plan that includes applying one or more other conservation practices, many of which are discussed elsewhere in this manual, such as Brush Management, Herbaceous Weed Treatment, Prescribed Burning, Range Planting, and so on.[168] Whenever one of these practices is applied, the standards and specifications for that practice will also apply. For this reason, it is difficult to discuss Restoration of Rare or Declining Natural Communities separately, as it more a case of applying other conservation practices with the specific end-goal of restoring and managing a habitat of special concern.[168]

This practice can be applied in many settings and does not only apply to dust-prone areas,[167] however when the plan includes improving the health of the vegetative community in an area that is susceptible to wind erosion, it will typically help decrease dust emission from that site through improved ground cover and increased root mass. Sometimes an area is taken out of commercial crop production to restore permanent vegetation associated with a rare or declining natural area.[169] Where this is the case, this practice positively impacts air quality in two ways: reduced erosion potential due to more stable soil surface conditions, and often reduced CO_2 emissions that are normally associated with crop production energy inputs.[170]

The biological communities eligible for this practice vary by state, and recommended procedures for restoration are quite specific to habitat type and location. The local FOTG should be consulted for practice details pertinent to the area of concern. Developing an appropriate restoration plan may involve consulting with other agencies and organizations that have expertise in conserving the target ecosystem, and with cultural specialists when species or habitats of local cultural importance are involved.[167,171,172] Appropriate target conditions should be determined using reference sites, ecological site descriptions, or other appropriate references.[167]

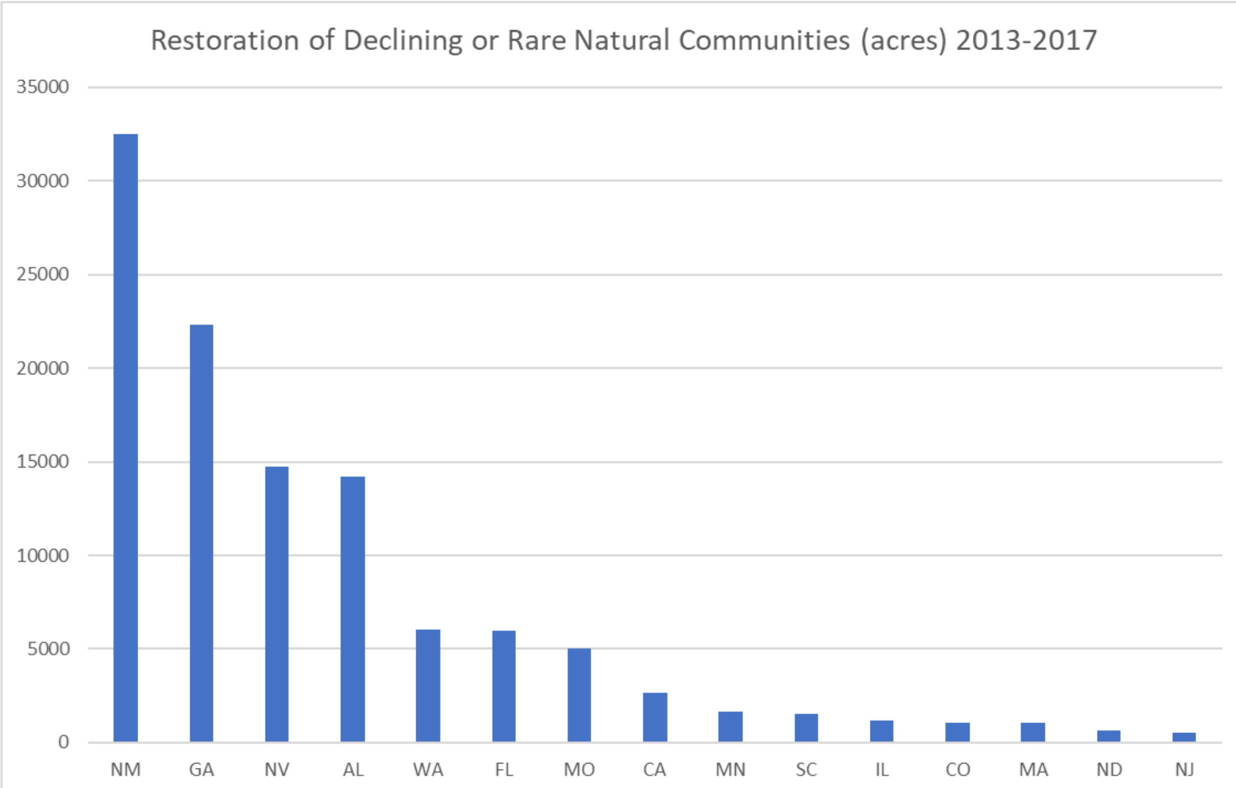

Figure 7-38. Top 15 states implementing Restoration of Rare or Declining Natural Communities (643) during 2013-2017.

Silvopasture Establishment – 381

Silvopasture is a management strategy whereby an operator can harvest multiple products from the same unit of land. It involves managing trees for high-value timber in a configuration and spacing that also leaves enough open canopy space to allow for the production of forage on the same plot.[173] Usually, the forage is grazed by livestock, which can provide a source of income in the short-term to the operator while the trees are maturing.[173] Shrubs may be included in the vegetation as well where compatible and desired,[174] such as for browse. The land manager may also in some cases opt to manage the forage or browse component to benefit wildlife, rather than grazing domestic livestock.[175]

Establishing silvopasture can help reduce wind erosion in several ways. Stands of trees and shrubs can reduce wind-driven sediment transport by intercepting airborne particulates. Trees can also reduce wind velocity by as much as 70 percent, while the ground cover provided by perennial forage helps to further protect the soil surface from erosion[176] and intercepts saltating particles.[177]

Figure 7-39. Cattle graze silvopasture that includes a stand of pine trees. Photo: USDA NRCS.[174]

Silvopasture is typically established by either planting trees into an area being used for forage production, or by thinning a forested area enough to let sunlight adequate for forage establishment and growth penetrate to the understory,[176,178] however trees and forage can also be established simultaneously.[174] Trees in silvopasture systems are often planted or left in rows with alleys of forage in between, but may also take other configurations, as appropriate to the site and operational goals.[176,178] Supplemental water may be needed to ensure establishment in some cases.[174] The thriving requirements of forage plants used should be compatible with the shade/sunlight conditions that will be present due to tree canopy.[176]

A good silvopasture operation requires intensive management and may have significant startup costs due to installation of fencing and watering facilities, establishment or removal of trees, and forage establishment where needed.[176] Maturing trees require pruning to produce high quality knot-free logs, and must also usually be thinned on a 5-7 year interval to maintain enough open canopy for forage production.[176] Grazing is usually rotational and must be carefully monitored to avoid damage to both trees and forage from overgrazing.[176] Tree seedlings and saplings are often vulnerable to damage from livestock and usually must be protected in some way, or alternately the pasture should be hayed rather than grazed, until the juvenile trees have reached a less vulnerable height and maturity stage.[176] Despite being somewhat labor intensive, silvopasture has many environmental and practical benefits.[176] Some key benefits and considerations are highlighted in the brochure "*Working Trees: Silvopasture, An Agroforestry*

Practice"[176] published by the USDA National Agroforestry Center (NAC). Silvopasture also increases carbon capture and storage.[178]

Appropriate tree and forage species and the best management techniques for successful silvopasture establishment and operation naturally have some variation from region to region. For this reason, it is important to seek guidance from local experts before beginning a project. Additional information on silvopasture is available from the USDA NAC[179] and from local NRCS offices and the FOTG. The local Cooperative Extension may also have helpful resources or personnel who can offer assistance. See Appendix B, Exhibit 7-1 for how to find soil reports in Web Soil Survey that may also be helpful in planning a silvopasture operation.

Silvopasture is not a widely used practice across the nation and no nationwide statistics for this practice were available to the authors at the time of creating this handbook.

Watering Facility – 614, Water Well – 642, Water Harvesting Catchment - 636

As stated previously, a watering facility does not in itself address wind erosion, but it does aid in the distribution of livestock over the grazed area for more uniform forage utilization. All watering facilities, by nature of trampling and grazing of congregated cattle, will result in small "sacrifice areas" around the water development where virtually no vegetation will grow. Conservation planners must be cognizant of this fact and locate these facilities where these impacts will be minimized, avoiding steep slopes and sandy soils that will be prone to erosion with no vegetated cover. Heavy Use Area Protection should be considered in the area immediately surrounding the watering facility, whereby gravel, concrete, geotextiles, and various mulching materials can be used to help keep soil in place.

Across the arid West where ranches are very large and water sources scant, it often becomes necessary to drill wells in suitable areas to obtain the desired livestock distribution. The Water Well (642) practice standard is used in these instances. Where water wells are not feasible or too costly, an alternative is the Water Harvesting Catchment (636). Both practices typically include tanks for water storage, pipelines for conveyance and distribution, fence for protection of facilities, and water troughs. Water wells will also require some form of water pump, whether it be electric, solar, or windmill.

Spacing of water developments is critical in getting proper livestock distribution and forage utilization across all pastures. Recommended spacing varies widely across the country based on climate, forage availability, grazing system used, livestock type and breed, and wildlife pressure. Recommended spacing can be expressed in number of watering facilities per unit of area, for instance on pastureland- one watering facility per 10 acres. Or, it can be expressed in travel distance, for instance on Southwest rangeland- livestock should not travel more than one mile between forage and water. In rough country, spacing is typically half of what would be normal for that general area. Incorrect spacing can result in overly large sacrifice areas around watering facilities that expose the soil to wind and water erosion. Consult the local NRCS Field Office, Cooperative Extension, or land grant university for recommendations specific to the area of application. Some reports available from Web Soil Survey can also be of use, and a help sheet on how to find them is included in Appendix B, Exhibit 7-1.

Figure 7-40. Top 15 states (by number installed) installing Watering Facility (614) during 2013-2017.

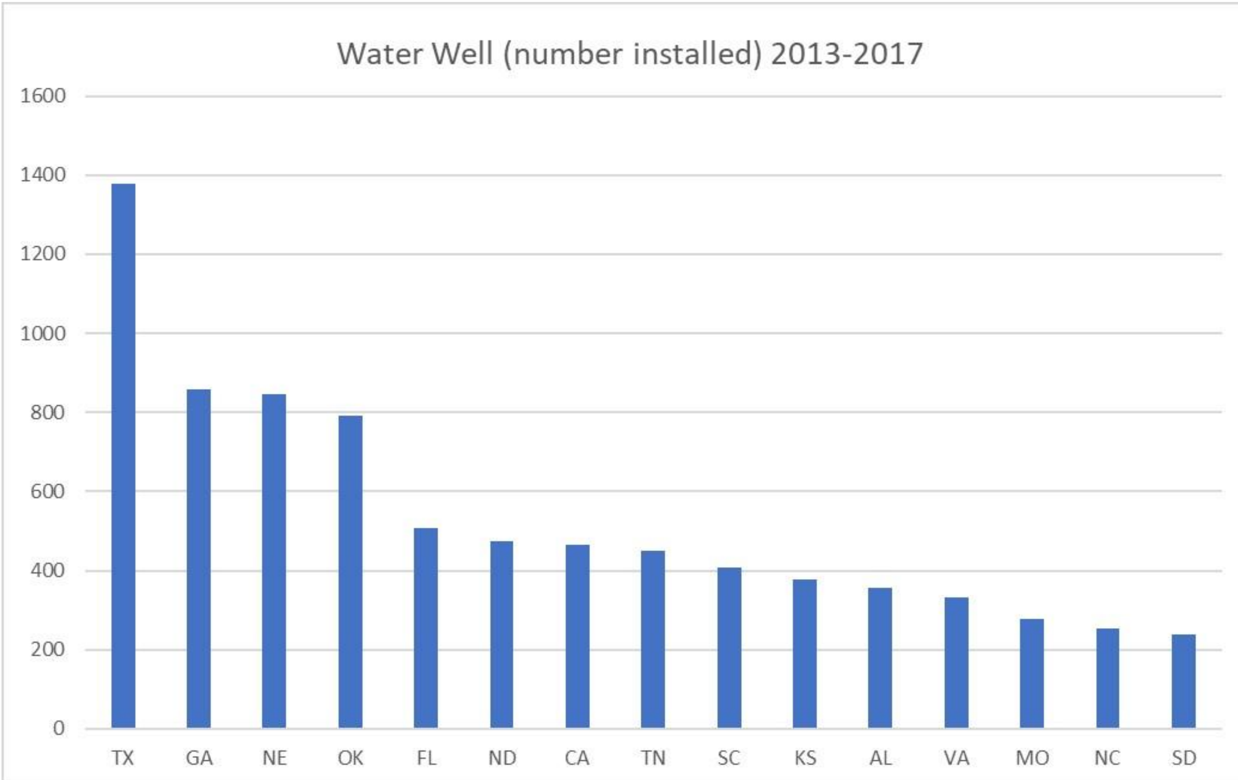

Figure 7-41. Top 15 states (by number installed) installing Water Well (642) during 2013-2017.

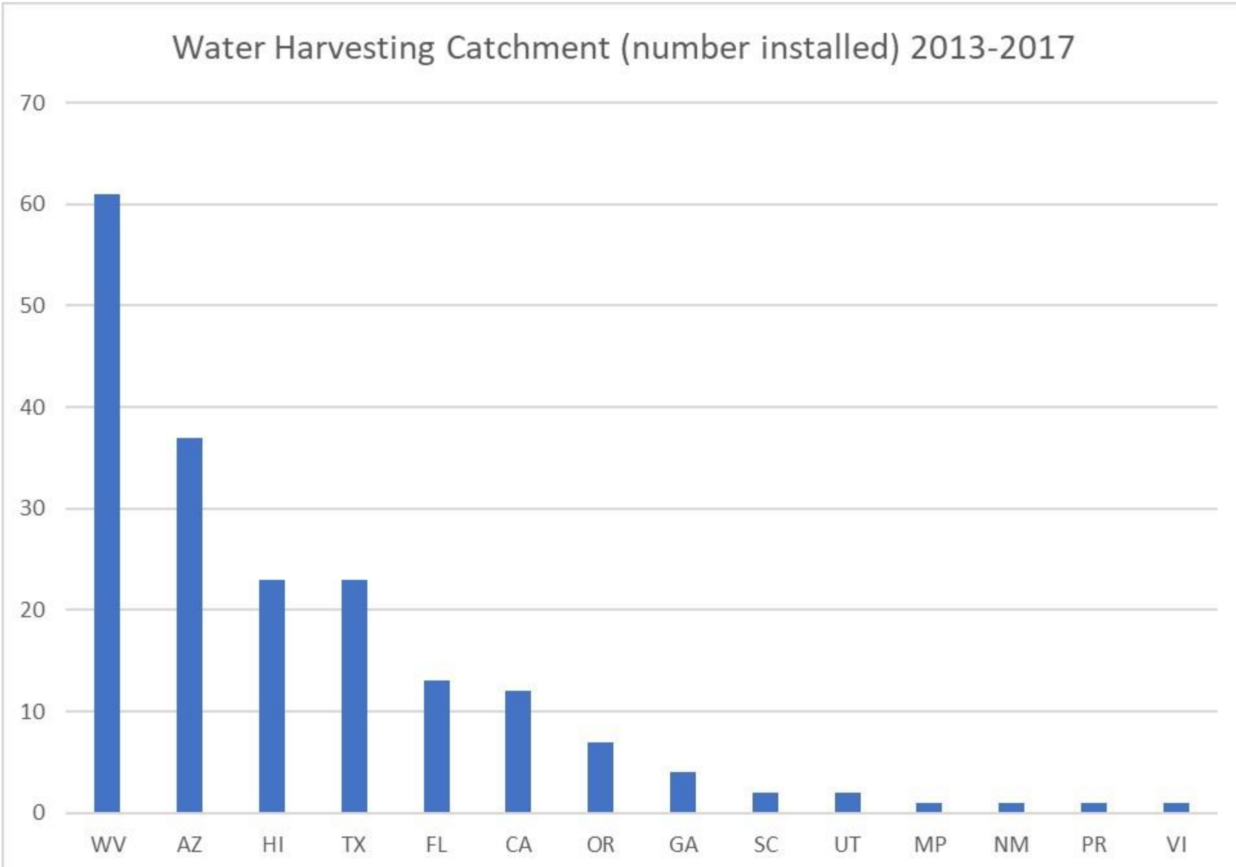

Figure 7-42. Top 14 states and U.S. territories (by number installed) installing Water Harvesting Catchment (636) during 2013-2017.

Figure 7-43. Water Harvesting Catchments are an alternative to wells where water wells are cost-prohibitive or of poor water quality. Photo: Steve Smarik, USDA NRCS, Maricopa County, Arizona.

Figure 7-44. Stock ponds are another water alternative to ensure equal livestock distribution and utilization across the range. Photo: Steve Smarik, USDA NRCS, Coconino County, AZ.

Chapter 8 : USDA Programs to Address Wind Erosion

Program information is current as of the printing of this handbook (June 2020), however please be aware that these programs may be subject to changes under the most current Farm Bill or other laws. Please contact your local USDA Service Center for additional details.

Natural Resources Conservation Service (NRCS) Programs

Subsequent to the planning process conducted by NRCS with the producer, as outlined in Chapter 5, a comprehensive set of conservation practices will be recommended. This technical assistance is provided through NRCS's voluntary Conservation Technical Assistance Program without a cost to the producer. The producer can then elect to pursue the recommended practices on his or her own accord, pace and expense. NRCS offers voluntary programs to eligible landowners and agricultural producers to provide financial assistance to help manage natural resources in a sustainable manner. Alternatively, producers may explore financial assistance through an assortment of programs that NRCS administers, such as Environmental Quality Incentives Program, Conservation Stewardship Program, and/or Regional Conservation Partnership Program.

Environmental Quality Incentives Program (EQIP)

EQIP is the flagship program for NRCS in getting conservation on the ground. EQIP provides financial and technical assistance to agricultural producers to address natural resource concerns by funding the installation of nearly every practice discussed in Chapters 6 and 7. The availability for financial assistance for some practices may be restricted in some areas due to the limited application of those practices in those areas. Any individual farmer or rancher wishing to control wind erosion on the agricultural lands they own and/or operate will find this program full of opportunity to sustain productivity and make their fields and pastures more resilient to extreme weather and climatic conditions. Producers across the country can choose from a robust set of practices to address erosion that meets their objectives and aligns with their production systems. The 2018 Farm Bill included language to allow EQIP more flexibility in addressing anticipated resource concerns. Also, it specifically recognizes that producers are facing resource concerns created by extreme weather events and enables NRCS to help assist producers adapt to and mitigate against increasing weather volatility. These additions to the Farm Bill should create more opportunity for farmers and ranchers to address wind erosion through EQIP.

NRCS makes payments under EQIP according to a Payment Schedule for each practice. The Payments Rates are collectively assembled in each state's Payment Schedule. The Payment Schedules for each state can be found on the NRCS website under Financial Assistance, State Payment Schedules.[180] The Payment Rates are determined in a multi-state region by analyzing the current costs for material and labor within the state and also the fair marketplace compensation for opportunity costs that may arise (e.g., conversion of productive land). Each state does have some discretion in applying a percentage to these average regional costs to determine the Payment Rate for that state, which is why the Payment Rate can vary for the same practice from state to state.

Nearly every conservation practice has multiple scenarios with various Payment Rates, based on the size, complexity, or the processes involved in installing the practice. For instance, the cost of a field border can vary widely based on whether you are planting introduced species, natives, or pollinator species. This is due mainly to seed costs. After selecting a state from the link above, a complete set of scenario descriptions can be downloaded that also shows how the Payment Rate is calculated. The list of practice scenarios for each state may be from a few hundred to over one thousand, depending on the diversity of agriculture in the state. The list does include Enhancement Scenarios used in the Conservation Stewardship Program, discussed under separate heading. Payment Schedules are developed with complete transparency to the public. Recommendations to the rates can be brought forth through conservation districts, local work groups and/or the State Technical Committee.

Financial assistance is provided to agricultural producers through Conservation Program Contracts (CPC). Producers select appropriate conservation practice scenarios from their conservation plan and agree to follow NRCS standards, specifications and designs provided for each practice. Each practice is established as a line item in the contract. In some cases, practice installation might include avoidance of identified cultural resources and measures to avoid effects to threatened and endangered species, but these requirements would be discovered during the conservation planning process, well before the CPC process. The CPC is generally scheduled for completion over a one to five-year period, based on the number of practices that are scheduled for installation.

To be eligible for EQIP, farmers, ranchers, forest landowners must establish or update the Farm Service Agency record for both the person(s) and the land for the application to be eligible and evaluated. Farm records for the person must indicate the applicant controls or owns eligible land; meets adjusted gross income (AGI) and payment limitation provisions; and be in compliance with highly erodible land and wetland conservation requirements.

Once your application has been filed and both you and your land are determined to be eligible for EQIP, NRCS will evaluate the current condition of the natural resource conditions or concerns on your land. Once you have chosen the practices to apply to your land, your application will be evaluated in the national, state, or local funding pool in which you have applied. Funding pools allow EQIP to target funding to specific natural resource concerns, locations or operations, nationally, by state, and locally. Applicants not selected may reapply in the next funding cycle with the same or modified proposal.

Conservation Stewardship Program (CSP)

The CSP is the largest conservation program in the United States, with 70 million acres of land across the country enrolled in the program as of 2016.[181] The program is designed to help operators build upon and enhance their existing conservation efforts. Through this program, producers can enroll their land in a five year contract with the NRCS, during which they receive payments to do two things – annual payments for installing new conservation activities and maintaining existing practices; and supplemental payments for adopting a resource-conserving crop rotation.[182] The payment schedule for adopted activities is structured similarly to that for EQIP payments (described above), with a predetermined fixed payment per given activity; the payment rates for eligible activities can be found in the same general location as the EQIP payment schedules (hyperlinked above).[180] Payments for maintaining existing conservation practices are fixed and based on the number of resource concerns already being met and the land use type.[183] There is also an option in some cases for supplemental payments for adopting or improving a resource-conserving crop rotation.[183] At the end of the five year term, producers who have successfully met their contracted resource stewardship requirements will have the option of renewing for an additional five years, provided they select additional conservation activities they will implement to meet or exceed stewardship thresholds for an additional two priority resource concerns.[181]

CSP is a program designed for "working lands" – agricultural or forestry operations that are actively being managed to produce agricultural or forestry products.[184] Producers on these lands are given the support and financial flexibility to improve upon their existing management through a variety of activities dubbed "enhancements". Enhancements are fine-tunings of NRCS conservation practices with a very specific goal. For example, Cover Crop (340) is a conservation practice that has multiple benefits and applications, and might be applied to meet any of a number of goals, depending on the situation in which it is applied. Cover crop to reduce wind erosion (E340102Z) is an application of this practice with the very specific goal of reducing wind erosion below tolerable threshold levels, and thus would be planned with this objective in mind.[185] A producer could even take it a step further and decide to adopt the "Crop Bundle #9 – Wind Erosion – Organic" enhancement bundle – a suite of practices which have been determined to work together synergistically to provide improved conservation of a particular resource concern,[186] in this case wind erosion on cropland (note that despite the name, Organic bundles can be applied on any land, not just organic operations[187]). Enhancement bundles result in a higher payment rate,[182] and many land managers find that the bundled practices make sense to implement together on their land.[186] An example of an enhancement bundle worksheet is included in Appendix B, Exhibit 8-1. An NRCS conservation planner will work one-on-one with a CSP applicant to identify the enhancements and/or enhancement bundle(s) that best support their management goals while simultaneously addressing the identified resource concern(s).[186]

The CSP program is open to all producers regardless of the size of their operation or the type of crops produced. Producers must, however, have the effective control of their land for the term of the proposed contract. Lands eligible for the program include private and tribal agricultural lands, cropland, grassland, pastureland, rangeland, and nonindustrial private forest land.[188] The CSP is an all or nothing type of enrollment – producers must enroll all agricultural or private forest land in their operation that they will have control of for the term of the contract.[189] Details on the application process and steps can be found on the NRCS's website for the CSP.[184] Applications are competitively ranked in terms of how well the applicant's current and future management system will address national, state, and local natural resource priorities.[189] There is also a new CSP Grasslands Conservation Initiative which applies to certain croplands which were planted to grass or pasture, including idle or fallow, during a specific period.[188] More information on this program can be obtained from the local NRCS.

Regional Conservation Partnership Program (RCPP)

With the 2014 Farm Bill, Congress recognized the growing interest of partners in conservation by establishing the RCPP. This program combines the benefits of EQIP, CSP, the Healthy Forest Reserve Program (HFRP), the Agricultural Conservation Easement Program (ACEP), and the Public Law 83-566 Watershed Authorities (PL-566) into one umbrella program that can use any combination of these programs or any single program to address a recognized natural resource problem on a watershed, landscape or community scale through partner involvement. HFRP and ACEP are conservation easement programs designed to protect and preserve healthy forests and productive agricultural lands, respectively, for years to come. RCPP requires an eligible partner to serve as sponsor for the project proposal and coordinate the requirement for matching funds from interested partners. Eligible partners include agricultural or silvicultural producer associations, farmer cooperatives or other groups of producers, state or local governments, American Indian tribes, municipal water treatment entities, water and irrigation districts, conservation-driven nongovernmental organizations and institutions of higher education, and conservation districts. If the project proposal includes the use of PL-566, the sponsor must meet the definition of an eligible sponsor under that authority, which is basically a unit of government with taxation authority and the capability of acquiring easements and rights-of-way.

The project sponsor submits a project proposal in response to a public announcement by NRCS. The proposal must address an eligible activity, of which erosion control is listed. The 2018 Farm Bill restructured this program to include a state pool, a multi-state pool and a Critical Conservation Area (CCA) pool. The CCA pools are regional in nature and structured by NRCS national headquarters. The other pools are vetted and ranked under the authority of the State Conservationists. This program was originally authorized under the 2014 Farm Bill and appropriations averaged about 250 million dollars per year and were funded through the individual programs mentioned above. With the 2018 Farm Bill, Congress authorized 300 million dollars per year of direct funding to RCPP. This signals the growing importance of this program.

Specifically for wind erosion, communities, conservation districts, state air quality departments, producer groups, tribes, and others will find RCPP to be an excellent means to leverage federal dollars with local and state to address a known local or regional wind erosion problem. In irrigated areas of the west that have suffered severe water shortages resulting in cutbacks to water supplies, RCPP may provide help to develop a plan, provide treatment alternatives, and financial assistance to install practices mentioned in this handbook.

FSA Programs

These programs may be subject to changes under the most current Farm Bill or other laws. Please contact your local USDA Service Center for additional details.

Conservation Loans

FSA Conservation Loans provide access to direct and guaranteed conservation loans for farmers and ranchers who wish to implement conservation measures on their farm or ranch but do not have the funds for the initial "up-front" costs associated with those measures.[190] Loans are available for conservation practices approved by the NRCS, including reducing soil erosion, improving water quality, and promoting sustainable and organic agricultural practices.[190] Several conservation measures that achieve these goals can also help control wind erosion. Some specific conservation practices listed on the program fact sheet that, depending on the specifics, might also help control wind erosion/dust emissions are: installing conservation structures, establishing forest cover, establishing or improving permanent pastures, and adapting other emerging or existing conservation practices, techniques or technologies. Several of the conservation practices discussed in Chapter 6 and Chapter 7 of this handbook could easily fall under these categories and thus might be eligible for a loan to implement. The eligibility of specific practices, however, should always be confirmed directly with the FSA (www.fsa.usda.gov/farmloans or find a local FSA office at www.farmers.gov) before proceeding with any plans or activities. Before financing for any project can be offered, the applicant must have a NRCS-approved conservation plan.[190]

Conservation Reserve Program (CRP)

USDA Farm Service Agency's (FSA) Conservation Reserve Program (CRP) is a voluntary program whereby participants enter into a contract with the FSA to repurpose environmentally sensitive agricultural land for conservation benefits instead of farming or ranching it.[191] These are longterm contracts, and the FSA pays participants a rental fee plus provides cost-share assistance in return for the participant establishing long-term resource conserving cover vegetation (such as approved trees or grasses).[191] The purpose of the program is to control soil erosion, improve water quality, and reduce loss of wildlife habitat on these environmentally sensitive lands.[192] Several practices identified under CRP are consistent with the NRCS practice "Conservation Cover (327)" which has been recognized by the NRCS as helping to control wind erosion. Land may be offered to be enrolled in CRP during the "general sign-up" opportunities that are periodically offered and announced by the USDA.[192] Land offers are bid into the program on a competitive basis during these enrollment periods and bids are ranked according to the Environmental Benefits Index (EBI).[191] Historically, eligible land "must be cropland that is planted or considered planted to an agricultural commodity for four of six crop years, and that is physically and legally capable of being planted (no planting restrictions due to an easement or other legally binding instrument) in a normal manner to an agricultural commodity."[191] Alfalfa or other multiyear grasses and legumes grown in a rotation not to exceed 12 years may also be eligible. "Land also must meet one of the following criteria: Have a weighted average erosion index of eight or higher; Be enrolled in a CRP contract that expires Sept. 30 or; Be located in a national or state CRP conservation priority area."[191]

Another option for participating in the CRP program is through Conservation Reserve Program – continuous enrollment. Under the continuous enrollment authority, environmentally sensitive land devoted to certain conservation practices may be offered and enrolled at any time.[191] Eligible practices are published by the FSA and can be found on their website as a subheading under the CRP program information.[193] Depending on the conservation practice identified, some might also help to control wind erosion even though the primary focus may be to address a different resource concern. For example, vegetation established to enhance water quality and/or control water erosion might also provide some protection from wind erosion as a secondary benefit. Acceptance of offered land under continuous enrollment is not competitive – offers are automatically accepted if land and producer eligibility requirements for the program are met and enrollment levels do not exceed the statutory cap.[194] Historically, in order to be eligible, "land must be cropland that is planted or considered planted to an agricultural commodity four of six crop years, and is physically and legally capable of being planted (no planting restrictions due to an easement or other legally binding instrument) in a normal manner to an agricultural commodity. Certain marginal pastureland that may be devoted to riparian buffers is also eligible."[194]

The Conservation Reserve Program (CRP) Grasslands is a part of the CRP that helps those who own or operate grasslands, including rangeland or pasturelands, protect their lands while retaining the right to use the land for livestock grazing.[195] Emphasis is placed on "support for grazing operations, plant and animal biodiversity, and eligible land containing shrubs and forbs under the greatest threat of conversion."[195] Participants receive rental payments from the FSA in return for following an approved CRP conservation plan. FSA will provide cost-share of no more than 50 percent of the participant's costs for establishing approved practices on eligible land.[195] Land must be currently planted in a grass cover in order to be eligible.[196] Small livestock operations with 100 or fewer grazing dairy cows or equivalent can submit applications to enroll up to 200 acres per farm.[196] Acceptance of offered land is competitive and all offers are ranked by the FSA.[196] Ranking criteria is published in the FSA fact sheet Conservation Reserve Program (CRP) – Grasslands,[196] however interested parties should contact the FSA directly to inquire about the most up to date criteria at the time of their application, and the dates for the current signup period. Conservation practices under the CRP Grasslands program potentially could have a preventative impact on controlling wind erosion by preserving grass cover on lands that might otherwise be converted to cropland or non-agricultural use, however this is speculation and not guaranteed.

Conservation Reserve Enhancement Program (CREP)

The CREP is similar to the CRP-continuous enrollment program in that land may be offered and enrolled on a continuous basis, however one may only enroll land if the state in which the land is in has a CREP agreement.[197] CREP is a partnership to address high priority conservation concerns.[197] Historically, farmers and ranchers have been paid an annual rental rate, along with other federal and state incentives as applicable, in return for removing environmentally sensitive land from production and instead establishing permanent vegetation that will enhance further conservation of the natural resources on that land.[197] Participation is voluntary, and the contract period is typically 10–15 years.[197] Interested producers should contact their local FSA office to find out if their state has an active CREP agreement.

Emergency Conservation Program (ECP)

ECP provides assistance to certain agricultural producers in restoring farmland and conservation structures that have been damaged by natural disasters, and for implementing emergency water conservation measures during a severe drought.[198] Assistance cannot be used to remedy or address conservation problems that existed before the applicable natural disaster.[198] Assistance may be used, however, to restore certain conservation structures that previously existed.[198] Restoring windbreaks/shelterbelts or access-control fences that have been damaged by a natural disaster might possibly be an eligible activity under this program, for example. This suggestion is provided as a speculative illustration only however, and inquiries about the specific eligibility of any proposed activity should be directed to a local FSA office, where more information about this program and producer eligibility requirements can also be obtained.

Emergency Forest Restoration Program (EFRP)

EFRP provides financial assistance to eligible owners of nonindustrial private forest (NIPF) land for use in the emergency restoration of land damaged by natural disasters.[199] The FSA County Committee inspects the damage to determine if forest land is eligible for EFRP.[199] The natural disaster must have resulted in damage that if untreated would impair or endanger the natural resources on the land and/or materially affect future use of the land. The land also must be suitable for growing trees and have existing tree cover (or had tree cover immediately before the natural disaster occurred).[199] Due to this being an emergency restoration program, it is possible that any wind erosion-controlling measures covered may be limited to restoring pre-existing conditions, however this suggestion is speculative and inquiries about the eligibility of any specific proposed activity should be directed to a local FSA office.

Chapter 9 : Glossary of Commonly Used Terms in Wind Erosion and Natural Resources Conservation

Term	Definition
A factor	The computed longtime average annual soil loss carried by runoff from specific field slopes in specified cropping and management systems. It is expressed in the Revised Universal Soil Loss Equation-2 (RUSLE2) model in tons/acre/year.
Abrasion	Breakdown of clods, crusts, and plant material by the impact of particles moved by wind in saltation. The impacting particles may also abrade. Abrasion causes soil aggregates to break down progressively as wind erosion continues.
Accelerated erosion	Erosion of soil resulting from disturbance of the natural landscape. It results largely from the consequences of human activity, such as tillage, grazing, and removal of vegetative cover.
Adsorption	The process by which atoms, molecules, or ions are taken up from the soil solution or soil atmosphere and retained on the surfaces of solids by chemical or physical binding.[200]
Aeolian	Processes relating to or arising from the action of the wind.[201]
Aerodynamic equivalent diameter	The diameter of a unit density sphere having the same settling velocity (due to gravity) as the particle of interest of whatever shape and density.[202]
Aggregate stability	The ability of a soil aggregate to resist various destructive forces, such as tillage, abrasion by wind or flowing water, or raindrop force.
Aggregation, soil	The cementing or binding together of primary soil particles (sand, silt, and clay) into a secondary unit, which unit contributes to the soil structure.
Agronomic rate	The rate at which fertilizers, organic wastes or other amendments can be added to soils for optimum plant growth.
Air-dry weight	Weight of a substance after it has been allowed to dry to equilibrium with the atmosphere.
Allelopathy	Production of a substance by one organism that inhibits one or more other organisms.
Amendment	A substance added to the soil to improve plant growth, such as lime.
Angle of deviation	The angle between prevailing wind erosion direction and a line perpendicular to: (1) the long side of the field or strip, when determining unsheltered distance using a wind erosion direction factor, or (2) row direction when determining effect of wind direction on the ridge roughness factor.
Available water holding capacity	The capacity of a soil to hold water in a form available to plants, usually expressed in inches of water per inch of soil depth. Commonly defined as the amount of water held between field capacity and wilting point.
Avalanching	The increase in rate of soil flow with distance downwind across an area being eroded by wind.
Biochemical oxygen demand (BOD)	The amount of oxygen required by aerobic organisms to carry out oxidative metabolism in water containing organic matter, such as sewage. BOD is used as an indirect measure of the concentration of biologically degradable material present in organic wastes. Also known as Biological Oxygen Demand.

Biomass	The total mass of living organisms in a given volume or mass of soil, or in a particular environment.
Buffer strip	A narrow strip of grass or other close-growing vegetation that, when placed along the contour on a slope, traps sediment that was produced on the hillslope above.
Bulk density, soil	The mass of dry soil per unit bulk volume. The value is expressed as Mg per cubic meter, Mg m^{-3}.
C factor—Water erosion	Cover and management factor in Revised Universal Soil Loss Equation (RUSLE). It combines the effects of prior land use, crop canopy, surface cover, surface roughness, and soil moisture to predict a soil loss ratio for a crop or other vegetation, cropping period, or season.
C factor—Wind erosion	Climatic factor in Wind Erosion Equation (WEQ). It is an index of climatic erosivity, specifically wind speed and surface soil moisture. The factor for any given location is based on long-term climatic data and is expressed as a percentage of the C factor for Garden City, KS, which has been assigned a value of 100.
Calcareous soil	Soil containing sufficient free calcium carbonate or magnesium carbonate to effervesce visibly when treated with cold 0.1 N hydrochloric acid.
	High content of lime (up to about 5 percent), particularly in the clay fraction, appreciably increases erodibility by wind.
Calcium carbonate equivalent	The content of carbonate in a liming material or calcareous soil calculated as if all of the carbonate is in the form of CaCO3. See also Lime, agricultural.
Canopy	The vertical projection downward of the aerial portion of plants, usually expressed as percent of ground so occupied.
Carbon cycle	The sequence of transformations whereby carbon dioxide is converted to organic forms by photosynthesis or chemosynthesis, recycled through the biosphere (with partial incorporation into sediments), and ultimately returned to its original state through respiration or combustion.
Carbonaceous compounds	Compounds that contain carbon.
Carbon-nitrogen ratio (C:N)	The ratio of the mass of organic carbon to the mass of organic nitrogen in soil, organic material, plants, or microbial cells.
Cation exchange capacity	The sum of exchangeable bases plus total soil acidity at a specific pH values, usually 7.0 or 8.0. It is usually expressed in centimoles of charge per kilogram of exchanger (cmolc kg^{-1}) or millimoles of charge per kilogram of exchanger.
Climatic erosivity	The relative influence of climate on field erodibility by wind in different regions, specifically the effects of average wind speed and effective soil surface moisture.
Clod	A compact, coherent mass of soil greater than 2 millimeters in equivalent diameter, often created by tillage or other mechanical disturbance of the soil.
Coarse fragments	Rock or mineral particles greater than 2 millimeters in diameter.
Compost	Organic residues, or a mixture of organic residues and soil, that have been mixed, piled, and moistened, with or without addition of fertilizer and lime, and generally allowed to undergo thermophilic decomposition until the original organic materials have been substantially altered or decomposed.
Contour farming	The practice of using ridges and furrows left by tillage to redirect runoff from a path directly downslope to a path around the hillslope.

Cover crop	Close-growing crop that provides soil protection, seeding protection and soil improvement between periods of normal crop production, or between trees in orchards and vines in vineyards. When incorporated into the soil, cover crops may be referred to as green manure crops.
Creep processes	See Surface creep.
Critical wind erosion period	Period of the year when the greatest amount of wind erosion can be expected to occur from a field under an identified management system. It is the period when the combination of vegetative cover, soil surface conditions, and expected erosive winds result in the greatest potential for wind erosion.
Crop furrow	A trench that is formed by a plow to construct the crop bed and commonly used to irrigate the crop.
Crop residue management	Maintaining stubble, stalks, and other crop residue on the soil surface or partially incorporated into the surface layer to reduce erosion, conserve soil moisture, and improve soil tilth.
Crop rotation	A planned sequence of several different crops grown on the same land in successive years or seasons, done to replenish the soil, reduce insect, weed and disease populations, or to provide adequate feedstocks for live- stock operations.
Crop tolerance to wind erosion	Ability of crop plants to tolerate wind-blown soil particles when in the seedling stage or exposure of plant roots where soil is eroded away, or burial of plants by drifting soil, or desiccation and twisting of plants by the wind.
Crust	A thin surface layer, where aggregates are bound together and the surface is sealed. It is more compact and mechanically stable than the soil material immediately beneath it. Crust is characterized by its dense, platey structure that becomes less distinct with depth until it merges with the soil below. Crust is a transitory condition.
Deposition	The accumulation of eroded soil material on the land surface when the velocity of the transporting agent (wind or water) is reduced.
Desert pavement	A non-erodible soil surface devoid of erodible materials or consisting of gravel or stones left on the land surface. It occurs in desert regions as a result of the removal of fine materials by wind or water erosion.
Detachment	The removal of transportable fragments of soil material from the soil mass by an eroding agent, usually falling raindrops, running water, wind, or windblown soil particles. Detachment is the process that makes soil particles or aggregates available for transport.
Drag partition scheme	A scheme used to represent surface roughness effects on wind erosion[203] - especially the absorption of wind momentum and sheltering of the soil surface by vegetation and other non-erodible roughness.
Drought year	Any year when precipitation is less than 80 percent of the long-term normal.
Dry aggregate	A compound or secondary air-dry soil particle that is not destroyed by dry sieving.
Dryland farming	Crop production without irrigation (rainfed agriculture).
Dust deposition	The settling of dust particles to the land surface under the force of gravity or in rainfall.[201]
Dust emission	The entrainment of fine soil particles and aggregates (dust), typically regarded as being smaller than 62.5 µm in diameter (e.g., silt and clays).[201]
Dust storm	A strong turbulent wind carrying large amounts of soil particles in suspension.

E tables	Tables derived from computer solutions (WEROS) of the Wind Erosion Equation that display values of average annual wind erosion per acre (E) for various combinations of soil erodibility (I), ridge roughness (K), climate (C), unsheltered distance (L), and vegetative cover (V).
Effective precipitation	That portion of the total rainfall precipitation which becomes available for plant growth.
Electrical conductivity (ECe)	The electrical conductance of an extract from a soil saturated with distilled water, normally expressed in units of siemens or decisiemens per meter at 25 °C.
Entrainment (soil)	To lift and transport (soil grains) by the flow of a fluid (the wind).[201]
Entrainment threshold	The threshold shear velocity required for particle movement to occur.[204–206]
Erodibility	The susceptibility of soil to erode. Soils with low erodibility include fine textured soils high in clay that are resistant to detachment, and coarse textured soils high in sand that have low runoff. Soils having a high silt content are highly susceptible to erosion. The K factor in Revised Universal Soil Loss Equation (RUSLE) expresses the erodibility of soil.
Erosive wind energy	The capacity of winds above the threshold velocity to cause erosion. Erosive wind energy is a function of the cube of wind speed and the duration of erosive winds.
Erosivity	The energy (amount) and intensity of rainstorms that cause soil to erode. Erosivity includes the effects of raindrop impact on the soil and the amount and rate of runoff likely to be associated with the rain.
Eutrophication	A process that increases the amount of nutrients, especially nitrogen and phosphorus, in a marine or aquatic ecosystem. Eutrophication occurs naturally over geological time but may be accelerated by human activities, such as waste disposal or land drainage, leading to an increase in algae and a decrease in diversity.
Evapotranspiration	The combined loss of water from a given area, and during a specified period of time, by evaporation from the soil surface and by transpiration from plants.
Fallow	The practice of leaving land uncropped, either weed-free or with volunteer vegetation, during at least one period when a crop would normally be grown; done to control weeds, or accumulate water or available plant nutrients.
Fertility, soil	The quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants or crops.
Fertilizer	Any organic or inorganic material of natural or synthetic origin (other than liming materials) that is added to a soil to supply one or more plant nutrients essential to the growth of plants.
Fertilizer analysis	The percent composition of a fertilizer as determined in a laboratory and expressed as total N, available phosphoric acid (P_2O_5) equivalent, and water-soluble potash (K_2O) equivalent.
Fibric organic soil materials	The least decomposed of all the organic soil materials containing very high amounts of fiber that are well preserved and readily identifiable as to botanical origin.
Field capacity (Field water capacity)	The content of water, on a mass or volume basis, remaining in a soil two to three days after being saturated with water, and from which free drainage is negligible.[200]

Friable	A term describing soils that when either wet or dry can be easily crumbled between the fingers.
Geologic erosion	The wearing away of the Earth's surface by the forces of water and wind. Sometimes referred to as natural erosion, it is responsible for the natural topographic cycles, as it wears away higher points of elevation and constructs valleys and alluvial plains.
Green manure crop	Any crop grown for soil improvement by being incorporated into the soil while green or soon after maturity.
Greenhouse effect	The absorption of solar radiant energy by the Earth's surface and its release as heat into the atmosphere; longer infrared heat waves are absorbed by the air, principally by carbon dioxide and water vapor, thus, the atmosphere traps heat much as does the glass in a greenhouse.
Groundwater	That portion of the water below the surface of the ground at a pressure equal to or greater than atmospheric. See also Water table.
Gully erosion, Classical	Erosion caused by the action of runoff water in concentrated flow channels.
Gully erosion, Ephemeral	Erosion that occurs from the action of runoff water which concentrates in shallow flow channels when rills converge. These flow channels are alternately filled with soil by tillage operations and reformed in the same general location by subsequent runoff events.
Hard seed	Seed that is dormant due to a seed coat impervious to either water or oxygen.
Hemic organic soil materials	Intermediate in degree of decomposition between the less decomposed fibric and the more decomposed sapric materials.
Hydraulic conductivity	The ease at which water flows through pore spaces and fractures.
Hydrologic cycle	The fate of water from the time of precipitation until the water has been returned to the atmosphere by evaporation and is again ready to be precipitated.
Hydromulcher	Specialized equipment for spraying hydromulch (a slurry of water, fiber mulch, tackifier, and sometimes seed and fertilizer) consisting of a 1,000 to 3,000 gallon tank mounted on a truck or trailer that is equipped with a special pump and continuous agitation system.[207]
Hydroseeding	Planting seed in a water mixture by pumping through a nozzle that sprays the mixture onto a seedbed. The water mixture may also contain addends such as fertilizer and mulches.
Inertial impaction	The deposition of large aerosol particles on the walls of an airway conduit. The impaction tends to occur where the airway direction changes.[208]
Inoculate	To treat, usually seeds, with microorganisms to create a favorable response. Most often refers to the treatment of legume seeds with Rhizobium or Bradyrhizobium to stimulate dinitrogen fixation.
Isolated field	A field where the rate of soil flow is zero at the windward edge of the field due to the presence of a stable border. An isolated field is not protected by barriers and is exposed to open wind velocities. The Wind Erosion Equation (WEQ) applies to conditions on an isolated field.
Isoline	A line on a map or chart along which there is a constant value of a variable such as wind velocity or climatic erosivity.
K factor—Water Erosion	Soil erodibility factor in Revised Universal Soil Loss Equation (RUSLE) that quantifies the susceptibility of soil particles to detachment and movement by water. The K value is the soil loss rate per erosion index unit for a specified soil

	as measured on a standard plot, which is defined as a 72.6-foot length of uniform 9 percent slope in continuous clean-tilled fallow.
K factor—Wind Erosion	The soil roughness factor K, for Wind Erosion Equation (WEQ). It is a measure of the effect of oriented roughness (ridges) and random roughness (cloddiness) on erosion. See Random roughness and Ridge roughness.
Knoll	An abrupt change in topography characterized by windward slope change greater than 3 percent and windward slope less than 500 feet long.
Knoll erodibility	The increase in wind erosion potential resulting from the compression of wind flowlines and accompanying increased velocity over the crest of knolls. A knoll erodibility factor is used to adjust estimated erosion where these conditions occur.
Land capability	The suitability of land for use without permanent damage. Land capability, as ordinarily used in the USA, is an expression of the effect of physical land conditions, including climate, on the total suitability for use, without damage, for crops that require regular tillage, for grazing, for woodland, and for wildlife. Land capability involves consideration of the risks of land damage from erosion and other causes and the difficulties in land use owing to physical land characteristics, including climate.
Land capability class	One of the eight classes of land in the land capability classification of NRCS; distinguished according to the risk of land damage or the difficulty of land use; they include:
	Land suitable for cultivation and other uses
	Class I—Soils that have few limitations restricting their use.
	Class II—Soils that have some limitations, reducing the choice of plants or requiring moderate conservation practices.
	Class III—Soils that have severe limitations that reduce the choice of plants or require special conservation practices, or both.
	Class IV—Soils that have very severe limitations that restrict the choice of plants, require very careful management or both.
	Class V—Soils that have little or no erosion hazard, but that have other limitations, impractical to remove, that limit their use largely to pasture, range, woodland, or wildlife food and cover.
	Land generally not suitable for cultivation (without major treatment) Class VI—Soils that have severe limitations that make them generally unsuited for cultivation and limit their use largely to pasture or range, woodland, or wildlife food and cover.
	Class VII—Soils that have very severe limitations that make them unsuited to cultivation and that restricts their use largely to grazing, woodland, or wildlife.
	Class VIII—Soils and landforms that preclude their use for commercial plant production and restrict their use to recreation, wildlife, water supply, or aesthetic purposes.
Leaching	The removal of soluble materials from one zone in soil to another via water movement in the profile.
Leeward	The side facing away from wind.[209]
Liebig's Law	The growth and reproduction of an organism is dependent on the nutrient substance that is available in minimum quantity.

Lime, agricultural	A soil amendment containing calcium carbonate, magnesium carbonate and other materials, used to neutralize soil acidity and furnish calcium and magnesium for plant growth. Classification, including calcium carbonate equivalent and limits in lime particle size, is usually prescribed by law or regulation.
Loess soil	Material transported and deposited by wind, consisting predominantly of silt-sized particles.
LS factor	The Revised Universal Soil Loss Equation (RUSLE) factor that accounts for the combined effects of length and steepness of slope on soil loss. The factor value represents the ratio of soil loss on a given slope length and steepness to soil loss from a slope that has a length of 72.6 feet and a steepness of 9 percent, where all other conditions are the same.
Management period	A period of time during a cropping sequence when cover and management effects are approximately uniform or otherwise result in uniform rates of erosion during the period.
Mineral soil	A soil composed mainly of, and having its properties determined by, mineral matter, with less than 20 percent organic matter. Compare Organic soil.
Mineralization	The conversion of an element from an organic form to an inorganic state as a result of microbial activity.
Moldboard plow	A plow with a large curved metal blade designed to invert the soil as it plows.
Mulch	Any material such as straw, sawdust, leaves, plastic film, loose soil, or similar material that is spread or formed upon the surface of the soil to protect the soil and/or plant roots from the effects of raindrops, soil crusting, freezing, evaporation, etc.
Mulch tillage	Managing the amount, orientation, and distribution of crop and other plant residue on the soil surface year-round, while growing crops where the entire field surface is tilled prior to planting.[210]
Net primary production	Net primary production is the rate at which all the plants in an ecosystem produce net useful chemical energy.[211]
Nitrogen cycle	The continuous process by which nitrogen circulates among the air, soil, water, plants, and animals of the earth. Nitrogen in the atmosphere is converted by bacteria into forms that green plants can absorb from the soil; animals eat these plants (or eat other animals that feed on the plants); the animals and plants die and decay; the nitrogenous substances in the decomposed organic matter return to the atmosphere and the soil.
Northwestern Wheat and Range Region (NWRR)	Areas of non-irrigated cropland in the Pacific Northwest and mountainous regions of the west. It includes portions of eastern Washington, north central Oregon, northern and southeastern Idaho, western Montana, western Wyoming, northern Utah and northern California. Rainfall and erosion processes in this region are dominated by winter events.
No-till/Strip till	Managing the amount, orientation and distribution of crop and other plant residues on the soil surface year-round, while growing crops in narrow slots, or tilled or residue free strips in soil previously untilled by full-width inversion implement.
Noxious	Harmful or poisonous.

Organic farming	A crop production system that reduces, avoids or largely excludes the used of synthetically-produced fertilizers, pesticides, growth regulators and livestock feed additives.
Organic soil	A soil that contains a high percentage (greater than 20 percent) of organic matter throughout the solum. Compare Mineral soil.
Oven-dry weight	The weight of a substance after it has been dried in an oven at 105 °C, to equilibrium.
P factor	The support practice factor in Revised Universal Soil Loss Equation (RUSLE). It is a measure of the soil loss with a specific support practice to the corresponding loss with upslope and downslope tillage. On cultivated land, support practices considered in Revised Universal Soil Loss Equation (RUSLE) include contouring, stripcropping, buffer strips, and terraces. These practices principally affect erosion by modifying the flow pattern, grade or direction of surface runoff and by reducing the amount and rate of runoff.
Particulate matter (PM)	Solid and liquid particles in the air, comprising the particulate portion of aerosols. PM_{10} particles have an aerodynamic diameter <10 µm and may be inhalable.[201]
Perennial plant	A plant that lives more than two years.[212]
Permanent wilting point (Wilting coefficient)	The largest water content of a soil at which indicator plants, growing in that soil, wilt and fail to recover when placed in a humid chamber. Often estimated by the soil water content at –1.5 Mpa (–15 bars) soil matric potential.
Permeability	The ease with which water, air, or plant roots penetrate or pass through a soil horizon.
Polypropylene	A tough and rigid, crystalline thermoplastic produced from propene (or propylene) monomer[213] commonly used as a mulching material for trees and other crops.
Precipitation effectiveness (P-E) index	An index of the effectiveness of precipitation, calculated from mean monthly precipitation and mean monthly temperature at a specific geographical location. A modified P-E index is used to represent effective surface soil moisture in calculation of the Wind Erosion Equation (WEQ) climatic factor C.
Preponderance	A ratio which expresses how much of the erosive wind energy occurs parallel to the prevailing wind erosion direction, as compared to the amount of erosive wind energy occurring perpendicular to the prevailing direction. A preponderance of 1.0 indicates that as much wind erosion force occurs perpendicular to the prevailing direction as occurs parallel to that direction. A higher preponderance indicates more of the force is parallel to the prevailing wind erosion direction.
Prevailing wind direction	The direction from which winds most commonly occur. This may not be the same as the prevailing wind erosion direction.
Prevailing wind erosion direction	The direction of erosive winds where there is potential for the greatest amount of soil to be moved, relative to the erosive force of winds from other directions.
Pure live seed	Percentage of pure germinating seed: (pure seed percentage × germination percentage)/100.
R equivalent (Req) factor	The factor used in place of the Revised Universal Soil Loss Equation (RUSLE) R factor in the Northwestern Wheat and Range Region of the United States to measure the unique effects of melting snow, rain on snow, and/or rain on

	thawing soil. Much of this soil loss occurs by rilling when the surface part of the soil profile thaws and snowmelt or rain occurs on the still partially frozen soil.
R factor	The rainfall and runoff factor in Revised Universal Soil Loss Equation (RUSLE) that accounts for the energy and intensity of rainstorms. It is a measure of total storm energy times the maximum 30-minute intensity.
Random roughness	The standard deviation of the soil surface elevations when changes because land slope or nonrandom (oriented) tillage marks are removed from consideration. Roughness ponds water in small localized depressions and reduces erosivity of raindrop impact and surface water flow.
Reference condition	A standard wind tunnel condition for small grain equivalent determination where small grain stalks 10 inches long are lying flat on the soil surface in 10-inch rows which are perpendicular to the wind direction, with stalks oriented parallel to the wind direction.
Relative field erodibility	An index of relative erodibility under field conditions. Wind tunnel erodibility is adjusted for the effect of unsheltered distance and of the resistance of soil textural classes to breakdown of surface crusts by abrasion and avalanching. Compared to the wind tunnel, erodibility of a field surface is greater because the longer unsheltered distance allows abrasion and avalanching to occur.
Representative concentration pathway	A greenhouse gas concentration (not emissions) trajectory adopted by the IPCC for its fifth Assessment Report (AR5) in 2014.[214]
Revised Universal Soil Loss Equation version 2 (RUSLE2)	An empirical model that predicts long-term average annual soil loss for a given set of climatic conditions, on a defined land slope, and under a specified cropping and tillage management system. Revised Universal Soil Loss Equation (RUSLE) is an update of the Universal Soil Loss Equation (USLE), and contains a computer program to facilitate calculations.
Rhizobia	Bacteria able to live symbiotically in roots of leguminous plants, from which they receive energy and often utilize molecular nitrogen. Collective common name for the genus Rhizobium.
Ridge roughness	The degree of oriented roughness determined by the height and width of ridges formed by tillage and planting implements. Ridges provide sheltered zones that trap moving soil particles.
Ridge-till	A type of tillage system where a crop is planted on ridges that were created during cultivation of the previous year's crop. The ridges are usually built when the previous crop is about 12 to 18 inches high, and then left to settle.[215] Ridge Till is now considered by NRCS to be a form of Reduced Tillage.
Rill	A small, intermittent water course with steep sides; usually only several centimeters deep.
Rill erosion	The removal of soil by concentrated water running through little streamlets or headcuts.[216]
Root pruning	A cultivation method which involves cutting back long roots on a tree or shrub, used to adjust above- and belowground plant sections by controlling root growth.[217,218] Commonly employed when a windbreak’s tree roots intrude into an adjacent cropped field and adversely affect crop growth.
Runoff	That portion of precipitation or irrigation on an area which does not infiltrate, but instead is discharged from the area.

Saline seep	Intermittent or continuous saline water discharge at or near the soil surface under dryland conditions that reduces or eliminates crop growth. It is differentiated from other saline soil conditions by recent and local origin, shallow water table, saturated root zone, and sensitivity to cropping systems and precipitation.
Saline soil	A nonsodic soil containing sufficient soluble salt to adversely affect the growth of most crop plants. The lower limit of saturation extract electrical conductivity of such soils is conventionally set at 4 dS m^{-1} (at 25 °C). Actually, sensitive plants are affected at half this salinity and highly tolerant ones at about twice this salinity.
Salt tolerance	The ability of plants to resist the adverse, nonspecific effects of excessive soluble salts in the rooting medium.
Salt-affected soil	Soil that has been adversely modified for the growth of most crop plants by the presence of soluble salts, with or without high amounts of exchangeable sodium.
Saltation	The movement of soil grains and aggregates along the soil surface in a leaping or hopping motion, typically larger than 62.5 µm and within ~1 m of the surface.
Sandblasting	The process of wind-driven soil and sand particles striking plant surfaces, often causing injury to the plant.[219,220]
Sapric organic soil materials	The most highly decomposed of the organic materials, having the highest bulk density, least amount of plant fiber, and lowest water content at saturation.
Seasonally variable K factor	The average annual soil erodibility K factor value that has been adjusted to reflect the temporal variability associated with freezing and thawing or wetting and drying cycles during the year.
Sediment mass flux	The mass of soil grains in saltation and/or suspended in the air (dust) per unit length or area per unit time; often separated into saltation (g m^{-1} s^{-1}) and dust (g m^{-2} s^{-1}) components.[201]
Sheet erosion	A form of water erosion in which a very thin layer is removed from the soil surface by detachment and overland flow.
Small grain equivalent (SGe)	The wind erosion control equivalent of vegetative cover, compared to a small grain standard. The standard (reference condition) is defined as small grain stalks 10 inches long lying flat on the soil surface in 10-inch rows which are perpendicular to the wind direction, with stalks oriented parallel to the wind direction. The small grain equivalent value is a function of kind, amount, and orientation of growing plants or plant residues on the soil surface.
Sodic condition	A condition with a high concentration of sodium in the cation exchange complex[221] that reduces water infiltration and adversely affects crop growth. Empirically recognized as when the exchangeable sodium percentage is 15 or above.
Soil erodibility index (I)	The potential soil loss, in tons per acre per year, from a wide, level, unsheltered, isolated field with a bare, smooth, loose, and non-crusted surface, under climatic conditions like those in the vicinity of Garden City, Kansas.
Soil loss tolerance (T)	The average annual soil erosion rate (tons/acre/year) that can occur in a field with little or no long-term degradation of the soil resource thus permitting crop productivity to be sustained for an indefinite period of time.
Soil surface moisture	Adsorbed water films surrounding surface soil particles that increase the soil resistance to erosion. In developing the climatic factor, soil surface moisture is

	assumed to be proportional to the Thornthwaite Precipitation-Effectiveness (P-E) Index.
Sorting	The practice of growing two or more crops in alternating strips along contours to control erosion.
Strawblower	A machine designed to chop and distribute straw as mulch.[222]
Strip-till	A combined tillage and planting operation that removes the previous crop's residue on only a very narrow portion of the seed bed to allow soil warming and sun to reach emerging seedlings.[223] Now considered by NRCS to be a form of No-till.
Sulfates	Salts containing the sulfate ion SO_4^{2-}.[224]
Surface armor	A layer of coarse fragments or other non-erodible particles resistant to abrasion that remain on the soil surface after the removal of fine particles by erosion.
Surface creep	Soil movement by wind in which the coarser fractions are transported by rolling and sliding along the ground surface, primarily by the impact of particles in saltation rather than by direct force of the wind. Particles greater than 0.5 mm (0.02 in) in size are usually moved in this manner.
Suspension	Soil movement in wind whereby the finer fractions are transported over long distances floating in the windstream. Suspension is usually initiated by the impact of saltating particles. Particles moving in this manner are usually less than 0.1 mm (0.004 in) in size. Many suspension-size particles are created by abrasion during erosion.
Threshold velocity	The minimum velocity at which wind will begin moving soil particles from a smooth, bare, non-crusted surface. The threshold velocity is usually considered to be 13 mph at 1 foot above the soil surface, or 18 mph at 30 feet height.
Tillage, Conventional	Primary and secondary tillage operations normally performed in preparing a seedbed and/or cultivating for a given crop grown in a given geographical area, usually resulting in little or no crop residues remaining on the surface after completion of the tillage sequence.
Tillage, Inversion	Reversal of vertical order of occurrence of layers of soil, or of the soil within a layer.
Tillage, Non-inversion	Tillage that does not mix (or minimizes the mixing of) soil horizons or does not vertically mix soil within a horizon.
Tillage, Subsoiling	Any treatment to non-inversively loosen soil below the Ap horizon with a minimum of vertical mixing of the soil. Any treatment to fracture and/or shatter soil with narrow tools below the depth of normal tillage without inversion and with a minimum mixing of the soil. This loosening is usually performed by lifting action or other displacement of soil dry enough so that shattering occurs.
Tilth	The physical condition of soil as related to its ease of tillage, fitness as a seedbed, and its impedance to seedling emergence and root penetration.
Total Maximum Daily Load (TMDL)	The maximum quantity of a particular water pollutant that can be discharged into a body of water without violating a water quality standard.
Transport	The movement of detached soil material across the land surface or through the air by wind or running water. Transport of soil particles in wind is by three modes: (l) saltation, (2) suspension, and (3) surface creep.
Transport capacity	The maximum amount of soil material that can be carried by wind or running water under given conditions.

Trap strip	A strip of grass or other erosion-resisting vegetation, planted between cultivated strips or fields and having sufficient width, height, and density to trap and store incoming saltation. Trap strips are usually not tall enough to create significant barrier effects.
Unit plot	A standard plot used to experimentally determine factor values in Universal Soil Loss Equation (USLE) and Revised Universal Soil Loss Equation (RUSLE). It is arbitrarily defined as being 72.6 feet long, with a uniform slope of 9 percent, in continuous fallow, tilled up and down the slope.
Universal Soil Loss Equation (USLE)	An empirical model that predicts long-term average annual soil loss for a given set of climatic conditions, on a defined land slope, and under a specified cropping and tillage management system.
Unsheltered distance	The distance across an erodible field, measured along the prevailing wind erosion direction, beginning at a stable border on the upwind side and continuing downwind to a non-erodible or stable area, or to the downwind edge of the area being evaluated.
Unsheltered field	A field or portion of a field characterized by the absence of windbreaks or barriers and fully exposed to open wind velocity.
Vegetative wind barrier	Narrow strips of annual or perennial vegetation planted at intervals across fields for wind erosion control, snow management, or protection of sensitive crops. Barriers have sufficient height and density to create a sheltered zone downwind. In the protected zone, wind velocities are reduced enough to prevent saltation from beginning. Vegetative barriers may also trap incoming saltation, but this is a secondary function.
Vertical dust flux	The emitted dust mass concentration per unit area per unit time.[225]
Water erosion	The detachment, transport, and deposition of soil particles by rainfall and runoff.
Water infiltration rate	The velocity at which downward-moving water enters the soil.[226]
Water table	The upper surface of ground water or that level in the ground where the water is at atmospheric pressure.
WEROS	A Fortran IV Program to Solve the Wind-Erosion Equation.
Wide field	Any field with sufficient width to allow the rate of soil flow to reach the maximum that an erosive wind can sustain. This distance is the same for any erosive wind. It varies only and inversely with erodibility of the field surface. That is, the more erodible the surface, the shorter the distance in which maximum flow is reached.
Wind erodibility group	A grouping of soils that have similar properties affecting their resistance to wind erosion.
Wind erosion	The net loss of soil from an area, considered the sum of all saltation and dust emission out of the area (loss) and deposition (gain) of sediment into the area from upwind sources (e.g., t ha^{-1}).[201]
Wind erosion direction factor	A numerical factor used to calculate the equivalent unsheltered distance. The factor accounts for field shape (length/width ratio), field width, preponderance, and angle of deviation of the prevailing wind erosion direction from a line perpendicular to the long side of the field or strip.
Wind erosion equation (WEQ)	An equation used to estimate wind erosion and design wind erosion control systems. E=(IKCLV) where E is the average annual soil loss expressed in tons per acre per year; I is the soil erodibility; K is the soil ridge roughness factor; C is the

	climatic factor; L is the equivalent unsheltered distance across the field along the prevailing wind erosion direction; and V is the equivalent vegetative cover.
Wind Roses	Graphical charts that characterize the speed and direction of winds at a location.[77]
Wind stripcropping	A method of farming whereby erosion-resistant crop strips are alternated with strips of erosion-susceptible crops or fallow. Erosion-resistant strips reduce or eliminate saltation and act as soil traps designed to reduce soil avalanching. Strips are perpendicular or nearly so to the direction of erosive winds.
Wind tunnel	A duct in which experimental situations are created and tested by exposure to air streams under controlled conditions. Both laboratory and portable field wind tunnels are used in wind erosion research.
Windbreak	A living barrier of trees or combination of trees and shrubs designed to reduce wind erosion, conserve energy or moisture, control snow deposition, or provide shelter for livestock or wildlife. When used to control wind erosion, windbreaks deflect wind forces and reduce wind velocity in the downwind sheltered zone below the threshold required for initiation of soil movement.
Yield	The amount of a specified substance produced (e.g., grain, straw, total dry matter) per unit area.

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Appendix B : Exhibits Referenced in Text

Exhibit 5-1: National and State Resource Concerns and Planning Criteria

National and State Resource Concerns and Planning Criteria
10/1/2013

<table>
<tr>
<td rowspan="2">Resource Concern - Cause
A resource concern (RC) is an expected degradation of the soil, water, air, plant, or animal resource base to an extent that the sustainability or intended use of the resource is impaired. Because NRCS quantifies or describes resource concerns as part of a comprehensive conservation planning process that includes client objectives, human and energy resources are considered components of the resource base. The “Cause” is the specific reason or threat to the resource that results in the resource concern.</td>
<td rowspan="2">Description of Concern</td>
<td rowspan="2">Land Use
* Required Assessment</td>
<td rowspan="2">Resource Concern Component
For planning purposes, Some resource concerns are divided into components where there is a clear distinction in the causal factors, the mitigating actions, and the anticipated environmental effect.</td>
<td colspan="2">Planning Criteria
A planning criterion is a quantitative or qualitative method to assess the existing condition of the natural resources on a site to determine whether additional treatment is needed to address a specific potential resource concern.
Planning Consideration - A planning consideration is a description of potential actions or activities that should be considered to help address an identified resource concern and/or to address unintended consequences of an action. Planning considerations are identified for resource concerns when it is not appropriate or technologically feasible to identify specific criteria or a threshold for treatment.</td>
<td rowspan="2">Measurement & Assessment Tools
Description of the technology or process for determining if assessment criteria are met.</td>
</tr>
<tr>
<td>Screening Level
Screening level criteria are defined, when appropriate, to identify sites with conditions that have little or no probability of needing additional treatment to address the specific resource concern. If the site meets the screening level criteria, then no other assessment is needed to document that planning criteria are met on this site. States can delete or edit nationally identified screening criteria to address localized conditions.</td>
<td>Basic Assessment Level
Basic assessment level criteria are used when a site does not meet screening level criteria, or when no screening level criteria are defined. Assessment levels are also used when formulating and evaluating alternatives. National criteria establish the minimum for all sites. States may add state-specific criteria to address local conditions.</td>
</tr>
</table>

National and State Resource Concerns and Planning Criteria
10/1/2013

SOIL	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
SOIL EROSION - Sheet, rill, & wind erosion	Detachment and transportation of soil particles caused by rainfall runoff/splash, irrigation runoff or wind that degrades soil quality.	• Crop* • Developed Land* • Farmsteads* • Associated Ag Land* • Designated Protected Area* • Other Rural Land* • Pasture*	Sheet & Rill	Permanent ground cover > 90% and slope < 10%	Water erosion rate ≤ T	RUSLE2
			Wind		Wind erosion rate ≤ T	WEPS
		• Forest*	Sheet & Rill Wind	Soil surface organic residue cover > 80%	Site is stable and without visible signs of erosion	Visual Inspection
		• Range*	Sheet & Rill Wind	State established criteria.	RHA - soil site stability - slight to moderate or less **OR** Rangeland Planned Trend is positive	RHA - Rangeland Health Assessment Rangeland Trend Worksheet
SOIL EROSION – Concentrated flow erosion	Untreated classic gullies may enlarge progressively by head cutting and/or lateral widening. Ephemeral gullies occur in the same flow area and are obscured by tillage. This includes concentrated flow erosion caused by runoff from rainfall, snowmelt or irrigation water.	• Crop*	Ephemeral gullies	Ephemeral gullies are not occuring	Conservation practices and managements are in place to prevent or control ephemeral gullies	Field measurements / observations
			Classic gullies	Classic gullies are not present	Classic gully management is adequate to stop the progression of head cutting and widening and are offsite impacts are minimized by vegetation and/or structures	
		• Forest* • Farmsteads* • Pasture* • Range* • Developed Land* • Associated Ag Land* • Designated Protected Area* • Other Rural Land*	Classic gullies	Classic gullies are not present	Classic gully management is adequate to stop the progression of head cutting and widening and are offsite impacts are minimized by vegetation and/or structures	
SOIL EROSION– Excessive bank erosion from streams shorelines or water conveyance channels	Sediment from banks or shorelines threatens to degrade water quality and limit use for intended purposes.	• Crop* • Forest • Range* • Developed Land* • Associated Ag Land* • Designated Protected Area* • Water* • Other Rural Land* • Farmsteads*		Streams, shoreline or channels are not adjacent to site	For shorelines and water conveyance channels; banks are stable or commensurate with normal geomorphological processes? **AND** If bank erosion is present, it is beyond the client's control or commensurate with normal geomorphological processes? **AND** For streambanks; SVAP2 bank condition element score >=5?	SVAP2
		• Pasture*			Bank erosion is it beyond the client's control or commensurate with normal geomorphological processes? **AND** PCS - streambank / shoreline erosion element score ≥ 4?	SVAP2 PCS - Pasture Condition Score

National and State Resource Concerns and Planning Criteria
10/1/2013

SOIL	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
SOIL QUALITY DEGRADATION - Subsidence	Loss of volume and depth of organic soils due to oxidation caused by above normal microbial activity resulting from excessive water drainage, soil disturbance, or extended drought. This excludes karst / sinkholes issues or depressions caused by underground activities.	• Crop • Forest • Associated Ag Land • Designated Protected Area • Pasture		Histisol soils are not present **OR** Histisols soils are not exhibiting subsidence	Subsidence is adequately managed to meet client's objectives	Client input / planner observation
SOIL QUALITY DEGRADATION – Compaction	Management induced soil compaction resulting in decreased rooting depth that reduces plant growth, animal habitat and soil biological activity.	• Crop • Forest • Associated Ag Land • Designated Protected Area • Other Rural Land		Soil compaction is not a problem **AND** Activities do not cause soil compaction problems	Compaction is managed to meet Client's production and management objectives	Observation of soil and/or plant condition Client input / planner observation
		• Pasture			PCS – compaction element score ≥ 4	PCS - Pasture Condition Score
		• Range			RHA - soil site stability - slight to moderate or less **OR** Compaction is managed to meet Client's production and management objectives	RHA - Rangeland Health Assessment Observation of soil and/or plant condition
SOIL QUALITY DEGRADATION – Organic matter depletion	Soil organic matter is not adequate to provide a suitable medium for plant growth, animal habitat, and soil biological activity.	• Crop*		Permanent ground cover > 80%	SCI > 0	RUSLE2 WEPS
		• Pasture			SCI > 0 **OR** **[**PCS - plant cover element score ≥ 4 **AND** PCS - plant residue element score ≥ 4 **]**	PCS - Pasture Condition Score RUSLE2
		• Range		Soil organic matter depletion is not a problem **AND** Activities do not cause soil organic matter depletion	**[**RHA - soil site stability slight to moderate or less **AND** RHA – biotic integrity attribute rating slight to moderate departure or less**]** **OR** Rangeland Planned Trend positive	RHA - Rangeland Health Assessment Rangeland Trend Worksheet
		• Forest			Ground cover meets state criteria specific to ecological site **OR** Soil organic matter is managed to meet Client objectives	Client input / planner observation

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SOIL	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
SOIL QUALITY DEGRADATION – Concentration of salts or other chemicals	Concentration of salts leading to salinity and/or sodicity reducing productivity or limiting desired use, or concentrations of other chemicals impacting productivity or limiting desired use.	• Crop • Pasture • Range • Associated Ag Land • Farmsteads		Activities do not cause salinity/sodicity problems	Conservation practices and managements are in place to mitigate on-site effects	Soil diagnostic evaluations

WATER	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
EXCESS WATER – Ponding, flooding, seasonal high water table, seeps, and drifted snow	Surface water or poor subsurface drainage restricts land use and management goals. Wind-blown snow accumulates around and over surface structures, restricting access to humans and animals.	• Crop • Forest • Farmsteads • Pasture • Range • Developed Land • Associated Ag Land • Designated Protected Area • Other Rural Land	Ponding and Flooding	Ponding or flooding not a problem **AND** **A**ctivities do not cause ponding/flooding problems	Excess water is managed to meet Client's objectives	Client input / planner observation
			Seasonal High Water Table	Seasonal high water table does not cause a problem		
			Seeps	Excess water from seeps does not cause a problem		
			Drifted Snow	Drifted snow does not cause a problem		
INSUFFICIENT WATER – Inefficient moisture management	Natural precipitation is not optimally managed to support desired land use goals or ecological processes.	• Crop • Developed Land • Forest • Associated Ag Land • Designated Protected Area		Moisture management is not a problem **AND** **A**ctivities do not cause inefficient moisture management problems	Runoff and evapotranspiration levels are minimized to meet Client's management objectives	Client input / planner observation
		• Range*			RHA - hydrologic function attributes slight to moderate or less	RHA - Rangeland Health Assessment
		• Pasture			PCS – compaction element score ≥ 4 **AND** PCS - plant cover element score ≥ 4	PCS - Pasture Condition Score
INSUFFICIENT WATER – Inefficient use of irrigation water	Irrigation water is not stored, delivered, scheduled and/or applied efficiently. Aquifer or surface water withdrawals threaten sustained availability of ground or surface water. Available irrigation water supplies have been reduced due to aquifer depletion, competition, regulation and/or drought.	• All*		PLU is not irrigated	The irrigation system components and management meet state specific efficiency criteria	State identified measurement and assessment tools - Farm Irrigation Rating Index (FIRI), State Version

WATER	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
WATER QUALITY DEGRADATION: Excess nutrients in surface and ground waters	Nutrients - organic and inorganic - are transported to receiving waters through surface runoff and/or leaching into shallow ground waters in quantities that degrade water quality and limit use for intended purposes.	• Crop*	Excess nutrients in surface water	Organic or inorganic nutrients are not applied **AND** PLU is not grazed	Nutrient and amendment applications are based on soil or tissue tests and nutrient budgets for realistic yields **AND** Conservation practices and managements are in place to minimize surface water impacts	Client input / planner observation Nutrient budget
			Excess nutrients in groundwater		Nutrient and amendment applications are based on soil or tissue tests and nutrient budgets for realistic yields AND Conservation practices and managements are in place to minimize groundwater impacts	
		• Pasture*	Excess nutrients in surface water		PCS - streambank / shoreline erosion element score ≥ 4 **AND** PCS - livestock concentration areas element score	PCS – Pasture Condition Score Nutrient budget
			Excess nutrients in groundwater			
		• Developed Land	Excess nutrients in surface water	Organic or inorganic nutrients are not applied	Nutrients if applied, are based on a soil test, tissue tests or nutrient budget **AND** Conservation practices and managements are in place to minimize surface water impacts	Nutrient Budget Client input / planner observation
			Excess nutrients in groundwater		Nutrients if applied, are based on a soil test, tissue tests or nutrient budget **AND** Conservation practices and managements are in place to minimize groundwater impacts	
		• Other Rural Land • Associated Ag Land • Designated Protected Area • Water • Forest • Range	Excess nutrients in surface water	Organic or inorganic nutrients are not applied **AND** PLU is not grazed **AND** There are no confined livestock areas	Nutrients if applied, are based on a soil test, tissue tests or nutrient budget **AND** Conservation practices and managements are in place to minimize surface water impacts	Nutrient Budget Client input / planner observation
			Excess nutrients in groundwater		Nutrients if applied, are based on a soil test, tissue tests or nutrient budget **AND** Conservation practices and managements are in place to minimize groundwater impacts	

WATER	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
WATER QUALITY DEGRADATION: Excess nutrients in surface and ground waters (continued)	Nutrients - organic and inorganic - are transported to receiving waters through surface runoff and/or leaching into shallow ground waters in quantities that degrade water quality and limit use for intended purposes.	• Farmsteads*	Excess nutrients in surface water	Organic or inorganic nutrients are not applied **AND** PLU is not grazed **AND** There are no confined livestock areas	Conservation practices and managements are in place to minimize surface water impacts **AND** Surface waters are protected from contamination due to runoff and leaching from storage sites, spill and other concentrated sources	Nutrient Budget Client input / planner observation
			Excess nutrients in groundwater		Conservation practices and managements are in place to minimize groundwater impacts **AND** Groundwater is protected from contamination due to runoff and leaching from storage sites, spill and other concentrated sources	
WATER QUALITY DEGRADATION – Pesticides transported to surface and ground waters	Pest control chemicals are transported to receiving waters in quantities that degrade water quality and limit use for intended purposes.	• All	Pesticides transported to surface water	Pest control chemicals are not applied	Pesticides are stored, handled, disposed and managed to prevent runoff, spills, leaks and leaching **AND** Conservation practices and managements are in place to minimize surface water impacts	Client input / planner observation WinPST
			Pesticides transported to groundwater	Pest control chemicals are not applied	Pesticides are stored, handled, disposed and managed to prevent runoff, spills, leaks and leaching **AND** Conservation practices and managements are in place to minimize groundwater impacts	
WATER QUALITY DEGRADATION – Excess pathogens and chemicals from manure, bio-solids or compost applications	Pathogens, pharmaceuticals, and other chemicals carried by land applied soil amendments are transported to receiving waters in quantities that degrade water quality and limit use for intended purposes. This resource concern also includes the off-site transport of leachate and runoff from compost or other organic materials of animal origin.	• Crop* • Farmsteads* • Forest • Developed Land • Associated Ag Land • Other Rural Land • Designated Protected Area • Water • Pasture* • Range	Pathogens and chemicals from manure, bio-solids, or compost applications transported to surface water	Potential sources of pathogens or pharmaceuticals are not applied on the land	Organic materials are applied, stored, and/or handled to mitigate negative impacts to surface water sources	Client input / planner observation
			Pathogens and chemicals from manure, bio-solids, or compost applications transported to groundwater	Potential sources of pathogens or pharmaceuticals are not applied on the land	Organic materials are applied, stored, and/or handled to mitigate negative impacts to groundwater sources	

WATER	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
WATER QUALITY DEGRADATION – Excessive salts in surface and ground waters	Irrigation or rainfall runoff transports salts to receiving water in quantities that degrade water quality and limit use for intended purposes.	• All	Excessive salts in surface water	Excess salt is not a problem **AND** Activities do not contribute to excess salt problem	Salt concentrations are managed to mitigate off-site transport to surface waters	Client input / planner observation
			Excessive salts in groundwater		Salt concentrations are managed to mitigate off-site transport to groundwater	
WATER QUALITY DEGRADATION – Petroleum, heavy metals and other pollutants transported to receiving waters	Heavy metals, petroleum and other pollutants are transported to receiving water sources in quantities that degrade water quality and limit use for intended purposes.	• All	Petroleum, heavy metals, and other pollutants transported to surface water	Activities do not present the potential for contamination by petroleum, heavy metals and other pollutants	Petroleum, heavy metals or other potential pollutants are stored and handled to avoid runoff to surface water	Client input / planner observation
			Petroleum, heavy metals, and other pollutants transported to groundwater	Activities do not present the potential for contamination by petroleum, heavy metals and other pollutants	Petroleum, heavy metals or other potential pollutants are stored and handled to avoid leaching to groundwater	
WATER QUALITY DEGRADATION – Excessive sediment in surface waters	Off-site transport of sediment from sheet, rill, gully, and wind erosion into surface water that threatens to degrade surface water quality and limit use for intended purposes.	• Crop* • Developed Land* • Farmsteads* • Other Rural Land • Associated Ag Land • Designated Protected Area • Water • Pasture*		Permanent ground cover > 90% and slope < 10% **AND** Classic gullies are not present **AND** Streams or shoreline are not on or adjacent to site	Upslope treatment and buffer practices address concentrated flows to water bodies **AND** SVAP2 - bank condition ≥ 5 **AND** Livestock and vehicle water crossings are stable **AND** Water erosion rate ≤ T **AND** Wind erosion rate ≤ T	RUSLE2 WEPS Client input / planner observation SVAP2
		• Forest*		There are no untreated sources of erosion **AND** Streams or shoreline are not on or adjacent to site	Upslope treatment and buffer practices address concentrated flows to water bodies **AND** Heavy use areas are stable **AND** SVAP2 - bank condition ≥ 5	Client input / planner observation SVAP2
		• Range*			RHA - hydrologic function attribute - slight to moderate or less **AND** SVAP2 - bank condition ≥ 5	RHA - Rangeland Health Assessment SVAP2

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WATER	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
WATER QUALITY DEGRADATION – Elevated water temperature	Surface water temperatures exceed State/Federal standards and/or limit use for intended purposes.	• All		Water courses on or adjacent to the site are not designated by a State Agency as a temperature impairment **OR** Water course temperature is not a client concern	[SVAP2 - riparian area quality element score ≥ 5 **AND** SVAP2 - riparian area quantity quality element score ≥ 5 **AND** SVAP2 - canopy cover element score ≥ 6] **OR** Existing conservation practices are in place to address water temperature	Client input / planner observation SVAP2

PLANT	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
DEGRADED PLANT CONDITION – Undesirable plant productivity and health	Plant productivity, vigor and/or quality negatively impacts other resources or does not meet yield potential due to improper fertility, management or plants not adapted to site. This includes addressing pollinators and beneficial insects.	• Crop • Farmsteads • Developed Land • Designated Protected Area • Associated Ag Land • Other Rural Land		Plant production and health is not a client concern	Plants are adapted to the site, meet production goals and do not negatively impact other resources **AND** Plant damage from wind erosion is below Crop Damage Tolerance levels	Client input / planner observation Crop Tolerance Table
		• Range*			Vegetation meet similarity index or range condition score of 60 or greater for desired plant community and has a positive trend **OR** RHA – biotic integrity attribute rating - slight to moderate departure or less	RHA - Rangeland Health Assessment Rangeland Trend Worksheet Similarity Index Worksheet
		• Pasture*		Plant production and health is not a client concern	PCS - 30 or above Plants are adapted to the site, meet production goals and do not negatively impact other resources	PCS - Pasture Condition Score
		• Forest		Plant production and health is not a client concern	Forest species are adapted to site **AND** Composition and stand density meets the Client's objectives and production goals	Forest Inventory plots and/or transects

PLANT	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
DEGRADED PLANT CONDITION – Inadequate structure and composition	Plant communities have insufficient composition and structure to achieve ecological functions and management objectives. This includes degradation of wetland habitat, targeted ecosystems, or unique plant communities.	• Forest • Designated Protected Area • Associated Ag Land • Water • Pasture		Plant communities support the intended land use and desired ecological functions	Plant communities contain adequate diversity, composition and structure to support desired ecological functions	Ecological Site Descriptions
		• Range*		Plant communities support the intended land use and desired ecological functions	Plant communities contain adequate diversity, composition and structure to support desired ecological functions **OR** RHA – biotic integrity attribute rating slight to moderate departure or less **OR** Vegetation meet similarity index of 60 or greater for desired plant community and has a positive trend	Ecological Site Descriptions RHA - Rangeland Health Assessment Rangeland Trend Worksheet
DEGRADED PLANT CONDITION – Excessive plant pest pressure	Excessive pest damage to plants including that from undesired plants, diseases, animals, soil borne pathogens, and nematodes. This concern addresses invasive plant, animal and insect species.	• Crop • Forest* • Farmsteads • Range* • Developed Land • Associated Ag Land • Designated Protected Area • Water • Other Rural Land		Plant productivity is not limited from pest pressure	Pest damage to plants are below economic or environmental thresholds or client-identified criteria **AND** Plant pests, including noxious and invasive species are managed to meet client objectives	Client input / planner observation
		• Pasture*		Plant productivity is not limited from pest pressure	PCS - insect and disease pressure element score ≥ 4 **AND** PCS - site adaptation element score ≥ 4	PCS - Pasture Condition Score
DEGRADED PLANT CONDITION– Wildfire hazard, excessive biomass accumulation	The kinds and amounts of fuel loadings - plant biomass - create wildfire hazards that pose risks to human safety, structures, plants, animals, and air resources.	• All		Wildfire hazard is not a concern	Fuel loads and fuel ladders are managed to provide defensible space and meet client objectives	Client input / planner observation

<table>
<tr><th>ANIMAL</th><th>Description</th><th>Land Use</th><th>Component</th><th>Screening</th><th>Assessment Level</th><th>Assessment Tools</th></tr>
<tr><td rowspan="3">INADEQUATE HABITAT FOR FISH AND WILDLIFE – Habitat degradation</td><td rowspan="3">Quantity, quality or connectivity of food, cover, space, shelter and/or water is inadequate to meet requirements of identified fish, wildlife or invertebrate species.</td><td rowspan="3">All with “wildlife” modifier - (Required when Land Use has a wildlife modifier)</td><td>Quantity, quality of food is inadequate to meet requirements of identified fish, wildlife or invertebrate species</td><td rowspan="3"></td><td>WHSI rating ≥ 0.5
AND (when surface stream present)
[SVAP2 – fish habitat complexity element score ≥ 7
AND
SVAP2 – aquatic invertebrate habitat element score ≥ 7]
OR
Conservation practices and management are in place that meet or exceed species or guild-specific habitat model thresholds
OR
Food is available in quality and extent to support habitat requirements for the species of interest</td><td rowspan="3">Species-specific wildlife habitat assessment tools

SVAP2

Generalized WHS Index finalized by States, and detailed models by selected species and habitat type</td></tr>
<tr><td>Quantity, quality of water is inadequate to meet requirements of identified fish, wildlife or invertebrate species</td><td>WHSI rating ≥ 0.5
AND (when surface stream present)
SVAP2 – aquatic invertebrate habitat element score ≥ 7
OR
Conservation practices and management are in place that meet or exceed species or guild-specific habitat model thresholds
OR
Water is available in quality and extent to support habitat requirements for the species of interest</td></tr>
<tr><td>Quantity, quality or cover/shelter is inadequate to meet requirements of identified fish, wildlife or invertebrate species</td><td>WHSI rating ≥ 0.5
AND (when surface stream present)
[SVAP2 – barriers to movement element score ≥ 7
AND
SVAP2 – fish habitat complexity element score ≥ 7
AND
SVAP2 – aquatic invertebrate habitat element score ≥ 7]
OR
Conservation practices and management are in place that meet or exceed species or guild-specific habitat model thresholds
OR
Cover is of available quality and extent to support habitat requirements for the species of interest</td></tr>
</table>

ANIMAL	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
INADEQUATE HABITAT FOR FISH AND WILDLIFE – Habitat degradation (continued)	Quantity, quality or connectivity of food, cover, space, shelter and/or water is inadequate to meet requirements of identified fish, wildlife or invertebrate species.	All with "wildlife" modifier - (Required when Land Use has a wildlife modifier)	Habitat continuity and/or space is inadequate to meet requirements of identified fish, wildlife or invertebrate species		WHSI rating ≥ 0.5 **AND** (when surface stream present) **[**SVAP2 – barriers to movement element score ≥ 7 **AND** SVAP2 – aquatic invertebrate habitat element score ≥ 7 **]** **OR** Conservation practices and management are in place that meet or exceed species or guild-specific habitat model thresholds **OR** The connectivity of habitat components are adequate to support stable populations of targeted species	Species-specific wildlife habitat assessment tools SVAP2 Generalized WHS Index finalized by States, and detailed models by selected species and habitat type
LIVESTOCK PRODUCTION LIMITATION – Inadequate feed and forage	Feed and forage quality or quantity is inadequate for nutritional needs and production goals of the kinds and classes of livestock.	• All with "grazed" modifier (Applicable when Land Use is grazed)			Livestock forage, roughage and supplemental nutritional requirements addressed.	Client input / planner observation GRAS - Grassland Resource Analysis System
LIVESTOCK PRODUCTION LIMITATION – Inadequate livestock shelter	Livestock lack adequate shelter from climatic conditions to maintain health or production goals.	• All with "grazed" modifier (Applicable when Land Use is grazed)			Artificial or natural shelters meet animal health needs and client objectives.	Client input / planner observation
LIVESTOCK PRODUCTION LIMITATION – Inadequate livestock water	Quantity, quality and/or distribution of drinking water are insufficient to maintain health or production goals for the kinds and classes of livestock.	• All with "grazed" modifier (Applicable when Land Use is grazed)			Water of acceptable quality and quantity adequately distributed to meet animal needs.	Client input / planner observation GRAS - Grassland Resource Analysis System - Tool for water distribution

ENERGY	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
INEFFICIENT ENERGY USE – Equipment and facilities	Inefficient use of energy in the Farm Operation increases dependence on non-renewable energy sources that can be addressed through improved energy efficiency and the use of on-farm renewable energy sources. As an example, this concern addresses inefficient energy use in pumping plants, on-farm processing, drying and storage.	• All		Client is not interested in improving equipment and facilities energy efficiency	A USDA approved energy audit been implemented that address equipment and facilities to meet client objectives **OR** On-farm renewable energy and/or energy conserving practices have been implemented to meet client objectives	Client input / planner observation USDA approved Energy Audit NRCS Energy Estimator
INEFFICIENT ENERGY USE – Farming/ranching practices and field operations	Inefficient use of energy in field operations increases dependence on non-renewable energy sources that can be addressed through improved efficiency and the use of on-farm renewable energy sources.	• All		Client is not interested in improving energy use in farm and ranch field operations	A USDA approved energy audit been implemented that address field operations to meet client objectives **OR** On-farm renewable energy and/or energy conserving practices have been implemented to meet client objectives	Client input / planner observation USDA approved Energy Audit NRCS Energy Estimator Conservation on the Farm Checklist

AIR	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
AIR QUALITY IMPACTS - Emissions of Particulate Matter - PM - and PM Precursors	Direct emissions of particulate matter - dust and smoke -, as well as the formation of fine particulate matter in the atmosphere from other agricultural emissions - ammonia, NOx, and VOCs - cause multiple environmental impacts, such as: - The unintended movement of particulate matter - typically dust or smoke - results in safety or nuisance visibility restriction. - The unintended movement of particulate matter and/or chemical droplets results in unwanted deposits on surfaces. - Increased atmospheric concentrations of particulate matter can impact human and animal health and degrade regional visibility.	• Crop • Pasture • Range • Forest • Other Rural Land • Associated Ag Land • Designated Protected Areas • Developed Land • Farmsteads		Activities are not present that contribute to agricultural source PM or PM precursor emissions PM Producing Activity Examples: • Prescribed Burn is conducted • Travel ways unpaved or untreated with binding agents • Engines (combustion source) • Tillage • Pesticides are applied • Fertilization (manure/ commercial) • CAFO/manure management) **AND** Episodes or complaints of emissions of PM (dust, smoke, exhaust, etc.), or chemical drift have not occurred	PM and PM Precursor emissions are managed to meet client objectives	Client input / planner observation
AIR QUALITY IMPACTS - Emissions of Greenhouse Gases - GHGs	Emissions increase atmospheric concentrations of greenhouse gases.	• All		Activities are not present that produce GHGs emissions GHG Producing Activities: • Fertilization (manure/commercial) • CAFO/manure management • Engines (combustion source) • Tillage **AND** GHGs are not regulated in this planning area	Greenhouse gas emissions are managed to meet client objectives	Client input / planner observation

AIR	Description	Land Use	Component	Screening	Assessment Level	Assessment Tools
AIR QUALITY IMPACTS - Emissions of Ozone Precursors	Emissions of ozone precursors - NOx and VOCs - resulting in formation of ground- level ozone that cause negative impacts to plants and animals.	• All		Operations are not present that produce ozone or precursor emissions Ozone Producing Activities: • Engines (combustion source) • Pesticide application • Burning • CAFO/manure management • Fertilization (manure /commercial)	Ozone precursor emissions are managed to meet client objectives	Client input / planner observation
AIR QUALITY IMPACTS - Objectionable odors	Emissions of odorous compounds - VOCs, ammonia and odorous sulfur compounds - cause nuisance conditions.	• Crop • Pasture • Farmsteads • Other Rural Land		Activities are not present that contribute to nuisance air quality conditions Nuisance Producing Activities: • Pesticide application • CAFO / manure management • Composting is conducted **AND** Odor sources are not regulated in this planning area **AND** Episodes or complaints of emissions of PM (dust, smoke, exhaust, etc.), or chemical drift have not occurred	Odors are managed to meet client objectives	Client input / planner observation

Exhibit 5-2: Wind Erodibility Group (WEG) and Wind Erodibility Index (from the National Soil Survey Handbook)

618.95 Wind Erodibility Groups (WEG) and Index

WEG 1,3,4,5,7	**Properties of Soil Surface Layer**	**Dry Soil Aggregates More Than 0.84 mm (wt.%)**	**Wind Erodibility Index (I) (tons/ac/yr)**
1	Very fine sand, fine sand, sand, or coarse sand[2]	1 2 3 5 7	310 250 220 180 160
2	Loamy very fine sand, loamy fine sand, loamy sand, and loamy coarse sand; very fine sandy loam and silt loam with 5 or less percent clay and 25 or less percent very fine sand; and sapric soil materials (as defined in *Soil Taxonomy*), except Folists.	10	134
3	Very fine sandy loam (but does not meet WEG criterion 2), fine sandy loam, sandy loam, and coarse sandy loam; noncalcareous silt loam that has greater than or equal to 20 to less than 50 percent very fine sand and greater than or equal to 5 to less than 12 percent clay.	25	86
4	Clay, silty clay, noncalcareous clay loam that has more than 35 percent clay and noncalcareous silty clay loam that has more than 35 percent clay; all of these do not have sesquic, parasesquic, ferritic, ferruginous, or kaolinitic mineralogy (high iron oxide content).	25	86
4L	Calcareous[6] loam, calcareous silt loam, calcareous silt, calcareous sandy clay, calcareous sandy clay loam, calcareous clay loam, and calcareous silty clay loam.	25	86
5	Noncalcareous loam that has less than 20 percent clay; noncalcareous silt loam with greater than or equal to 5 to less than 20 percent clay (but does not meet WEG criterion 3); noncalcareous sandy clay loam; noncalcareous sandy clay; and hemic soil materials (as defined in *Soil Taxonomy*).	40	56
6	Noncalcareous loam and silt loam that have greater than or equal to 20 percent clay; noncalcareous clay loam and noncalcareous silty clay loam that have less than or equal to 35 percent clay; silt loam that has parasesquic, ferritic, or kaolinitic mineralogy (high iron oxide content).	45	48
7	Noncalcareous silt; noncalcareous silty clay, noncalcareous silty clay loam, and noncalcareous clay that have sesquic, parasesquic, ferritic, ferruginous, or kaolinitic mineralogy (high content of iron oxide) and are Oxisols or Ultisols; and fibric soil materials (as defined in *Soil Taxonomy*).	50	38
8	Soils not susceptible to wind erosion due to rock and pararock fragments at the surface and/or wetness; and Folists.	--	0

The following footnotes are applied in the order listed:

(i) For all WEGs except 1 and 2 (sands and loamy sand textures), if percent rock and pararock fragments (>2mm) by volume is 15-35, reduce "I" value by one group with more favorable rating. If percent rock and pararock fragments by volume is 35-60, reduce "I" value by two favorable groups except for sands and loamy sand textures which are reduced by one group with more favorable rating. If percent rock and pararock fragments is greater than 60, use "I" value of 0 for all textures except sands and loamy sand textures which are reduced by three groups with more favorable ratings. An example of more favorable "I" rating is next lower number: "I" factor of 160 to "I" factor of 134 or "I" factor of 86 to "I" factor of 56. The index values should correspond exactly to their wind erodibility group (e.g., "I" factor of 56 = WEG 5).

(ii) The "I" values for WEG 1 vary from 160 for coarse sands to 310 for very fine sands. Use an "I" of 220 as an average figure.

(iii) All material that meets criterion 3 in the required characteristics for andic soil properties as defined in the *Keys to Soil Taxonomy*, 11th edition. Such material is placed in WEG 2 regardless of the texture class of the fine-earth fraction.

(iv) All material that meets criterion 2, but not criterion 3, in the required characteristics for andic soil properties as defined in the *Keys to Soil Taxonomy*, 11th edition. Such material is placed in WEG 6, regardless of the texture class of the fine-earth fraction. The only exception to this is for Cryic Spodosols which have a medial substitute class and a MAAT < 4 degrees C.; these soils are placed in WEG 2.

(v) For surface layers or horizons that do not meet the required characteristics for andic soil properties but do meet Vitrandic, Vitritorrandic, Vitrixerandic, and Ustivitrandic subgroup criteria (thickness criterion excluded) move one wind erodibility group (WEG) with a less favorable rating.

(vi) Calcareous is a strongly or violently effervescent reaction (class) of the fine-earth fraction to cold dilute (1N) HCL; a paper "Computing the Wind Erodible Fraction of Soils" by D. W. Fryear et.al (1994) in the Journal of Soil and Water Conservation 49 (2) 183-188 raises a yet unresolved question regarding the effect of carbonates on wind erosion.

(vii) For mineral soils with thin 'O' horizons, the WEG is based on the first mineral horizon.

Exhibit 5-3: Resource Concern Guide, Soil Erosion - Wind

United States Department of Agriculture

NRCS Natural Resources Conservation Service

Arizona Planning Guide for Natural Resource Concerns

Soil Erosion - Wind

Resource Concern Description – Detachment and transport of soil particles caused by wind degrade soil quality and/or damage plants.

Planning Criteria – Land use and management do not cause accelerated wind erosion.

1. Wind erosion on cropland and pastureland does not exceed the established soil loss tolerance “T” for the soil.
2. On rangeland the soil site stability is slight to moderate or less.
3. On forestland the site is stable without visible signs of erosion.

Methods for evaluating resource condition

- Visual assessment (pedestals, blow-out areas)
- Rangeland Health Assessment
- Wind Erosion Prediction System (WEPS)

Conservation Practices that may be needed as part of a Conservation Management System to achieve Planning Criteria for this resource concern include those listed here.

314	Brush Management
327	Conservation Cover
328	Conservation Crop Rotation
340	Cover Crop
342	Critical Area Planting
588	Cross Wind Ridges
589C	Cross Wind Trap Strips
324	Deep Tillage
382	Fence
386	Field Border
512	Forage and Biomass Planting
655	Forest Trails and Landings
666	Forest Stand Improvement
548	Grazing Land Mechanical Treatment
561	Heavy Use Area Protection
422	Hedgerow Planting
603	Herbaceous Wind Barriers
441	Irrigation System, Microirrigation
443	Irrigation System, Surface and Subsurface
447	Irrigation System, Tailwater Recovery
449	Irrigation Water Management
484	Mulching
528	Prescribed Grazing
550	Range Planting
562	Recreation Area Improvement
329	Residue and Tillage Management, No Till
345	Residue and Tillage Management, Reduced Till
557	Row Arrangement
610	Salinity and Sodic Soil Management
442	Sprinkler System
585	Stripcropping
609	Surface Roughening
612	Tree/Shrub Establishment
645	Wildlife Upland Habitat Management
380	Windbreak/Shelterbelt Establishm

Exhibit 5-4: Resource Concern Guide, Air Quality Impacts - Emissions of Particulate Matter (PM) and PM Precursors

United States Department of Agriculture
NRCS Natural Resources Conservation Service

Arizona Planning Guide for Natural Resource Concerns

Air Quality Impacts – Emissions of Particulate Matter (PM) and PM Precursors

Resource Concern Description – Direct emissions of particulate matter such as dust and smoke, as well as the formation of fine particulate matter in the atmosphere from other agricultural emissions - ammonia, NOx, and VOCs - cause multiple environmental impacts, including but not limited to:

- The unintended movement of particulate matter - typically dust or smoke - results in safety or nuisance visibility restriction.
- The unintended movement of particulate matter and/or chemical droplets results in unwanted deposits on surfaces.
- Increased atmospheric concentrations of particulate matter can impact human and animal health and degrade regional visibility.

Planning Criteria –PM and PM Precursor emissions are managed to meet client objectives.

Methods for evaluating resource condition

- Visual Assessment
- Client Interview
- EPA Air Quality Guidelines
- State and County Air Quality Guidelines
- NRCS Agricultural Air Quality Conservation Measures Guide
- Emissions Calculator
- RUSLE2
- WEPS
- Manure Management Planner (MMP)
- Nutrient Budget
- Pesticide planning and mitigation worksheet

Conservation Practices that may be needed as part of a Conservation Management System to achieve Planning Criteria for this resource concern include those listed here.

309 Agrichemical Handling Facility
371 Air Filtration and Scrubbing
591 Amendments for Treatment of Agricultural Waste
366 Anaerobic Digester
372 Combustion System Improvement
328 Conservation Crop Rotation
340 Cover Crop
375 Dust Control from Animal Activity on Open Lot Surfaces
373 Dust Control on Unpaved Roads and Surfaces
512 Forage and Biomass Planting
595 Integrated Pest Management
441 Irrigation System, Microirrigation
443 Irrigation System, Surface and Subsurface
449 Irrigation Water Management
590 Nutrient Management
338 Prescribed Burning
329 Residue and Tillage Management, No Till
345 Residue and Tillage Management, Reduced Till
442 Sprinkler System
633 Waste Recycling
632 Waste Separation Facility
313 Waste Storage Facility
634 Waste Transfer
629 Waste Treatment
359 Waste Treatment Lagoo

Exhibit 5-5: Example of a "T Chart"

Conservation Practice Effects

Conservation Cover (Ac) 327

Definition: Establishing and maintaining permanent vegetative cover
Major Resource Concerns Addressed: Soil Erosion and Water Quality.
Benchmark Condition: Annually tilled highly erodible low productivity cropland.
Date: October, 2016 **Developer/Location:** Hal Gordon, OR

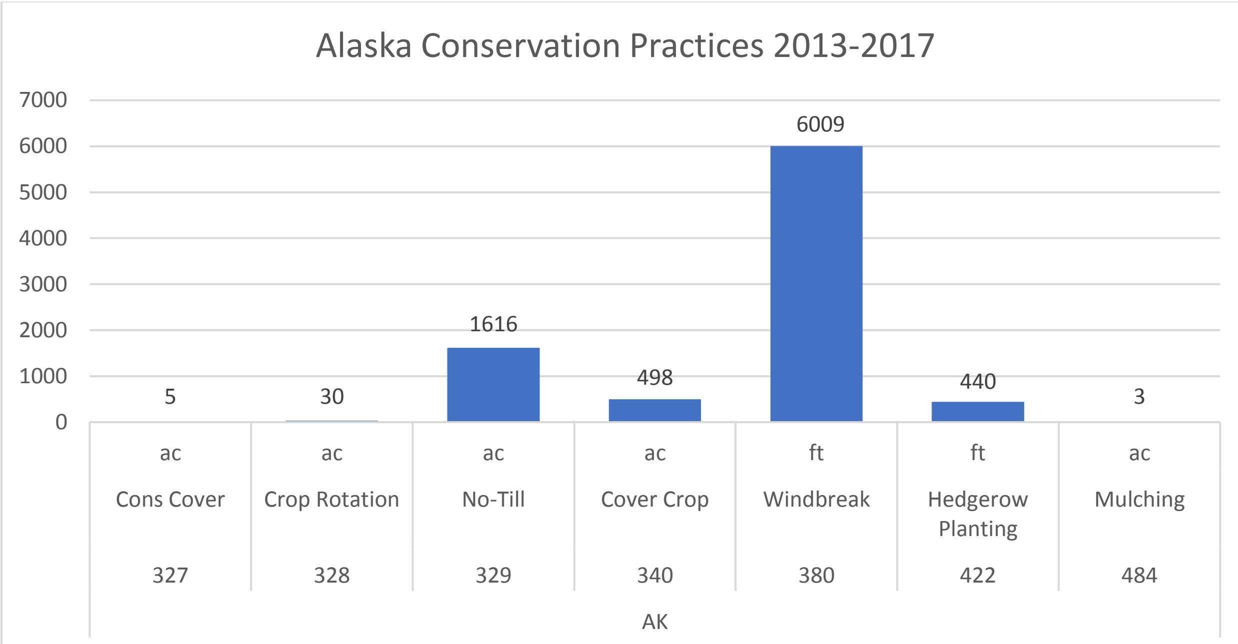
Positive Effects	Negative Effects
Soil • Increased vegetation and cover will improve infiltration and decrease sheet and rill, wind, and gully erosion. • Streambank, shoreline, and channel erosion is reduced. • Organic matter will increase with residue and root establishment. • Compaction and subsidence is will decrease with fewer field operations. • Concentration of salts or other chemicals is reduced with permanent cover. **Water** • Runoff, flooding, ponding, seeps or seasonal high water table may be reduced with increased water use. • Permanent vegetation can trap snow. • Soil moisture will increase. • Reduced nutrient and pesticide use, less transport to surface and ground water. • Less runoff and infiltration of salts, pathogens and chemicals from manure. • Less sediment in surface water. **Air** • Fewer emissions of particulate matter, permanent vegetation reduces wind erosion and generation of fugitive dust. • Emissions of ozone precursors and CO2 will be reduced with less machinery use. **Plants**	**Land** • Land use will be changed or land taken out of production if cropland is converted to permanent cover. **Capital** • No additional field equipment required. • Materials, seedbed and planting costs. • Annual operation and maintenance costs to maintain vegetation and reduce pests. • Reduced farm income (forgone income). **Labor** • None. **Management** • None. **Risk** • Reduced whole farm flexibility and timing by taking land out of agricultural production. • Reduced or lost crop production. • Reduced cash flow. • Seeps may increase with deeper and more numerous roots and higher soil infiltration rates.

• **Plant community productivity and health will increase.** • **Permanent vegetation may slow the spread of noxious weeds.** **Animals** • **Fish and wildlife habitat, food, cover and shelter will improve.** • **Fish and wildlife habitat continuity (space) will increase and may be used to connect other cover areas.** **Energy** • **Less fuel and oil will be used with reduced machinery use.** **Human** • **Cultural resources may be protected from erosion.** • **Labor, management and capital will decrease as land is taken out of production.** • **Reduced time cultivating previous crop.** • **Create sustainability of natural resources that support farm business.** • **Increase the property value (real estate).** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.**	
• **Net Effect: Soil health will improve, erosion will be reduced and water quality improved at a significant cost. Profitability will decrease as land is taken out of production.**	

Commonly Associated Practices: Brush Management, Critical Area Planting, Fence, Tree/Shrub Establishment, Upland Wildlife Habitat Management

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, and adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, and put all units in the same time frame using amortization ($/Acres/Year) or net present value ($/Acre), so that benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist, and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Exhibit 6-1: Cropland Wind Erosion Practices by State



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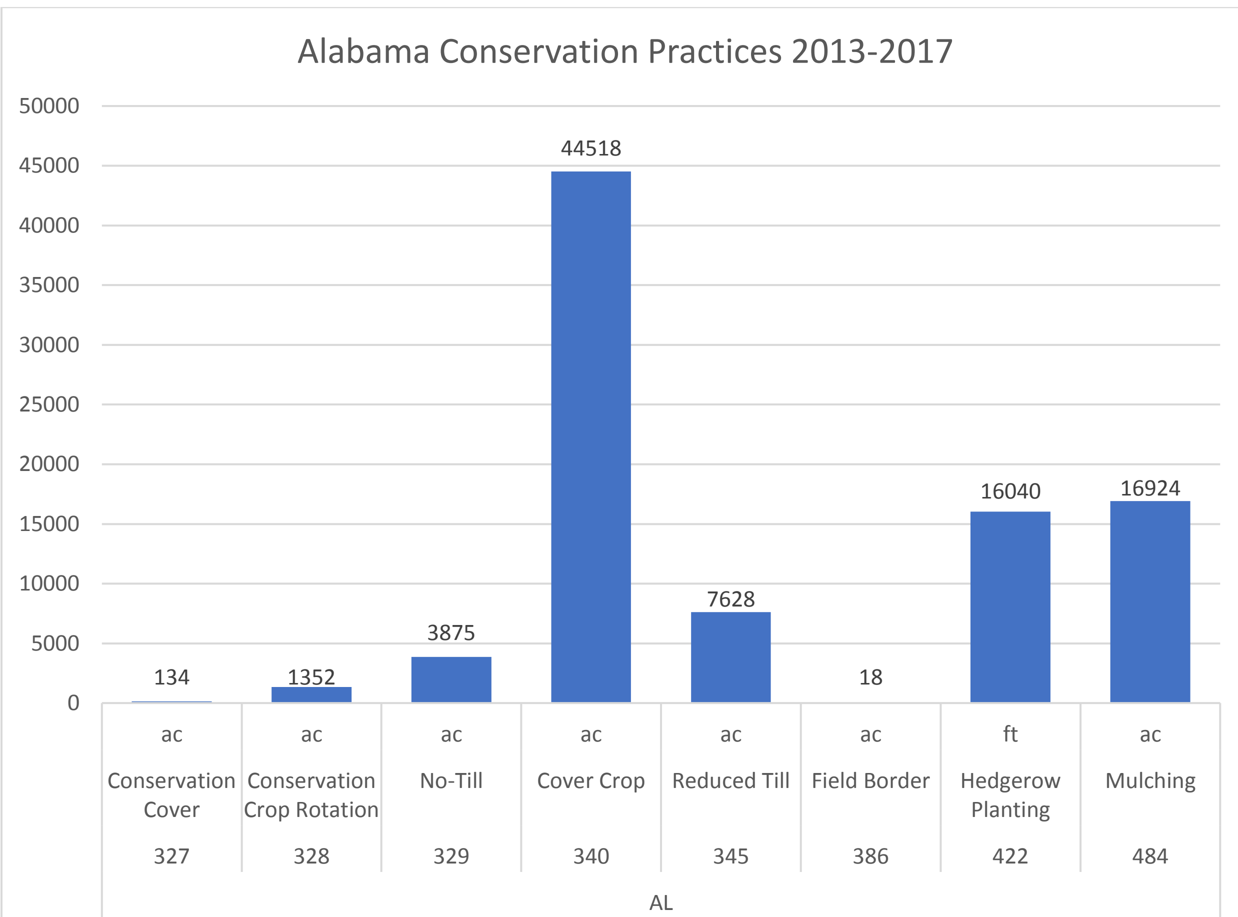

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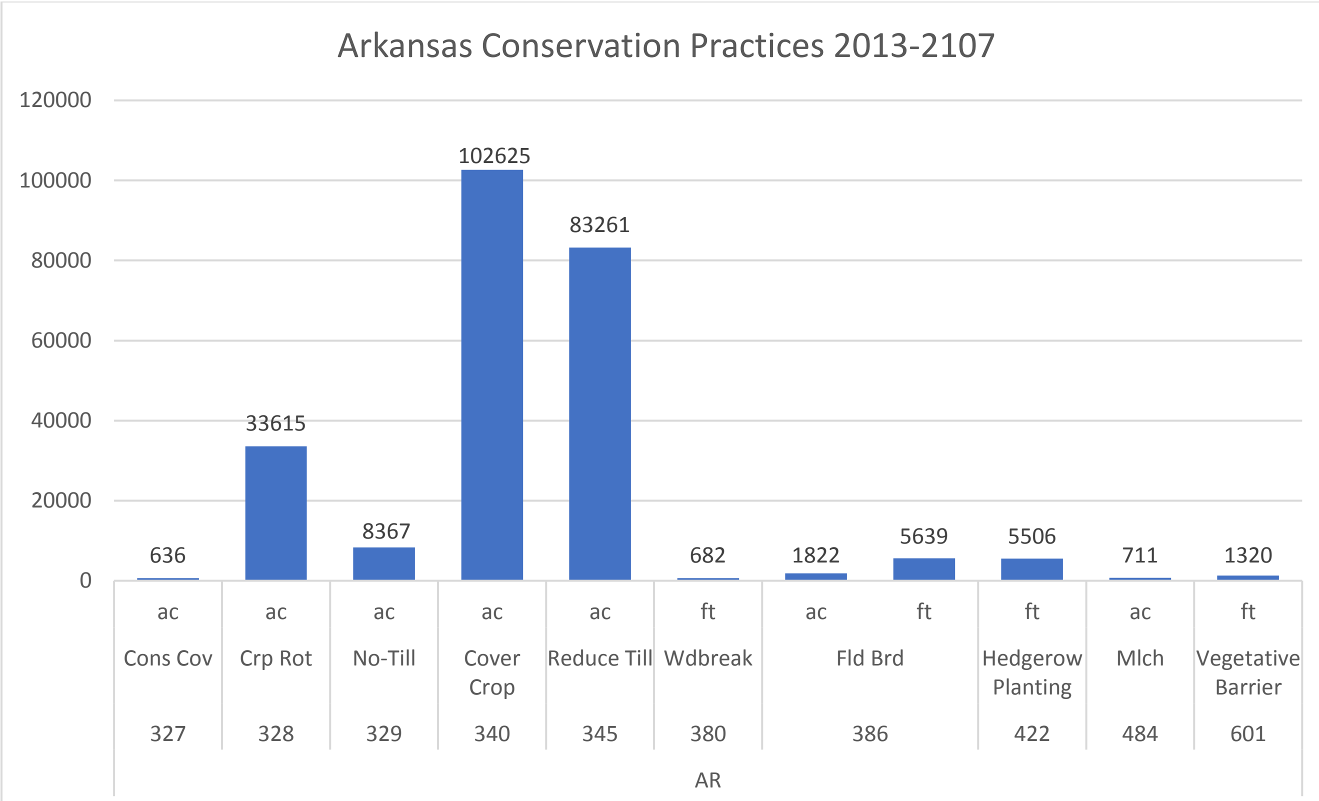
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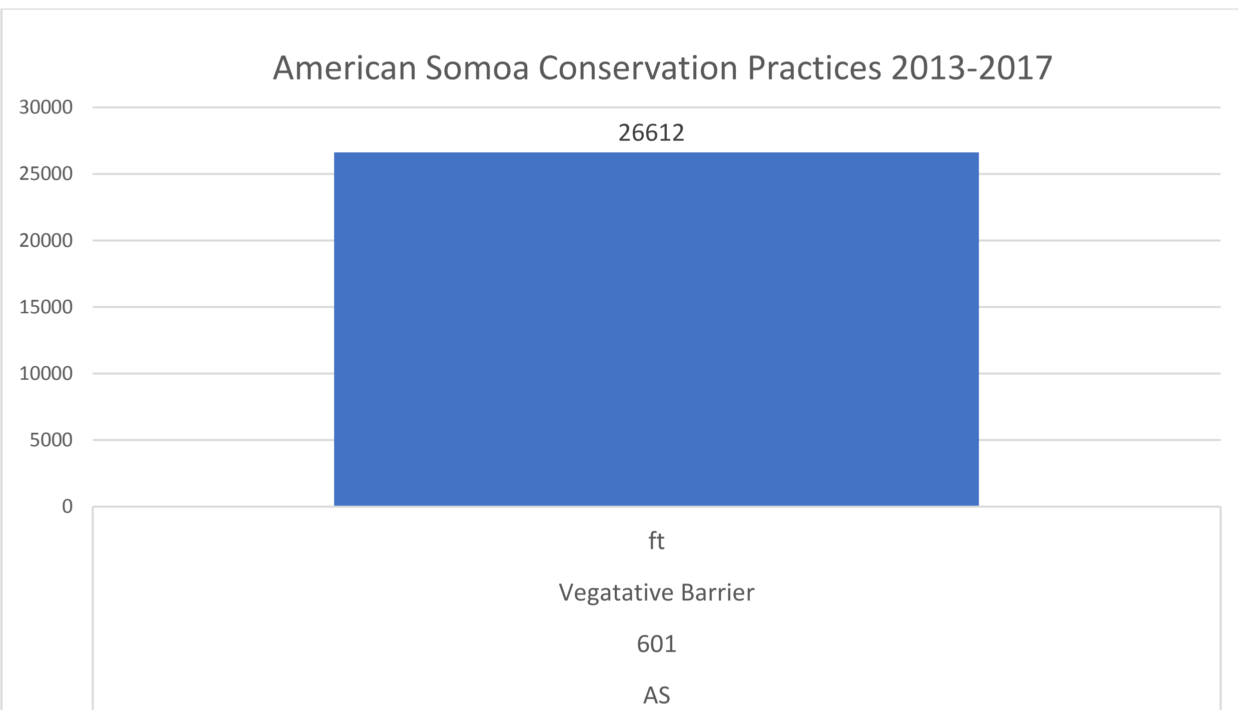
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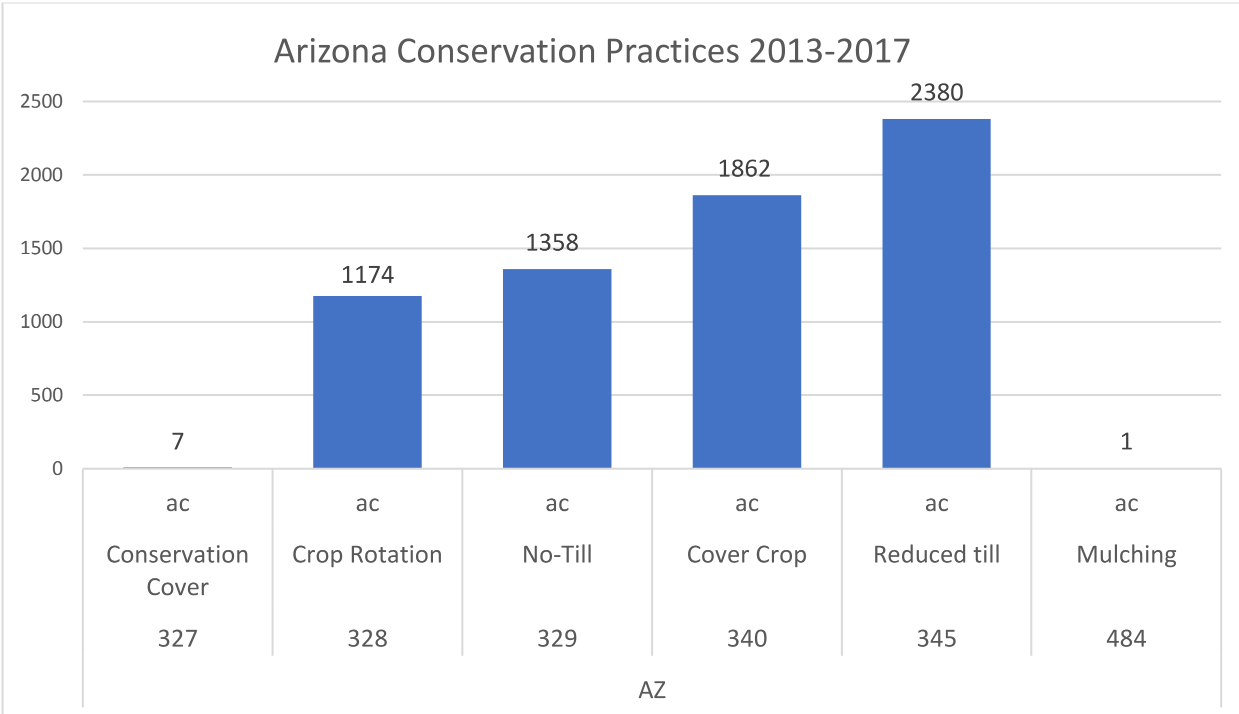
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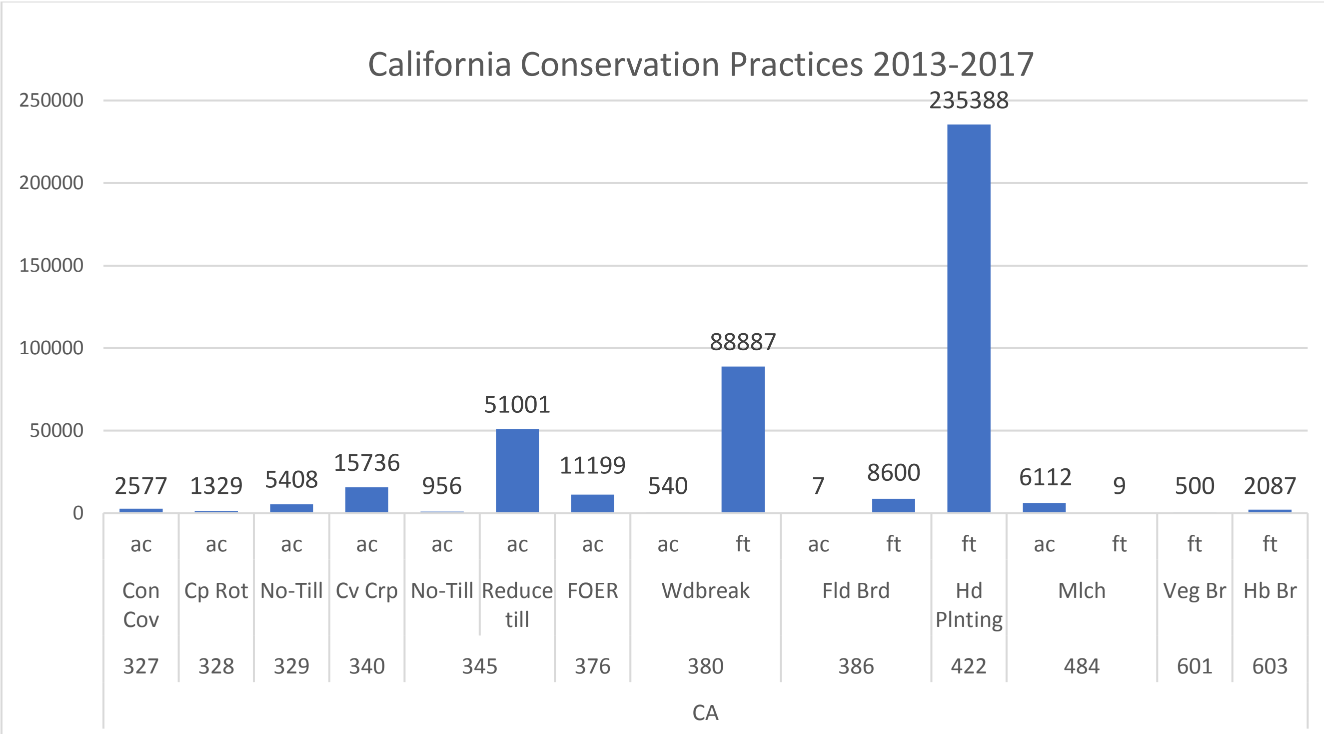
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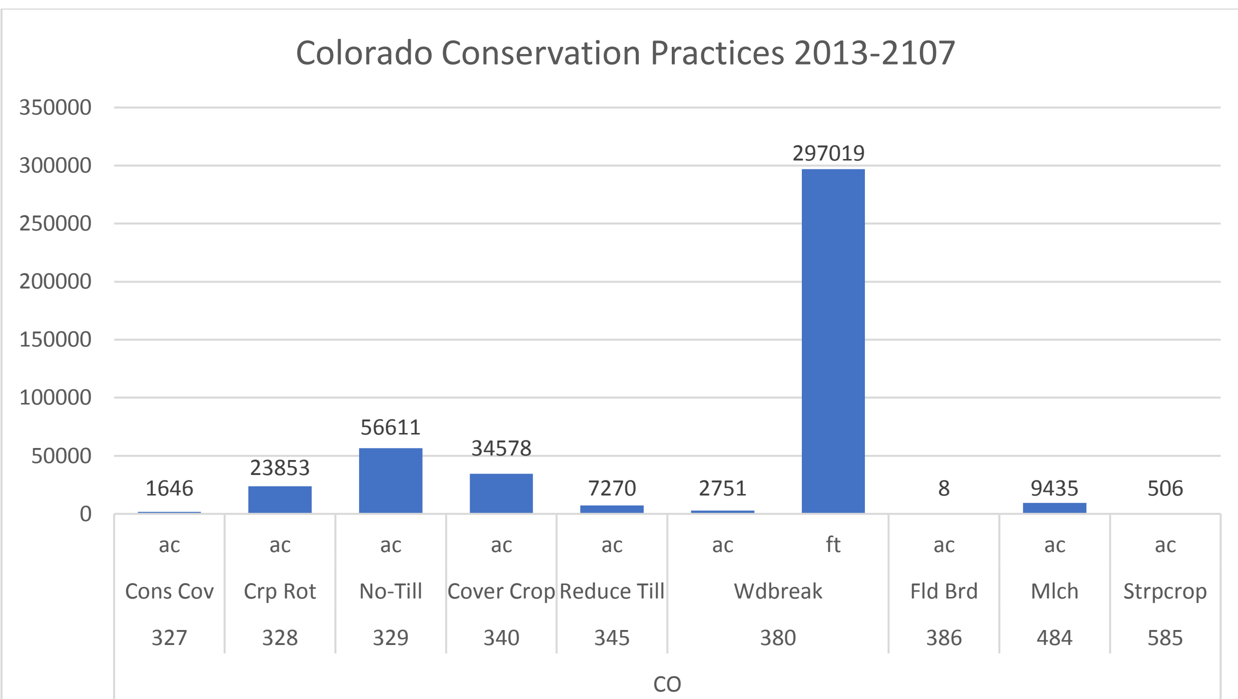
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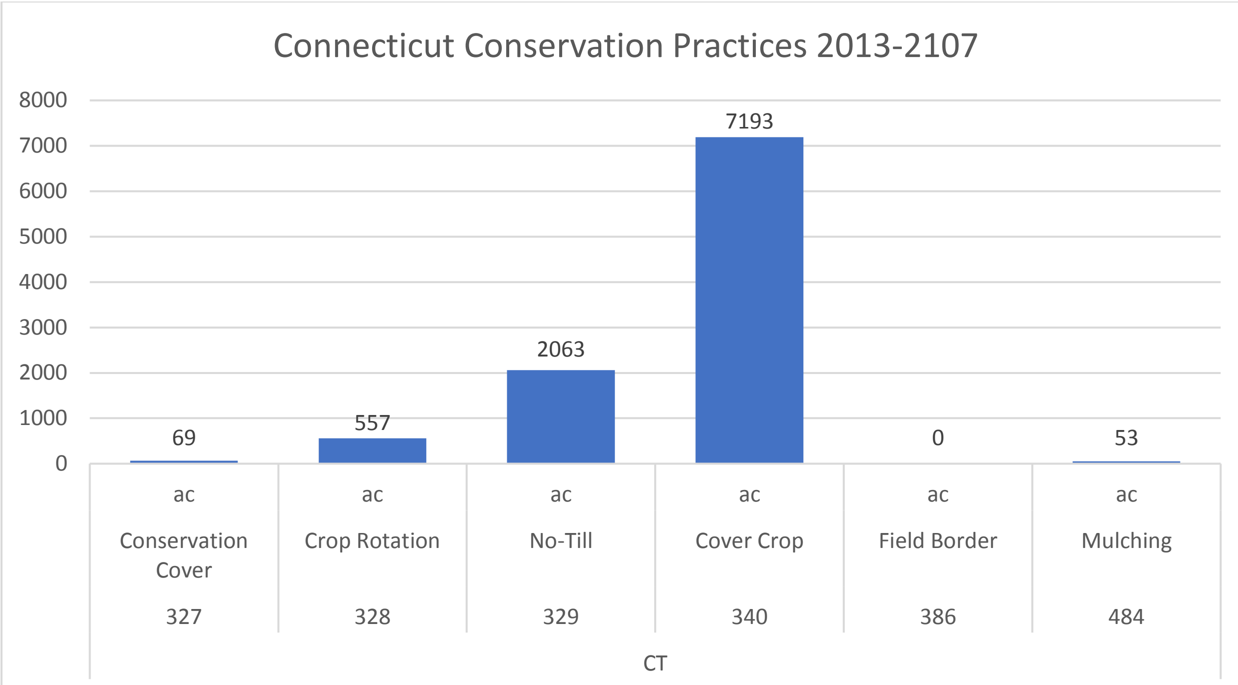
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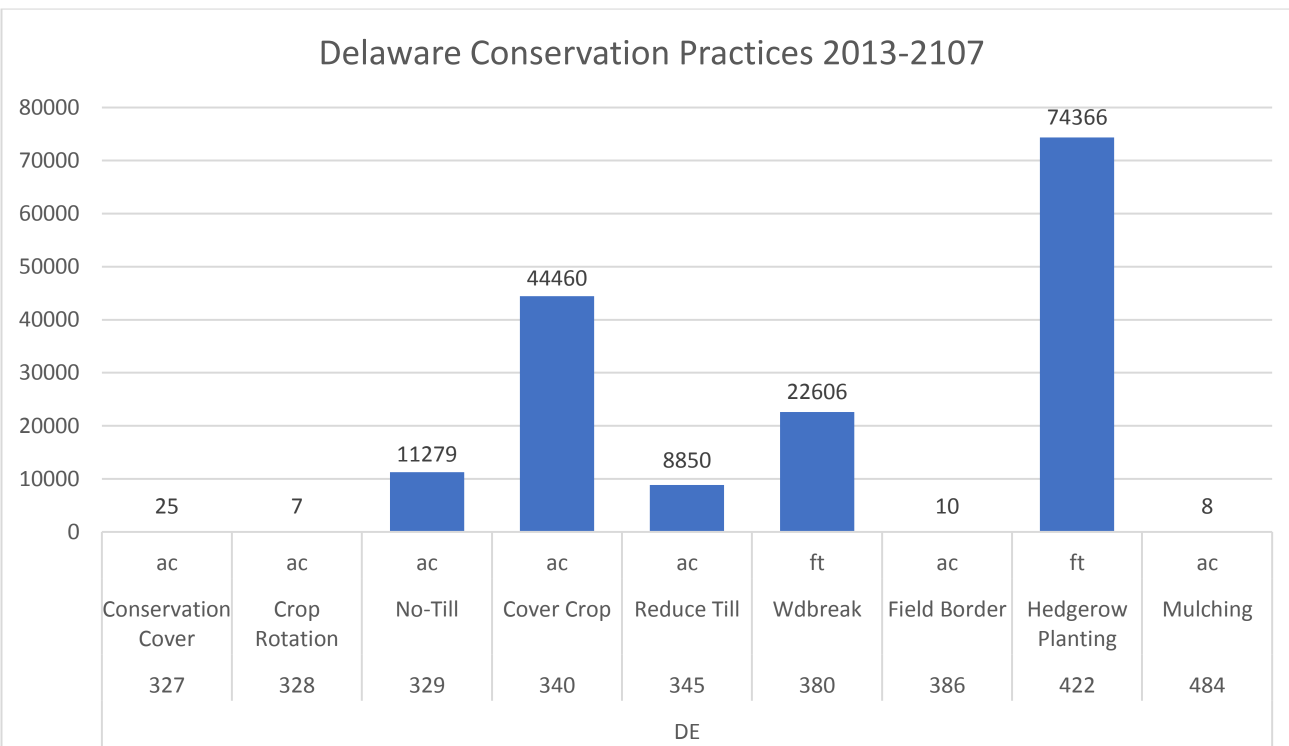
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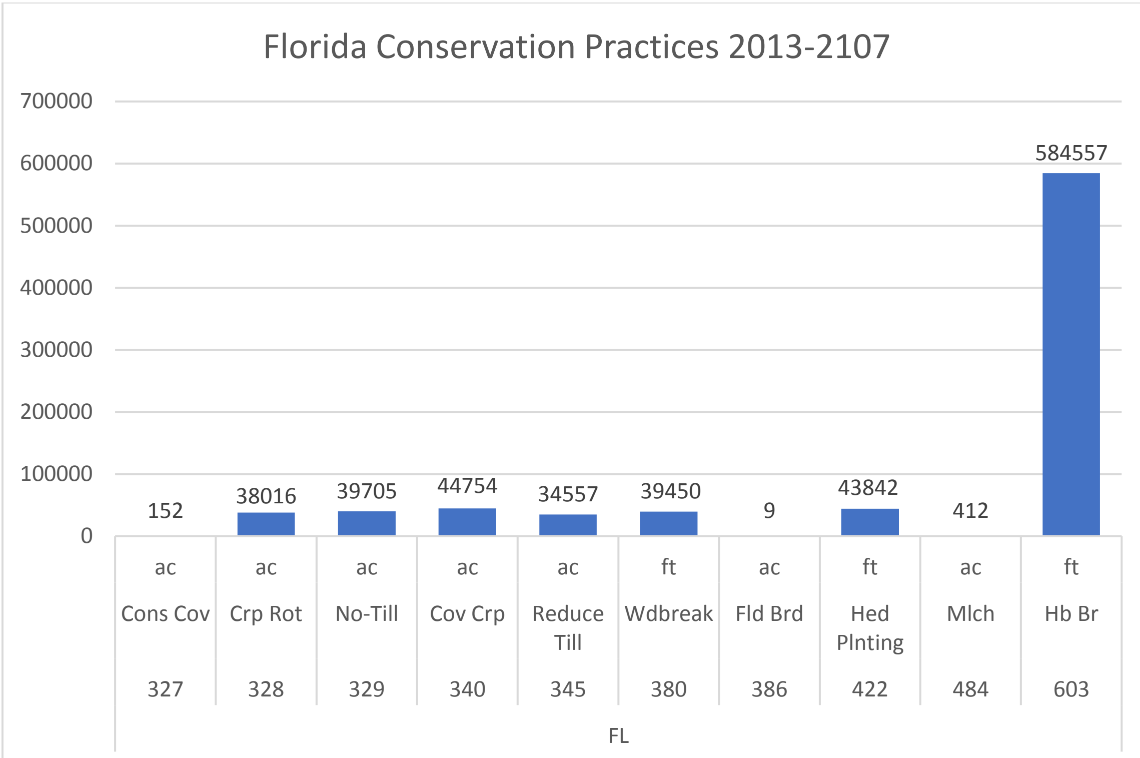

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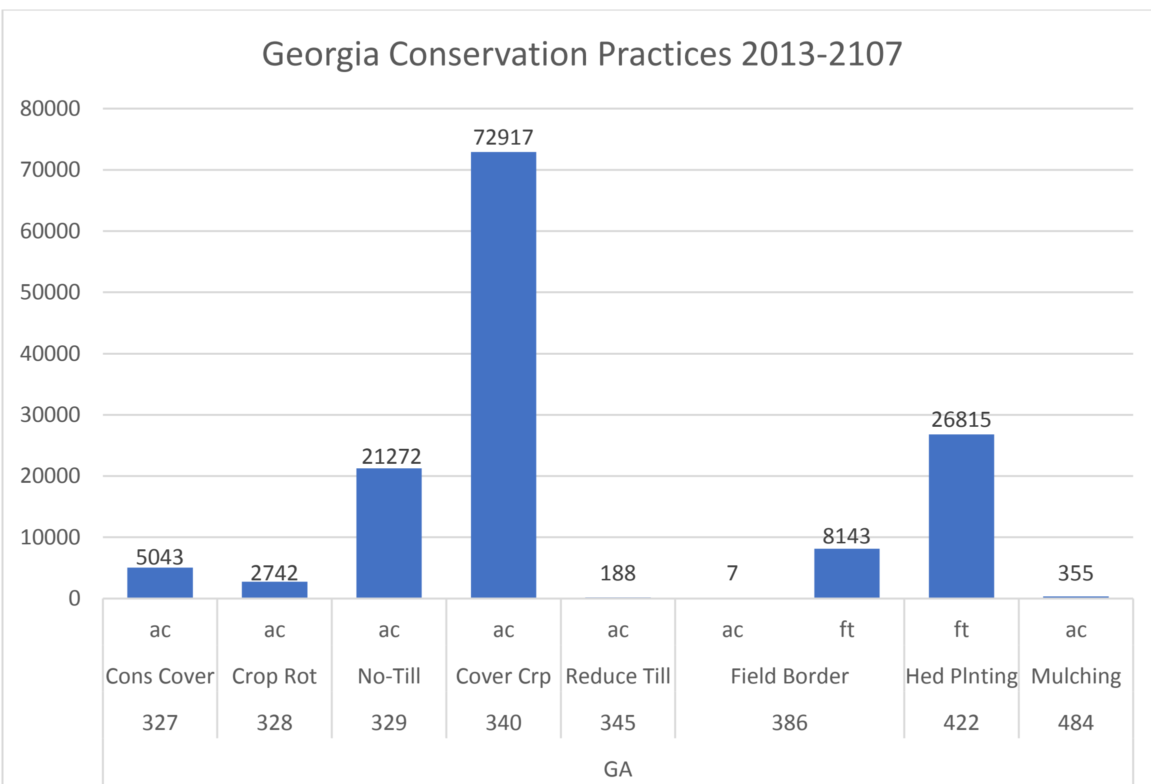

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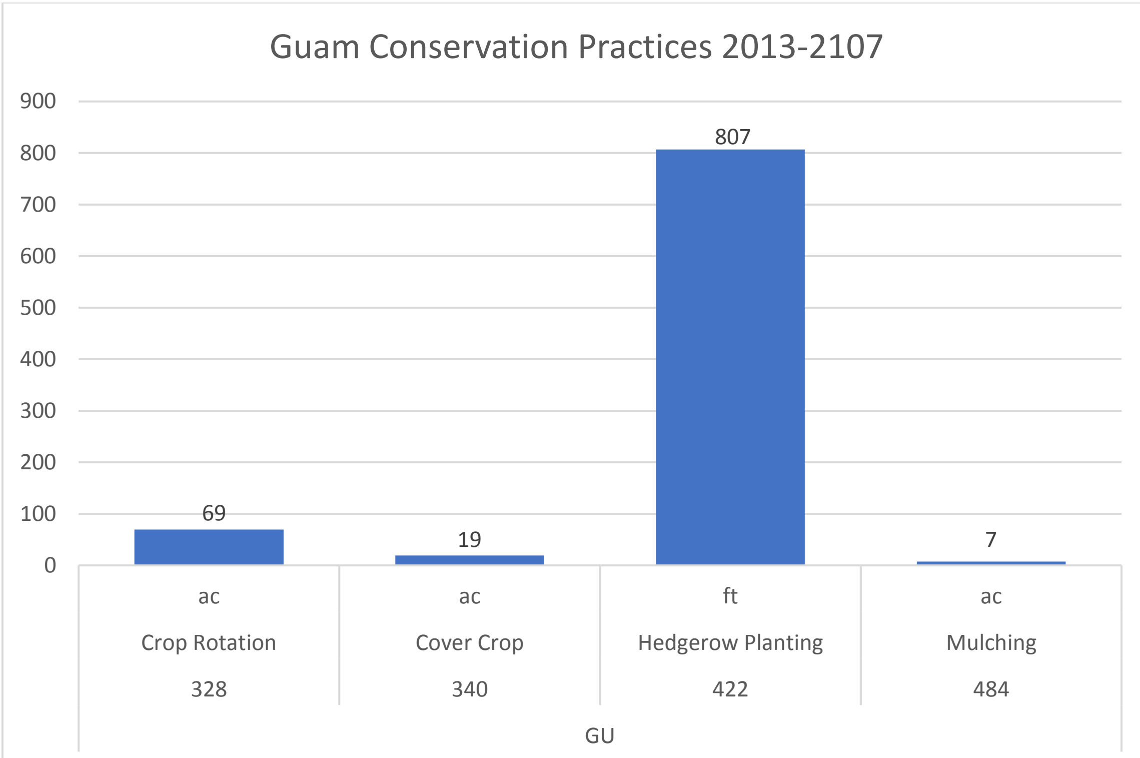
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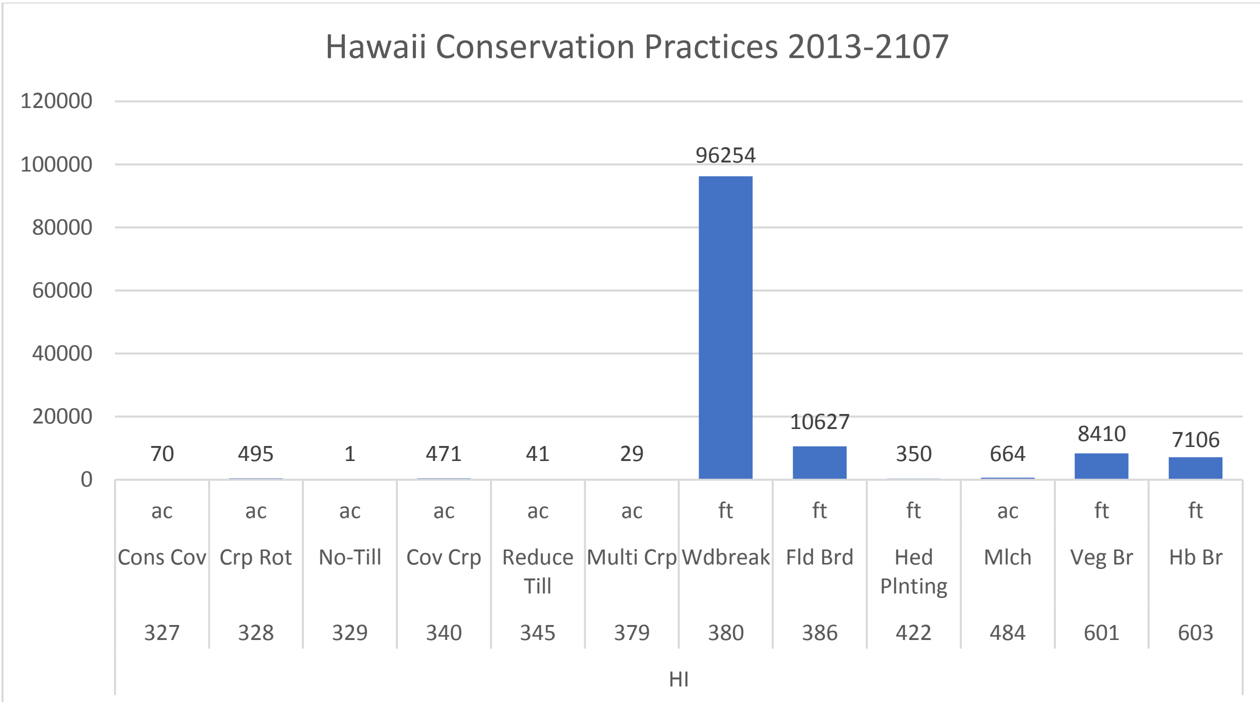
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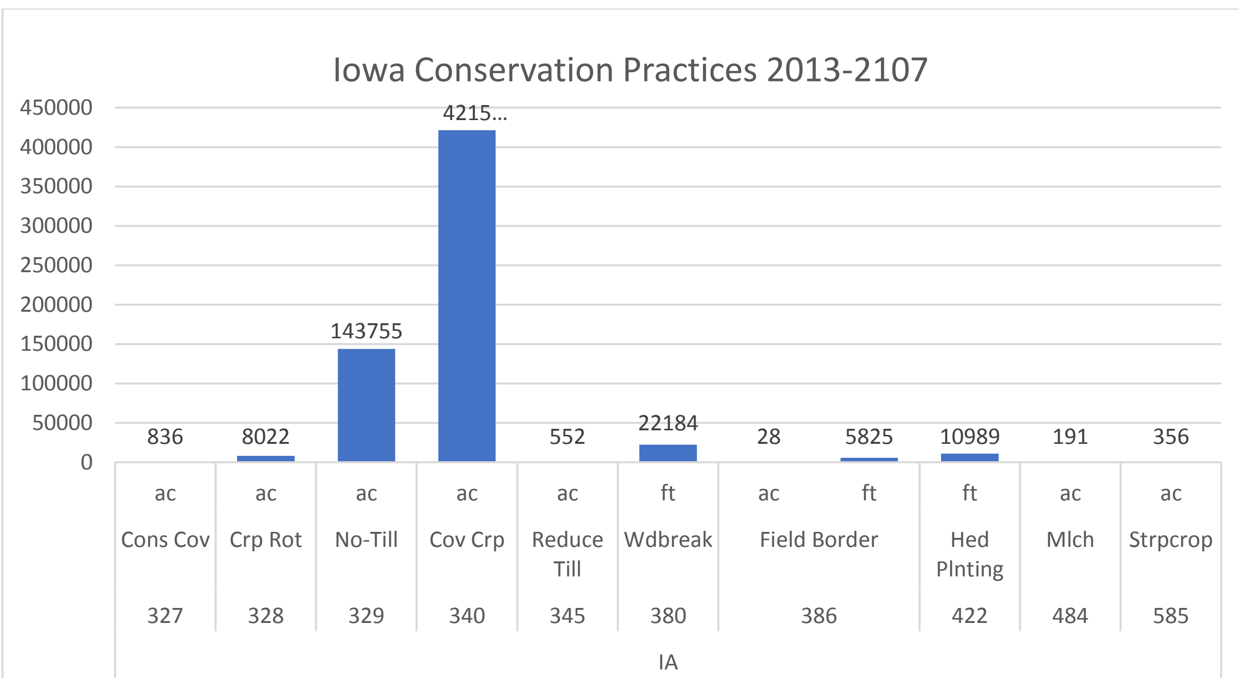
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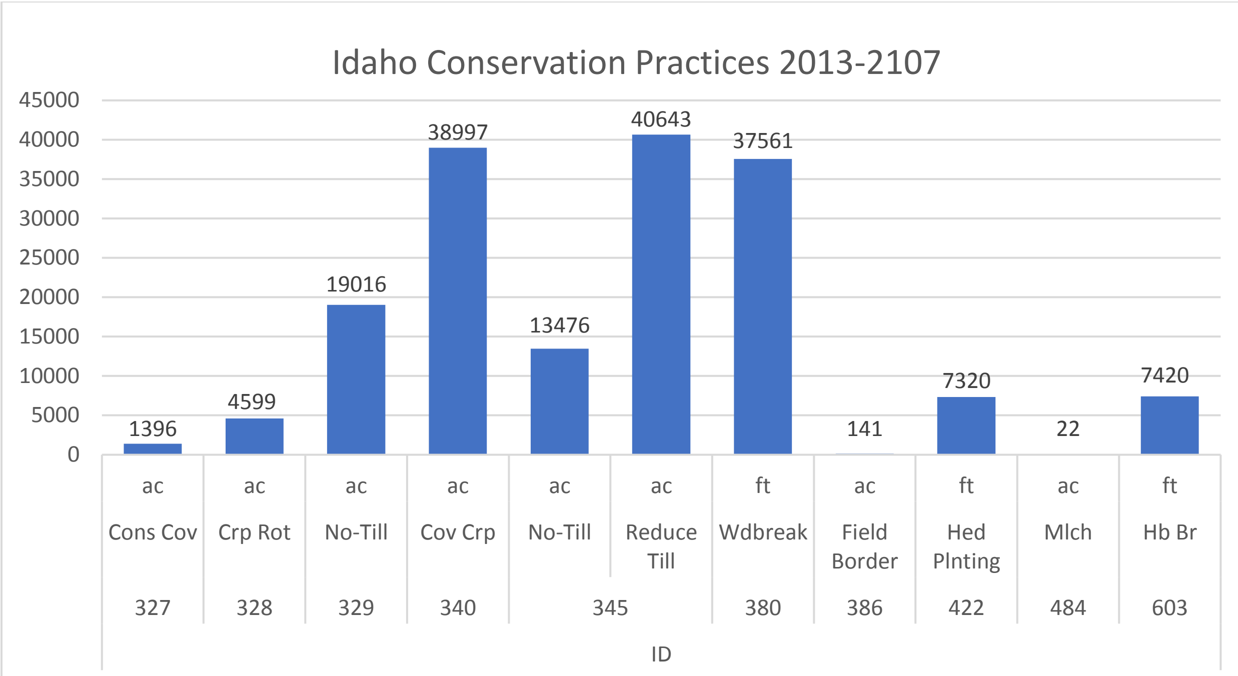
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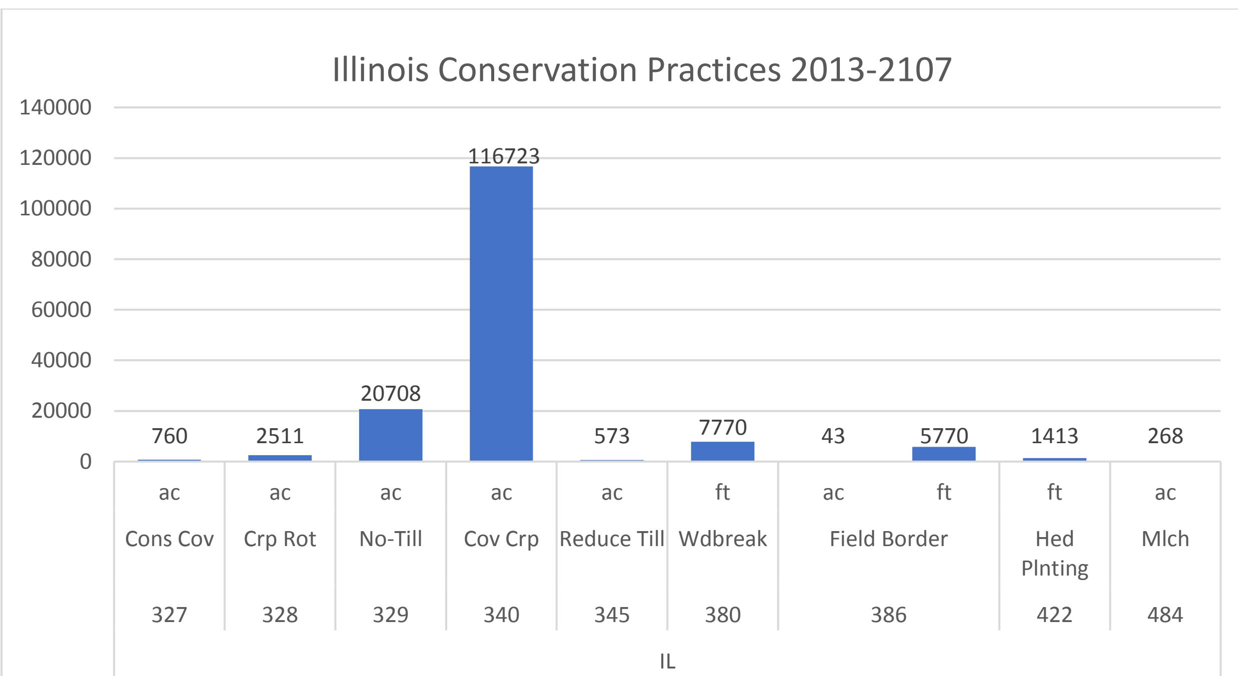
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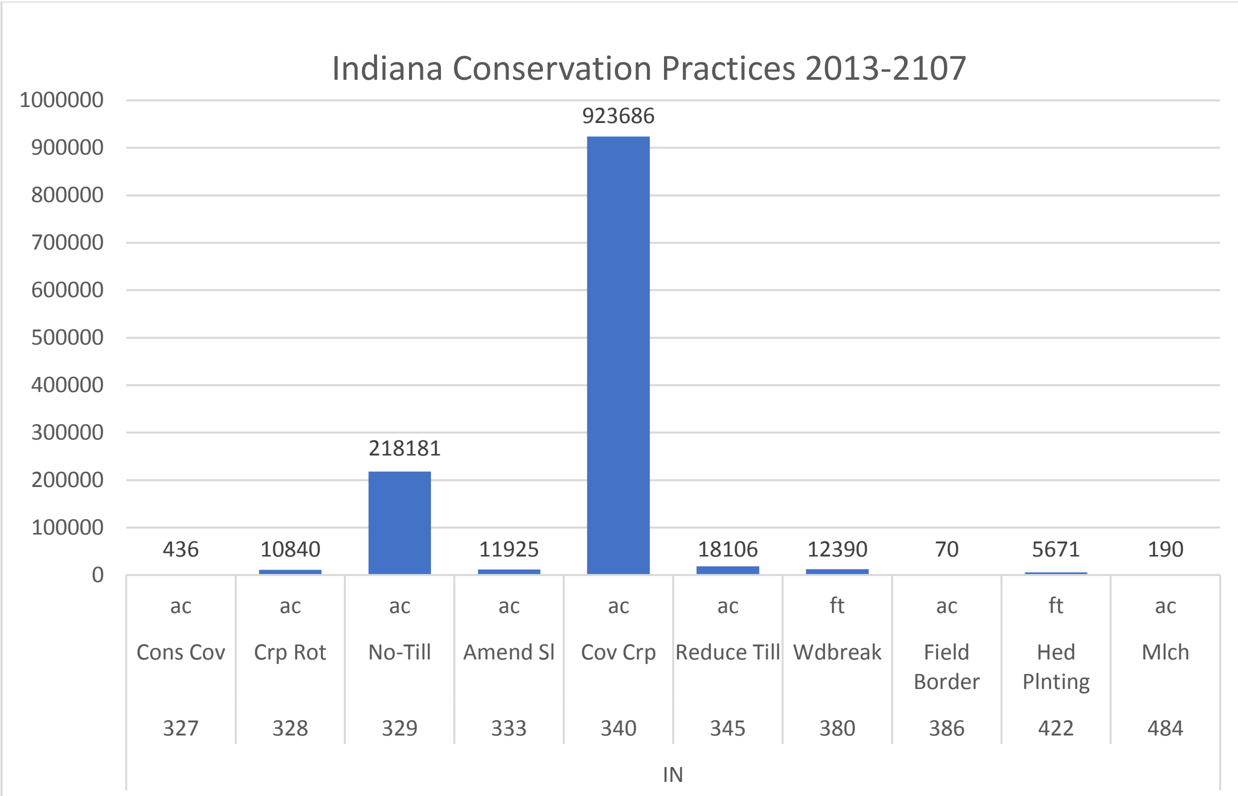
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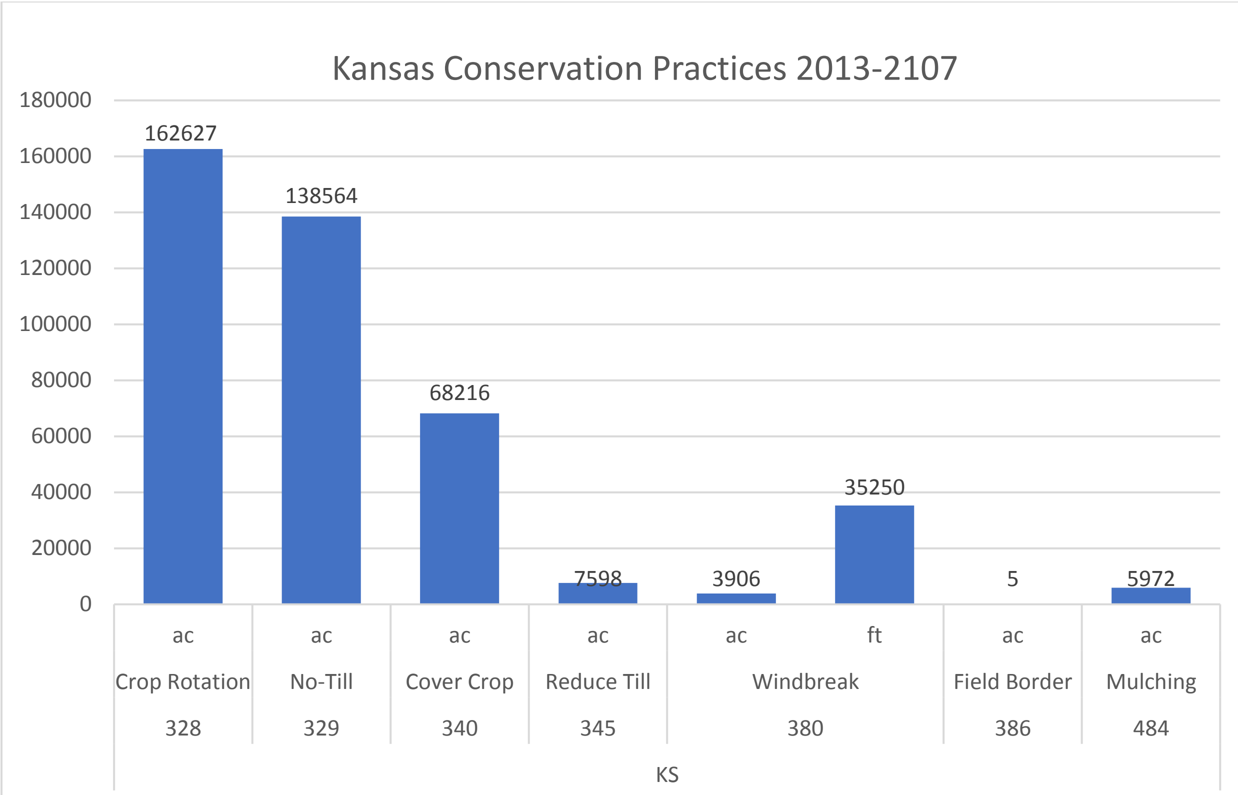
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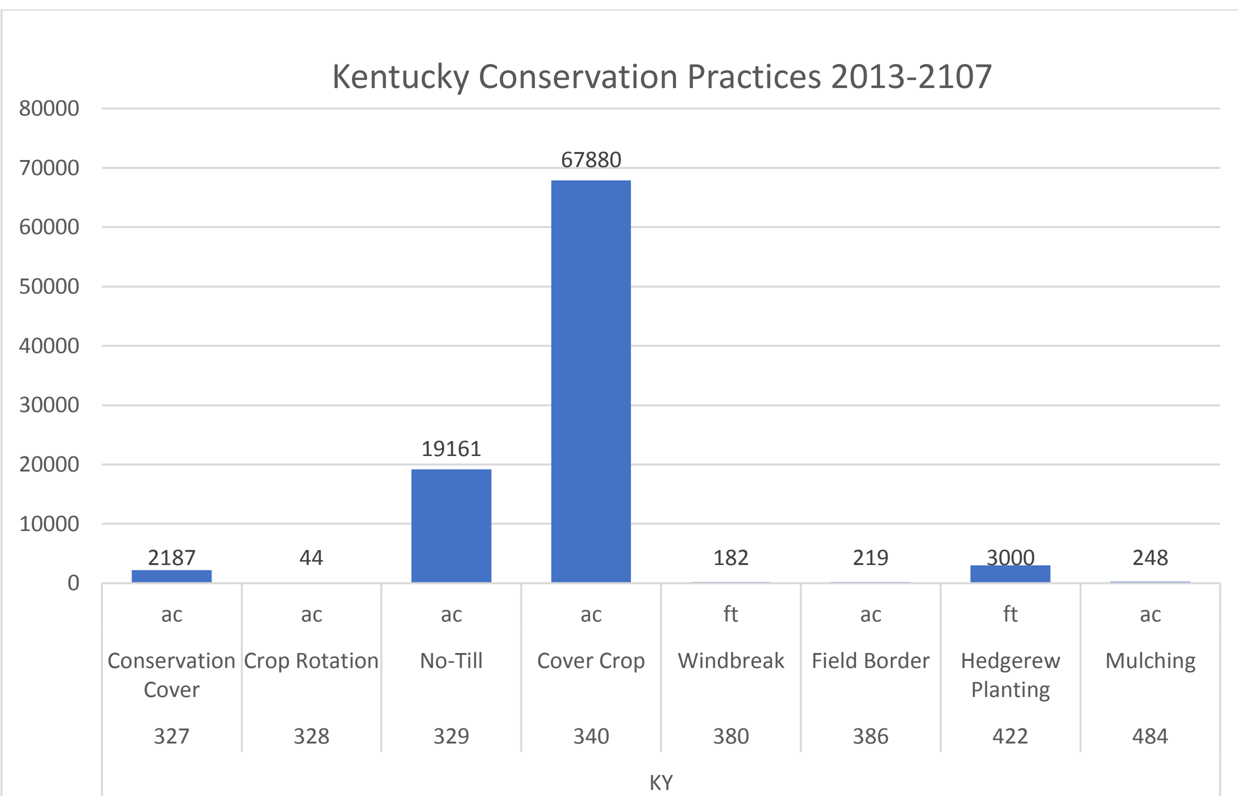
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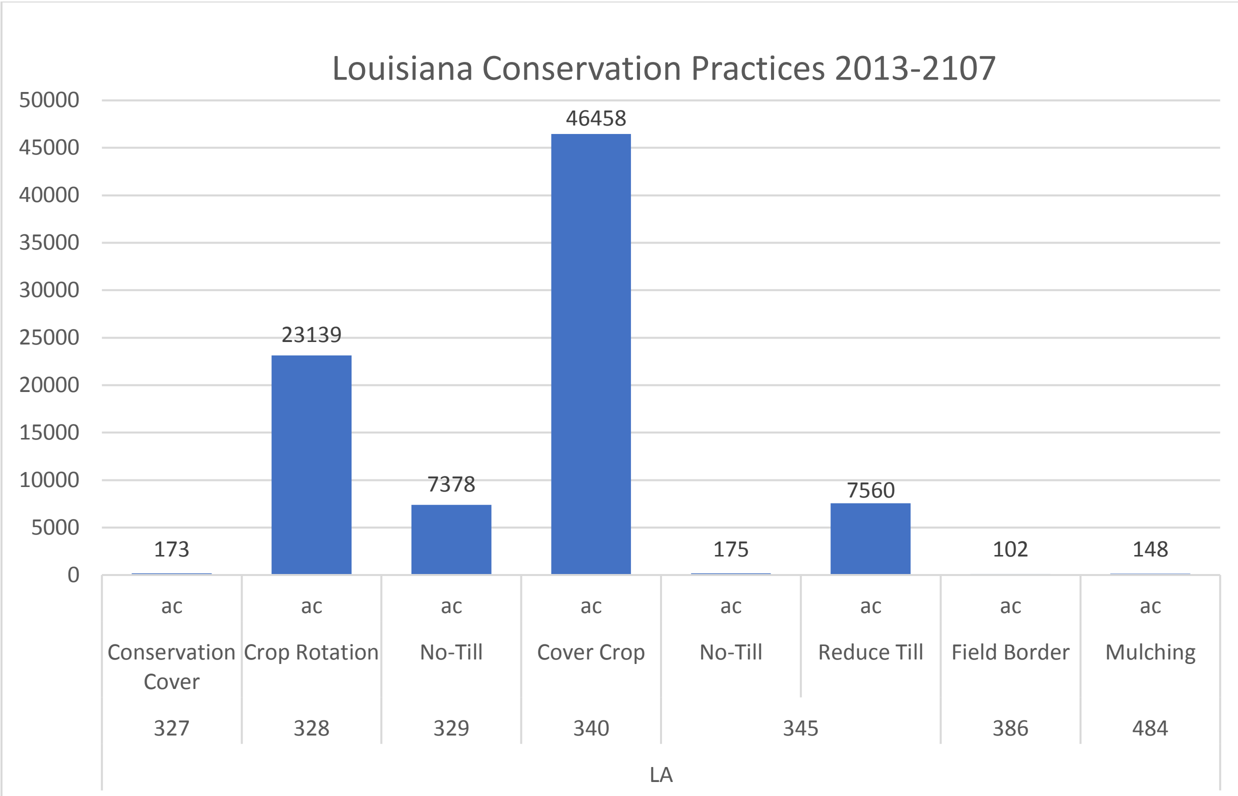
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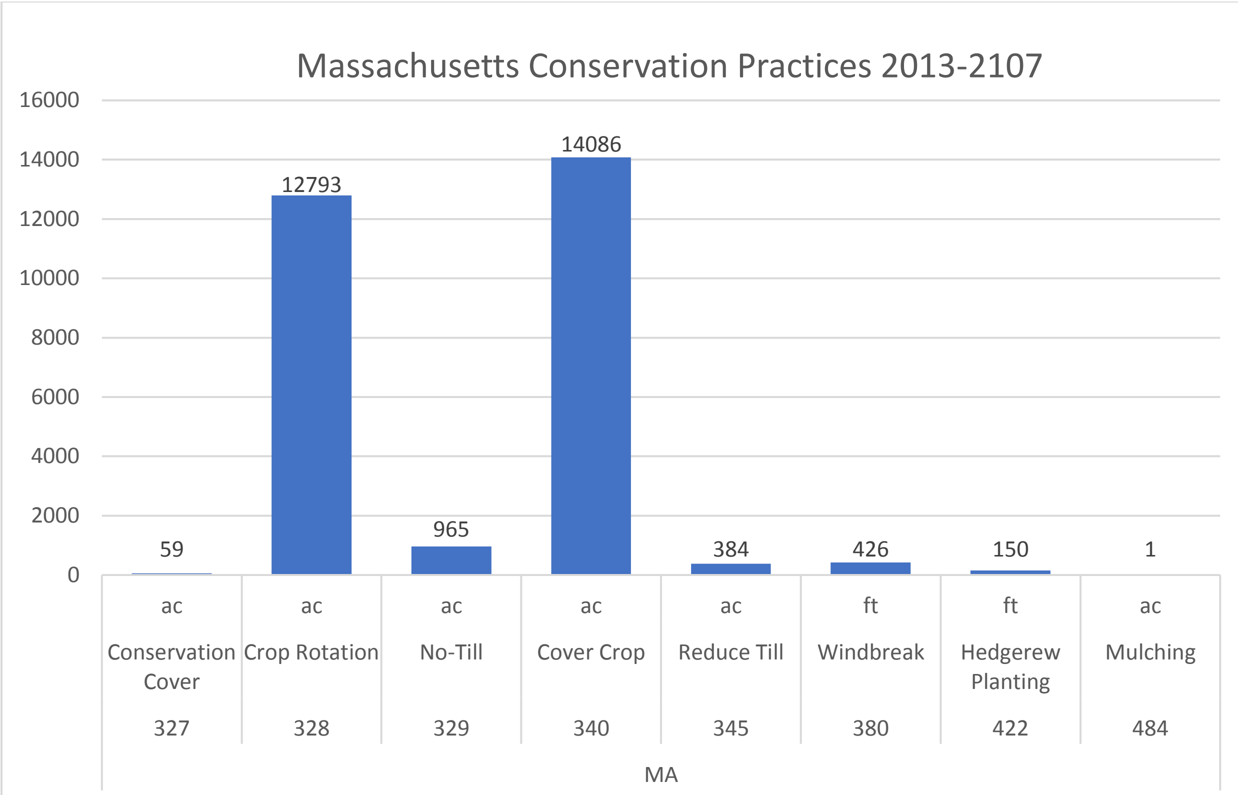
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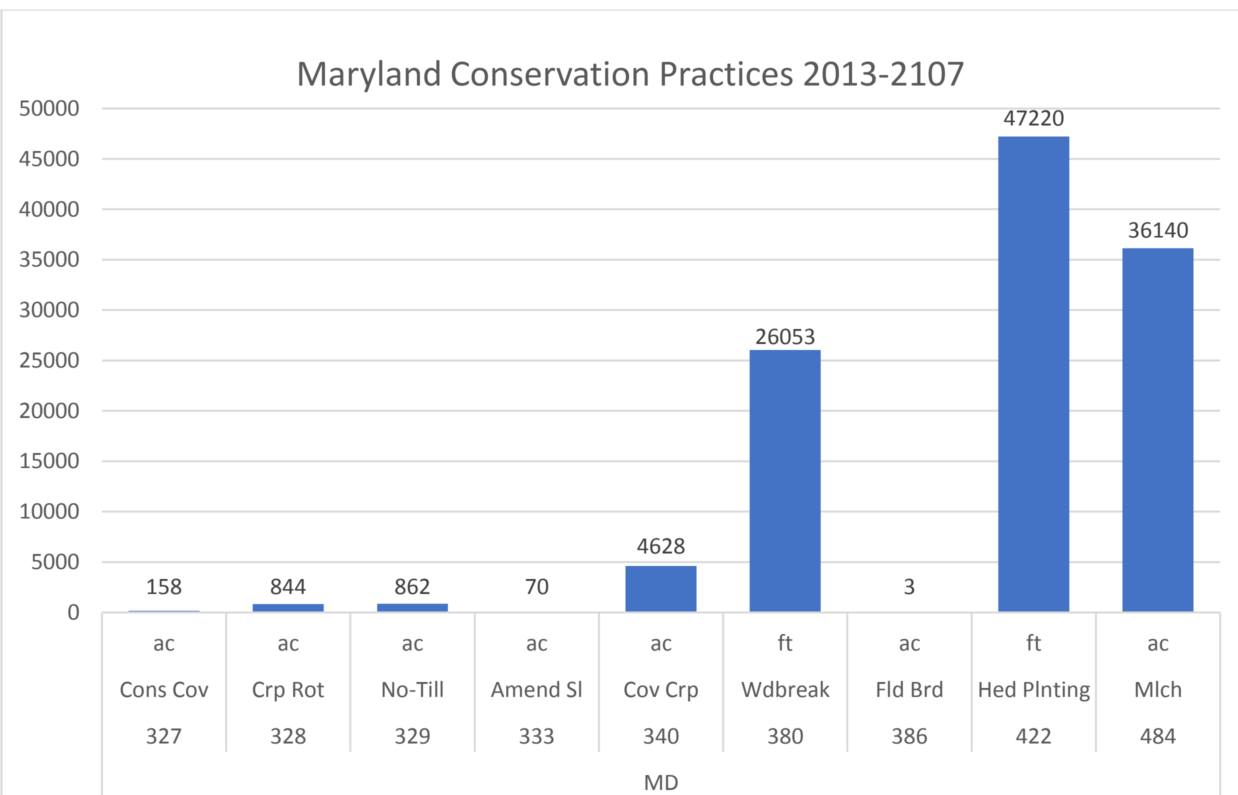
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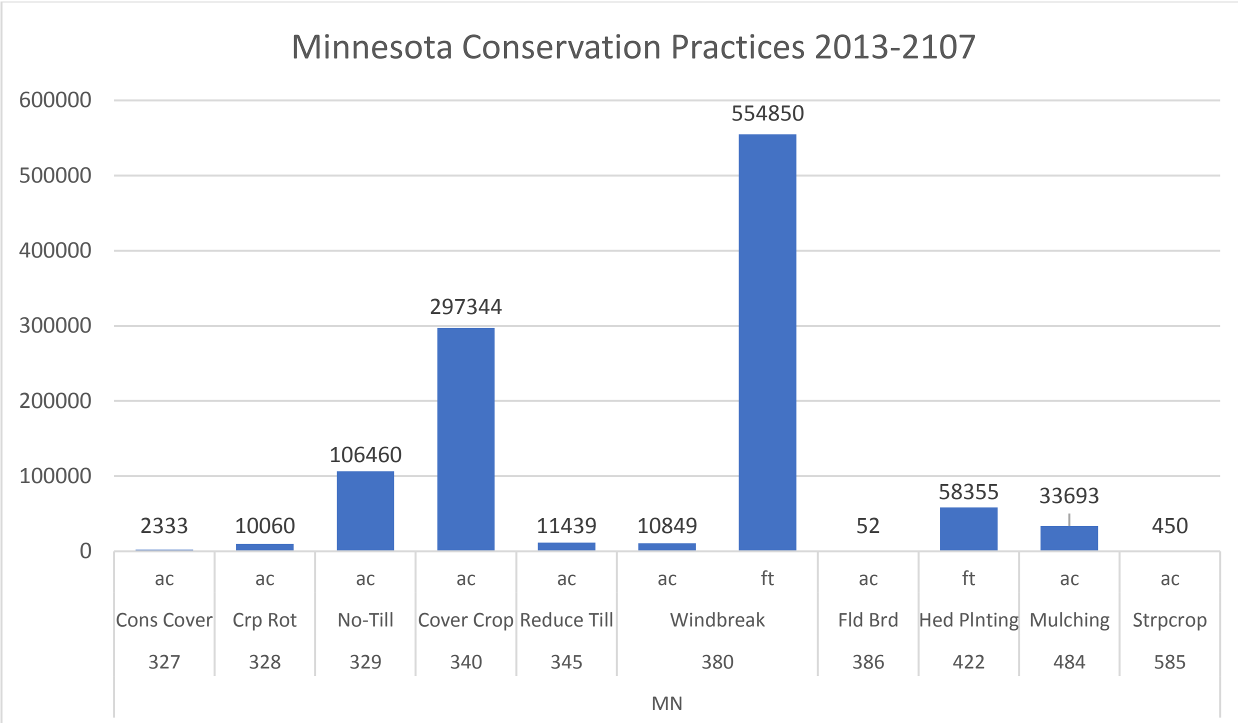
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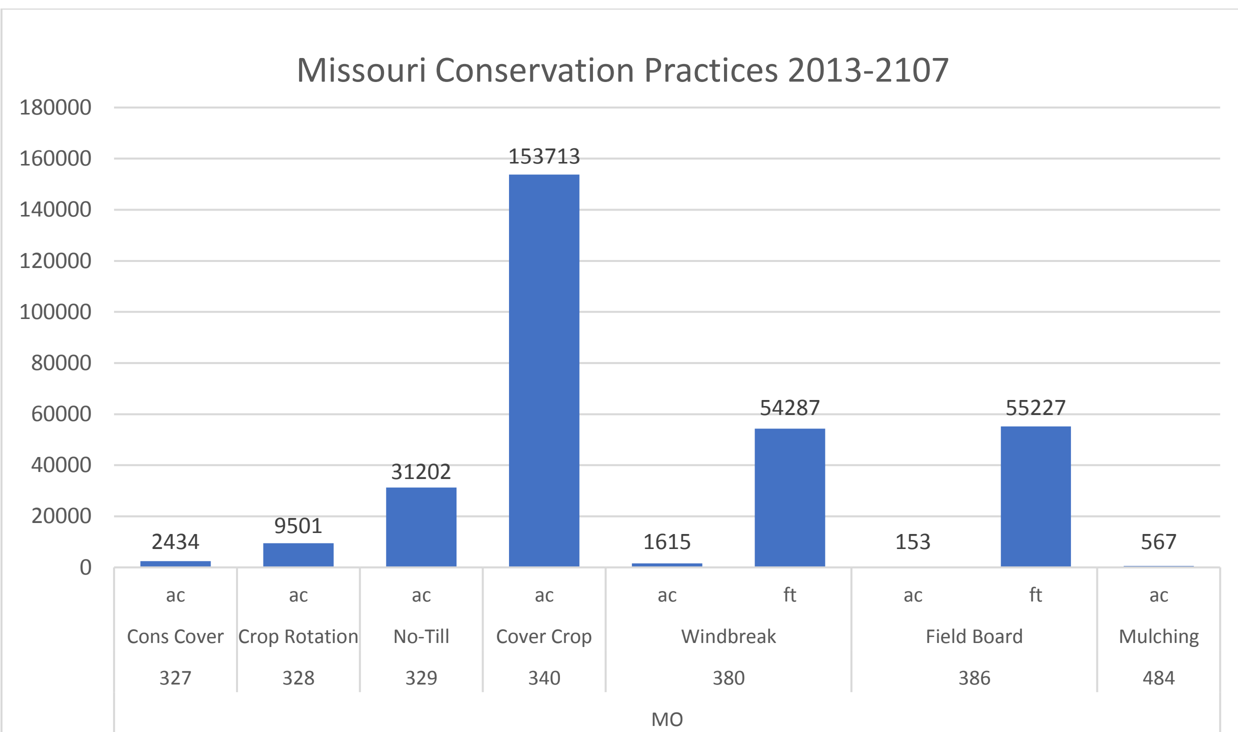
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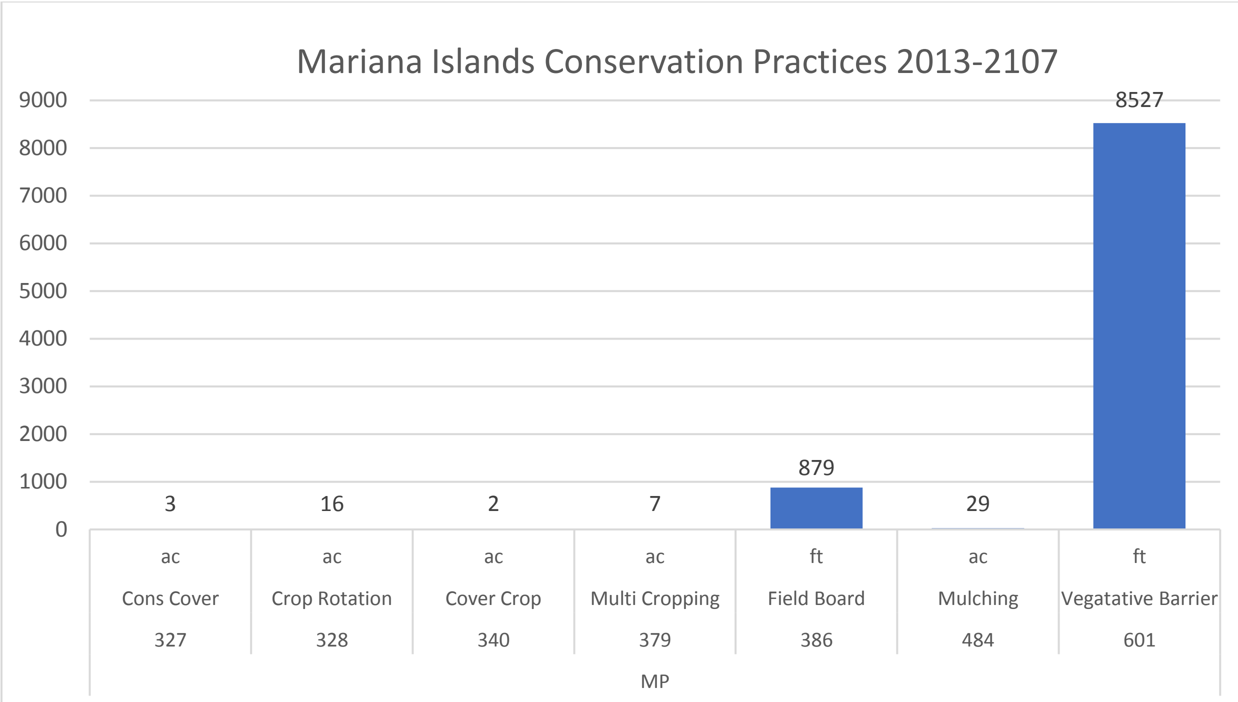

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8527
ac
Cons Cover
327
ac
Crop Rotation
328
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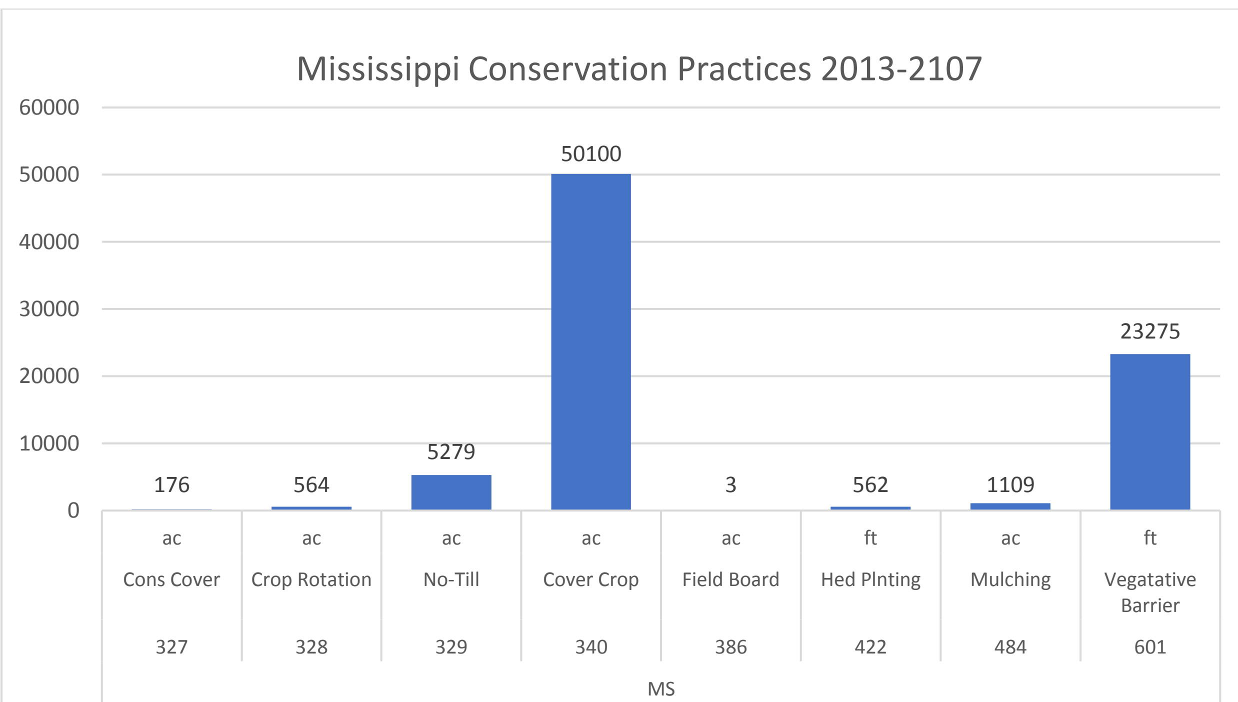
Cover Crop
340
ac
Multi Cropping
379
ft
Field Board
386
ac
Mulching
484
ft
Vegatative Barrier
601
MP



Mississippi Conservation Practices 2013-2107
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23275
ac
Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
329
ac
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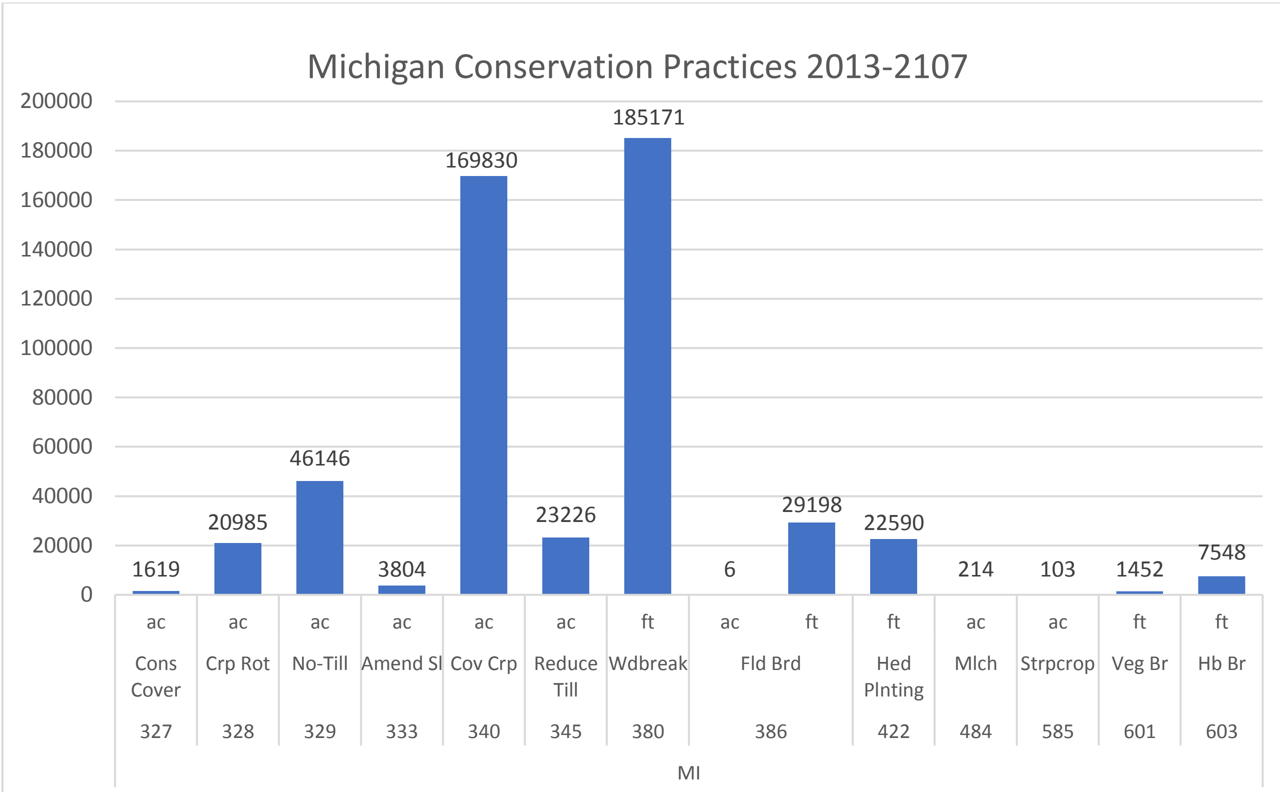
Field Board
386
ft
Hed Plnting
422
ac
Mulching
484
ft
Vegatative Barrier
601
MS



Michigan Conservation Practices 2013-2107
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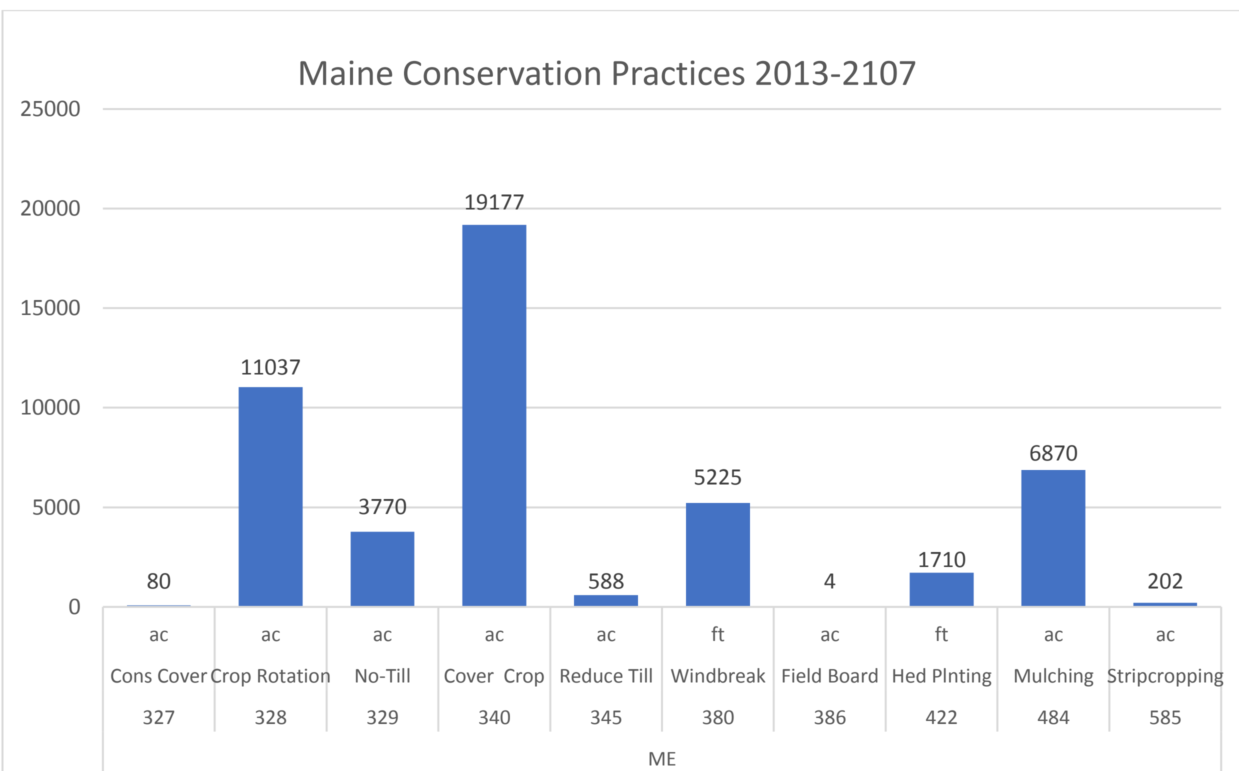
46146
3804
169830
23226
185171
6
29198
22590
214
103
1452
7548
ac
Cons Cover
327
ac
Crp Rot
328
ac
No-Till
329
ac
Amend Sl
333
ac
Cov Crp
340
ac
Reduce Till
345
ft
Wdbreak
380
ac
ft
Fld Brd
386
ft
Hed Plnting
422
ac
Mlch
484
ac
Strpcrop
585
ft
Veg Br
601
ft
Hb Br
603
MI



Maine Conservation Practices 2013-2107
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80
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588
5225
4
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6870
202
ac
Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
329
ac
Cover Crop
340
ac
Reduce Till
345
ft
Windbreak
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Field Board
386
ft
Hed Plnting
422
ac
Mulching
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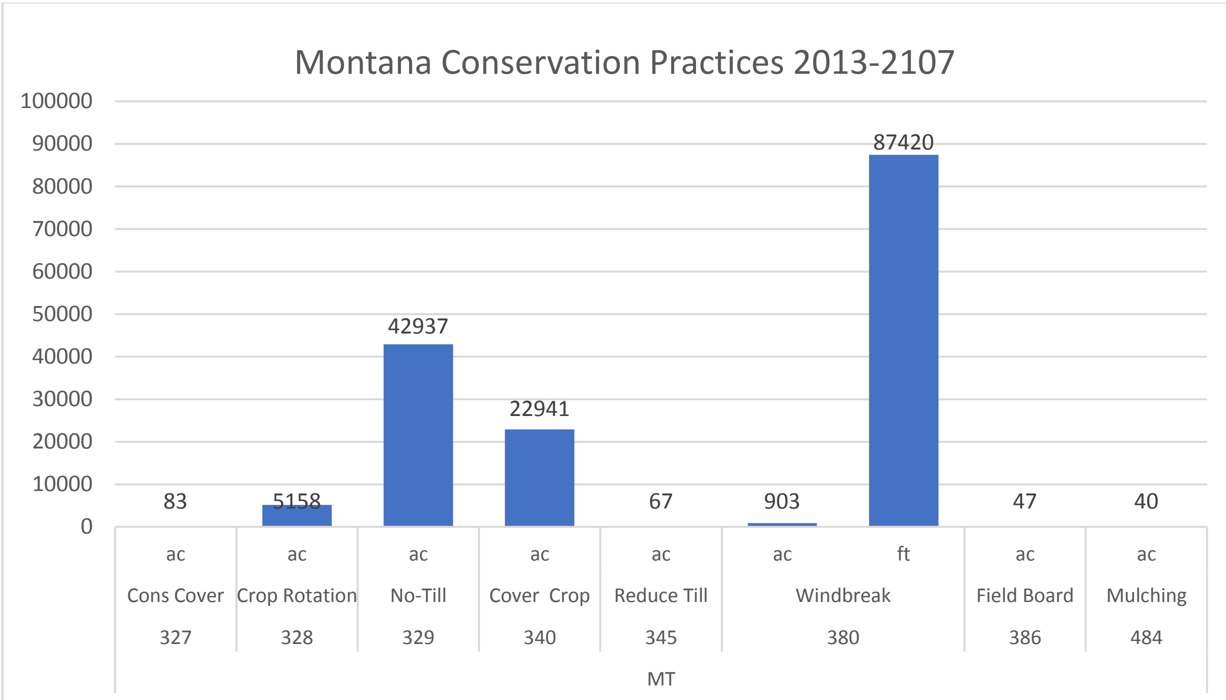
ac
Stripcropping
585
ME



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22941
67
903
87420
47
40
ac
Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
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ft
Windbreak
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ac
Field Board
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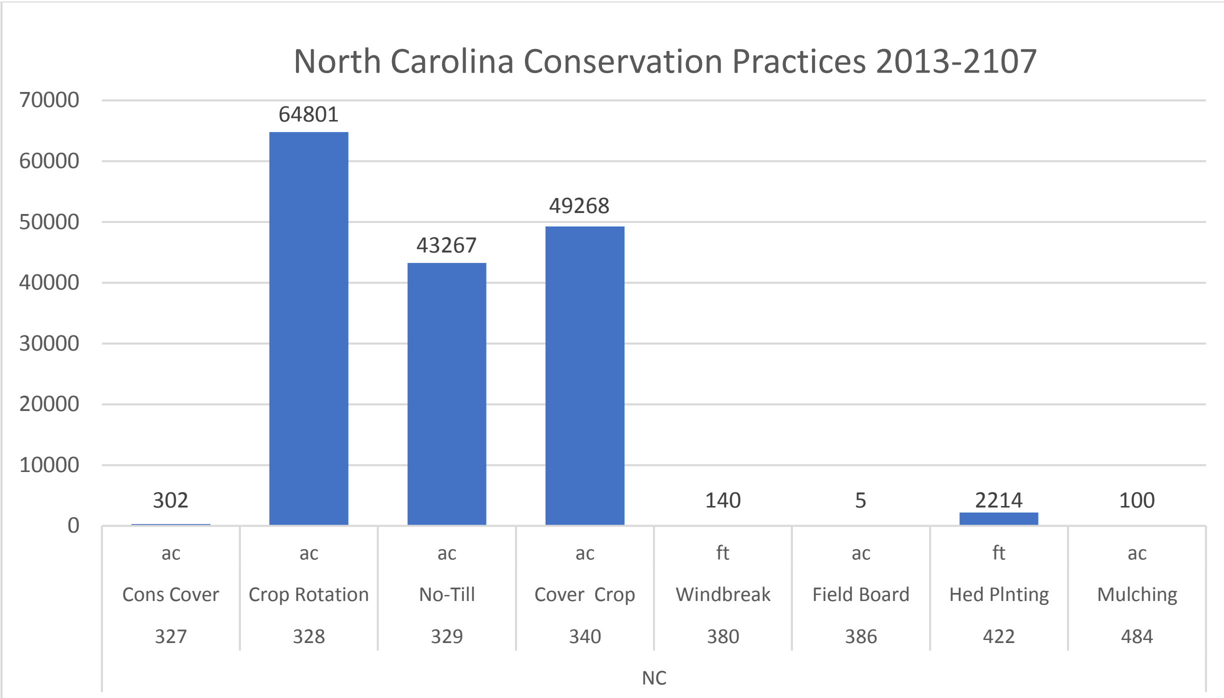
ac
Mulching
484
MT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43267
49268
140
5
2214
100
ac
Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
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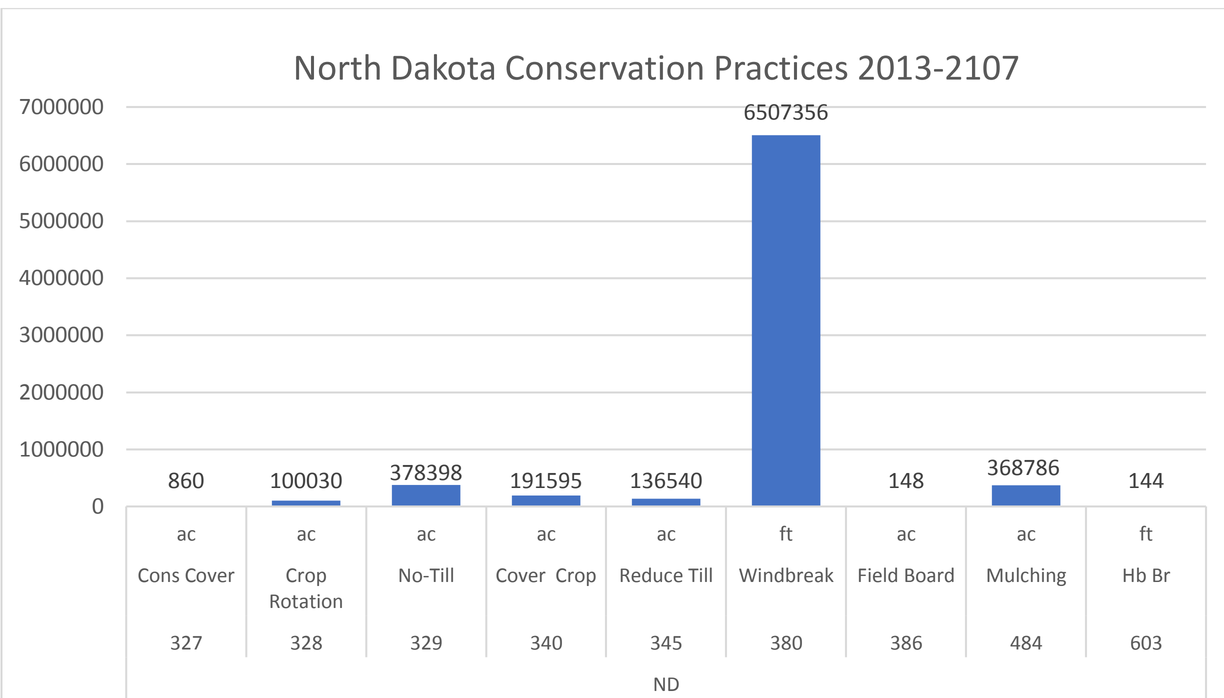
ft
Windbreak
380
ac
Field Board
386
ft
Hed Plnting
422
ac
Mulching
484
NC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4000000
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6507356
148
368786
144
ac
Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
329
ac
Cover Crop
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ft
Windbreak
380
ac
Field Board
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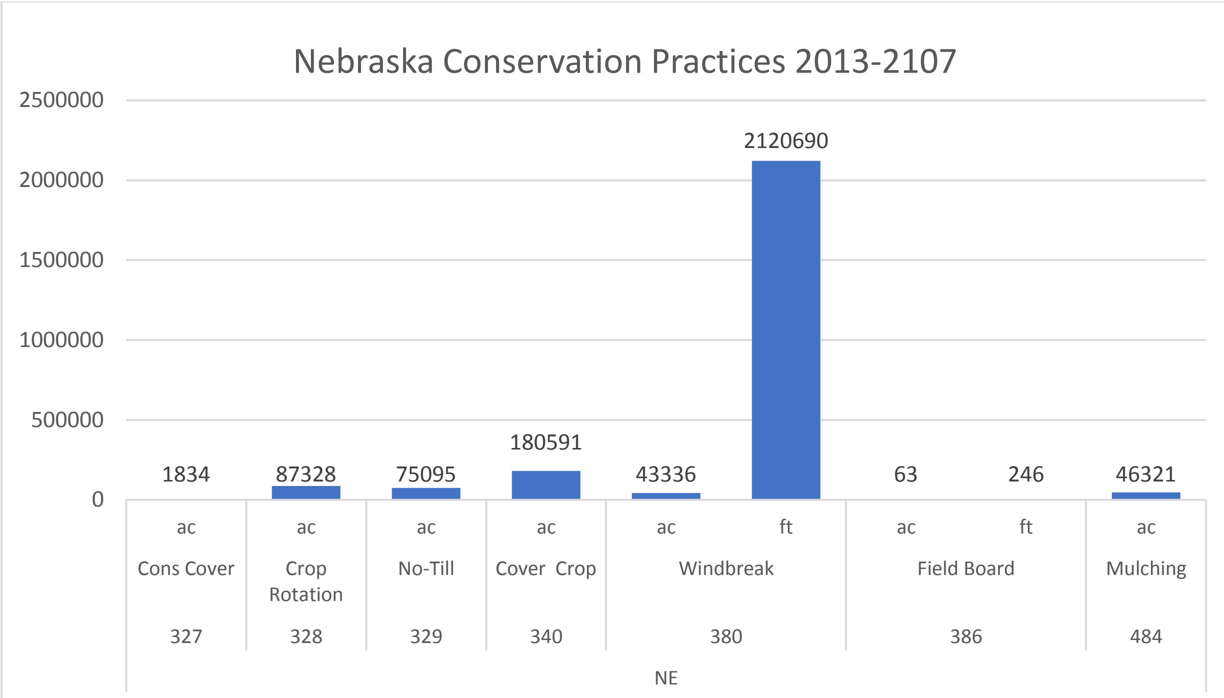
ac
Mulching
484
ft
Hb Br
603
ND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75095
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43336
63
246
46321
ac
ac
ac
ac
ac
ft
ac
ft
ac
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Crop Rotation
No-Till
Cover Crop
Windbreak
Field Board
Mulching
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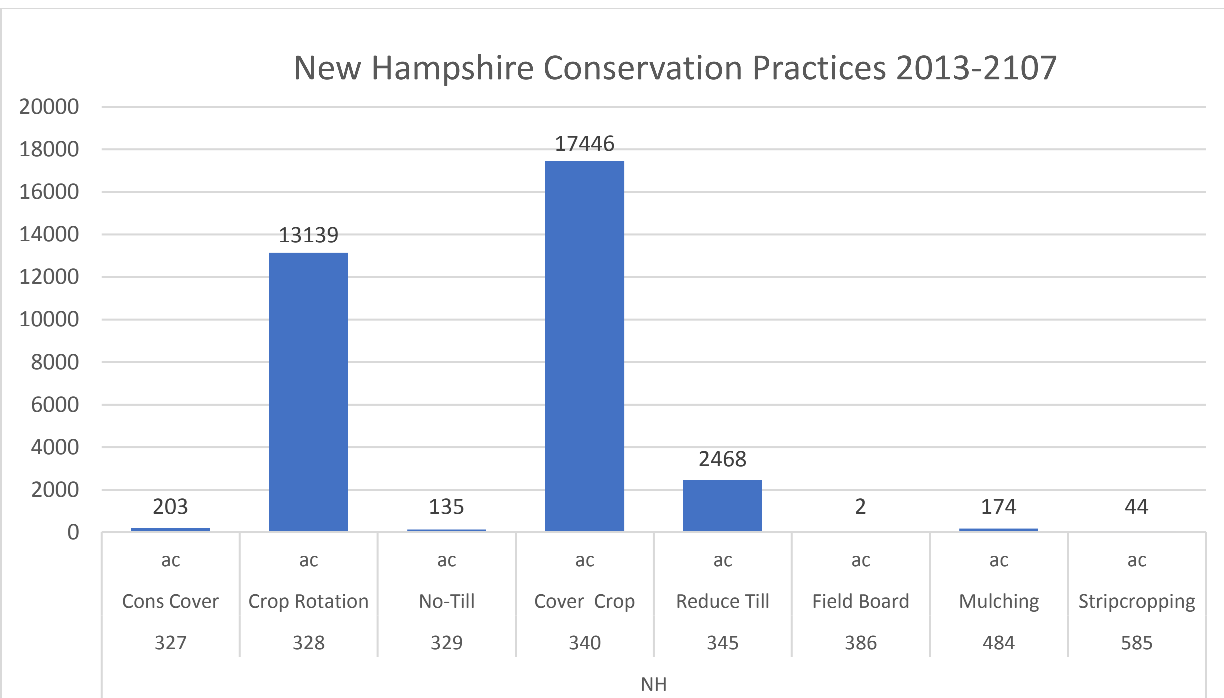
380
386
484
NE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4000
2000
0
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13139
135
17446
2468
2
174
44
ac
ac
ac
ac
ac
ac
ac
ac
Cons Cover
Crop Rotation
No-Till
Cover Crop
Reduce Till
Field Board
Mulching
Stripcropping
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328
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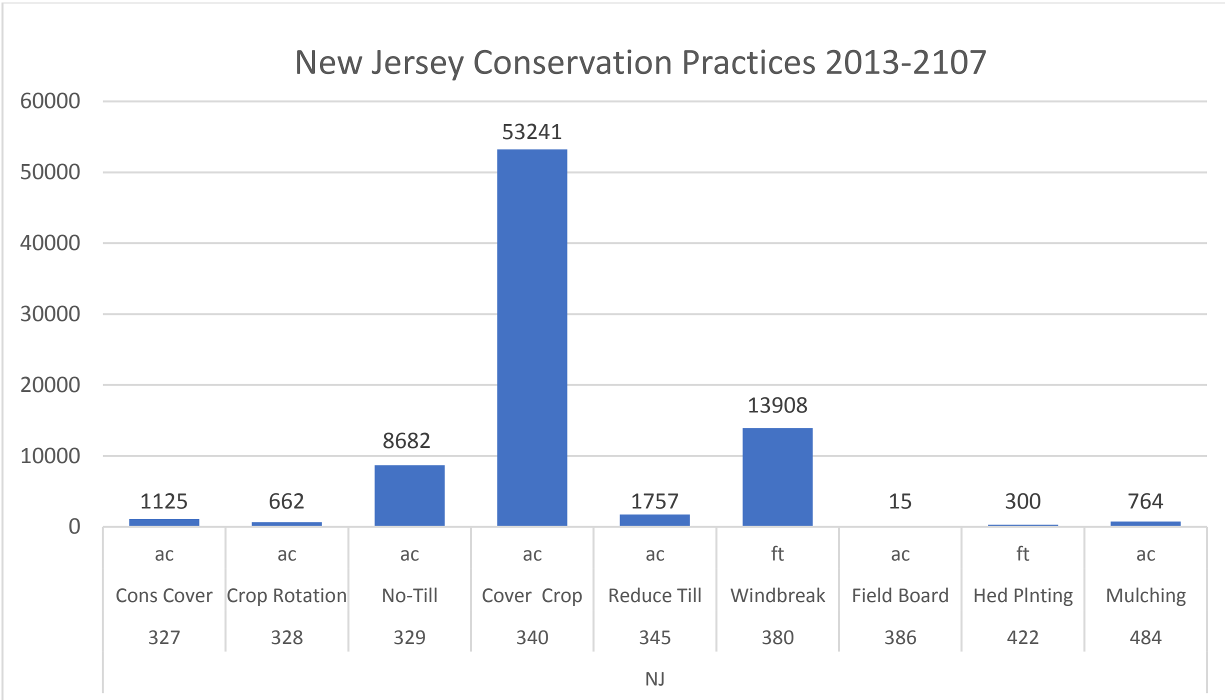
340
345
386
484
585
NH



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53241
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15
300
764
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Cons Cover
327
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Crop Rotation
328
ac
No-Till
329
ac
Cover Crop
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Reduce Till
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ft
Windbreak
380
ac
Field Board
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Hed Plnting
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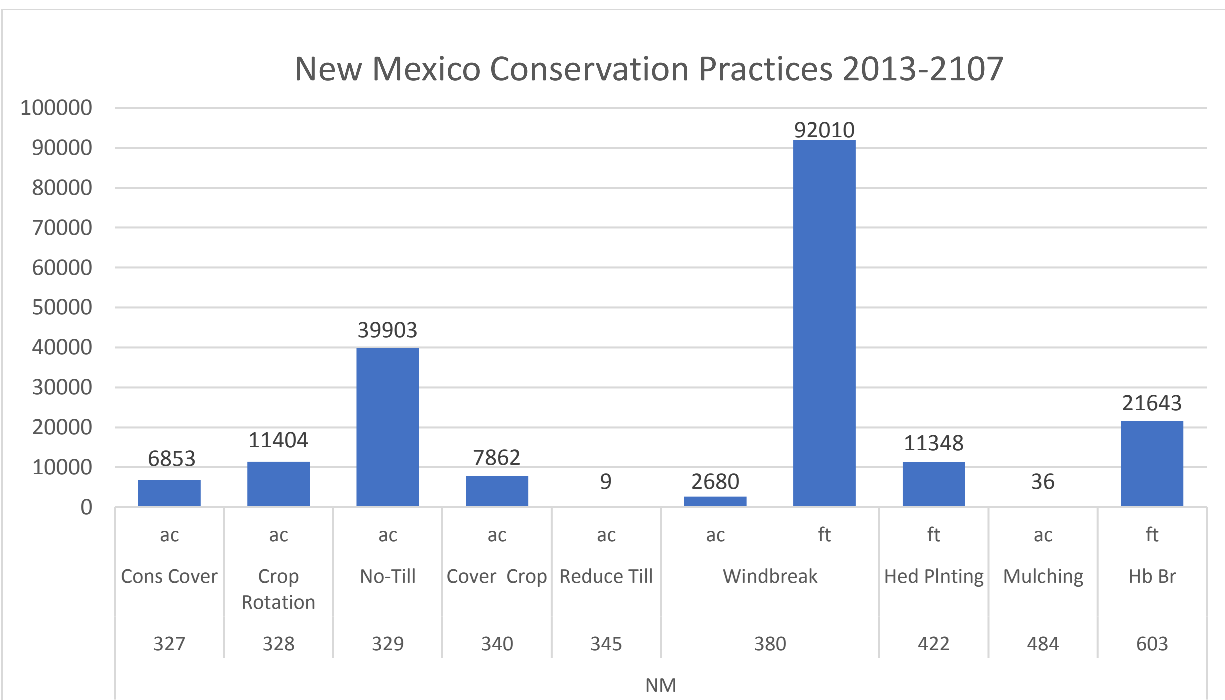
Mulching
484
NJ



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60000
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40000
30000
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39903
7862
9
2680
92010
11348
36
21643
ac
Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
329
ac
Cover Crop
340
ac
Reduce Till
345
ac
ft
Windbreak
380
ft
Hed Plnting
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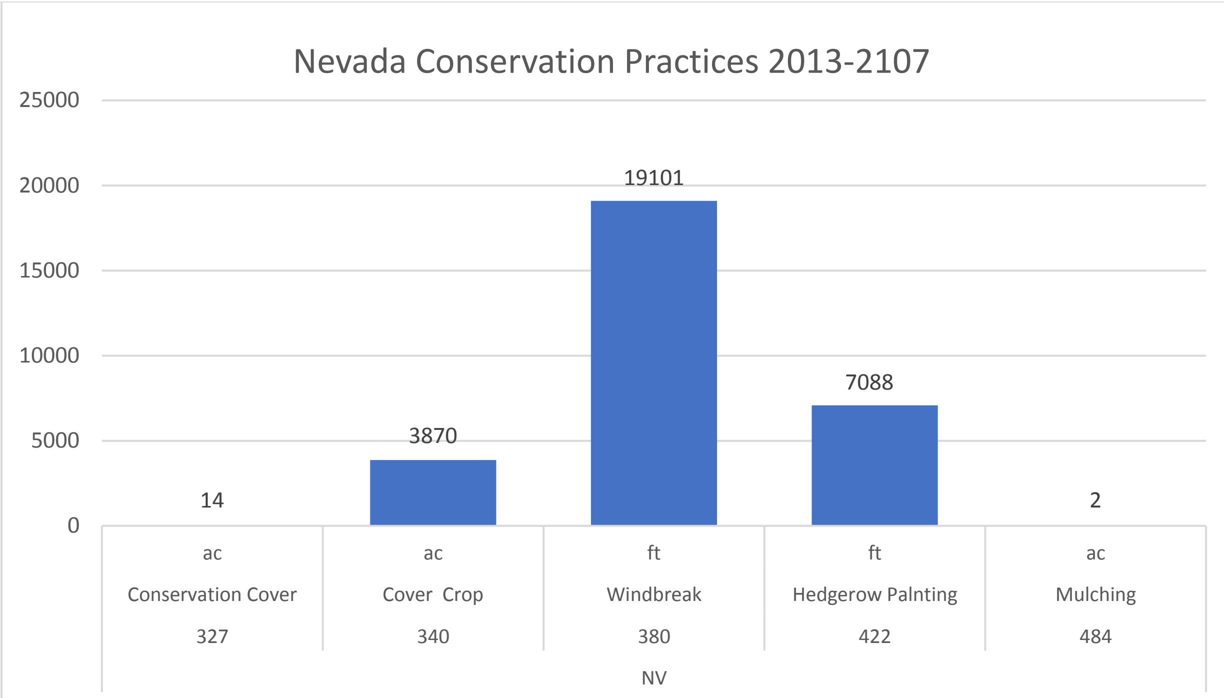
ac
Mulching
484
ft
Hb Br
603
NM


Nevada Conservation Practices 2013-2107
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7088
3870
14
2
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Cover Crop
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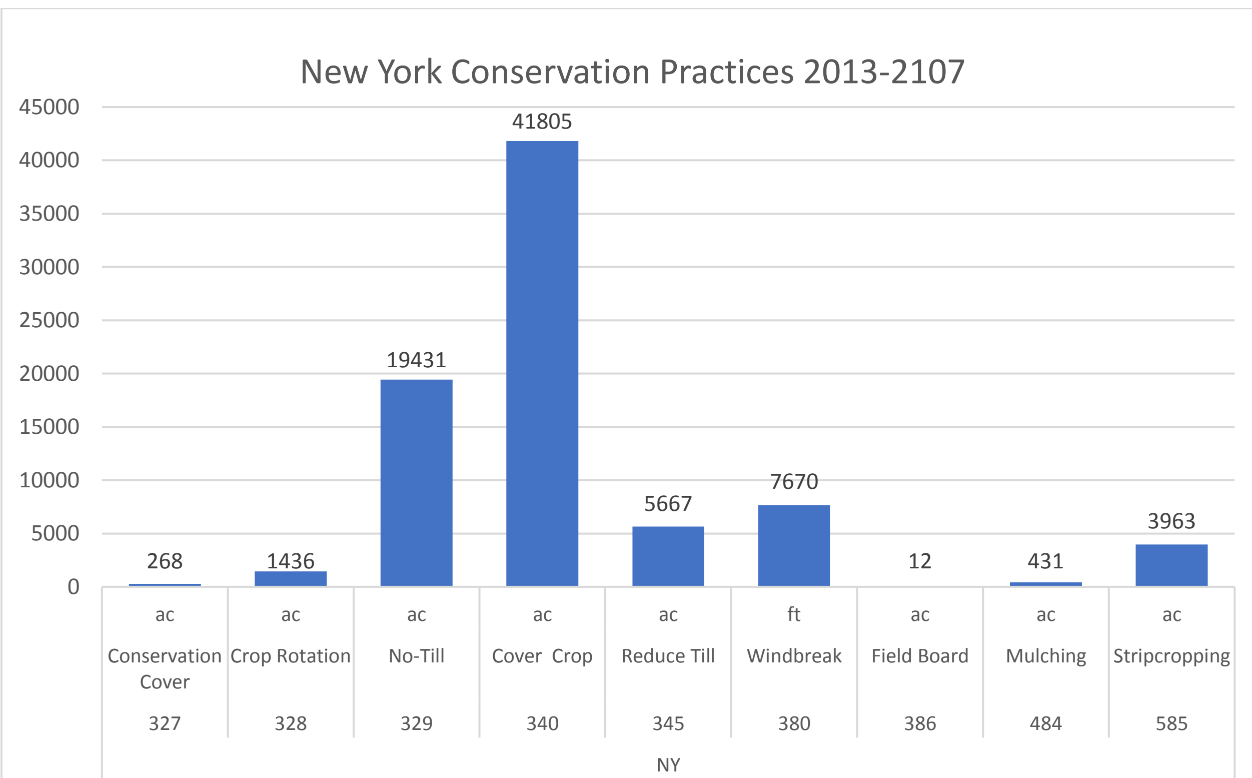
ft
Windbreak
380
ft
Hedgerow Palnting
422
ac
Mulching
484
NV


New York Conservation Practices 2013-2107
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25000
20000
15000
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5667
7670
3963
268
1436
12
431
ac
Conservation Cover
327
ac
Crop Rotation
328
ac
No-Till
329
ac
Cover Crop
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ac
Reduce Till
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ft
Windbreak
380
ac
Field Board
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Mulching
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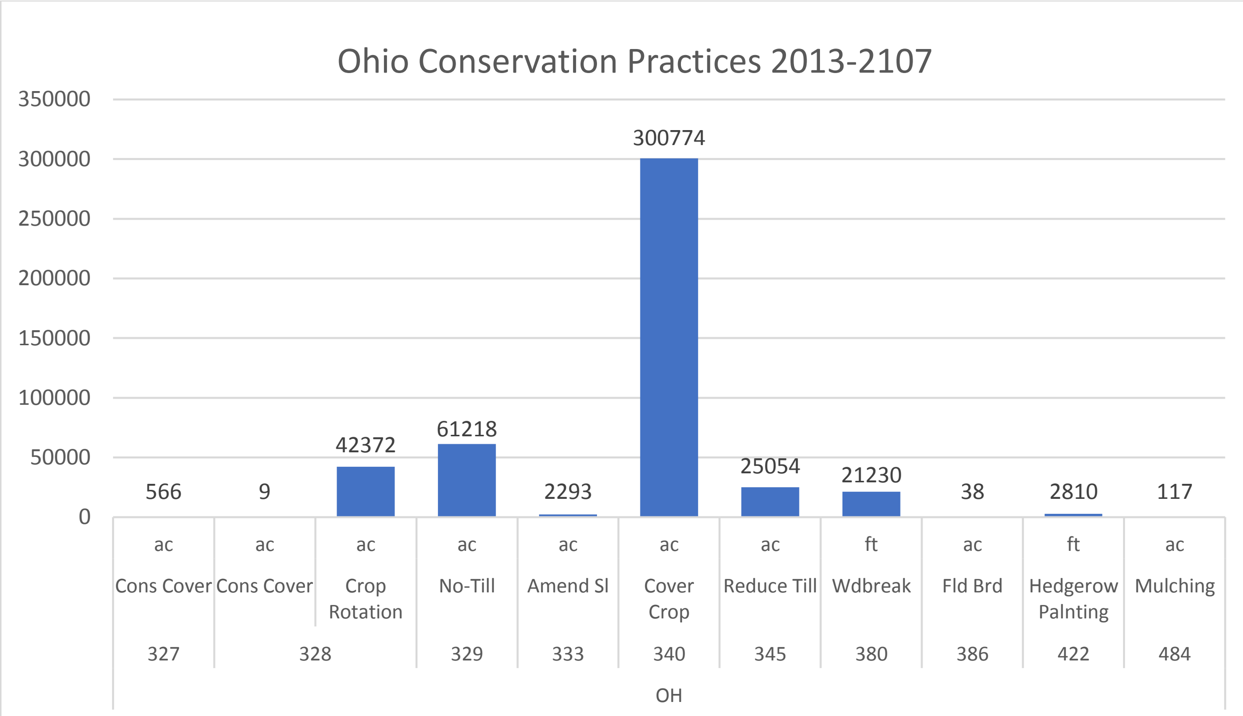
Stripcropping
585
NY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61218
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25054
21230
38
2810
117
ac
ac
ac
ac
ac
ac
ac
ft
ac
ft
ac
Cons Cover
Cons Cover
Crop Rotation
No-Till
Amend Sl
Cover Crop
Reduce Till
Wdbreak
Fld Brd
Hedgerow Palnting
Mulching
327
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333
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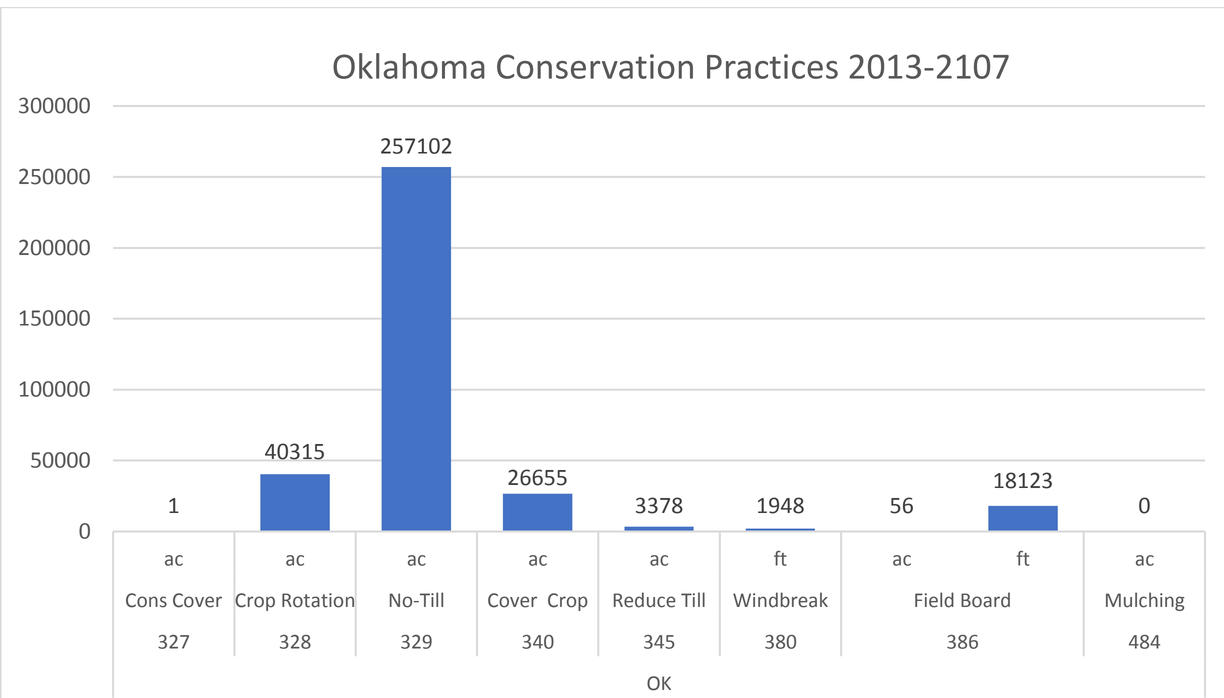
422
484
OH


Oklahoma Conservation Practices 2013-2107
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26655
3378
1948
56
18123
0
ac
ac
ac
ac
ac
ft
ac
ft
ac
Cons Cover
Crop Rotation
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Cover Crop
Reduce Till
Windbreak
Field Board
Mulching
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328
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386
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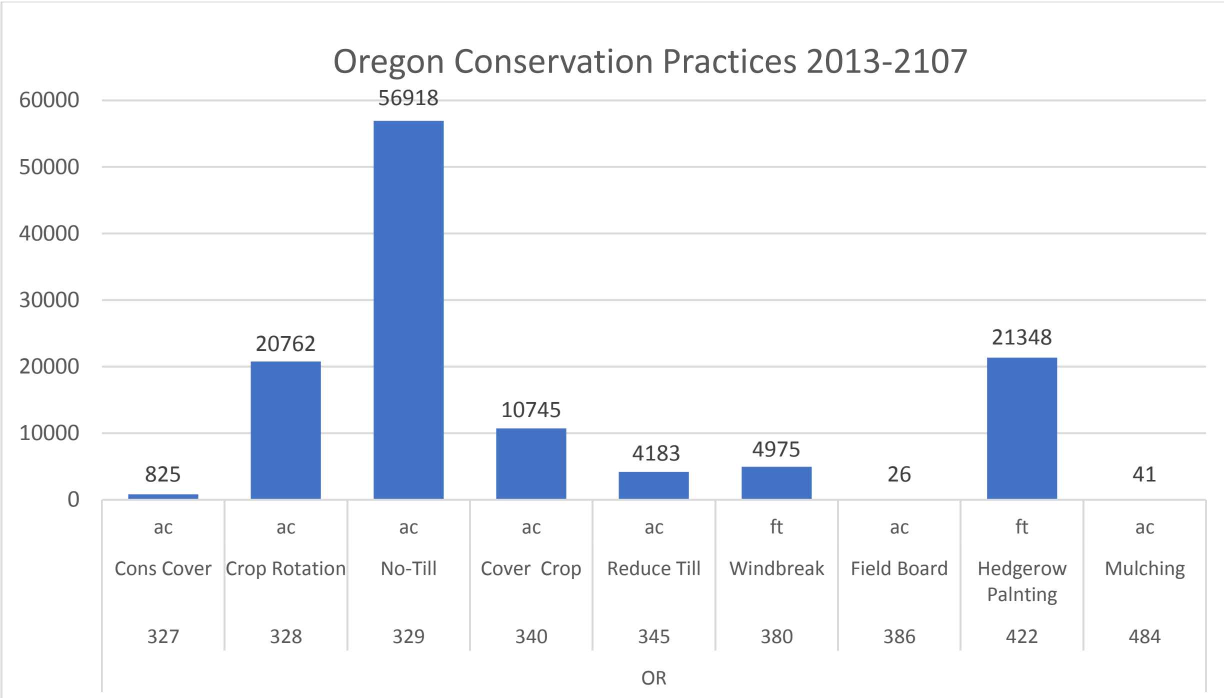
OK


Oregon Conservation Practices 2013-2107
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825
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56918
10745
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4975
26
21348
41
ac
Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
329
ac
Cover Crop
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Reduce Till
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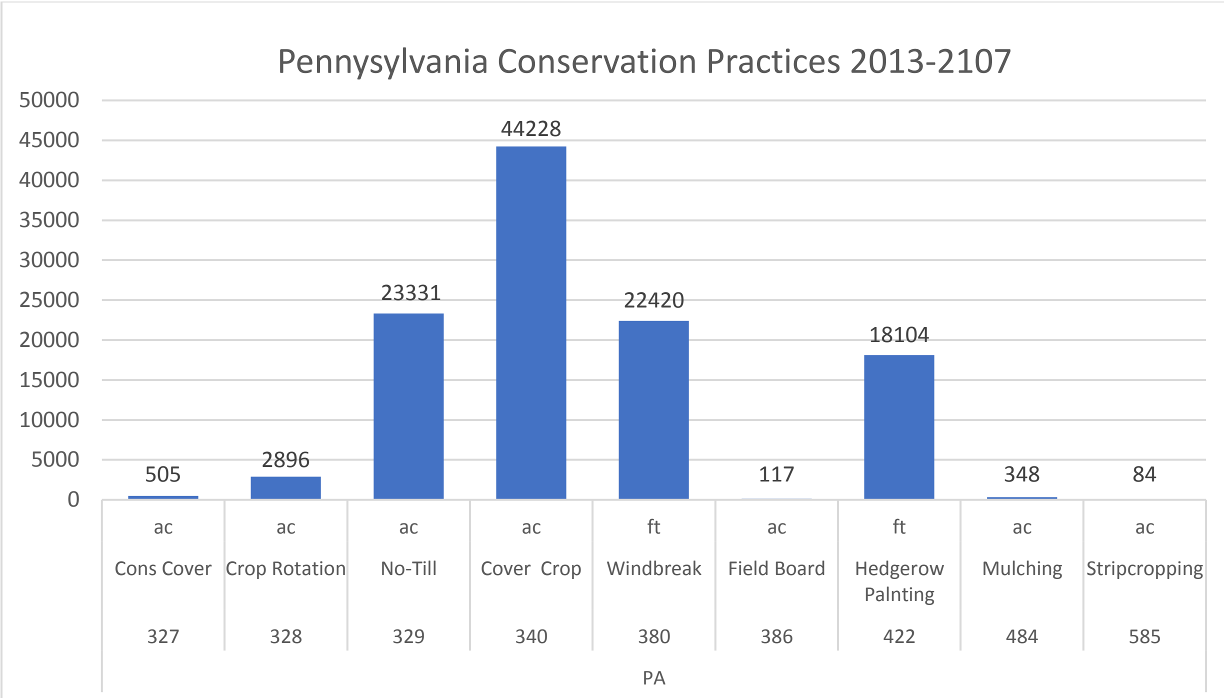
ft
Windbreak
380
ac
Field Board
386
ft
Hedgerow Palnting
422
ac
Mulching
484
OR


Pennysylvania Conservation Practices 2013-2107
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35000
30000
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20000
15000
10000
5000
0
505
2896
23331
44228
22420
117
18104
348
84
ac
Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
329
ac
Cover Crop
340
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Windbreak
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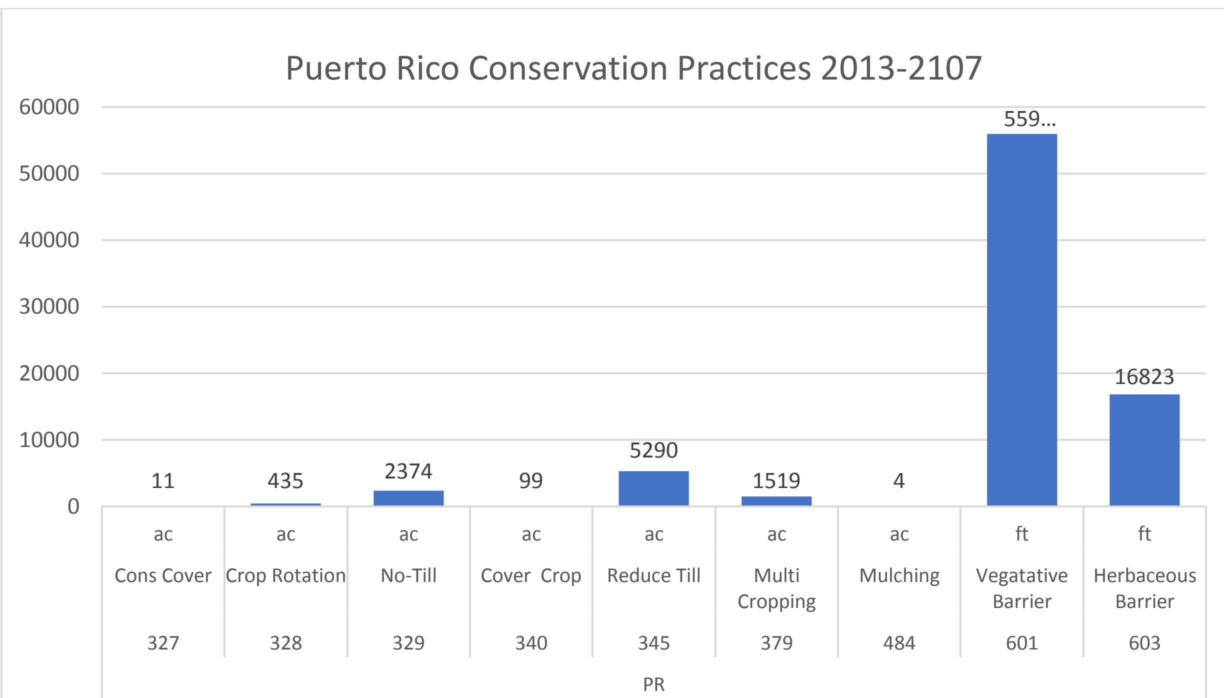
Field Board
386
ft
Hedgerow Palnting
422
ac
Mulching
484
ac
Stripcropping
585
PA


Puerto Rico Conservation Practices 2013-2107
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99
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4
559...
16823
ac
Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
329
ac
Cover Crop
340
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Reduce Till
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ac
Multi Cropping
379
ac
Mulching
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ft
Vegatative Barrier
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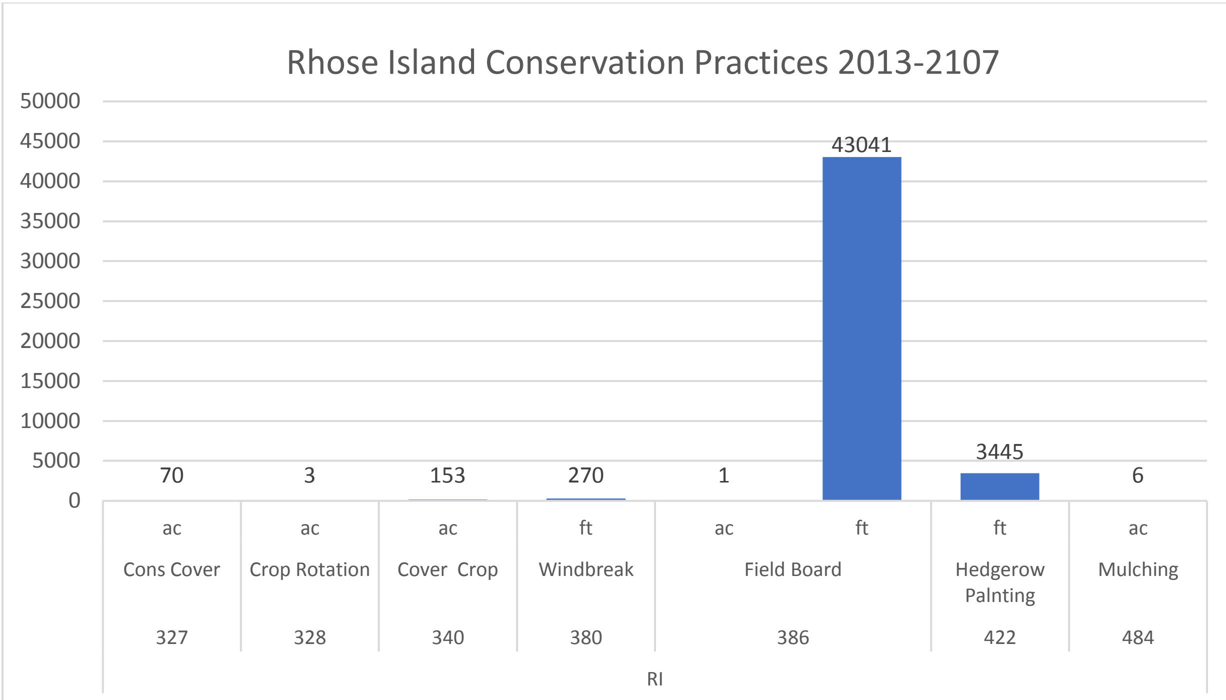
ft
Herbaceous Barrier
603
PR


Rhose Island Conservation Practices 2013-2107
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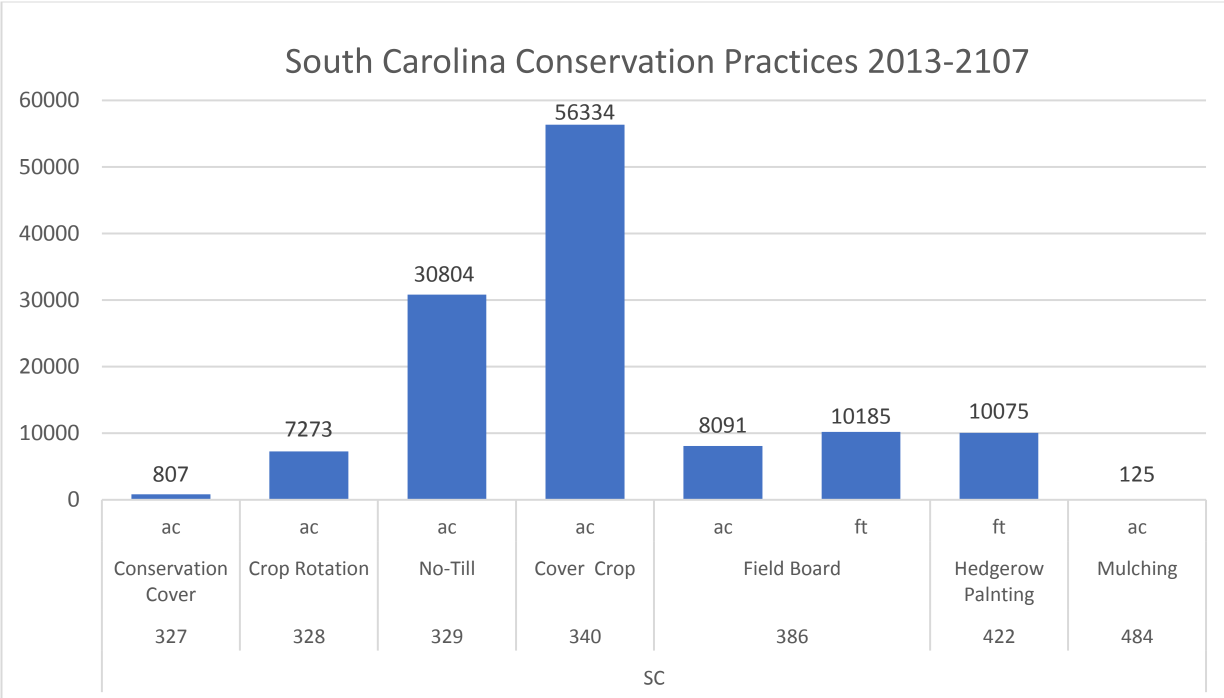
153
270
1
43041
3445
6
ac
ac
ac
ft
ac
ft
ft
ac
Cons Cover
Crop Rotation
Cover Crop
Windbreak
Field Board
Hedgerow Palnting
Mulching
327
328
340
380
386
422
484
RI


South Carolina Conservation Practices 2013-2107
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56334
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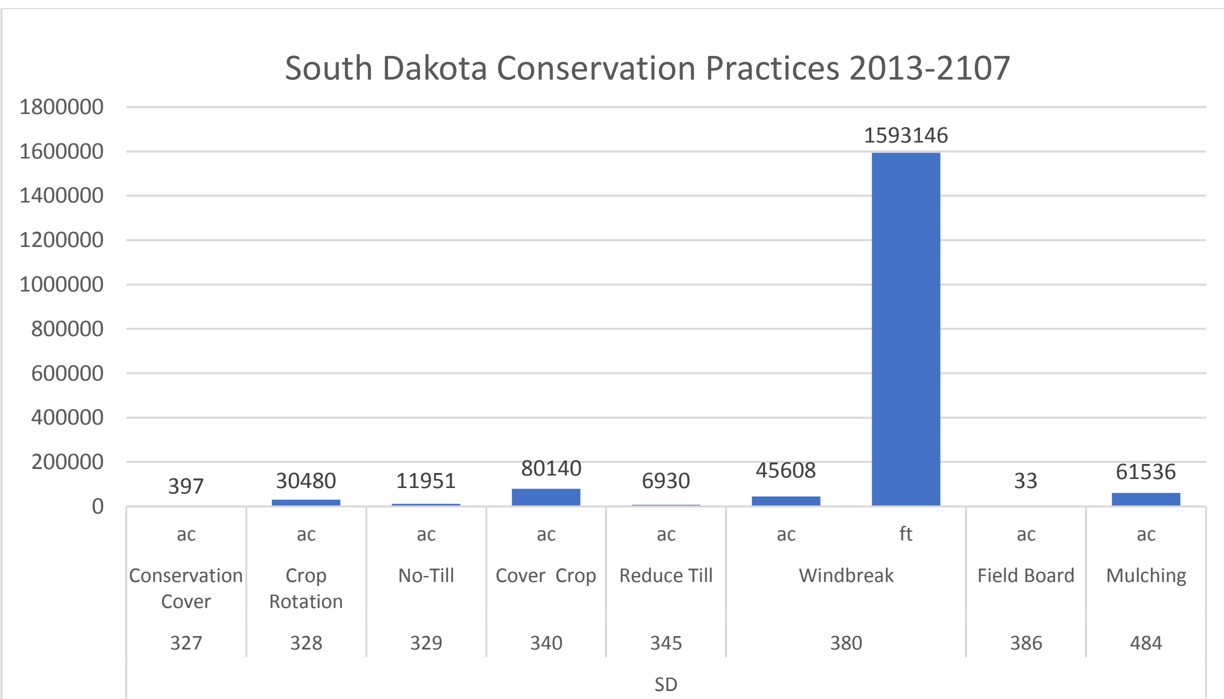
10185
10075
125
ac
ac
ac
ac
ac
ft
ft
ac
Conservation Cover
Crop Rotation
No-Till
Cover Crop
Field Board
Hedgerow Palnting
Mulching
327
328
329
340
386
422
484
SC


South Dakota Conservation Practices 2013-2107
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80140
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33
61536
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ac
ac
ac
ac
ac
ft
ac
ac
Conservation Cover
Crop Rotation
No-Till
Cover Crop
Reduce Till
Windbreak
Field Board
Mulching
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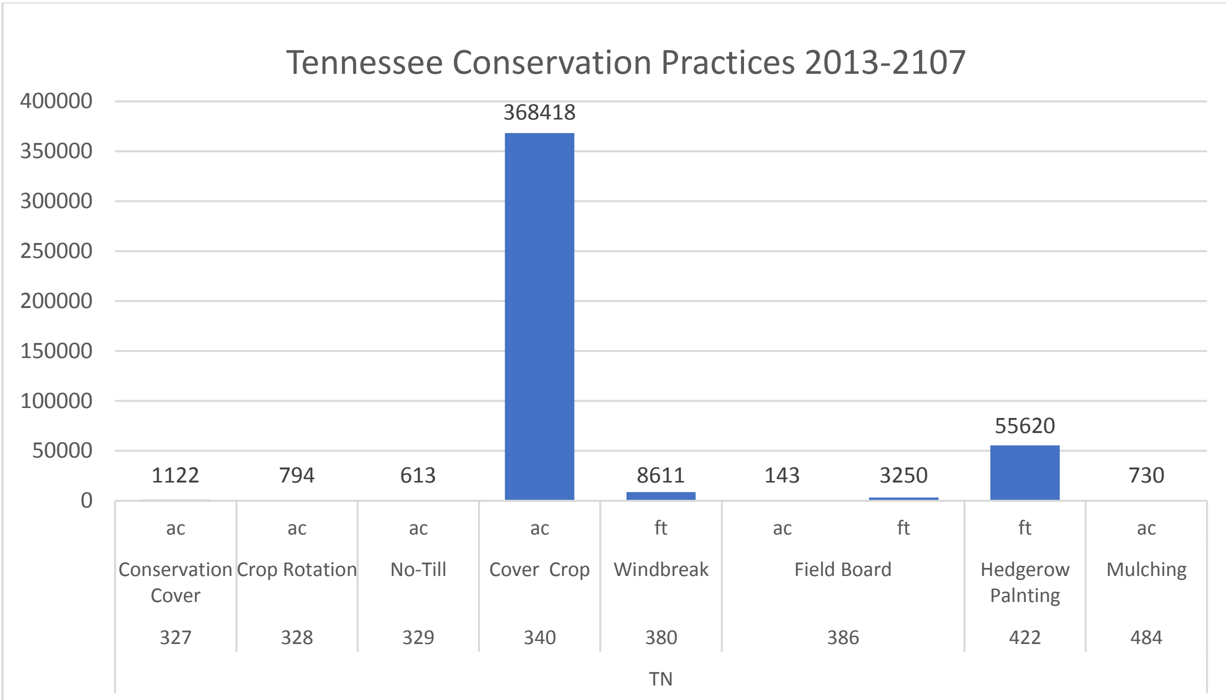
484
SD


Tennessee Conservation Practices 2013-2107
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613
368418
8611
143
3250
55620
730
ac
Conservation Cover
327
ac
Crop Rotation
328
ac
No-Till
329
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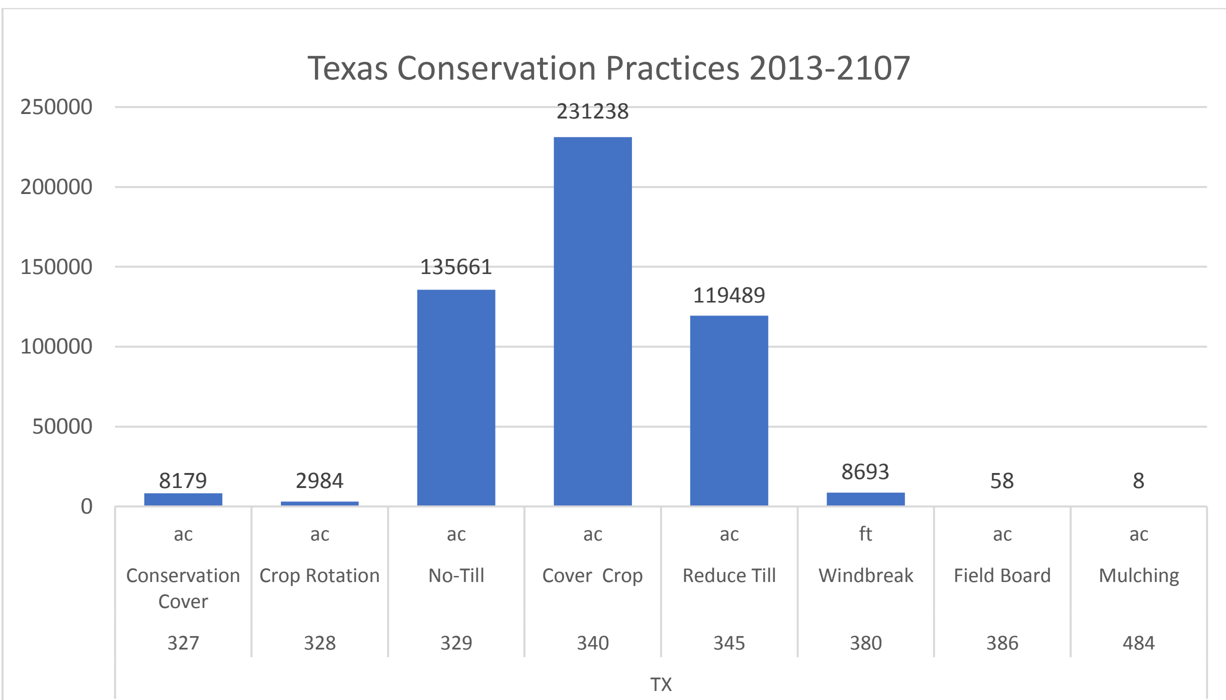
Windbreak
380
ac
ft
Field Board
386
ft
Hedgerow Palnting
422
ac
Mulching
484
TN


Texas Conservation Practices 2013-2107
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ac
Conservation Cover
327
ac
Crop Rotation
328
ac
No-Till
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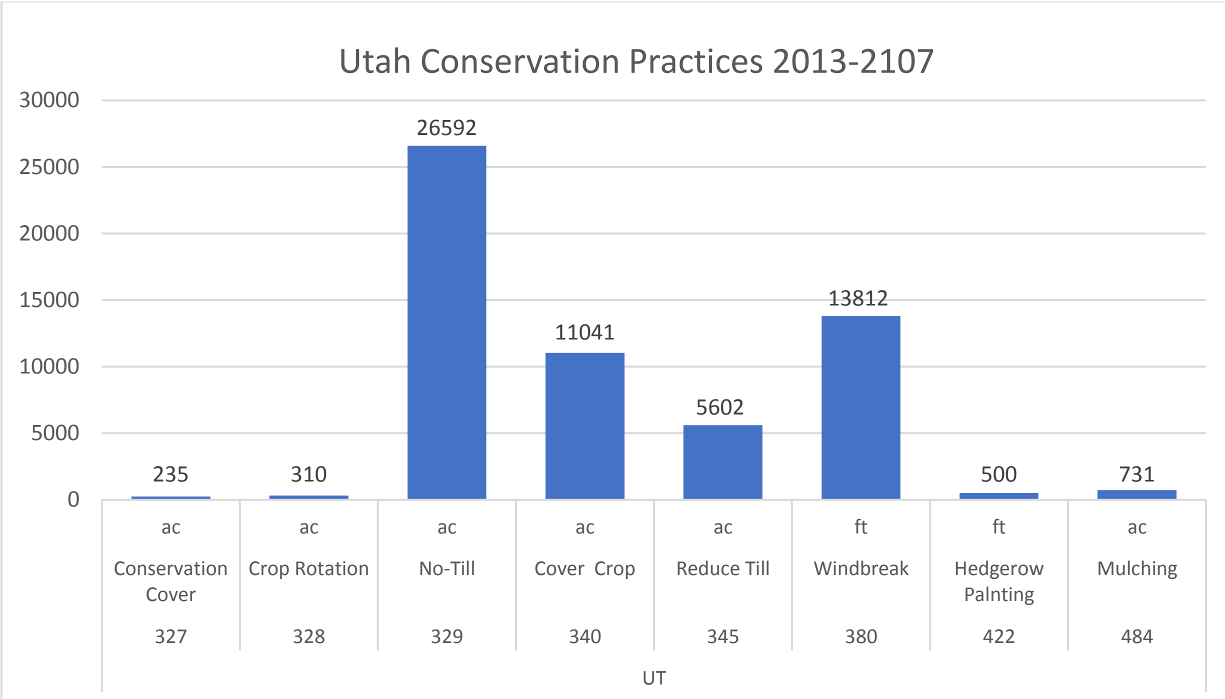
ac
Reduce Till
345
ft
Windbreak
380
ac
Field Board
386
ac
Mulching
484
TX



Utah Conservation Practices 2013-2107
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26592
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5602
13812
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731
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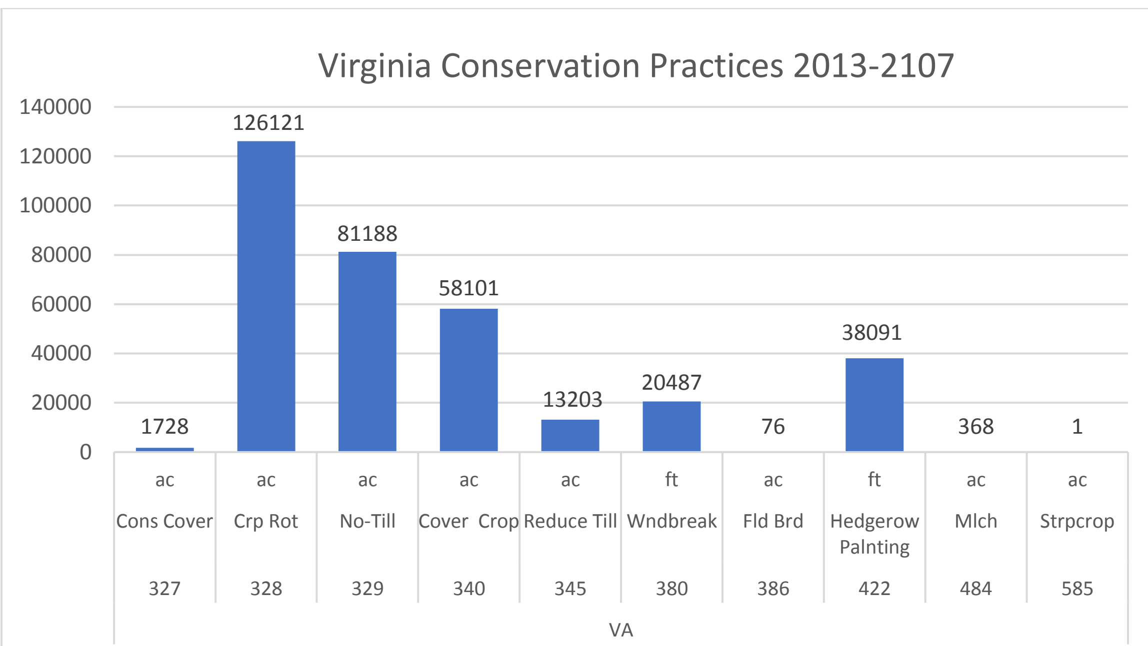
ac
ac
ac
ac
ft
ft
ac
Conservation Cover
Crop Rotation
No-Till
Cover Crop
Reduce Till
Windbreak
Hedgerow Palnting
Mulching
327
328
329
340
345
380
422
484
UT



Virginia Conservation Practices 2013-2107
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58101
13203
20487
76
38091
368
1
ac
ac
ac
ac
ac
ft
ac
ft
ac
ac
Cons Cover
Crp Rot
No-Till
Cover Crop
Reduce Till
Wndbreak
Fld Brd
Hedgerow Palnting
Mlch
Strpcrop
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328
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340
345
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386
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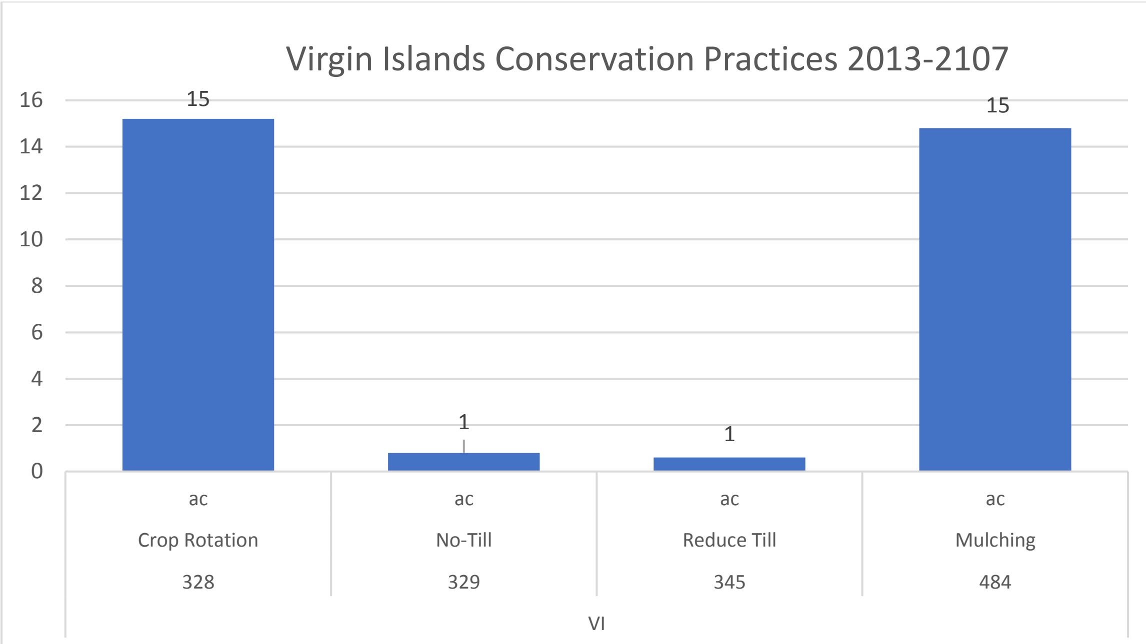
484
585
VA



Virgin Islands Conservation Practices 2013-2107
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Crop Rotation
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No-Till
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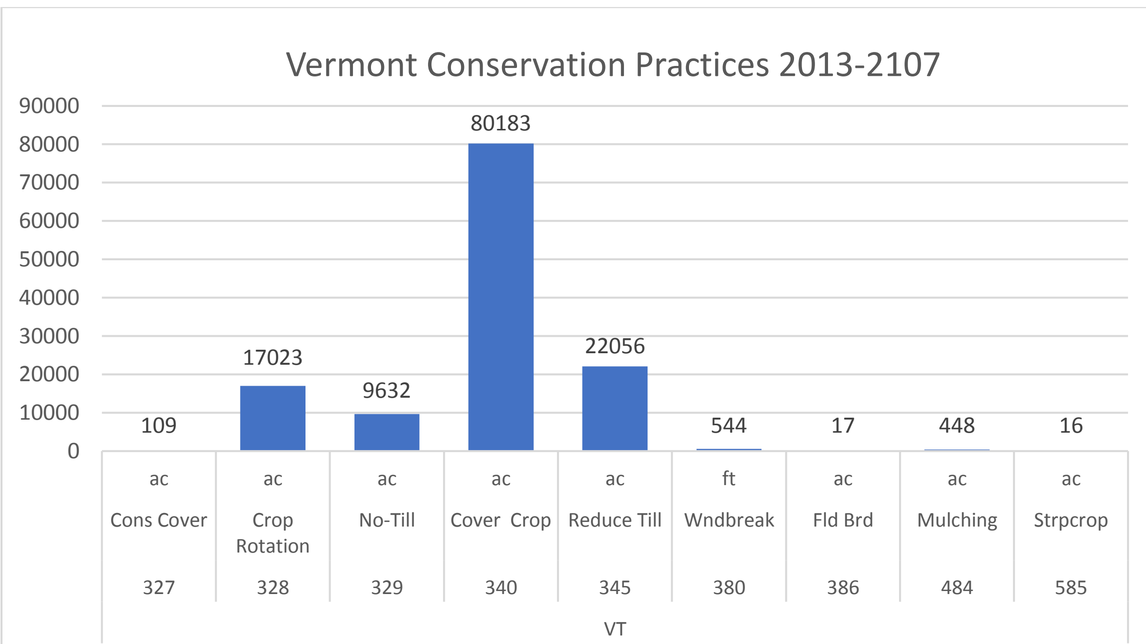
ac
Reduce Till
345
ac
Mulching
484
VI



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544
17
448
16
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Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
329
ac
Cover Crop
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ac
Reduce Till
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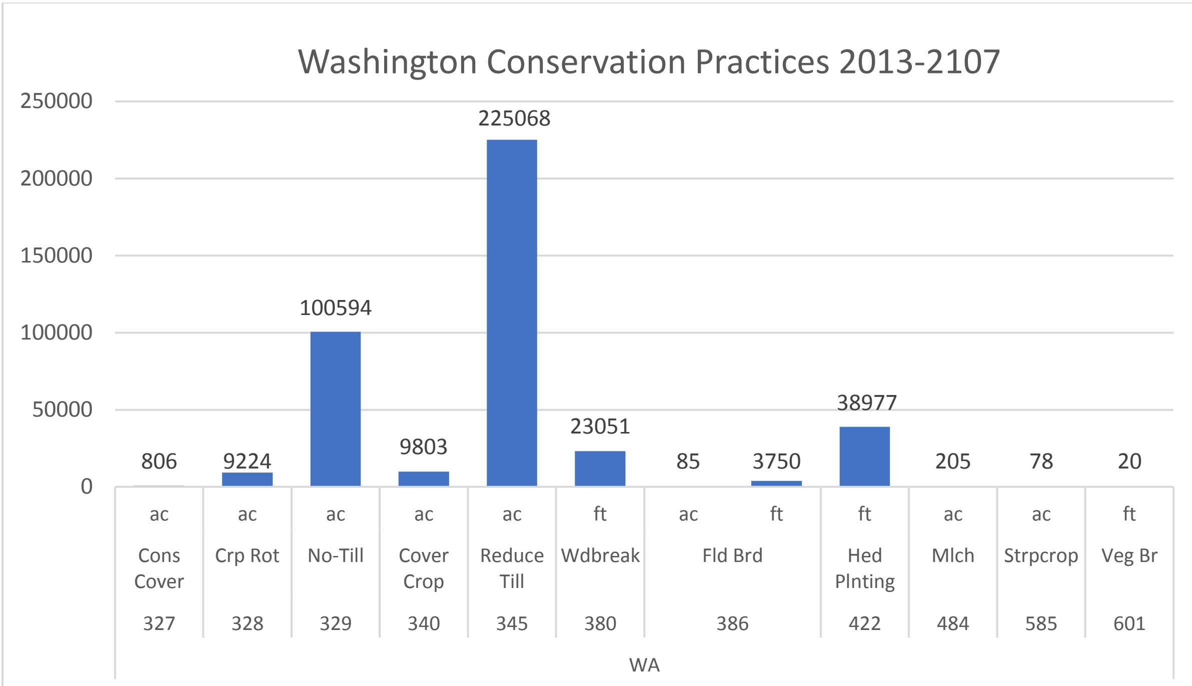
ft
Wndbreak
380
ac
Fld Brd
386
ac
Mulching
484
ac
Strpcrop
585
VT


Washington Conservation Practices 2013-2107
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205
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20
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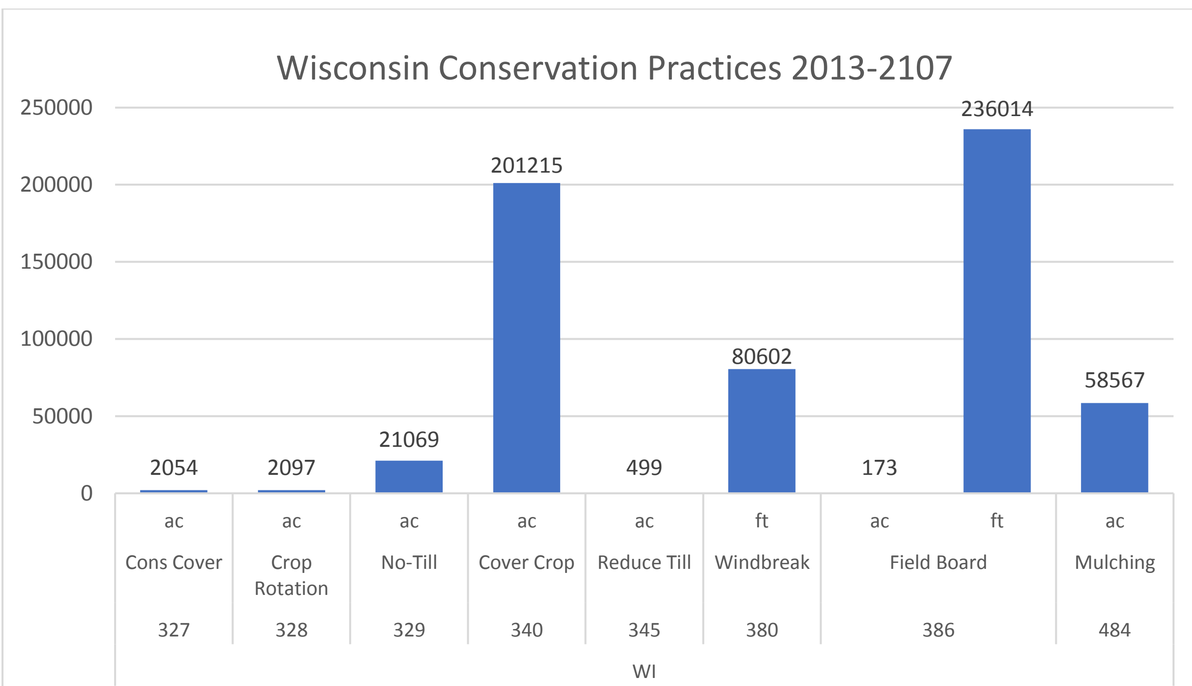
Cons Cover
327
ac
Crp Rot
328
ac
No-Till
329
ac
Cover Crop
340
ac
Reduce Till
345
ft
Wdbreak
380
ac
ft
Fld Brd
386
ft
Hed Plnting
422
ac
Mlch
484
ac
Strpcrop
585
ft
Veg Br
601
WA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2097
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201215
499
80602
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236014
58567
ac
Cons Cover
327
ac
Crop Rotation
328
ac
No-Till
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Cover Crop
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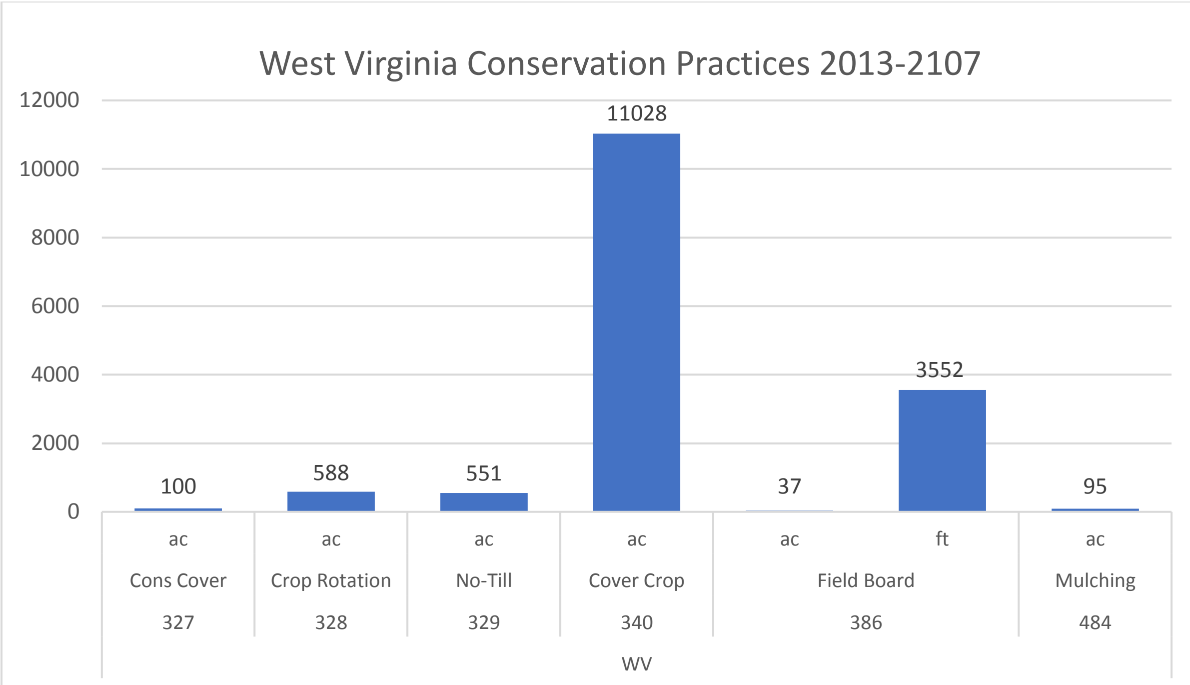
ac
Reduce Till
345
ft
Windbreak
380
ac
ft
Field Board
386
ac
Mulching
484
WI


West Virginia Conservation Practices 2013-2107
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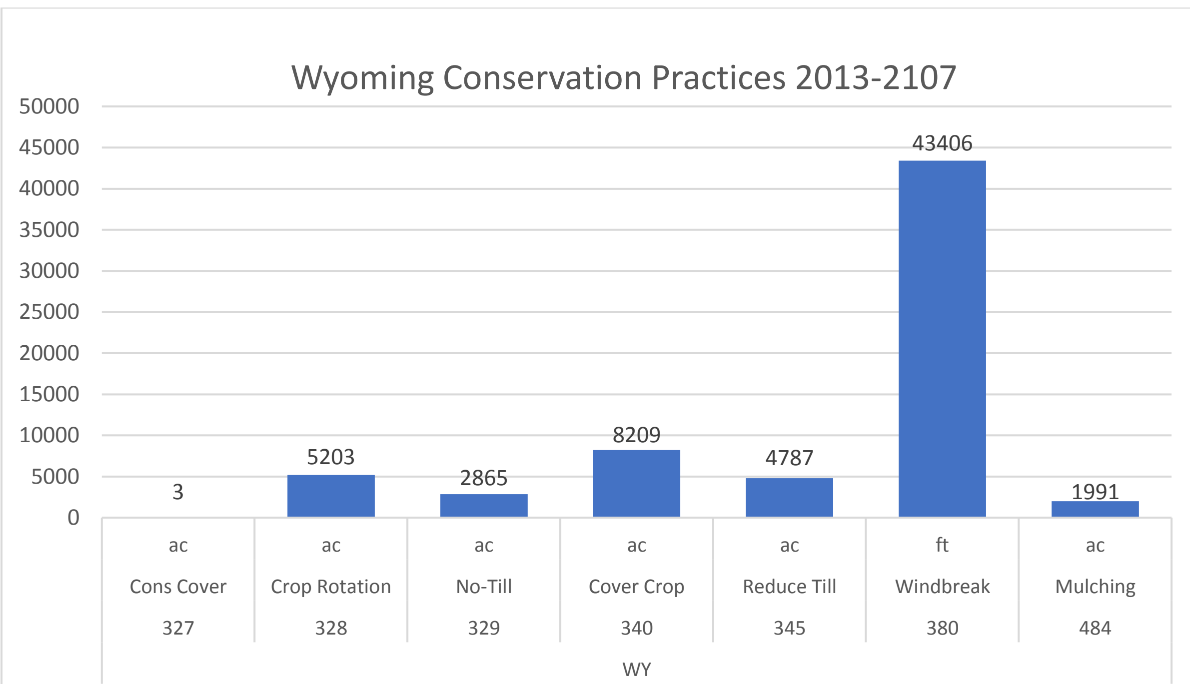
8000
6000
4000
2000
0
100
588
551
11028
37
3552
95
ac
ac
ac
ac
ac
ft
ac
Cons Cover
Crop Rotation
No-Till
Cover Crop
Field Board
Mulching
327
328
329
340
386
484
WV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Crop Rotation
No-Till
Cover Crop
Reduce Till
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Mulching
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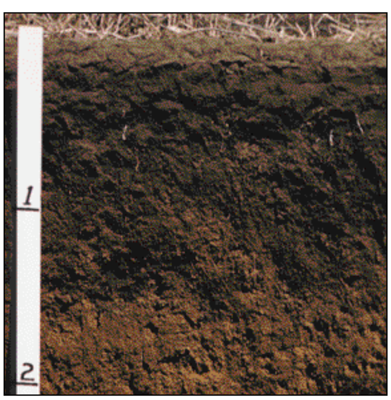
Exhibit 6-2: The Soil Conditioning Index (SCI)



NRCS
Natural Resources Conservation Service

The Soil Conditioning Index
and improving your score

What is the Soil Conditioning Index?

The Soil Conditioning Index (SCI) is a tool that can predict the consequences of cropping systems and tillage practices on soil organic matter. Organic matter is a primary indicator of soil quality and an important factor in carbon sequestration and global climate change.

The SCI has three main components:
1) **OM or Organic Matter**. This accounts for the amount of organic material returned to the soil. Organic material from plant or animal sources may be either grown and retained on the site or imported to the site.
2) **FO or Field Operations**. This accounts for the effect of field operations which stimulate organic matter breakdown. Tillage, planting, fertilizer application, spraying and harvesting crush and shatter plant residues and aerate or compact the soil. These effects increase the rate of residue decomposition and affect the placement of organic material in the soil profile.
3) **ER or Erosion**. This accounts for the effect of removal and/or sorting of surface soil material by the sheet, rill, and/or wind erosion processes which are predicted by water and wind erosion models. It does not account for the effect of concentrated flow erosion such as ephemeral or classic gullies. Erosion contributes to loss of organic matter and decline in long-term productivity.

The SCI gives an overall rating based on these components. If the rating is a negative value, the system is predicted to have declining soil organic matter. If the rating is a positive value, the system is predicted to have increasing soil organic matter. The model is designed to aid Natural Resources Conservation Service (NRCS), landowners and Conservation District staffs in planning and designing cropping systems and residue management practices to resolve low organic matter, poor soil tilth, and other soil quality-related problems during conservation planning. The Revised Universal Soil Loss Equation Version 2 (RUSLE2) is the official NRCS tool that is used to calculate SCI.

Why is the SCI important?

The SCI is a quick way to characterize the organic matter dynamics of a farming system. Organic matter is a critical component of soil function for several reasons. Surface residue protects soil from the impact of rain and wind. As residue decays, it feeds microbes that improve soil structure and water infiltration, and thus reduces runoff. Soil organic matter contributes to nutrient and water holding capacities. Regular varying inputs of organic material foster a diverse microbial community that supports plant health and productivity.

The SCI along with RUSLE2, the NRCS soil erosion prediction model, can help assess two basic components of good soil management: building organic matter and controlling erosion.

SCI and the 2004 Conservation Security Program

The SCI plays a critical role in the implementation of the Conservation Security Program (CSP). It is used to determine the basic eligibility of cropland for CSP. Cropland must have a score of greater than 0.0 to be eligible for the program. Once an application is accepted into CSP, the SCI is one of the tools used to help determine the potential payment amount. All CSP applications will be assigned an enrollment category, which is partially based on the SCI score.

The Index is also used to help calculate some of the enhancement payment component of the CSP contract. Another NRCS tool, the Soil Tillage Intensity Rating (STIR), is also used to help determine enhancement payments. STIR, also automatically calculated by RUSLE2, measures the amount of soil disturbance based on tillage operations.

Other SCI Uses

The SCI is a component of several practice standards in NRCS technical guides. It is designed to help plan and design conservation crop rotations and residue management practices when low organic matter, poor soil tilth, surface crusting, or erosion are identified as concerns.

What do the numbers mean?

The SCI does not indicate a desirable or target level of soil organic matter, but it will predict if a particular management system will have a positive or negative effect on SOM. For example, a near-zero SCI value indicates that soil organic matter levels are probably being maintained, but soil health may still be poor if the soil organic matter is being maintained at a low level.

If the calculated index is a negative value, soil organic matter levels are predicted to decline under that production system. If the index is a positive value, soil organic matter levels are predicted to increase under that system.

Cautions

Organic matter is an important factor determining soil quality in many systems, but it is not the only factor. Other important aspects of soil quality include quality of organic matter, sedimentation, soil biota, nutrient management, contaminants, soil pH, bulk density and infiltration rate. These are not directly reflected in the Soil Conditioning Index, but can be improved to some extent with gains in organic matter.

Improving your score

Consider some of the following to help increase your SCI score.

- Raise crops that produce high amounts of residue that are retained on the field
- Utilize cover crops when possible to increase organic matter.
- Utilize manure or crop mulch to add organic matter to the soil
- Limit the number of tillage operations.
- Limit the amount of soil disturbance each operation created--A field cultivation operation normally disturbs less soil than a chisel type operation.
- Minimize the amount of wind and water erosion occurring on the field.
- Use production techniques that will increase crop and residue production.

Helpful websites

For SCI:

- http://soils.usda.gov/sqi/soil_quality/land_management/sci.html

For CSP:

- http://www.nrcs.usda.gov/programs/csp/
- http://www.ia.nrcs.usda.gov/programs/csp.html

For RUSLE2:

- http://fargo.nsert.purdue.edu/rusle2_dataweb/RUSLE2_index.htm

Exhibit 6-3: Cover Crop Economics Tool Factsheet

USDA United States Department of Agriculture

Natural Resources Conservation Service

COVER CROP$ TOOL

An Economics Decision Support Tool

Economics 101

Interest in cover crops is growing across Iowa and the country. The reason? The potential benefits they offer farmers. Before jumping on the trend, it is important to assess the impacts cover crops may have on your operation. Adding cover crops means new operational costs and other benefits—some with a real cash value. That's what most farmers want to know. NRCS has a new tool to assess the economics and focus on new costs and benefits. That knowledge is key to the decision-making process. It can improve farmers' ability to commit to using cover crops as a long-term and successful conservation solution on their farm.

About The Tool

The specific costs and benefits associated with adding cover crops to a rotation are highly variable and site specific. NRCS encourages producers and landowners interested in assessing the economic considerations for their farm to download the "Cover Crop Economics Decision Support Tool." This tool is a partial budgeting tool based in a spreadsheet. It helps producers, landowners, planners and others make informed decisions when considering adding cover crops to their production system. The tool is available for download from the NRCS IA website at **http://www.nrcs.usda.gov/wps/portal/nrcs/main/ia/technical/dma/econ/**. For more details, visit your local NRCS office.

What The Tool Tells You

Offering a partial budget analysis, the tool focuses only on operational changes you make. To keep the analysis relevant, the focus is on actual costs and benefits farmers see when they add cover crops. We focus on benefits easily expressed in terms of dollars. The tool offers a simple economic and financial comparison that does not require in-depth crop budgets or enterprise analysis data. Concepts that the tool considers include:

- *Time Frame* — When assessing the economics of cover crops, the 'time horizon,' or length of time you evaluate really matters. The short-term view, typically less than 10 years, assesses immediate benefits from cover crop use. The long-term view assesses continued and long-term use of cover crops, which may lead to more economic benefits like improved soil health.

Potential Benefits —

- *Direct Nutrient Credits* – These are credits farmers expect to receive and use for the cash crop they will plant after the cover crop. This credit counts as 'already applied' fertilizer that is readily available for the crop, reducing actual fertilizer farmers would normally purchase. Typically, these nutrient credits are associated with legume cover crops specifically managed to provide nitrogen credits.

- *Herbicide/Insecticide/Fungicide Input Reductions* – Cover crop residue, surface vegetation competition, and subsurface microbial activity may result in reduced chemical application needs for the following cash crop. For example, having an early season mulch layer may eliminate the need and costs for herbicide treatments.

- *Yield Increases* – When cover crops solve yield-limiting problems like compaction and moisture availability, growth of your next cash crop can improve. The tool calculates this benefit by assessing the value of the added yield per acre.

- *Reduced Erosion* – Cover crops may immediately reduce onsite soil erosion. This benefit includes an estimate of the fertility value per ton typically lost to soil erosion, which is now under control. In some cases, reducing erosion with cover crops also reduces machinery costs to repair gullies and clean sediment out of ditches.

- *Grazing (short-term benefit)* – Using cover crops for grazing livestock that are already part of the farming operation is one of the most reliable ways to capture value from cover crops. Grazing cover crops can improve daily weight gain in stockers and offset hay and feed costs.

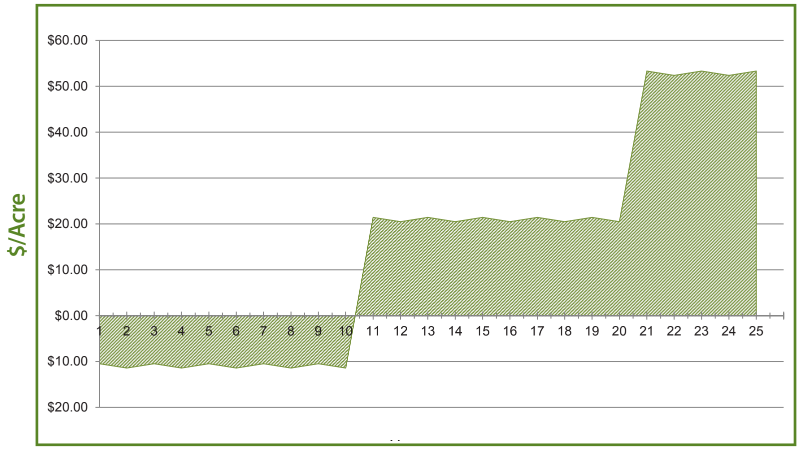
- *Overall Soil Fertility (long-term benefit)* – When used as part of a crop rotation over many years, cover crops impact both physical and biological soil properties. These soil improvements may result in the soil's ability to increase available nitrogen, phosphorus and potassium in plants/crops. This can offset the purchase of additional nutrients for crop production from external sources.

- *Improved Water Storage and Infiltration (long-term benefit)* – As soil organic matter increases, the soil's ability to store water also increases. The economic benefits of improved soil infiltration and water storage can reduce irrigation costs or increase the soil's resilience from drought in dryland systems and curb yield losses.

General Notes on the Tool:

- Please review the instruction page to understand data inputs required by users and the results the tool provides.
- The tool's analysis depends upon user-supplied values. Where users are unsure of exact variables, they can use the tool to run "what if" scenarios based on different potential ranges of data inputs. The model will store and retrieve up to 5 default scenarios and offer a starting point for running the model.
- The tool provides analysis results both numerically and graphically.
- A References & Citations page is included, which provides users with additional technical and scientific details used to build the tool.
- Results are presented in two ways, showing immediate short-term net benefits and long-term net benefits (up to 50 years). The long-term benefits assess the impact of improved soil health with continued use of cover crops.

Financial Analysis Net Benefits



Years

Example from the tool's graphic display of financial results for a scenario assessing 25 years of including cover crops into a corn/soybean rotation where 10 years are required to change soil organic matter 1%. Graphic shows change in operating costs, negative numbers represent increased operating costs.

Exhibit 6-4: Cover Crop Chart

USDA United States Department of Agriculture
Agricultural Research Service

Cover Crop Chart

AREA 4 SCD Cooperative Research Farm

GROWTH CYCLE	PLANT ARCHITECTURE	RELATIVE WATER USE
A = Annual	♈ = Upright	💧 = Low
B = Biennial	✱ = Upright-Spreading	💧💧 = Medium
P = Perennial	≈ = Prostrate	💧💧💧 = High

----------COOL---------- ----------WARM----------

--GRASS-- ----------BROADLEAF---------- --GRASS--

----------LEGUME----------

A **ANNUAL FESCUE** 💧 ♈									A **BROWNTOP MILLET** 💧 ♈
A **BARLEY** 💧 ♈								A **AMARANTH** 💧 ♈	A **FOXTAIL MILLET** 💧 ♈
A **OAT** 💧💧 ♈	A/B **CAMELINA** 💧 ♈	A/P **MUSTARD** 💧 ✱	A **BALANSA CLOVER** ≈ ✱	A **CHICKPEA** 💧 ✱	A/P **MEDIC** 💧 ♈	A **COWPEA** 💧 ✱	A **CLUSTER BEAN** 💧 ✱	A **BUCKWHEAT** 💧💧 ♈	A **PEARL MILLET** 💧 ♈
A **SPELT** ♈	A **PHACELIA** 💧 ♈	A/B **CANOLA** 💧💧 ✱	A **BERSEEM CLOVER** 💧💧 ♈	A **PEA** 💧 ♈	A **LUPIN** 💧 ♈	A/P **LABLAB** 💧 ≈ ✱	A/P **JACK BEAN** 💧 ✱	A **QUINOA** 💧💧 ♈	A **PROSO MILLET** 💧💧 ♈
A **WHEAT** 💧💧 ♈	A **FLAX** 💧💧 ♈	A **RADISH** 💧💧💧 ✱	A **CRIMSON CLOVER** 💧💧 ✱	A **LENTIL** 💧 ✱	A **FABA BEAN** 💧💧 ♈	A/P **FENUGREEK** 💧 ♈	A **VELVET BEAN** 💧 ✱	P **CHICORY** 💧💧 ✱	A **GRAIN SORGHUM** 💧💧 ♈
A **CEREAL RYE** 💧💧💧 ♈	A **KALE** 💧💧 ✱	B **TURNIP** 💧💧💧 ✱	B/P **RED CLOVER** 💧💧 ♈	A/P **LESPEDEZA** 💧💧 ≈ ✱ ♈	A/B **SWEET CLOVER** 💧💧 ♈	A/P **PIGEONPEA** 💧 ✱	A **MUNG BEAN** 💧💧 ✱	A **CUCURBITA** 💧💧💧 ≈	A **SUDAN GRASS** 💧💧 ♈
A **TRITICALE** 💧💧💧 ♈	A **SPINACH** 💧💧 ✱	B **BEET** 💧💧💧 ✱	P **WHITE CLOVER** 💧💧 ≈ ✱	P **BIRDSFOOT TREFOIL** 💧💧 ≈	P **ALFALFA** 💧💧💧 ♈	A **PARTRIDGE PEA** 💧💧 ♈	A **SOYBEAN** 💧💧 ✱	A **SAFFLOWER** 💧💧💧 ♈	A **TEFF** 💧💧 ♈
P **SALINE TOLERANT** ♈	A/B **CHARD** 💧💧💧 ✱	A/B **CARROT** 💧💧💧 ✱	P **KURA CLOVER** 💧💧 ≈	A/B **VETCH** 💧💧 ≈	P **SAINFOIN** 💧💧💧 ♈	A **SUNNHEMP** 💧💧 ♈	A/P **PEANUT** 💧💧💧 ≈ ✱	A **SUNFLOWER** 💧💧💧 ♈	A **CORN** 💧💧💧 ♈

V 3.0 February 2018

◈ *Additional Information*

USDA United States Department of Agriculture
Agricultural Research Service

◈ Back to Cover Crop Chart

Cover Crop Chart

The Cover Crop Chart is produced and distributed by the staff of the Northern Great Plains Research Laboratory at Mandan, ND.

The Cover Crop Chart represents a compendium of information from multiple sources. Primary sources of information included the Midwest Cover Crops Council, USDA-SARE, USDA-NRCS PLANTS database, and relevant peer-reviewed journal articles. Designation of warm/cool season crops is based on prevalent growth habits and not photosynthetic pathway. Ranges for seeding depth take into consideration moisture conditions at planting and variation in soil texture. Values for crude protein and C:N ratio assume homogenous samples of aboveground plant material unless stated otherwise. Information on specific crops is occasionally generalized, approximate, and/or incomplete and may not reflect performance in on-farm conditions. USDA-ARS makes no guarantee to the performance of specific crops based on information provided herein. Content and data for crops were assembled by Holly Johnson and Mark Liebig with input from Dave Archer, V.C. Baligar, Heather Dose, Wayne Duckwitz, Marvin Hatzenbuhler, John Hendrickson, Naeem Kalwar, Robert Kolberg, Nancy Jensen, Steve Merrill, Kristine Nichols, Delmer Schlenker, Marty Schmer, Eric Scholljegerdes, Don Tanaka, Cal Thorson, and Dawn Wetch. Chart design by Mark Liebig, Holly Johnson, and Jill Gunderson. The Cover Crop Chart was originally generated with input from producers and technicians in the Area IV Soil Conservation Districts of North Dakota and NRCS staff at the Bismarck and Dickinson Field/Area Offices.

- Useful cover crop resources:
  - Managing Cover Crops Profitably, 3rd Ed. Andy Clark (Ed.). Handbook Series Book 9, Sustainable Agriculture Network, Beltsville, MD.
  - Midwest Cover Crops Council, www.mccc.msu.edu
  - Sustainable Agriculture Research and Education Program, University of California-Davis, www.sarep.ucdavis.edu
  - USDA-NRCS, PLANTS Database, www.plants.usda.gov

For further information please contact:

Cover Crop Chart
USDA-ARS Northern Great Plains Research Laboratory
P.O.Box 459 Mandan, ND 58554-0459
Voice: 701 667-3079 FAX: 701 667-3054
https://www.ars.usda.gov/plains-area/mandan-nd/ngprl/

Crop Sequence Effects

CROP RESIDUE	- - - - - - - HIGH RISK CROPS (Crops with the worst performance following a particular residue) - - - - - - -								
Barley	Barley								
Wheat	Wheat								
Canola	Canola	Mustard	Pea	Dry Bean	Flax	Safflower			
Mustard	Soybean	Sunflower							
Flax	Flax								
Pea	Pea	Flax							
Lentil	Lentil								
Chickpea	Buckwheat	Lentil							
Soybean	Canola	Wheat	Barley						
Buckwheat	Chickpea	Sunflower	Grain Sorghum	Sunflower					
Safflower	Safflower	Sunflower	Soybean	Mustard	Dry Bean				
Sunflower	Sunflower	Canola	Pea	Lentil	Buckwheat	Grain Sorghum	Corn	Wheat	Barley
Proso Millet	Proso Millet	Grain Sorghum	Buckwheat						
Grain Sorghum	Grain Sorghum	Proso Millet	Pea	Lenti	Wheat				
Corn	Corn	Wheat	Buckwheat	Grain Sorghum	Proso Millet				

Table adapted from Crop Sequence Calculator (v. 3.1).
Software available for download at https://www.ars.usda.gov/plains-area/mandan-nd/ngprl/

◈ Back to Cover Crop Chart

Annual fescue
(*Vulpia myuros* L.; *Fetuca* sp.)

- Cool Season, grass
- Annual
- Upright plant architecture
- Alternate names: Rattail fescue, Foxtail fescue
- Low water use
- Poor salinity tolerance
- Seeding depth: ¼ – 1 inch
- Crude protein: hay 8-10%
- Benefits from arbuscular mycorrhizal associations

Back to Cover Crop Chart

Cool Season Grass

Barley
(*Hordeum vulgare* L.)

- Cool Season, grass
- Annual
- Upright plant architecture
- Low water use
- Good salinity tolerance
- Seeding depth: ¾ – 2 inches
- Crude protein: hay 10-15%, grain 11-15%
- C:N ratio: 20
- Benefits from arbuscular mycorrhizal associations
- Self pollinator (wind)
- Rated 'very good' at scavenging nitrogen from the soil

◈ *View table for known crop sequence effects*

◈ *Back to Cover Crop Chart*

Cool Season Grass

Oat
(*Avena sativa* L.)

- Cool Season, grass
- Annual
- Upright plant architecture
- Medium water use
- Fair salinity tolerance
- Seeding depth: 1 – 2 inches
- Crude protein: hay 9-15%, grain 13-18%
- C:N ratio: 33
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)
- Rated 'very good' at scavenging nitrogen from the soil

Back to Cover Crop Chart

Cool Season Grass

Spelt

(*Triticum spelta* L.; *Triticum aestivum* var. *spelta*(L.) L.H. Bailey)

- Cool season, grass
- Annual
- Upright plant architecture
- Good to fair salinity tolerance
- Seeding depth: ½ – 1 ½ inches
- Crude protein: overall 11-14%, grain 13-16%
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)
- An efficient available nitrogen accumulator among cool season grasses
- Spelt is an older cereal grain and is more prone to lodging than wheat

Back to Cover Crop Chart

Cool Season Grass

Wheat
(*Triticum aestivum* L.)

- Cool season, grass
- Annual
- Upright plant architecture
- Includes spring and winter wheat varieties
- Medium water use
- Good to fair salinity tolerance
- Seeding depth: ½ – 1 ½ inches
- Crude protein: straw 4-10%, grain 12-16%
- C:N ratio: leaf 15-29, stem 31-65, root 24-74 , straw 80-95 [*end of season*]
- Benefits from arbuscular mycorrhizal associations
- Self pollinator (wind)
- Rated 'very good' at scavenging nitrogen from the soil

◈ *View table for known crop sequence effects*

◈ *Back to Cover Crop Chart*

Cool Season Grass

Cereal rye
(*Secale cereale* L.)

- Cool Season, grass
- Annual
- Upright plant architecture
- High water use
- Good salinity tolerance
- Seeding depth: ¼ – 2 inches
- Crude protein: straw 4%, grain 14%
- C:N ratio: 40 – 50*
  - * This number can vary based on whether the plant was grown in monoculture or a biculture and the stage the plant was in when it was tested
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)
- Rated 'very good' at scavenging nitrogen from the soil

◈ *Back to Cover Crop Chart*

Cool Season Grass

Triticale

(*Triticale hexaploide* Lart.;*Triticosecale rimpaui* Wittm.)

- Cool Season, grass
- Annual
- Upright plant architecture
- Fall and spring types available
- High water use
- Good salinity tolerance
- Seeding depth: 1 ½ – 2 inches
- Crude protein: hay 9-16%, grain 17%
- C:N ratio: 20
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)


Photo by Ken Miller, Rancher
Huff North Dakota


Photo by Matt Liebman, Iowa State University www.mccc.msu.edu

Back to Cover Crop Chart

Cool Season Grass

Saline Tolerant Grasses

- Cool Season, grass
- Perennial
- Upright plant architecture
- Low to moderate water use
- Moderate to high salinity tolerance
- Seeding depth: ¼ – 1 inch
- Crude Protein: 7 – 19%
- Forms arbuscular mycorrhizal associations
- Many species are available in this category; each varies slightly in plant characteristics

See the next six slides for more detail

◈ Back to Cover Crop Chart

Saline Tolerant

Cool Season Grass

RS Hybrid Wheatgrass

(*Elymus hoffmannii* K.B. Jensen & K.H. Asay)

- Cool season, grass
- Perennial
- Upright plant architecture
- Alternate name: Green wheatgrass
- Low water use
- Moderate to high salinity tolerance
- Seeding depth: ¼ – ½ inch
- Crude protein: 7 – 12%
- RS hybrid wheatgrass is a hybrid between quackgrass (*Elymus repens*) and bluebunch wheatgrass (*Pseudoroegneria spicata*)

Back to Cover Crop Chart

Saline Tolerant

Cool Season Grass

Tall Wheatgrass
(*Thinopyrum ponticum* (Podp.))

- Cool season, grass
- Perennial (introduced)
- Upright plant architecture
- Alternate name: Rush wheatgrass
- Moderate water use
- Excellent salinity tolerance
- Seeding depth: ¼ – 1 inch
  *shallower for finer textured soils
- Crude protein: 7 – 19%
  - vegetative >10%
  - late bloom 6%
  - fully mature 2-3%

Back to Cover Crop Chart

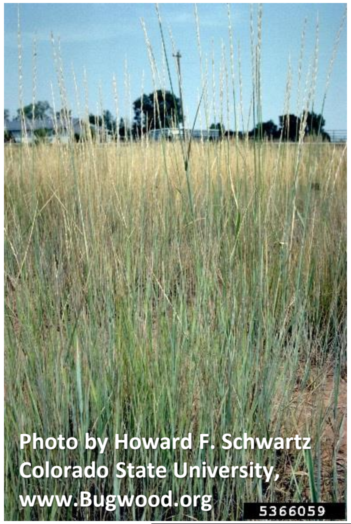
Saline Tolerant

Cool Season Grass

Intermediate Wheatgrass

(*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey)

- Cool season, grass
- Perennial (introduced)
- Upright plant architecture
- Alternate name: Pubescent wheatgrass
- Low to moderate water use; drought tolerant
- Good salinity tolerance
- Seeding depth: ½ – 1 inch
- Crude protein: 8 – 17%*
  *Northern Plains: may fall below 4% at the end of the season
- Cross-pollinates.
- Spreads vegetatively; under ideal conditions, it can slowly spread into adjacent communities
- Persistence of stand is limited (typically < 5 yr)



◈ Back to Cover Crop Chart

Saline Tolerant

Cool Season Grass

Slender Wheatgrass
(*Elymus trachycaulus* (Link) Gould ex Shinners)

- Cool season, grass
- Perennial, short-lived (native)
- Upright plant architecture
- Low water use; will not tolerate water-logged soils
- Good salinity tolerance
- Seeding depth: ¼ – ¾ inch
- Crude protein: 22 – 25% (Spring); less than 10% (fall)
- May form arbuscular mycorrhizal associations

Back to Cover Crop Chart

Saline Tolerant

Cool Season Grass

Russian Wildrye
(*Psathyrostachys junceus* (Fisch.) Nevski)

- Cool season, grass
- Perennial (introduced)
- Upright plant architecture
- Low water use
  - drought tolerant
  - does not tolerate flooding
- Good salinity tolerance
- Seeding depth: ¼ – ½ inch
  - Sensitive to seeding depth – too deep will inhibit seed germination
- Crude protein: 5 – 17 %
- Difficult to establish

◈ Back to Cover Crop Chart

Saline Tolerant

Cool Season Grass

Alkaligrass

(*Puccinellia sp.* Parl.)

- Cool season, grass
- Perennial
- Upright plant architecture
- Nuttall's alkaligrass, *Puccinellia nuttalliana* [Schult.] Hitch.
  - Native to semi-arid, North American zones
- Weeping alkaligrass, *Puccinellia distans* [Jacq.] Parl.
  - Introduced [Eurasia]
  - Highest salinity tolerance of this genus
- Low to moderate water use
  - Can survive arid areas as well as marsh, basin, or wetland zones
- Excellent salinity tolerance
- Seeding depth: ¼ - ½ inch

- ***This slide completes the review of saline tolerant grasses***

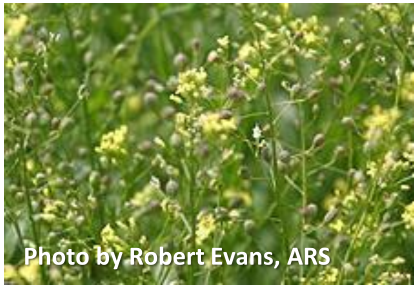
Back to Cover Crop Chart

Saline Tolerant

Cool Season Grass

Camelina
(*Camelina sativa* (L.) Crantz)

- Cool Season, broadleaf
- Annual, Biennial
- Upright plant architecture
- Alternate names: False flax, gold-of-pleasure, linseed dodder, largeseed falseflax, leindotter, Siberian oilseed
- Low water use
- Fair salinity tolerance
- Seeding depth: ⅛ – ¼ inch
- Crude Protein: 46%
- C:N Ratio: stems 40-95; pods 25-70; seed 12-16
- Does not form arbuscular mycorrhizal associations
- Mainly a self pollinator but benefits genetically from exposure to high population of pollinators
- Sensitive to soil herbicide imidazolinones and sulfentrazone
- Volunteer plants can become problematic
- Potentially allelopathic for flax



Back to Cover Crop Chart

Cool Season Broadleaf

Phacelia
(*Phacelia tanacetifolia* Benth.)

- Cool Season, broadleaf
- Annual
- Upright plant architecture
- Low water use
- Low salinity tolerance
- Seeding depth: ⅛ – ¼ inch
- C:N ratio: 10 – 15
- Forms arbuscular mycorrhizal associations
- Attracts beneficial insects

◈ *Back to Cover Crop Chart*

Cool Season Broadleaf

Flax
(*Linum usitatissimum* L.)

- Cool Season, broadleaf
- Annual
- Upright plant architecture
- Medium water use
- Fair salinity tolerance
- Seeding depth: ½ – 1 ½ inch
- Benefits from arbuscular mycorrhizal associations
- Flowers attract pollinators

◈ Back to Cover Crop Chart

Cool Season Broadleaf

Kale
(*Brassica napus* L. var. *pabularia*)

- Cool Season, broadleaf
- Annual
- Alternate names: also found under
  Brassica oleracea – Acephala group
- Upright and spreading plant architecture
- Major types:
  - Siberian
  - Russian
- Medium water use
- Fair salinity tolerance
- Seeding depth: ¼ – ½ inch
- Crude protein: ≈30%
- C:N ratio: 10 – 30
- Does not form arbuscular mycorrhizal associations

◈ Back to Cover Crop Chart

Spinach
(*Spinacia oleracea* L.)

- Cool Season, broadleaf
- Annual
- Upright and spreading plant architecture
- Low to medium water use
- Poor salinity tolerance
- Seeding depth: ¼ – ½ inch
- Crude protein: ≈20%
- C:N ratio: 6 – 8
- Sensitive to acid soils
- Does not form arbuscular mycorrhizal associations

Back to Cover Crop Chart

Cool Season Broadleaf

Chard
(*Beta vulgaris* L. ssp. *cicla* (L.) W.D.J. Koch)

- Cool season, broadleaf
- Annual, Biennial
- Upright spreading plant architecture
- Alternate names: Swiss chard, silverbeet, perpetual spinach, spinach beet, crab beet, bright lights, seakale beet, and mangold
- High water use
- Poor salinity tolerance
- Seeding depth: ½ - 1 inch
- Crude Protein: 32%
- Does not form arbuscular mycorrhizal associations
- Self pollinator (wind)

◈ Back to Cover Crop Chart

Cool Season Broadleaf

Mustard
(*Brassica sp.* L.)

- Cool Season, broadleaf
- Annual,Perennial
- Upright and spreading plant architecture
- Major types: Indian, Oriental, brown, yellow
- Related to crambe
- Low water use
- Poor salinity tolerance
- Seeding depth: ¼ – ½ inch
- Crude protein: hay 10%, grain 24-35%
- C:N ratio: 10 – 30
- Does not form arbuscular mycorrhizal associations
- Rated 'good' at scavenging nitrogen from the soil
- Plants from the *Brassica* group have potential to release compounds or metabolic by-products that work as bio-toxins against bacteria, fungi, insects, nematodes, and weeds
- Flowers may attract pollinators

◈ *View table for known crop sequence effects*

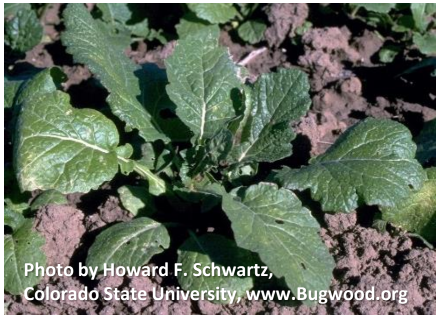
◈ *Back to Cover Crop Chart*

Cool Season Broadleaf

Canola
(*Brassica napus*)

- Cool Season, broadleaf
- Major types:
  - Annual (spring-type)
  - Biennial (winter-type)
- Upright and spreading plant architecture
- Alternate name: Rapeseed
- Medium water use
- Good salinity tolerance
- Seeding depth: ¼ – 1 inch
- Crude protein: shoots 20-30, hay 16%, grain 21%, silage 12%, pasture 17%
- C:N ratio: leaf 12-16, stem 21-37, root 24-43
- Does not form arbuscular mycorrhizal associations
- Rated 'very good' at scavenging nitrogen from the soil
- Flowers attract pollinator

◈ *View table for known crop sequence effects*



◈ *Back to Cover Crop Chart*

Cool Season Broadleaf

Radish
(*Raphanus sativus*)

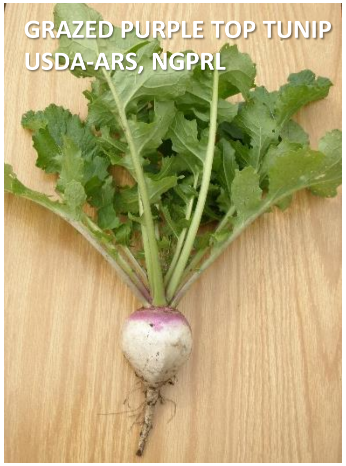
- Cool Season, broadleaf
- Annual
- Upright and spreading plant architecture
- Root crop
- Major types:
  - Oilseed (var. *oleiformis*)
  - Forage (var. *niger*): Daikon
- High water use
- Poor salinity tolerance
- Seeding depth: ¼ – ½ inch
- Crude protein: 26-30%
- C:N ratio: oilseed 19 – 20
- Does not form arbuscular mycorrhizal associations
- Rated 'very good' at scavenging nitrogen from the soil
- Flowers attract pollinators

◈ Back to Cover Crop Chart

Cool Season Broadleaf

Turnip
(*Brassica rapa* L. var. *rapa*)

- Cool Season, broadleaf
- Biennial
- Upright and spreading plant architecture
- Root crop
- High water use
- Poor salinity tolerance
- Seeding depth: ¼ – ½ inch
- Crude protein: tops 16%, root 12 – 14%
- C:N ratio: shoots 20 – 30, root 10 – 20
- Closely related to rutabaga
- Does not form arbuscular mycorrhizal associations
- Rated ‘good’ at scavenging nitrogen from the soil
- Flowers attract pollinators



◈ Back to Cover Crop Chart

Cool Season Broadleaf

Beet
(*Beta vulgaris*)

- Cool Season, broadleaf
- Biennial
- Upright and spreading plant architecture
- Root crop
- High water use
- Variable salinity tolerance, depending on beet type
- Seeding depth: ½ - ¾ inch
- Crude protein: tops 12-15%, root 7-10%
- C:N ratio: tops 11 – 14
- Does not form arbuscular mycorrhizal associations
- Rated 'good' at scavenging nitrogen from the soil
- Self pollinator (wind)
- Multiple sub-species including garden beets and sugar beets

Back to Cover Crop Chart

Cool Season Broadleaf

Carrot
(*Daucus carota* var. *sativus* L.)

- Cool Season, broadleaf
- Major types:
  - Biennial (cultivated)
  - Annual (wild)
- Upright and spreading plant architecture
- Root crop
- High water use
- Seeding depth: ⅛ - ¼ inch
- Crude protein: 10%
- Forms arbuscular mycorrhizal associations
- Plants may bolt and flower starting in second year of growth
- Flowers may attract pollinators

Back to Cover Crop Chart

Cool Season Broadleaf

Balansa Clover
(*Trifolium michelianum* Savi *ssp. balansae* (Boiss.) Ponert)

- Cool season, broadleaf
- Annual, short-lived Perennial
- Legume (N-fixation)
- Upright, upright spreading, or prostrate plant architecture
  - multibranched rosette but prostrate when grazed
- Also called bigflower clover
- Moderate salinity tolerance
- Seeding depth: ¼ inch
- Crude protein: 15 - 20%
  - variable depending on plant stage @ harvest
- C:N ratio: 15
- Requires inoculation with root-nodule bacterium *Rhizobium sp.* at planting
- Flowers attract pollinators

◈ *Back to Cover Crop Chart*

Cool Season Legume

Berseem Clover

(*Trifolium alexandrinum* L.)

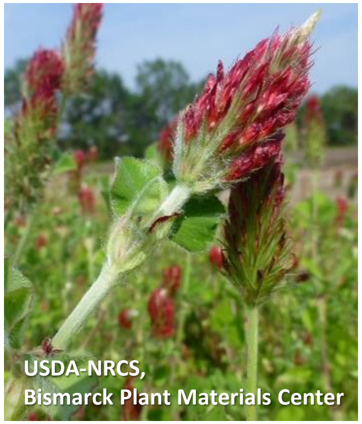
- Cool Season, broadleaf
- Annual
- Legume (N-fixation)
- Upright plant architecture
- Alternate name: Egyptian clover
- Low water use
- Fair salinity tolerance
- Seeding depth: ¼ – 1 inch
- Crude protein: 27-29%
- C:N ratio: 18 – 23
- Forms arbuscular mycorrhizal associations
- Flowers attract pollinators

◈ *Back to Cover Crop Chart*

Cool Season Legume

Crimson Clover
(*Trifolium incarnatum* L.)

- Cool season, broadleaf
- Annual
- Legume (N-fixation)
- Upright and spreading plant architecture
- Medium water use
- Poor salinity tolerance
- Seeding depth: ¼ - ½ inch
- Crude protein: 18%
- C:N ratio: 16 - 19
- Forms arbuscular mycorrhizal associations
- Flowers attract pollinators



◈ Back to Cover Crop Chart

Cool Season Legume

Red Clover
(*Trifolium pratense* L.)

- Cool Season, broadleaf
- Biennial, short-lived Perennial
- Legume (N-fixation)
- Upright plant architecture
- Two types:
  - medium, perennial or biennial; (2-3 cuts per season)
  - mammoth (1 cut per season)
- Medium water use
- Poor salinity tolerance
- Seeding depth: ¼ – ½ inch
- Crude protein: 15%
- C:N ratio: 15 – 23
- Forms arbuscular mycorrhizal associations
- Flowers attract pollinators

◈ Back to Cover Crop Chart

Cool Season Legume

White Clover
(*Trifolium repens* L.)

- Cool Season, broadleaf
- Perennial
- Legume (N-fixation)
- Upright and spreading or prostrate plant architecture
- 3 Types grouped by size:
  1. Large: tallest of the white clovers, upright architecture, high forage quality but less durable [var. Ladino]
  2. Intermediate: most common white clover, flowers earlier, and has a higher heat tolerance, upright architecture [var. Dutch white, New Zealand White]
  3. Small: lowest growing type, prostrate; survives grazing [var. Wild White]
- Medium water use
- Poor salinity tolerance
- Seeding depth: ¼ inch
- Crude protein: 24 – 30%
- C:N ratio: 13 – 23
- Forms arbuscular mycorrhizal associations
- Flowers attract pollinators
- Aggressive growth in some regions or habitats; may displace desirable vegetation if not properly managed

Back to Cover Crop Chart

Cool Season Legume

Kura Clover
(*Trifolium ambiguum* M. Bieb.)

- Cool season, broadleaf
- Perennial
- Legume (N-fixation)
- Prostrate plant architecture
- Also called Caucasian, honey, and pellet clover
- Moderate water use
- Poor salinity tolerance
- Seeding depth: ¼ – ½ inch
- Crude protein: 23 – 25%
- Forms arbuscular mycorrhizal association
- Flowers attract pollinators

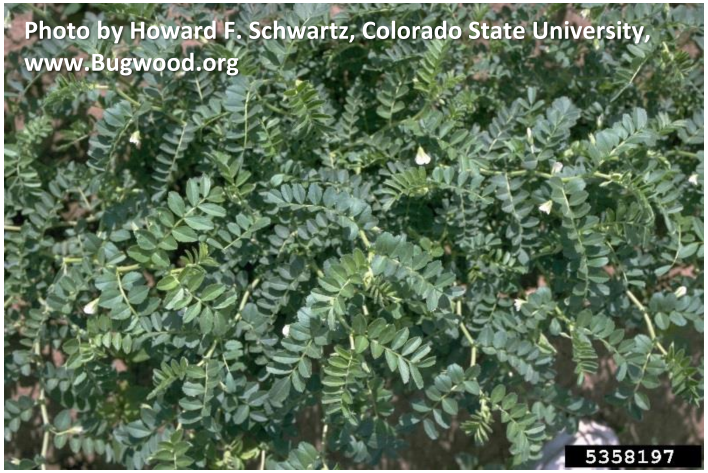
Back to Cover Crop Chart

Cool Season Legume

Chickpea
(*Cicer arietinum* L.)

- Cool Season, broadleaf
- Annual
- Legume (N-fixation)
- Two types
  - Desi
  - Kabuli
- Upright and spreading plant architecture
- Alternate name: garbanzo bean
- Low water use
- Poor salinity tolerance
- Seeding depth: 1 ½ – 2 inches
- Crude protein: straw 6%, grain 22%
- C:N ratio: leaf 10-15, stem 26-56, root 16-27
- Forms arbuscular mycorrhizal associations
- Flowers attract pollinators

◈ *View table for known crop sequence effects*



◈ *Back to Cover Crop Chart*

Cool Season Legume

Pea

(*Pisum satuvum arvense* L.)

- Cool Season, broadleaf
- Annual
- Legume (N fixation)
- Upright plant architecture (vine)
- Low water use
- Poor salinity tolerance
- Seeding depth: 1 – 3 inches
- Crude protein: hay 14%, grain 24%, silage 15%
- C:N ratio: leaf 13-25, stem 27-83, root 17-27
- Forms arbuscular mycorrhizal associations
- Flowers attract pollinators

◈ *View table for known crop sequence effects*

◈ *Back to Cover Crop Chart*

Cool Season Legume

Lentil
(*Lens culinaris* Medik.)

- Cool Season, broadleaf
- Annual
- Legume (N-fixation)
- Upright and spreading plant architecture
- Low water use
- Poor salinity tolerance
- Seeding depth: 1 – 1 ½ inch
- Crude protein: hay 14%, grain 28%, silage 15%
- C:N ratio: leaf 11-21, stem 25-49, root 22-30
- Forms arbuscular mycorrhizal associations
- Self-pollinated but flowers may attract pollinators

◈ *View table for known crop sequence effects*

◈ *Back to Cover Crop Chart*

Cool Season Legume

Lespedeza

- Cool Season, broadleaf
- Legume (N-fixation)
- Variable plant architecture
- Seeding depth: ¼ - ½ inch
- Forms arbuscular mycorrhizal associations
- Lespedeza species are considered useful for forage, wildlife habitat, and reducing erosion
- Native & Introduced species
  - Native (U.S.)
    - Roundhead lespedeza, *Lespedeza capitata* (Michx.)
  - Introduced
    - Common lespedeza, *Kummerowia striata* (Thunb.) Schindl.
    - Korean lespedeza, *Kummerowia stipulacea* (Maxim.) Makino
      - Annuals
    - Sericea lespedeza *Lespedeza cuneata* (Dum. Cours.) G. Don
      - Perennial
- *Introduces species are adapted for warmer climates but have the potential to become weed-like* (*and are considered noxious weeds in certain areas of the U.S.*)

Roundhead lespedeza, Photos by Chris Evans
Illinois Wildlife Action Plan
www.Bugwood.org

◈ *Back to Cover Crop Chart*

Cool Season Legume

Birdsfoot trefoil
(*Lotus corniculatus* L.)

- Cool Season, broadleaf
- Perennial, short lived
- Legume (N-fixation)
- Prostrate plant architecture
- Low to medium water use
- Fair salinity tolerance
- Seeding depth: ¼ – ½ inch
- Crude protein: hay 16 - 22%
- Forms arbuscular mycorrhizal associations
- Attracts pollinators

◈ Back to Cover Crop Chart

Cool Season Legume

Vetch
(*Vicia sp.*)

- Cool Season, broadleaf
- Annual, Biennial
- Legume (N-fixation)
- Prostrate plant architecture (vine)
- Common examples include hairy, purple, common, and smooth vetch
- Low to medium water use
- Poor salinity tolerance
- Seeding depth: 1 ½ – 2 ½ inches
- Crude protein: 13-20%
- C:N ratio: 10 – 19
- Forms arbuscular mycorrhizal associations
- Attracts pollinators

Hairy Vetch

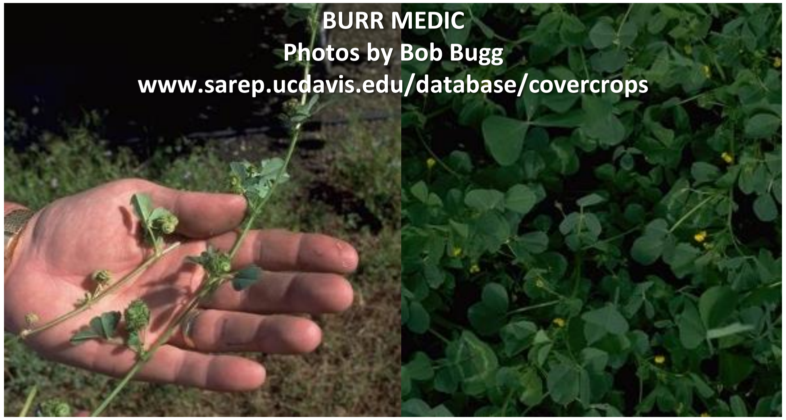
Common Vetch, Photos by Annie Young-Mathews, USDA-NRCS Corvallis Plant Materials Center

◈ *Back to Cover Crop Chart*

Cool Season Legume

Medic
(*Medicago* spp.)

- Cool Season, broadleaf
- Annual, Perennial
- Legume (N-fixation)
- Upright and spreading plant architecture
- Over 35 known medic species exist. Common examples include barrel, black, & burr.
- Low water use
- Poor to fair salinity tolerance
- Seeding depth: ¼ inch
- Crude protein: black medic 19-21%
- Forms arbuscular mycorrhizal associations
- Attracts pollinators



Back to Cover Crop Chart

Cool Season Legume

Lupin
(*Lupinus sp*. L.)

- Cool Season, broadleaf
- Annual
- Legume (N-fixation)
- Upright plant architecture
- Examples include blue, narrow-leaved, European yellow, white, Spanish, etc.
- Low water use
- Prefers acid soils
- Seeding depth: 1 – 2 inches
- Crude protein: silage 15%
- C:N ratio: leaf 12-30, stem 25-49
- Does not form arbuscular mycorrhizal associations
- Flowers attract pollinators

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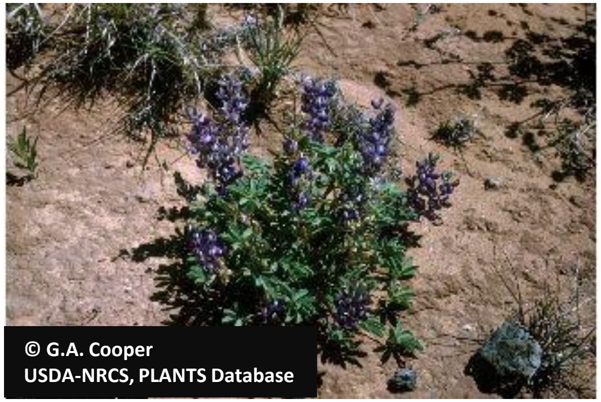
USDA-NRCS, PLANTS Database



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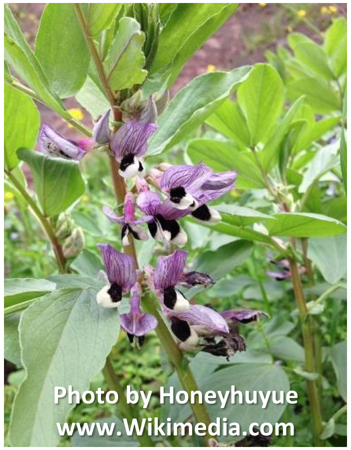
Photos by Bob Bugg
www.sarep.ucdavis.edu/database/covercrops

Back to Cover Crop Chart

Cool Season Legume

Faba Bean
(*Vicia faba* L.)

- Cool season, broadleaf
- Annual
- Legume (N-fixation)
- Upright plant architecture (vine)
- Alternate names: Bell bean, horse bean, Fava bean
- Medium water use; poor drought tolerance
- Moderate salinity tolerance (depending on variety)
- Seeding depth: 2-4 inches
- Crude protein: 17%
- Forms arbuscular mycorrhizal associations
- Flowers attract pollinators



◈ Back to Cover Crop Chart

Cool Season Legume

Sweetclover
(*Melilotus sp.* L)

- Cool Season, broadleaf
- Annual, Biennial
- Legume (N-fixation)
- Two types
  - yellow *Melilotus officinalis* L.
  - white *Melilotus alba* L.
- Upright plant architecture
- Moderate water use
- Fair salinity tolerance
- Seeding depth: ½ inch
- Crude protein: 11-18%
- C:N ratio: 12 – 23
- Forms arbuscular mycorrhizal associations
- Attracts pollinators

WHITE TYPE

YELLOW TYPE

◈ *Back to Cover Crop Chart*

Cool Season Legume

Alfalfa
(*Medicago sativa* L.)

- Cool Season, broadleaf
- Perennial
- Legume (N-fixation)
- Upright plant architecture
- Alternate name: lucerne
- High water use
- Poor salinity tolerance
- Seeding depth: ¼ – ½ inch
- Crude protein: 14-22%
- C:N ratio: 11 – 13
- Non-dormant cultivars can perform like an annual
- Forms arbuscular mycorrhizal associations
- Good at scavenging nitrogen from the soil
- Attracts pollinators


Photo by John Wright (Mississauga Ontario)
www.mccc.msu.edu


Photo by John Hilty (Urbana, IL)
www.mccc.msu.edu

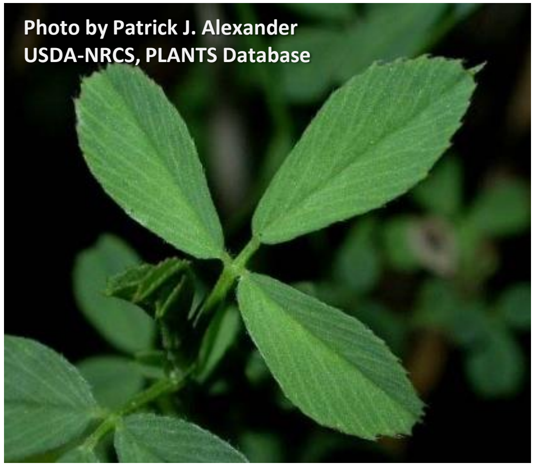


Photo by Patrick J. Alexander
USDA-NRCS, PLANTS Database

Back to Cover Crop Chart

Cool Season Legume

Sainfoin
(*Onobrychis viciifolia* Scop.)

- Cool Season, broadleaf
- Perennial
- Legume (N-fixation)
- Upright plant architecture
- Medium to high water use
- Fair to poor salinity tolerance
- Seeding depth: ¼ – ¾ inch
- Crude protein: 13-20%
- Forms arbuscular mycorrhizal associations
- Attracts pollinators

◈ Back to Cover Crop Chart

Cool Season Legume

Cowpea
(*Vigna unguiculata* L.)

- Warm Season, broadleaf
- Annual
- Legume (N-fixation)
- Upright and spreading plant architecture (vine)
- Alternate names: Southern pea, black-eye pea
- Low water use
- Fair salinity tolerance
- Seeding depth: ¾ – 1 inch
- Crude protein:
  - grain and leaves 19-30%
  - stems 13-17%
- C:N ratio: 18 – 22
- Forms arbuscular mycorrhizal associations
- Attracts pollinators

◈ Back to Cover Crop Chart

Warm Season Legume

Lablab
(*Lablab purpureus* (L.) Sweet)

- Warm Season, broadleaf
- Annual, Perennial
- Legume (N-fixation)
- Upright and spreading (vine) or prostrate plant architecture
  - Planting date determines growth habit
- Formerly called *Dolichos lablab* L.
- Alternate names: *Val* bean, , hyacinthbean, Indian butter bean, helmet bean, Egyptian kidney bean,
- Low water use
- Poor salinity tolerance
- Seeding depth: 1-4 inch
- Crude protein:
  - leaves 21-38%
  - seeds 20-28%
- C:N ratio: 17 (green manure/Brazil); 34 (North Carolina)
- Doesn't easily form arbuscular mycorrhizal associations

Back to Cover Crop Chart

Warm Season Legume

Fenugreek
(*Trigonella sp.* L.)

- Warm Season, broadleaf
- Annual, Perennial
- Legume (N-fixation)
- Two types:
  - cultivated [*T. corniculata*];
  - forage or sickle fruit [*T. foenum-graecum*]
- Upright plant architecture
- Alternate name: Greek hay
- Low water use
- Poor salinity tolerance
- Seeding depth: 1 – 2 inches
- Crude protein: 16 – 25%
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)
- Used as a forage, spice, and for health benefits*

  *contains nutraceuticals:

  1. steroidal sapogenin
  2. galactomannan
  3. isoleucine

Back to Cover Crop Chart

Warm Season Legume

Pigeonpea
(*Cajanus cajan* (L.) Millsp.)

- Warm season, broadleaf
- Annual, Perennial
- Legume (N-fixation)
- Upright and spreading plant architecture
- Alternate names: Angola pea, Congo pea, dhal, no-eye pea, gungo pea, and red gram
- Low water use
- Moderate to high salinity tolerance
- Seeding depth: 1 ½ – 4 inches
- Crude protein: 28-36%; leaf alone 10 – 15%
- C:N ratio: 20
- Forms arbuscular mycorrhizal associations
- Mostly self-pollinated

◈ Back to Cover Crop Chart

Warm Season Legume

Partridge Pea

(*Chamaecrista fasciculata* (Michx.) Greene var. *fasciculata* ; *Cassia fasciculata* Michx.; *Cassia chamaecrista* L.);

- Warm season, broadleaf
- Annual
- Legume (N-fixation)
- Upright plant architecture
- Alternate names: sleeping plant, prairie senna, large-flowered sensitive-pea, locust weed, dwarf cassia, golden cassia
- Low to moderate water use
- Seeding depth: ¼ ” – ¾ ” inch
- Forms arbuscular mycorrhizal associations
- Attracts pollinators, especially bees
- Used as a green manure, forage, or fiber crop
  - Forage is nutritious but also contains cathartic substance in fresh material or hay which can potentially be dangerous to cattle. Check before feeding to livestock
- Attractive to wildlife, particularly several game bird species
- Potential for phytoremediation (tolerance to cadmium)

Photos by Alan Shadow
USDA-NRCS,
East Texas Plant Materials Center

◈ *Back to Cover Crop Chart*

Warm Season Legume

Sunnhemp
(*Crotalaria juncea* L.)

- Warm season, broadleaf
- Annual
- Legume (N-fixation)
- Upright plant architecture
- Low to moderate water use
- Poor salinity tolerance
- Seeding depth: ½" – 2 ½" inches
- 'Good' N-fixation capacity
- Forms arbuscular mycorrhizal associations
- Self pollinates (wind) as well as cross-pollinates (insects/birds)
- Rated 'Excellent' at controlling soil nematodes
- Used as a green manure, forage*, or fiber crop

  * Certain cultivars contain alkaloids which are poisonous to livestock; check before feeding to animals

'Tropic Sun' Sunn hemp
Georgia Plant Materials Program

Back to Cover Crop Chart

Warm Season Legume

Cluster bean
(*Cyamopsis tetragonoloba* L. Taub)

- Warm Season, broadleaf
- Annual
- Legume (N-fixation)
- Upright and spreading plant architecture
- Alternate names: Guar, guar bean, c
- Low water use
- Good salinity tolerance
- Seeding depth: 1 – 1 ½ inch
- Crude protein:
  - Straw 7 – 10%
- C:N ratio: 65 (residue)
- Forms arbuscular mycorrhizal associations
- Self-pollinated
- Can be used as a green manure or forage
- Plant extract (gum) has industrial uses

◈ *Back to Cover Crop Chart*

Warm Season Legume

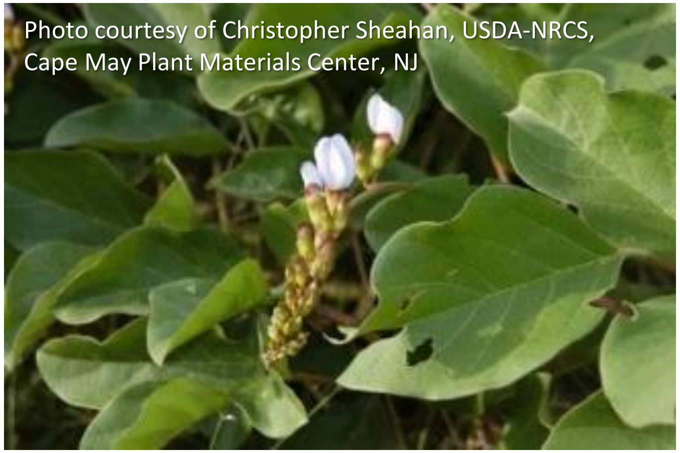
Jack bean
(*Canavalia ensiformis* (L.) DC.)

- Warm Season, broadleaf
- Annual, Perennial
- Legume (N-fixation)
- Upright and spreading plant architecture (vine)
- Alternate names: wonderbean, sword-bean,
- coffee bean, giant stock-bean, horse-bean
- Low water use
- Fair salinity tolerance
- Seeding depth: 1 – 3 inches
- Crude protein: ≈ 30%
- C:N ratio: 21 (green manure/Brazil)

* **Special Note:**

HUMAN: Although young pods/green seeds can be eaten, mature beans can contain harmful compounds and must be cooked prior to eating

LIVESTOCK: Because of the potential toxic compounds in the seed, meal must be heat-treated to denature the enzymes or limited to 30% of the ration



Back to Cover Crop Chart

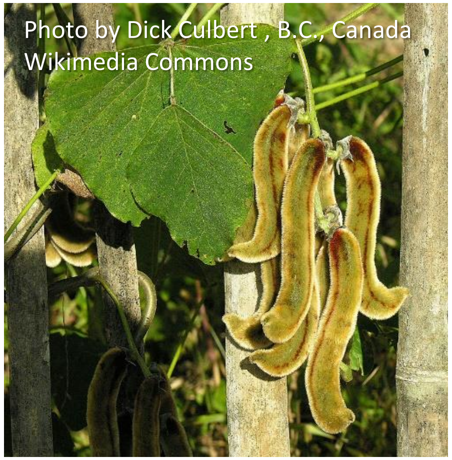
Velvet bean

(*Mucuna pruriens* (L.) DC.)

- Warm Season, broadleaf
- Annual, Biennial
- Legume (N-fixation)
- Upright and spreading plant architecture (vine)
- Alternate names: Itchy bean, buffalobean, bengal bean, devil bean, cowitch
- Low water use
- Seeding depth: 1-3 inches*
  - * In some circumstances, can be planted as deep as 4 inches
- Crude protein:
  - leaves 11-23%
  - grain 20-35%
- C:N ratio: 29
- Does not form arbuscular mycorrhizal associations
- Moderate at accumulating nitrogen

<u>**Special Note:**</u>

- * Seed contains an amino-acid (L-dopa) that may be used for medicinal purposes. However, if untreated it can be toxic to humans or <u>*non-ruminant*</u> animals
- * Tiny hairs on mature pods are a skin irritant. To avoid, terminate plant before seed production.



◈ *Back to Cover Crop Chart*

Warm Season Legume

Mung bean
(*Vigna radiata* L.)

- Warm Season, broadleaf
- Annual
- Legume (N-fixation)
- Upright and spreading plant architecture
- Low to medium water use
- Poor salinity tolerance
- Seeding depth: 1 ½ – 3 inches
- Crude protein: 16-23%
- C:N ratio: 10 – 15
- Forms arbuscular mycorrhizal associations
- Self-pollinated

◈ Back to Cover Crop Chart

Soybean
(*Glycine max* (L.) Merr.)

- Warm Season, broadleaf
- Annual
- Legume (N-fixation)
- Upright and spreading plant architecture
- Medium water use
- Poor salinity tolerance
- Seeding depth: 1 – 2 inches
- Crude protein: hay 17%, grain 42%
- C:N ratio: leaf 14, stem 39, root 34
- Forms arbuscular mycorrhizal associations
- Self-pollinated but flowers may attract pollinators

◈ *View table for known crop sequence effects*

◈ *Back to Cover Crop Chart*

Peanut

(Annual - *Arachis hypogaea* L.; Perennial – *Arachis glabrata* L.)

- Warm season, broadleaf
- Annual, Perennial
- Legume (N-fixation)
- Upright and spreading (annual) or prostrate (perennial) plant architecture
- Alternate name: Groundnut
- High water use
- Poor salinity tolerance
- Seeding depth: 1 – 4 inches

  **Perennial peanuts are planted using rhizomes only*
- Crude Protein: 13 – 20%
- Forms arbuscular mycorrhizal associations
- Mainly self-pollinate (wind); small % cross-pollinate
- Rated ‘Efficient’ at scavenging P & K from soil
- Perennial varieties used as cattle forage

Annual Peanut - *Arachis hypogaea*

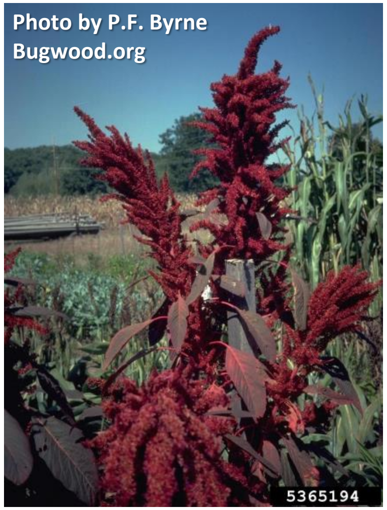
Perennial Peanut - *Arachis glabrata*

Back to Cover Crop Chart

Warm Season Legume

Amaranth
(*Amaranthus sp.*)

- Warm Season, broadleaf
- Annual
- Upright plant architecture
- Over 50 species; some exhibiting glyphosate resistance
- Low water use
- Tolerant of heat and drought
- Seeding depth: ½ – 2 inches
- Crude protein: ≈14%
- Does not form arbuscular mycorrhizal associations
- Self-pollinated (wind)
- Flowers may attract pollinators



◈ Back to Cover Crop Chart

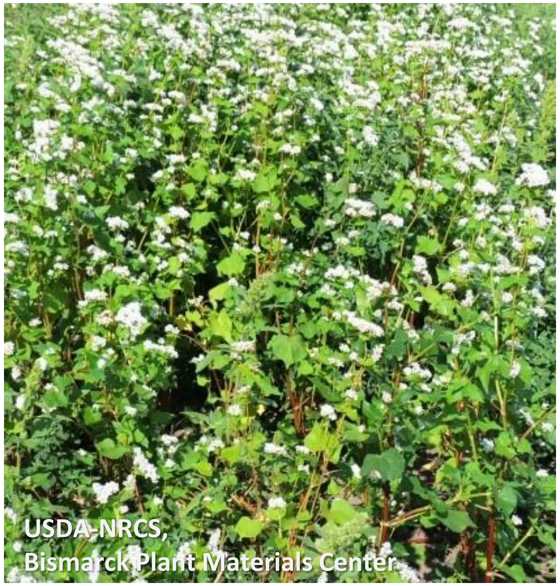
Warm Season Broadleaf

Buckwheat

(*Fagopyrum esculentum* Moench; *Fagopyrum sagittatum* Gilib)

- Cool Season, broadleaf
- Warm season growth characteristics
- Annual
- Upright plant architecture
- Medium water use
- Poor salinity tolerance
- Enhances soil P availability
- Seeding depth: ½ inch
- Crude protein: straw 5%, grain 13%
- C:N ratio: leaf 8-10, stem 12-32, root 28-47
- Does not form arbuscular mycorrhizal associations
- Attracts pollinators

◈ *View table for known crop sequence effects*



◈ *Back to Cover Crop Chart*

Warm Season Broadleaf

Quinoa
(*Chenopodium quinoa* Willd.)

- Warm season, broadleaf
- Annual
- Upright plant architecture
- Moderate water use
- Good salinity tolerance
- Seeding depth: ½ - 1 inch
- Crude protein: 14%
- C:N ratio: 14-25
- Does not form arbuscular mycorrhizal associations
- Self pollinates (wind); up to 15% may cross-pollinate
- Not susceptible to cereal diseases; slightly vulnerable to soil nematodes
- No registered herbicides for quinoa at this time

◈ Back to Cover Crop Chart

Warm Season Broadleaf

Chicory
(*Cichorium intybus* L.)

- Warm Season, broadleaf
- Perennial
- Upright and spreading plant architecture (vine)
- Alternate names: French endive, succory
- Medium water use
- Seeding depth: ⅛ – ½ inch
- Crude protein: 10-32%
- Forms arbuscular mycorrhizal associations
- Attracts pollinators
- Rated 'very good' at scavenging nitrogen from the soil
- Highly invasive

◈ Back to Cover Crop Chart

Warm Season Broadleaf

Cucurbita sp. [Family]

- This is a broad grouping including squash, gourd, cucumber, melon, and pumpkin
- Warm Season, broadleaf
- Annual
- Prostrate plant architecture (vine)
- Seeding depth: ½ – 1 inch
- Forms arbuscular mycorrhizal associations
- Attracts pollinators
- Can be used for weed suppression as a ‘smother crop’

Photos by Howard F. Schwartz
Colorado State University,
www.Bugwood.org

Back to Cover Crop Chart

Warm Season Broadleaf

Safflower
(*Carthamus tinctorius* L.)

- Warm Season, broadleaf
- Annual
- Upright plant architecture
- High water use
- Good salinity tolerance
- Deep rooted
- Effective at 'mining' mobile nutrients deep in the soil profile
- Seeding depth: 1 – 1 ½ inch
- Crude protein: hay 10-13%, grain 18%
- C:N ratio: leaf 21, stem 56, root 73
- Forms arbuscular mycorrhizal associations
- Flowers attract pollinators

◈ *View table for known crop sequence effects*

◈ *Back to Cover Crop Chart*

Warm Season Broadleaf

Sunflower
(*Helianthus annuus* L.)

- C3 plant with warm season growth characteristics, broadleaf
- Annual
- Upright plant architecture
- High water use
- Fair salinity tolerance
- Deep rooted
- Effective at 'mining' mobile nutrients deep in the soil profile
- Seeding depth: 1 – 3 ½ inches
- Crude protein: silage 11-12%, grain 20-28%
- C:N ratio: leaf 11-14, stem 41-46, root 50-68, flower 14-19
- Forms arbuscular mycorrhizal associations
- Flowers attract pollinators

◈ *View table for known crop sequence effects*

◈ *Back to Cover Crop Chart*

Warm Season Broadleaf

Browntop Millet
(*Urochloa ramosa* (L.) Nguyen)

- Warm Season, grass
- Annual, Perennial
- Upright plant architecture
- Alternate name: dixie signalgrass
- Moderate water use
- Seeding depth: ½ - 1 inch
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)

<u>Special Notes:</u>

* *If grown under dry or cold conditions, plant has potential to accumulate toxic levels of nitrate. Test before feeding to livestock.*

* *Regarded as a weedy species in some areas of the United States.*

* *Can be used for soil remediation of lead and zinc contamination.*

Photo Courtesy of Jeff McMillian, Hosted by the USDA-NRCS, PLANTS Database

Photo Courtesy of Jeff McMillian, Hosted by the USDA-NRCS, PLANTS Database

◈ Back to Cover Crop Chart

Warm Season Grass

Foxtail Millet
(*Setaria italica* L.)

- Warm Season, grass
- Annual
- Upright plant architecture
- Alternate name: Italian millet
- Low water use
- Poor salinity tolerance
- Seeding depth: 1 inch
- Crude protein: hay 15%
- C:N ratio: 44
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)

◈ *Back to Cover Crop Chart*

Warm Season Grass

Pearl Millet
(*Pennisetum glaucum* L.)

- Warm Season, grass
- Annual
- Upright plant architecture
- Low water use
- Poor salinity tolerance
- Seeding depth: ½ – 1 inch
- Crude protein: hay 13%
- C:N ratio: 50
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)

◈ *View table for known crop sequence effects*

◈ *Back to Cover Crop Chart*

Warm Season Grass

Proso Millet
(*Panicum milaceum* L.)

- Warm Season, grass
- Annual
- Upright plant architecture
- Medium water use
- Poor salinity tolerance
- Seeding depth: 1 inch
- Crude protein: hay 10%
- C:N ratio: leaf 12-16, stem 12-35, root 17-26
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)

◈ *View table for known crop sequence effects*

◈ *Back to Cover Crop Chart*

Grain Sorghum
(*Sorghum bicolor* L. Moench)

- Warm Season, grass
- Annual
- Upright plant architecture
- Alternate name: Sorghum-sudan grass

  **Grain sorghum and sudan grass were formerly separate species that have been combined. They are separated in the chart due to different plant attributes.*
- Medium water use
- Fair salinity tolerance
- Seeding depth: 1 – 2 inches
- Crude protein: hay 7%, stover 5%, grain 10%
- C:N ratio: leaf 11-17, stem 10-27, root 22-30
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)
- Stress conditions that limit growth (e.g., drought, frost) can contribute to prussic acid accumulation in leaves

◈ ***View table for known crop sequence effects***

◈ *Back to Cover Crop Chart*

Warm Season Grass

Sudan grass
(*Sorghum bicolor* L. Moench)

- Warm Season, grass
- Annual
- Upright plant architecture
- Alternate name: Sorghum-sudan grass

  **Grain sorghum and sudan grass were formerly separate species that have been combined. They are separated in the chart due to different plant attributes.*
- Medium water use
- Fair salinity tolerance
- Seeding depth: 1 inch
- Crude protein: hay 7-11%, silage 6-17%
- C:N ratio: 48 - 63
- Forms arbuscular mycorrhizal associations
- Rated 'Excellent' at nutrient scavenging
- Self pollinator (wind)
- Stress conditions that limit growth (e.g., drought, frost) can contribute to prussic acid accumulation in leaves
- Known alleopathic effects on annual ryegrass

◈ *Back to Cover Crop Chart*

Warm Season Grass

Teff
(*Eragrostis tef* (Zuccagni) Trotter)

- Warm Season, grass
- Annual
- Upright plant architecture
- Medium water use
- Poor salinity tolerance
- Seeding depth: ½ inch
- Crude protein: 10-18%
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)

Back to Cover Crop Chart

Warm Season Grass

Corn
(*Zea mays* L.)

- Warm Season, grass
- Annual
- Upright plant architecture
- High water use
- Poor salinity tolerance
- Seeding depth: 1 – 2 inches
- Crude protein: grain 9-10%, stover 5%, silage 8-11%
- C:N ratio: stalk 11-65, leaf 13-20, root 20-49
- Forms arbuscular mycorrhizal associations
- Self pollinator (wind)

◈ *View table for known crop sequence effects*

◈ *Back to Cover Crop Chart*

Warm Season Grass

Exhibit 6-5: A Comprehensive Guide to Cover Crop Species Used in the Northeast United States

United States Department of Agriculture

NRCS Natural Resources Conservation Service **Plant Materials Program**

Big Flats Plant Materials Center
3266-A State Route 352, Corning, NY 14830 • P 607.562.8404 • F 607.562.8516 • http://Plant-materials.nrcs.usda.gov

A Comprehensive Guide to Cover Crop Species Used in the Northeast United States

Prepared by: Shawnna Clark

The following sections include 22 species that are used throughout the Northeast as cover crops. After each section and at the end of this review, the sources of information used are listed. Each reference will provide a more in depth description for the values given. This is a guide, based on literature from books, journal articles, and web sites, and will differ based on location and annual climatic differences.

Annual Ryegrass or Italian Ryegrass *(Lolium multiflorum)*

~annual, cool season, winter or spring annual (bunchgrass)

Planting Dates:	**Source**
mid-summer-early fall (@ least 40d before frost)	11
Mar 15- May 1 or July 20- Sept 15	3, 42, 76
Seeding Rates (lbs/A):	
20-30 bc; 10-20 dr; 8-15 mix	3, 11
12-15 mix; 20-25	42
(depends on use)	
Seeding Depth (in):	
.25-.5	3,11
Flowering Dates:	
June-Aug	71
Root System:	
shallow, dense fibrous	3, 91, 71
Winter-Kill Temp:	
will over winter	3, 71
Competition with weeds	
excellent	11, 3, 71
Total Dry Matter Biomass (lbs/A)	
2600 (OSU Extension)	90
3300-4000 (seeded early spring or late summer in ME)	20
1840 (Nov planted, seeded in March)	71
4000-8000 (multi-cut system, over full season with high moisture and fertility)	11
1300-2000 (fall seeded)	91
Root Biomass (lbs/A):	
778 (Nov planted, harvest in March	71

Percent N (%):	**Source**
2.1-2.4	90, 71
ave 1.5 (fall seeded)	91
1.37	71
C:N Ratio:	
20:1-31:1	49,71
lbs/bu:	
24-26	
seeds/lb:	
217000-230000	71,77, 42, 49
Re-seeding Characteristics:	
very high, if not killed	11, 3, 71
Mix with:	
legumes, grasses	11
Soils:	
wide range, best in loam	3
5-8 pH	71
Shade Tolerance:	
intolerant	71
N (lbs/A): (high N user)	
43 (takeup) (if survives winter, CA Study from UCSARP)	11,71
62 (recycled)	90
~60 by mid-May following corn in MD study	11

Additional Comments:

~good for erosion control, improving aggregate stability
~can tolerate some flooding
~uses of a lot of water and N

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Austrian Winter Pea *(Pisum sativum)*

~summer annual legume (north)

Planting Dates:	**Source**
early spring as early as possible	11, 20
Mar-Apr or Sept-Oct	2
Aug or spring	66
Seeding Rates (lbs/A):	
60-90 dr	91
30-40; 20-30 mix	2, 77
140	3
100-220	20
Seeding Depth (in):	
.25-2	2, 51, 71
Inoculants:	
Rhizobium leguminosarum biovar viceae	77
Flowering Dates:	
32-55 d after seeding	71
Canopy Cover:	
26-36" fall	11
Root System:	
Shallow fibrous	66, 71
Winter-Kill Temp:	
will winter kill, but generally winter hardy (10 F)	11,71
sustained below 18 F	11
Will not overwinter N of MD	66
Competition with weeds:	
high	11
Total Dry Matter Biomass (lbs/A)	
4000 (aboveground, in North East)	41, 67
5100-6200 (ME seeded early spring))	20, 90
5000 (planted in spring) (North East)	11, 41
3000 (NY)	30

Root Biomass (lbs/A):	**Source**
350-1000	88
Percent N:	
2.6	90
3-4	71
N (lbs/A) (producing):	
170-190 (PA)	66
90-150 (depending on incorporation)	11
119 (Southern Tier NY)	30
ave 99	26
50-150 (PA)	51
C:N Ratio:	
9:1-11:1	26
17:1	90
lbs/bu:	
60	2
seeds/lb:	
18000	76
Re-seeding Characteristics:	
does not re-seed well	32
Mix with:	
cereals, brassicas, and other legumes	66, 71
Soils:	
4.2-8.3 pH	71
well limed, well drained clay or heavy	
Shade Tolerance:	
Semi-tolerant	11
Cost ($/lb)	
.60-1.20	11

Additional Comments:

~decomposes fast (low C:N ratio)

~reduces soil erosion, and supplies N to soil

~intolerant to salinity, drought, or water-logged soils

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Barley *(Hordeum vulgare)*

~spring, cool season annual, cereal grass

Planting Dates:	**Source**
Apr-May or Aug-Oct	2, 64
spring or summer	33, 43
spring	11, 20, 42
Sept 10-Sept 30	51
Seeding Rates (lbs/A):	
80-120 or 60-90 mix (bc)	2, 20
50-100 dr; 80-125 bc; 25-50 mix (spring)	11
50-125	43
72-96	42
90-120	64
Seeding Depth (in):	
.75-2	2, 43, 51, 11
Flowering Dates:	
mid-late summer	71
Root System:	
fibrous	11
Winter-Kill Temp:	
17.6 F	71
Competition with weeds:	
excellent	43, 71
Total Dry Matter Biomass (lbs/A):	
4500 (aboveground, killed end of Apr)	51
2570 (cut May 9 PA, seeded in fall)	92
3000-10000 (aboveground, grown until full bloom, SE US)	43
ave 8800 (spring seeded in ME)	20

Percent N:	**Source**
3.5 (PA Rodale)	92
1.2	71
N (lbs/A):	
38 (PA, Rodale)	92
45-50 (killed end of Apr)	51
62 (top N) (seeded fall; killed in May)	26, 29
C:N Ratio:	
20:1	71
medium	78
lbs/bu:	
48	2, 51
seeds/lb:	
13500-14000	2, 42, 51
Re-seeding Characteristics:	
does not re-seed well	71
Mix with:	
annual legumes, other small grains	11
Soils:	
5-8.5 pH	78
light soils	11
Shade Tolerance:	
intolerant	78
Cost $/lb:	
.17-.37	11

Additional Comments:

~drought tolerant, high salt tolerance; quick growing, reduces soil erosion

~does not tolerate wet soils, low fertile soils, good salinity tolerance

~scavenger of excess nutrients and adds OM

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Brown Mustard *(Brassica juncea)*

~annual cool season forb

Planting Dates:	**Source**
Apr-May 15 (summer cover crop)	48
mid July-Aug (after cash crop)	3
mid May-June	11
spring (less in MI) or summer-fall (better)	33, 11
Seeding Rates (lbs/A):	
10-12 dr; 10-15 bc	71
5-12 dr; 10-15bc	3, 11
6-8	48, 33
Seeding Depth (in):	
.5-1.5	3, 48
Flowering Dates:	
Mid to late May	3
4-6 wks after planting	3, 71
Root System:	
taproot	59, 71
Winter-Kill Temp:	
17-25 F	11, 71, 78
Competition with weeds:	
allelopathic; very high	3, 30, 71
Total Dry Matter Biomass (lbs/A):	
8500 (Salinas Valley, CA)	11
Root Biomass (lbs/A):	
700 lbs/A (East Lansing MI)	61

	Source
N content (lbs/A):	
328 on high residual N veg ground	11
C:N Ratio:	
15:1; low	71, 78
lbs/bu:	
18	78
seeds/lb:	
200000-230000	48,78
Re-seeding Characteristics:	
high, do not let go to seed	3
Mix with:	
cereals, vetch	71
Soils:	
loam to heavy soils	59
pH 5.5-7.5	11
Shade Tolerance:	
intolerant	78
Cost /lb ($):	
1.50-3.00	11
66/A	11

Additional Comments:

~do NOT use in rotations with other Brassicas

~good for weed suppression, nematode and soil fungal control, breaking up compacted soils, organic matter

~flowers will attract honey bees

~breaks down fast

~cannot tolerate flooding

~do not over-seed, too much will infect leaves with diseases

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Rapeseed or Canola *(Brassica napus)*

~annual spring forb (winter-types are Brassica rapa)

~canola is rapeseed that has been bred to have low conc. of glucosinates and erucic acid in the seed

Planting Dates:	**Source**
6 wks prior to killing frost	59, 87
Apr 1- May 1 or Aug 1- Sept 1	2, 71, 76
spring around corn time planting	59
Aug	3, 84
Seeding Rates (lbs/A):	
4-12	51
5-10 dr; 8-14 bc	3, 11, 87
5-8 dr; 4-6 mix	2, 72
Seeding Depth (in):	
.25-1	3, 71
Flowering Dates:	
early spring	76
Canopy Cover:	
80% or more	11
Root System:	
deep taproot	11
Winter-Kill Temp:	
low temps ~10 F (winter-type cultivars)	11
In ME will winter kill	
Competition with weeds:	
high (rapeseed)	59, 71
Total Dry Matter Biomass (lbs/A)	
1500-2500 lbs/A (ND)	48
4000-6700 lbs/A (seeded mid-June, harvested Sept)	3, 73
6200-8000 lbs/A 90d after seeding	30, 59
2500-3500 (MD)	84, 87

Root Biomass (lbs/A)	**Source**
4000-7600 (MA; MD)	72, 82
1000 (MD sampled in fall)	94
Percent N:	
low	78
Biomass of N (lbs/A)(accumulate):	
120 lbs/A	11
C:N Ratio:	
20:1-30:1 shoots: 10:1-20:1 roots	11
lbs/bu:	
50	48
seeds/lb:	
140000-157000	48, 49, 76
Re-seeding Characteristics:	
high in proper conditions	59, 76
Mix with:	
small grains	59
Soils:	
pH above 6	87
coarse textured	84
Shade Tolerance:	
intolerant	11
Cost/lb ($)	
1.00-2.00; 80-100 $/A	11, 30

Additional Comments:

~supplies organic matter, weeds suppression, enhances soil properties, captures nitrate, erosion control, use as forage

~does not perform well on poorly drained soils

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Turnips *(Brassica rapa)*

~annual, biennial cool season forb

Planting Dates:	Source
Aug-fall	3
spring-fall	87
~4wks prior to ave date of first 28 F	11
Seeding Rates (lbs/A):	
4-7 dr; 10-12 bc	3, 11
1.5-2	87
2-8 alone; 1-2 mix	
Seeding Depth (in):	
.25-.75	3
Flowering Dates:	
late spring	78
Root System:	
taproot	11
Winter-Kill Temp:	
yes- below 25 F	11
Competition with weeds:	
high	3, 11, 49
Total Dry Matter Biomass (lbs/A):	
4000-6700 lbs/A (seeded mid-June, harvested Sept, WI)	73
6200-8000 in PA	59
Root Biomass (lbs/A):	

C:N Ratio:	Source
20-30 shoots; 10-20 roots	11
lbs/bu:	
55	
seeds/lb:	
140000-220000	49, 77, 78
Re-seeding Characteristics:	
Will re-seed	
Mix with:	
cereals, vetch	11
Soils:	
5-8 pH	78
5.5-8.5	11
Shade Tolerance:	
intolerant	
Cost/lb ($):	
1.00-2.00	11

Additional Comments:

~grows very fast and alleviates soil compaction
~low drought tolerance and a high fertility requirement

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Buckwheat (*Fagopyrum esculentum*)

~annual warm season forb/green manure

Planting Dates:	**Source**
12 wks prior to 1st frost	51, 48, 59, 71
June 15-Aug 15	33, 43, 64, 73
June	55
June-July	2,3
Seeding Rates (lbs/A):	73
30-50	2,3, 71
50dr; 70 bc	55
36-72	32
60-80	43, 51, 48, 64
50-60 dr; up to 96 bc	11
Seeding Depth (in):	
.5-1	2, 3, 43, 51
1-2	48, 55
Flowering Dates:	
mid summer	78
4-6 wks after seeding	17, 64, 71
Root System:	48
fine, extensive, fibrous, superficial	14, 64, 59, 71
Winter-Kill Temp:	
frost intolerant	71
Competition with weeds:	
it sown well, excellent	71
Canopy Cover:	55
dense	
Total Dry Matter Biomass (lbs/A):	
2000-3000 (NC)	14,17,43
1200-1800 lbs/A (PA, WI)	51, 55
4000-6000 (6-8 weeks after seeding)	11
Root Biomass (lbs/A):	

Percent N:	**Source**
1.25	17, 71
N (lbs/A):	
43 aboveground (NC)	14
C:N Ratio:	
34:1 (NC)	14
lbs/bu:	
48-52	2
seeds/lb:	
15000-20000	2, 78
Re-seeding Characteristics:	
yes, incorporate after 1 week flowering	14
~mow at 40 days	
Mix with:	
cowpeas, sesbina	71
Soils:	
most, poor on heavy limestone	51
avoid wet soils	
Shade Tolerance:	
intolerant	71
Cost ($/A):	
30	14
30-32	11
11.00-12.50/bu	66

Additional Comments:

~use as smother crop, bee pasture, weed suppression, nutrient scavenging
~absorbs Ca, P

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Camelina sativa

~annual, summer oilseed crop or winter annual in warmer climates

Planting Dates:	Source
spring when soil temp is at least 38-40 F	87
Can be frost seeded in late Nov-Dec	96
Seeding Rates (lbs/A):	
3-5	87
Seeding Depth (in):	
.25-.50	
Flowering Dates:	
42-45 days from planting	96
Root System:	
Tap root	
Winter-Kill Temp:	
12	87
Competition with weeds	
good	87
Total Dry Matter Biomass (lbs/A):	
1800-2000 lbs of seed/A (sowed mid-march-april, harvested sept)	87
1000-1100 at 45 degrees N latitiude	96

Percent N:	Source
2.42-2.73 (shoots)	Xue Pan, Nova Scotia University
C:N Ratio:	
High; due to its high cellulose content	
lbs/bu:	
50	
Institute of Agricultural and Trade Policy (http://www.iatp.org/iatp/publications.cfm?accountID=258&refID=97279)	
seeds/lb:	
225000-550000	87
Re-seeding Characteristics:	
Will produce viable seeds	96
Mix with:	
Legumes, spring wheat	87
Soils:	
Marginal lands	96
Shade Tolerance:	
Low-medium	
Cost:	
$4.00/ lb	Ernst
$45-$65/A (reference directly below0	
Institute of Agricultural and Trade Policy (http://www.iatp.org/iatp/publications.cfm?accountID=258&refID=97279)	

Additional Comments:

~tolerates drought stress
~Germinates and emerges in early spring before cereal grains.

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Cereal Rye *(Secale cereale)*

~winter annual cereal grain (mainly for NE cv. 'Aroostook")

Planting Dates:	**Source**
Aug 1- Sept 30	75
late summer-fall	74
Late Aug-early Oct	64
2wks before kill frost/ 4wks after	18
Seeding Rates (lbs/A):	
90-120 (winter rye)	42
100-140; 50-60 mix	64
60-120 dr; 90-120 broadcast	3, 11
60-200	59
112-168	18
Seeding Depth (in):	
.75-2	55
Flowering Dates:	
early spring (Apr-May)	71, 78
Root System:	
extensive, fibrous	11, 71
Winter-Kill Temp:	
will over winter	11
Competition with weeds:	
high	11, 71
Total Dry Matter Biomass (lbs/A):	
2800-4000 (in ME seeded late summer/fall)	11, 90, 20, 79
6000-7000 (planted Sept, harvested mid-May WI)	29, 73
4000 lbs/A aboveground	18
1600 lbs/A top	51
Root Biomass (lbs/A):	
848 lbs/A 5 months after seeding	71
600 lbs/A	18, 89

Percent N:	**Source**
.89-1	90, 71
N (lbs/A):	
40-45 lbs/A N uptake	26
171 lbs/A of N in roots	71
313 lbs of N/A in tissue	71
80 accumulated(by May 19 plowdown in NY)	74
C:N Ratio:	
40:1 monoculture	71
25:1 biculture	71
40:1 @ boot; 14:1 young	51
48:1-50:1	14, 90
35:1	74
lbs/bu:	
56	
seeds/lb:	
15000-18000	42, 48, 55 ,77 ,78
Re-seeding Characteristics:	
high if let go to seed	71
Mix with:	
legumes, other grasses, vetches, brassica	11, 71
Soils:	
4.5-8.2 pH range	71, 78
low fertile	55
light loams, sandy	11
Shade Tolerance:	
intolerant	
Cost/lb ($);	
.18-50	11
6.00-8.0/ bu	66

Additional Comments:

~prevents soil erosion, quick forage for grazing
~excellent scavenger for N and K, adds organic matter, suppresses weeds

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Forage Radish *(Raphanus sativus)*; Oilseed Radish

~Annual cool season Forb

Planting Dates:	**Source**
late summer-fall	3, 43
4-10 wks before killing frost in fall	59
Seeding Rates (lbs/A):	
7-10 dr; 10-13 bc	3,43
Seeding Depth (in):	
.25-.5	10, 43
Flowering Dates:	
50-60days	
(Lesley Campbell, and Allison Snow OSU)	
Root System:	
Taproot (8-14 inches)	3, 59
Winter-Kill Temp:	
20-25 F (Dec-Jan)	82, 11
Competition with weeds:	
yes; allelopathic	87
Total Dry Matter Biomass (lbs/A):	
3000 lbs/A for late Aug planting	87
3600 lbs/A aboveground	46, 81, 82
3000lbs/A in 60d	10
6500	90
Canopy Cover:	
within 1-4 months closed canopy (depends on growing conditions)	71
Root Biomass (lbs/A):	
3000 (MD, sampled at max growth in fall)	94
as high as 3700 (belowground)	11

Percent N:	**Source**
2.67	36
2.11	90
N (lbs/A):	
140(in MI and in MD)-200 lbs/A of N released in early spring	11, 71, 94
170 (in MD)	
184 N recycling	90
C:N Ratio:	
13:1	36, 71
19.5	90
lbs/bu:	
50	48
seeds/lb:	
140000	48, 77
Re-seeding Characteristics:	11
Will re-seed in warmer climates	
Mix with:	
other brassicas, mustards, small grains or crimson clover	11
Soils:	
well drained, pH 5.5-8.5	10
Shade Tolerance:	
intolerant	
Cost/lb ($):	
1.5-2.50	11
Cultivars:	
Groundhog Forage Radish	

Additional Comments:

~quick forage for grazing, high N,P, S, Ca, B content

~significant amounts of N may be lost if next crop not planted in time to recapture N

~not recommended for planting in either corn or soybeans

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Hairy Vetch *(Vicia villosa)*

~winter annual legume

Planting Dates:	**Source**
Aug 1-Sept	2, 3, 38, 51, 64, 66, 71, 75, 77, 87
sow by Oct 15	71
@ least 30-40d before killing frost	59
Inoculants:	
Type "C" Nitragen	71
Seeding Rates (lbs/A):	
25-40 dr	2
15-20 dr; 25-30 bc	3, 11
20-40 dr	66
Seeding Depth (in):	
.25-1.5	2, 51, 71, 77,87
Flowering Dates:	
May-July	59, 71, 78
mid July-Aug	
Root System:	
taproot	71
Winter-Kill Temp:	
will survive winter if planted 30-40d before frost	66
Competition with weeds	
high, once established	2
Total Dry Matter Biomass (lbs/A):	
2000-5000	8, 29, 90
4000 aboveground (PA, drilled at end of Sept)	66
4300-7000 lbs/A	71
3000-4000 lbs/A (normal, fall seeded in ME)	20, 30, 51, 59, 67

Percent N:	**Source**
2.5-4	90, 71, 87
3.76	8
N (lbs/A): (most occurs in May)	3
80-160 lbs/A provide	51
averaging 110 lbs N/A contribution (planted by mid-Sept, N available by mid-May)	11, 59, 67
ave 110-115 (N content)	26, 30, 60
140-150	38
71-85 (NC Coastal Plain)	80
C:N Ratio:	
10:1-15:1	26
8:1-15:1	11
11:1	71
lbs/bu:	
60	2, 51
seeds/lb	
16000-20000	2, 51, 77, 78
Re-seeding Characteristics:	
high, has fraction of hard seed	3, 59, 71
10-20% hard seed	66
Mix with:	
cereal grains, grass, brassicas	11
Soils:	
6-7 pH	11, 71
does not perform well on poorly drained soils	61
does best on sandy loam soils	59, 71
Shade Tolerance:	
tolerant	11
Cost/lb ($)	
1.70-2.50	11
~1.00	66

Additional Comments:

~supplies N to soil, improves soil tilth, erosion control, suppresses weeds
~most useful in veg crop production when sown in late summer

~High P and K requirement

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Japanese Millet *(Echinochloa esculenta)*

~summer annual grass

Planting Dates:	**Source**
after frost	43
June 15-July 15 (in MN and WI)	55
April- July	2,91, 48
Seeding Rates (lbs/A):	
15-30 dr; 25-35 bc; 8-12 mix	2
20-30 best	14, 20, 43, 71
10-15	48, 55, 91
Seeding Depth (in):	
.5-1	2, 43, 55, 71
Flowering Dates:	
Ripe grain after 45 days from seeding	
End of June-Sept (www.ext.msstate.edu/pubs/pub2111.htm)	
Root System:	
Extensive Fibrous	20
Winter-Kill Temp:	
yes	43
Competition with weeds	
high	43, 71
88-91% weed suppression 6wks after seeding	64
Total Dry Matter Biomass (lbs/A):	
3000 (NC)-5000 lbs/A	14, 73
high yields	55

	Source
Biomass of N (lbs/A):	
35 lbs/A aboveground (NC)	14
C:N Ratio:	
42:1 (NC)	14
lbs/bu:	
35	2
50	14
seeds/lb:	
143000	2
Re-seeding Characteristics:	
Medium to high	
Mix with:	
Over seed into spring crop	20
Soils:	
Med-heavy soils	
5.8 or greater pH	
Shade Tolerance:	
Cost ($/A):	
14.50	14

Additional Comments:

~drought tolerant

~late season green forage
~Exceptional wildlife plant

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Oats *(Avena sativa)*

~annual cool season grass

Planting Dates:	**Source**
Mar 15-Apr 25	52, 75, 87
Aug-early Sept	64, 71, 73
early spring-July 1	43
no later than Sept 15	18
Spring (green manure) or fall (winter cover)	3
Seeding Rates (lbs/A):	
80-110 dr; 110-140 bc	3, 87
64-120; or 60-90 mix	2
60-96	42, 48, 51, 73, 75
Seeding Depth (in):	
.5-2	2, 43, 51, 77, 87
Flowering Dates:	
late spring	71, 78
Root System:	
fibrous	
Winter-Kill Temp:	
18 F	71, 87
Competition with weeds	
strong when in a mix; allelopathic	71
Total Dry Matter Biomass (lbs/A)	
2500 lbs/A	18, 46
8000-12000 lbs/A	17, 71
2000-8000 (up to 8000 in spring seeded)	11, 43
5000-6000 (planted mid-Apr, harvested late June, WI)	73
5000 (harvested between boot and dough in VT)	
Root Biomass (lbs/A):	
977 lbs/A	18

Percent N:	**Source**
1.2-1.5	17, 71
Cover:	
80% if planted as early as possible	11
N (lbs/A):	
12 lbs/A catch	71
77 (absorb in 8-10 weeks in NE)	11
C:N Ratio:	
33:1	71
lbs/bu:	
32	2, 48, 87
seeds/lb:	
15500-19400	2, 42, 48, 87
Re-seeding Characteristics:	
low when left over winter	71
Some may survive, incorporate in spring	3
Mix with:	
vetches, brassicas, barley	71
Soils:	
tolerate pH as low as 4.5	71
best on loam-heavy loam	
Shade Tolerance:	
intolerant	
Cost/lb ($):	
.17-37	11
3.85-5.00/bu	66

Additional Comments:

~primary use for veg. crops, nurse crop for legumes

~suppresses weeds, erosion control

~quick cover

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Perennial Ryegrass *(Lolium perenne)*

~cool season perennial grass

Planting Dates:	**Source**
April-late Sept	77, 87
Mar-May or Aug 1- Sept 15	71
Feb-May or Aug-Sept	2, 64
early spring	20, 42
Seeding Rates (lbs/A):	
14-25	66
20-40; 4-15 mix	2, 42
15-20; 4-8 mix	87
18-25; 10-15 mix	71
18-20	64
Seeding Depth (in):	
.25-.5	2, 71, 77, 87
Flowering Dates:	
mid-spring	78
May-Sept	71
Root System:	
extensive fibrous	70
Winter-Kill Temp:	
more cold hardy than annual, but will in extreme temps	59, 64
Competition with weeds:	
yes, best in a mix	71
Total Dry Matter Biomass (lbs/A):	
1750 lbs/A	18
3000-4000 (early summer in ME)	20
Root Biomass (lbs/A):	
1500 lbs/A	18
6000 (Sown in corn and sampled following spr. Before plowing, OH; all parts underground) 42 (N content)	60

Percent N:	**Source**
2.3	71
Biomass of N (lbs/A):	
60 lbs/A in aboveground tissue	71
C:N Ratio:	
14-40 (based on plant growth stage)	
lbs/bu:	
24	2, 42, 55, 78
seeds/lb:	
227000-240000	2, 42, 55, 77, 78
Re-seeding Characteristics:	
High, if not winter killed	64
Mix with:	
clovers, trefoil, other grasses	71
Soils:	
not tolerant of pH above 8	71
best on heavy soils with good drainage	
Shade Tolerance:	
tolerant	
Cost/lb ($);	
.7-1.30	11
.44-1.05	66

Additional Comments:

~good nutrient scavenger, establishes readily, excellent wear tolerance, high nutritive value

~great for erosion control

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Phacelia tanacetifolia

~annual cool season forb

Planting Dates:	Source
late spring- summer	
Seeding Rates (lbs/A):	
11-18 7-12 dr	
Seeding Depth (in):	
.25"	
Flowering Dates: (blue flower)	
6-8 weeks after seeding (late aug-sept)	71
Root System:	
extensive fibrous	71
Winter-Kill Temp:	
18 F	
Competition with weeds	
yes, grows quick	71
Total Dry Matter Biomass (lbs/A):	
ave 4000 lbs/A aboveground	71
8500	85
Root Biomass (lbs/A):	
1300 lbs/A in 6 months	71

Percent N:	Source
4	71
Biomass of N (lbs/A):	
94.6 lbs/A supplied to system	71, 85
178 lbs/A N belowground	71
127 lbs/A N aboveground	71
C:N Ratio:	
10-15	
lbs/bu:	
n/a	
seeds/lb:	
235000	
Re-seeding Characteristics:	
low	
Mix with:	
Soils:	
Wide range	
Shade Tolerance:	
Not shade tolerant	
Cost:	
Not widely available, expensive- American Meadows VT $15.95/lb	

Additional Comments:

~N catch crop, nectar source
~Low water use

One of the top producing honey producing flowers for honeybees and is also highly attractive to bumblebees and syriphid flies.

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Red Clover *(Trifolium pratense)*

~short-lived biennial/perennial legume

Planting Dates:	**Source**
Feb-May or Aug-Sept	2, 42
Feb 1-Apr 15 or Aug 1-Sept 15	3
April-May	51
Seeding Rates (lbs/A):	
8-12; 4-8 mix	2
10-15 bc; 6-15 dr	51
10-12; 6-8 mix	42, 87
12-14; 8-10 mix	73
Seeding Depth (in):	
.25-5	2, 42, 51, 77, 87
Inoculants:	
Rhizobium leguminosarium biovar trifoli	
Flowering Dates:	
May	3, 78
Root System:	
thick, deep taproot	51, 59, 66, 87
Winter-Kill Temp:	
low	87
Competition with weeds:	
Total Dry Matter Biomass (lbs/A):	
2000-2500	29,90, 54, 59, 87
4000-8000 full season over wintered	11
4000-6000 (spring, fall seeded in ME)	20
Root Biomass (lbs/A):	
1000 (averaged at 48 dates, OH)	60
(N content in roots 22/A)	

Percent N:	**Source**
2.61-2.77	90, 71
Biomass of N (lbs/A):	
100-150 lbs/A fix	39
70-120 (In OH, PA, over wintered 75 by May 15, up to 120 by June 22)	3,11, 66
125.1 lbs/A in aboveground; 46.3 lbs/A in roots	71
70-80 seeded and turned under in spring	59
C:N Ratio:	
15:1	90, 71
lbs/bu:	
60	
seeds/lb:	
252000-275000	2, 49, 42,51
Re-seeding Characteristics:	
kill before go to seed, will re-seed	63
Mix with:	
small grains, sweetclover, corn, soybeans, grass	11
Soils:	
loams- clays,	43
6.2-7 pH preference	59
Shade Tolerance:	
very tolerant	43, 66
Cost/lb ($):	
1.40-3.30	11
.90-1.30	66
Distinct types:	
Medium, and Mammoth	11

Additional Comments:

~can cause bloat in livestock

~addition of N to system, weed suppression, erosion control

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Sorghum-Sudangrass *(Sorghum bicolor x S. bicolor var. sudanese)*

~warm season summer annual grass

Planting Dates:	**Source**
late spring-midsummer (May 1-July 1)	2, 3, 43, 48, 64, 55, 73, 75
when soil is at least 70 F	43
Seeding Rates (lbs/A):	
25-30	51
20	2, 55, 73, 75
30-40dr; 40-50 bc	43, 71
Seeding Depth (in):	
.5-1	2, 42
Flowering Dates:	
early summer	78
Aug	71
Root System:	
fibrous	71, 75
Winter-Kill Temp:	
very frost sensitive	42, 71
Competition with weeds:	
very high	48, 71
Total Dry Matter Biomass (lbs/A):	
4000-5000 (planted in early summer ME)	20
6000-10000 (seeded July 1, harvested mid-Aug WI)	73
7000 (NC)	14
13000-18000 (potential in WY, planted May-July 1)	59, 93
Root Biomass (lbs/A):	
1350	21

Percent N:	**Source**
.68-1.5	90 71
Biomass of N (lbs/A):	
185 lbs N/A recycled	90
78 aboveground (NC)	14
C:N Ratio:	
63:1	90
50:1	14, 71
lbs/bu:	
56	55, 87
seeds/lb:	
14000-28000	2, 42, 49, 55, 87
Re-seeding Characteristics:	
Low in the northeast	
Mix with:	
buckwheat, sesbina, sunn hemp, soybeans, cowpeas	59
Soils:	
can tolerate 8-9 pH	71
Or as low as 5 pH	11
Shade Tolerance:	
intolerant	
Cost/lb ($):	
.4-1.00	11
16.20/A	14

Additional Comments:

~great use for SOM; Heat and Drought tolerant

~very high salt tolerance

~if stressed or succumb to frost, can produce prussic acid

~great scavenger for residual N, Suppresses weeds, builds soil tilth, breaks up compacted soils

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Yellow Blossom' Sweetclover *(Melilotus officinalis)*

~cool season biennial legume

Planting Dates:	**Source**
Feb1-May or July 20-Aug 30	2. 33, 56, 71, 77, 49
Seeding Rates (lbs/A):	
20-30	33
6-15; 3-8 in a mix	2
10-15	71
9-20	20, 43, 59
Flowering Dates:	
May-Aug (kill before flowering to max N benefit)	71, 78
Late June- July	64
Root System:	
deep taproot	11, 49, 59, 71
Winter-Kill Temp:	
winter hardy	49, 71
Competition with weeds:	
Grow slowly in first 60d	11
Total Dry Matter Biomass (lbs/A):	
2000-6000	54
up to 3000 in establishment year (NE)	11, 67
7500 lbs/A aboveground 2nd year (ME)	20, 59
Root Biomass (lbs/A):	
2640 (Nov seeding yr. OH) 95 (N content)	60
800 (July, yr following seeding, OH) 13 (N content)	90
Inoculant:	
Sinorhizobium meliloti and Rhizobium leguminosarum biovar trifolii	

Percent N:	**Source**
2	71
N (lbs/A):	
90-170 lbs/A fix ((in OH 125 by May 15 to 155 by June 22)	11, 43
130-150 lbs/A fix (NE)	49, 67
averages ~100	59
C:N Ratio:	
12-23	78
lbs/bu:	
60	2, 48, 55
seeds/lb:	
240000-260000	2, 48, 49, 55, 78
Re-seeding Characteristics:	
high (hard seed)	18, 43
Mix with:	
small grains, red clover	11
Soils:	
6.5-7	59
best loam soils, tolerate heavy clay-light sand	59
Shade Tolerance:	
intolerant	
Cost/lb ($):	
1.00-3.00	11

Additional Comments:

~drought, flood, and salt tolerant

~good cover for wildlife, and can be harmful to livestock (Coumadin)

~good smother crop or catch crop, rapid growth rate

~greatest warm weather biomass producer of any legume

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Triticale *(X Triticosecale)*

~annual cool season cereal crop

Planting Dates:	Source
Aug - Oct 15 (winter crop)	20,43,75,87
late Apr- mid May (spring crop)	48,73
Aug 25-Sept 25 (winter crop)	3
Mar-Apr or Aug-Oct	2
Seeding Rates (lbs/A):	
75-100	20, 48
80 dr; increase 30% if bc	3
90-120; 60-90 mix	2
Seeding Depth (in):	
1.25-2	2,3,48
Flowering Dates:	
48 days to heading	55
Root System:	
fibrous	
Winter-Kill Temp:	
Winter hardy	3
Competition with weeds:	
Moderate, not as good as rye	
Total Dry Matter Biomass (lbs/A):	
6000-7000 (planted Sept, harvested early June WI and in WY)	73, 93
4000-8000 flag leaf stage	3,43,56
2000 (late Aug planting)	87
7000 (harvested June 2 in Arlington, WI)	55
4000 (harvested between boot and dough in VT)	16

Biomass of N (lbs/A):	
Kill before stems elongate for best N value	3
66.2	
C:N Ratio:	
20:1	
lbs/bu:	
48-50	2, 48
seeds/lb:	
15000-18000	2, 49,77
Re-seeding Characteristics:	
high	
Mix with:	
Other winter grains	
Soils:	
fertile, well drained	48
Shade Tolerance:	
Not tolerant	

Additional Comments:

~use as a double crop and erosion control on highly erodible lands

~Good at reducing root rot in vegetables

~Advantage over wheat, can be sown earlier for more fall growth

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Wheat *(Triticum aestivum)*

~annual, winter cereal grain

Planting Dates:	**Source**
mid Sept-Oct 1	3, 42, 43, 51, 64
Aug 15-Spet 15	
Mar-Apr or Aug-Oct	2
Seeding Rates (lbs/A):	
90-120	42, 51
120-160 dr	87
60-120; 60-90 in a mix	2
80-110	64
Seeding Depth (in):	
1-2	2, 43, 51, 87
Flowering Dates:	
Spring (winter wheat)	
Root System:	
fibrous	
Winter-Kill Temp:	
winter hardy	3
Competition with weeds:	
Low, especially annual grasses	
Total Dry Matter Biomass (lbs/A):	
2500-4500 lbs/A	51,64, 87
3800 (harvested between boot and dough in VT)	16
4000-5500 (if planted in Aug, in CO)	11, 59
3000-7000	43
Root Biomass (lbs/A):	
1300	21

Percent N:	**Source**
1.67	8
N (lbs/A):	
40-45 lbs/A scavenges	26, 51
50 (tops)	29
C:N Ratio:	
20:1	26
Leaf: 15-29; stem: 31-65; root: 24-74; straw: 80-95 (end of season)	
lbs/bu:	
60	2
seeds/lb:	
11000-18000	2, 42, 77
Re-seeding Characteristics:	
later than ryes	18
Mix with:	
annual legumes, ryegrass, small grains	11
Soils:	
well drained, med texture,	
Shade Tolerance:	
tolerant	78
Cost/lb ($);	
.10-.30	11

Additional Comments:

~good in rotation with veg crops

~excellent N scavenger

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White Clover (*Trifolium repens)*

~perennial, cool season legume
~'Ladino' is longer lived than 'Dutch' or 'New Zealand'

Planting Dates:	**Source**
Feb-May or Aug-Oct	2
early spring-late summer	59, 66
spring or Aug 15-Sept 10	3, 42
Feb 1-May 1 or July 20- Aug 20	77
Seeding Rates (lbs/A):	
4-6; 2-4 in a mix	2, 71
6-14	59, 66
5-9 dr; 7-14 bc	3
8-10; 1-2 mix	42
Seeding Depth (in):	
.25-5	2, 77, 87
Innoculant:	
Rhizobium leguminsarum biovar trifoli	
Flowering Dates:	
late spring- summer	78
Root System:	
shallow, taproot	71, 87
Winter-Kill Temp:	
winter hardy	71
Competition with weeds:	
high (once established)	71
Total Dry Matter Biomass (lbs/A):	
600-1400	90, 54
3000-6500	71
Root Biomass (lbs/A):	

Percent N:	**Source**
2-3	90, 71
N (lbs/A):	
116 lbs/A to the system	71
ave 130 lbs/A (plow at bud or early flower stage and in PA)	11, 59, 66
C:N Ratio:	
13:1	90
12:1	71
lbs/bu:	
60	2, 48
seeds/lb:	
711000-860000	2, 42, 48, 49, 77, 78, 87
Re-seeding Characteristics:	
yes under favorable conditions	71, 87
Also has creeping stolons	3
Mix with:	
grasses	71
Soils:	
6-7 pH	59, 87
tolerate wet, loam clay	.3
Shade Tolerance:	
tolerant	3, 11, 71
Cost/lb ($):	
1.10-4.00	11
2.00-3.00	66

Additional Comments:

~stoloniferous
~thrives in moist, shady condition
~causes bloat in horses
~poor summer growth, low yields

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Exhibit 6-6: North Dakota NRCS Specification for Design of Windbreaks

CONSERVATION PRACTICE SPECIFICATION
Windbreak/Shelterbelt Establishment – 380

This document provides conservation planners with the parameters, procedures, and requirements for developing site-specific plans for windbreak and shelterbelt systems for a variety of purposes. Where appropriate, specific references are cited to provide detailed information needed for a successful design. Note: FOTG refers to NRCS' Field Office Technical Guide.

The supporting documents needed to complete a windbreak design are:

- Windbreak Suitability Groups are found in county specific Interpretive Tables in FOTG – Section II – Soil Information.
- Tree Care and Management is located in FOTG Section I – Reference Subjects – Windbreaks and Woodland.
- Expected 20-Year Tree Heights by Windbreak Suitability Groups is located in FOTG Section II – Windbreaks and Forest.
- Tree and Shrub Characteristics table is located in FOTG Section I – Reference Subjects – Windbreaks and Woodland.

No matter the purpose of the planting, most plantings are simply modifications of two basic windbreak/shelterbelt designs.

1. Building site or livestock shelterbelts, which are multiple row plantings, designed to protect farmsteads, feedlots or other building sites. They may be designed to protect livestock or other animals wherever that protection is needed.
2. Field windbreaks that are single- or multiple-row plantings designed to prevent erosion, protect crops and roads, to harvest snow, to provide noise or visual screens or to supplement building site or livestock shelterbelts.

WINDBREAK SUITABILITY GROUPS

To determine which trees will grow satisfactorily on which soils and to determine the expected heights after 20 years, refer to Windbreak Suitability Groups found in county specific Interpretive Tables in FOTG – Section II – Soil Information for each soil component and Expected 20-Year Tree Heights, respectively.

WOODY PLANT STOCK

To determine which type of plant stock is appropriate for windbreak/shelterbelts refer Tree Care and Management, page 2.

STOCK STORAGE HANDLING AND CARE REQUIREMENTS

To determine proper stock storage, handling and care requirements, refer to Tree Care and Management pages 3-4.

SITE PREPARATION

To determine an appropriate method of site preparation, refer to Tree Care and Management pages 4-8.

PLANTING

To determine an appropriate planting technique for a particular stock used in a windbreak/shelterbelt system, refer to Tree Care and Management pages 8-11.

ORIENTATION, LOCATION, SETBACKS

When designing a windbreak, consider the effects of the surrounding topography and land management on the ability of the windbreak to perform its function. Conversely, consider the positive and potentially negative impacts the windbreak may have on the surrounding land uses. A sample of the items to consider include: areas of snow drifts, water runoff from melting snow, water erosion potential, stifling of air flows during the summer, visibility hazards, ice blockage of drains, etc.

Orientation

Wherever possible the plantings should be oriented perpendicular to troublesome winds. Since winds rarely blow from the same direction all the time, base the design on the predominant wind direction during the time that the area needs protection. For snow control or harvest purposes and for winter livestock or farmstead protection in North Dakota, predominant winter winds come from the northwest, except in the Red River Valley where they generally come from the north-northwest.

However, not all damaging storms come from the predominant wind direction. Individual sites can vary considerably. Late season snowstorms could plug a road from a southeast direction or fragile crops could be blasted by a hot, dry wind from the southwest. Determine what needs protection and from where the damaging winds originate and locate the windbreak/shelterbelt accordingly.

Locations

<u>All Windbreaks</u>

Windbreak design is often based upon the downwind protection provided by the windbreak at 20 years of age. This distance is measured in multiples of windbreak height at 20 years and is referred to as H. H = height of tree or shrub, measured at 20 years unless otherwise noted. For certain situations H may be multiplied by values other than 10. (15-20 H for a snow spreading windbreak.)

On sloping land they should be located as near to the contour as possible to reduce erosion risks and water loss.

In western North Dakota or on droughty soils consider locating windbreaks to allow the diverting of water from adjacent areas into the windbreak for supplemental moisture.

Windbreaks to trap snow for supplemental water in stock ponds should be located in a position to dump the majority of the snow close to, or in, the stock pond or major tributaries. Avoid tree species such as cottonwood, willow etc. that are heavy water users. Windbreaks for this purpose should be as narrow and dense as possible (ex: twin-row conifer or twin-row shrub).

Windbreaks will be positioned to avoid causing visibility problems at road intersections, curves and driveway entrances. Generally speaking, the trees or shrubs at maturity should not spread into the right-of-ways of roads. Refer to <u>Tree and Shrub Characteristics</u> for the spread (width) of plants at maturity.

Maximum snow deposition will usually occur within a zone located 2-5 H from the most windward dense row. This relationship holds true for dense windbreaks as well as porous windbreaks. Differences in snowdrift depth are more pronounced on more dense windbreaks.

Tree and shrub plantings on native range and/or wetlands is permitted only after alternative treatments have been evaluated and then only to protect infrastructure (building sites, roads, livestock).

<u>Primary Windbreaks</u>

Windbreaks primarily for wind protection and snow control are usually located to the north and west of the area needing protection.

Windbreaks needed primarily for wind protection of crops shall be located in a manner that places them between the troublesome winds at the critical stage of the crop needing protection.

Snow traps located 50-150’ upwind of the primary windbreak can increase effectiveness of the rest of the windbreak system by reducing the amount of snow needing to be stored in the primary windbreak. (MLRA 55 and 56).

Trapping of snow outside the primary windbreak in Major Land Resource Areas 53, 54, and 58 should be planned with caution, since the removal of snow moisture from the root zone of the main windbreak may adversely impact the life and effectiveness of the windbreak.

All areas needing protection should be located within the 10H - 15 H zone on the leeward side of the windbreak. Estimates of 20-year heights of trees and shrubs needed to calculate areas of protection can be found in Expected 20-Year Tree Heights.

Field windbreaks designed for snow spreading may be spaced up to 20 H apart.

Secondary Windbreaks

Secondary windbreaks are located on the leeward sides, usually the south and east, of the area protected by the primary windbreak.

Secondary windbreaks usually consist of shrubs or short trees to stop the rare snowstorm from the south or east while allowing summer breezes to penetrate the protected area.

Setbacks

All Windbreaks

Windbreaks shall be located no closer than 16 feet away from any property line unless a signed agreement between both owners exists that would permit a closer planting.

According to North Dakota Century Code, no trees or shrubs may be placed within 33 feet of a section line unless written permission has first been secured from the county commissioners or township supervisors.

No trees shall be placed within the easement area of overhead transmission lines unless permission has been secured from the appropriate utility company.

As per international treaty, no trees or shrubs shall be planted in a location where the foliage, at maturity, will encroach upon the 20' wide (10' each side) line-of-site vista along the Canada-USA border.

Windbreaks that are adjacent to, or cross, legal and private drainage ways should be set back at least 100' to prevent snow and ice buildup that will restrict spring drainage.

In all cases, if local units of government have established more restrictive setback distances, then the more restrictive regulations will apply.

Primary Windbreaks

For windbreaks north and/or west of the area needing protection, the most windward row must be at least 200 feet from the area to be protected. See Figure 1.

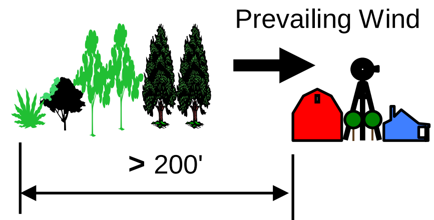


Figure 1

When measuring from roadways, the measurement should begin at the edge of the road surface nearest to the proposed windbreak. See Figure 2. The most windward row of a snow trap can be used for setback measurement purposes. This setback distance also applies to the ends of windbreaks that are perpendicular to roads and areas needing protection.

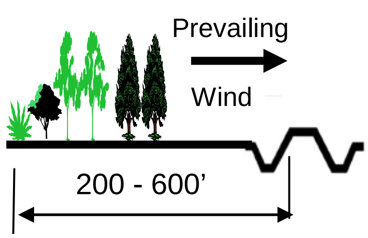


Figure 2

The setback distances may be reduced by 50 feet if topography, healthy field windbreaks upwind, reduced fetch distances, or long term crop management practices can be expected to remove 50 percent or more of the typical snow load before it reaches the main windbreak.

Leeward rows of primary windbreaks, located to the north or west of a road, even with the minimum 200-foot setback to the windward row, should be no closer than 100 feet to the nearest traveled portion of a public road. See Figure 3.

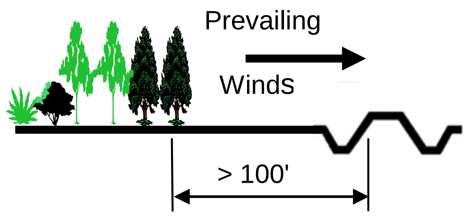


Figure 3

For snow control, windbreaks should not be placed farther from the area needing protection than 35 times the expected 20-year height of the tallest species to be planted or 600 feet, whichever is smaller.

Windbreaks planted to the south or east of roadways shall be located no closer to the road than 5 times (5H) the mature heights of the trees and/or shrubs in order to reduce upwind snow deposition and shading problems. Refer to Tree and Shrub Characteristics for mature plant heights. When measuring from roadways, measurements begin at the portion of the road surface nearest the proposed planting. See Figure 4.

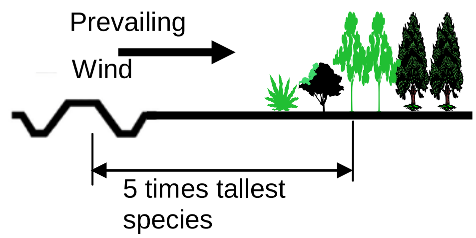


Figure 4

Secondary Windbreaks

In North Dakota, secondary windbreaks are usually located to the south and east of the areas needing protection. Secondary windbreaks should be located far enough away from the area needing protection to allow snow deposition where it won't be a problem and to provide year-round accessibility in and around the area protected.

The inside tree or shrub row in windbreaks on the south and east of areas needing protection shall not be any closer than 100 feet. Where solar gain during the winter is important, windbreaks on the south side of a building site shall be no closer than 3 times the mature height of the tallest plant. Exercise caution in utilizing tall trees in secondary windbreaks that may restrict summer breezes.

WINDBREAK DESIGN

General Information

Windbreak tree species shall be selected that are compatible with the soils on which they will be planted. Refer to the Expected 20-Year Tree Heights, located in FOTG – Section II – Windbreaks and Forest, to determine which plants will grow on which soils. Most soil map units contain small percentages of minor soil components. See Windbreak Suitability Groups by County in Section II FOTG to determine component soils within each map unit. Ensure that the species selected are compatible with these minor components as well. Changes in soil properties within the planting site may require a species change within the row. If there is any doubt, select species appropriate for the most limiting soil condition.

Unless otherwise noted, 20-year plant heights will be used to determine setback distances and the extent of protected areas. Expected 20-year heights of trees and shrubs, under good management, can be found in Expected 20-Year Tree Heights.

Maximum snow depth can be expected within 2-5 H from the tallest tree or shrub row, under normal winter conditions. The deepest part of the snowdrift will be closest to dense windbreaks and will be located progressively farther away from the windbreak as windbreak density decreases.

Zones of protection will vary, depending upon density and height of the windbreak. Generally, the denser the windbreak the greater the wind speed reduction and the smaller the zone of protection.

No more than two rows in any windbreak system shall be of the same species unless site conditions restrict the number of available species.

Ends of windbreaks should extend at least 200' past the area needing protection to account for end effects and to allow for shifts in wind direction.

If there is insufficient space or suitable soils to install the normally required minimum number of rows, a narrower windbreak is permissible, though a minimum of 1 shrub row and 2 deciduous tree rows- or 2 coniferous rows- shall be established.

Design Purpose

<u>All Windbreaks</u>

Design living snow fences and farmstead and feedlot windbreaks, for circumstances worse than average. I.e.: Don't scrimp on setbacks, number of rows or diversity of species.

Field windbreaks can be designed for average conditions for the time of year during which protection is needed.

The minimum number of rows for a primary windbreak will vary, depending upon the purpose of the planting. Refer to Table 1 for spacings to achieve targeted within-row densities.

Any design of one or more rows is acceptable for a secondary windbreak.

<u>For Snow Control</u>

Two or more rows of deciduous trees and/or non-suckering shrubs; or one or more rows of conifers and/or suckering shrubs. Multiple rows of different species are strongly encouraged. Refer to Table 1 for within-row and between-row spacings.

<u>For Snow Spreading on Cropland, or Pastureland</u>

Suckering shrubs, spruces, junipers, cedars or arborvitaes are not suitable.

The windbreak shall consist of one row of non-suckering shrubs, deciduous trees, larches or pines. Multiple rows of pines or shrubs may become too dense to effectively spread snow. Extra maintenance is required when relying upon a single row to ensure that no gaps develop in the windbreak.

Lower limbs may be pruned or plants thinned, especially on pines or shrubs respectively, to increase snow distribution, reduce drift height and subsequent delays in field operations near the windbreak. Refer to Table 1 for within-row and between-row spacings.

<u>For Erosion Control</u>

One or more rows of deciduous shrubs, trees or conifers are appropriate for erosion control windbreaks. See Table 1 for in-row spacings to achieve desired density. Use wind erosion formulas to determine windbreak spacing across a field to achieve desired soil protection. For some sensitive crops, any erosion, even if below soil loss limits, may be damaging to the crop. Windbreak systems shall be designed to limit the maximum of soil erosion to, or less than, the amount the planned crop will tolerate. To determine these tolerances, refer to table 502-4 – “Crop tolerance to blowing soil” in part 502 of the National Agronomy Manual. The National Agronomy Manual is located in FOTG – Section I – Erosion Prediction.

<u>For Traditional Crop Protection</u>

Plant one or more rows of deciduous shrubs, trees or conifers. Use 10 times the 20-year height, measured parallel to the problem wind to determine the protected area. This measurement- when combined with the results of the most current wind erosion calculations- will yield the appropriate windbreak spacings. To increase farmability between windbreaks, reduce the spacings between windbreaks to those of even tool bar widths. Increased windbreak density increases crop protection benefits but slightly reduces the overall area receiving benefits. Be alert to how increased density for crop protection may result in delayed spring fieldwork because of narrow, deep snowdrifts. Refer to Table 1 for within-row and between-row spacings.

For Specialty Crop Protection

Usually, more than one row of non-suckering shrubs or deciduous trees will be needed to provide adequate wind protection. One or more rows of suckering shrubs or conifers may provide the desired protection. Refer to Table 1 for within-row and between-row spacings. Ensure that the planting has adequate density close to the ground. Assume that a planting achieving 60-80 percent density will reduce soil loss to zero within the 10H protective zone.

Depending upon requirements of the crop, additional secondary windbreaks may be needed to provide protection during critical crop stages.

Note: Be alert to creating frost pocket conditions by entirely encircling the crop field or by placing windbreaks downslope from specialty crop fields. Frost pocket conditions can be lessened by pruning the lower 3-4 feet of branches from trees as they mature to prevent cold air from concentrating on sensitive crops; however this will also reduce crop protection provided by the windbreak.

Livestock and Building Site Protection

6 rows of trees and shrubs, minimum, for Major Land Resource Areas (MLRA) 53, 54, 58.

8 rows of trees and shrubs, minimum, for MLRA 55, 56.

Assuming that proper setback distances have been observed in the design, then the number of rows in a livestock/building site windbreak may be reduced by one for each of the following that occurs:

- Spruce, juniper, redcedar, or a suckering shrub is planted in the most windward row.
- An effective field windbreak system is already established with the most leeward row no more than 300' from the proposed windbreak.
- A snowtrap of juniper, redcedar, closely spaced shrubs, or a twin-row high-density deciduous tree or shrub planting, is located 50-100' windward of the proposed windbreak.

Refer to Table 1 for within row and between row spacings.

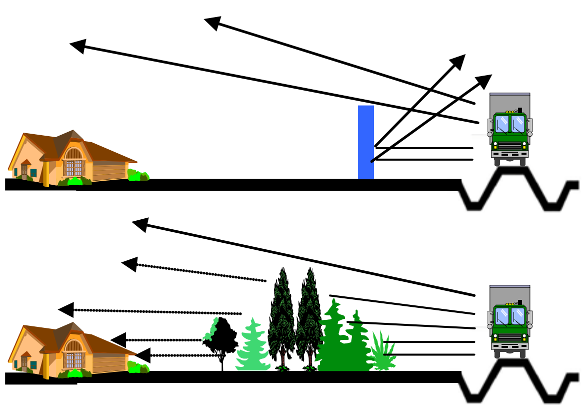


Figure 5: How Sound Barriers Work

For Noise Barriers

Noise barriers reduce noise by deflecting the noise away from the observer, by absorbing some of the noise before it reaches the observer or both. See Figure 5. They are most effective when they can be placed as close as possible to the noise source. Barriers should be placed within 50-80 feet of the nearest traffic lane. See Figure 6.

The amount of noise reduction attained is dependent upon the type of surface between the observer and the source over which the noise passes as well as the width, setback distance and composition of the noise barrier. Vegetation, especially standing vegetation, reduces and attenuates noise better than bare or hard surfaces. Where year-round noise reduction is desired, conifers should constitute the majority of the planting. See Table 1 for spacings.

Deciduous trees or shrubs can be used where noise reduction is needed only during the growing season. See Table 1 for spacings.

Tree and/or shrub barriers, when combined with landforms, either earthen or constructed, show greater benefits in noise reduction than do landforms alone or trees alone. See Figure 7.

When landforms or constructed barriers are incorporated into the design they should be as tall as the vehicle or object making the noise and may be constructed of soil or other materials. If constructed of soil the landforms should be planted to tall grasses, shrubs or trees for maximum effectiveness.

Barriers for reducing high-speed truck noise must be at least 75' wide if only trees or shrubs are used or at least 50' wide if vegetation is combined with a landform.

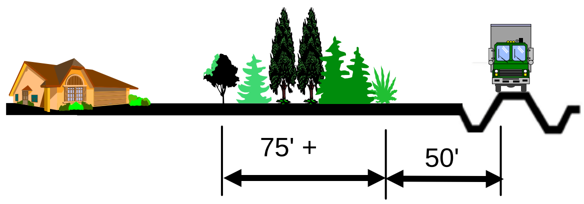


Figure 6: Vegetative Sound Barrier

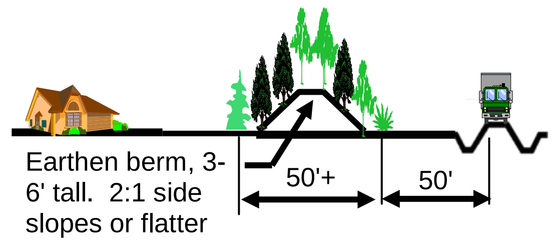


Figure 7: Vegetative Noise Barrier and Landform

Barriers for reducing moderate noise levels (cars) must be at least 40' wide if only trees or shrubs are used or at least 20' wide if vegetation is combined with a landform.

Noise barriers must be twice as long as the distance from the observer to the noise source.

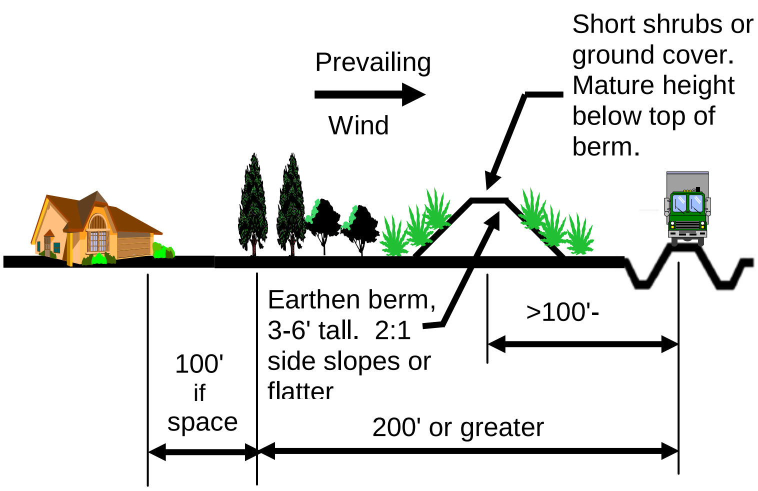


Figure 8 Where Sound and Snow are Problems

No matter how severe the noise, noise barriers shall not be positioned where the barriers will cause snow deposition or drifting on the road sufficient to create a safety hazard to the traveling public. For many of these situations a living snow fence system is often needed upwind from the observer, thereby reducing the amount of snow that could cause a problem. See Figure 8 for one alternative to address this problem where there is no room to establish a living snowfence system upwind from the observer.

Information for designing noise barriers was obtained from an article by David I Cook and David Van Haverbeke in the Journal of Soil and Water Conservation, November-December 1972, pages 259-261.

For Visual Screens

Rows of trees or shrubs shall be placed between the observer and the undesirable view needing to be screened. Plantings shall be at least one row of conifers or at least 3 rows of deciduous trees or shrubs or a combination of deciduous and coniferous plants. Increasing the number of rows in the planting will increase the effectiveness in blocking unsightly vistas.

Often visual screens will be designed with species that are aesthetically pleasing to the observer or landowner. Refer to Tree and Shrub Characteristics for species-specific information.

Plantings may be established immediately adjacent to the sight to be screened, which allows more open spaces around the observer. The plantings may be placed closer to the observer to site-specific needs or landowner objectives. See Table 1 for in-row and between-row spacings.

Where visual screens may cause snow problems on roads or building sites, the more restrictive setback distances for snow control must be followed.

For Wildlife

When the primary purpose of a planting is to improve conditions for wildlife, it is best to refer to the Upland Wildlife Habitat Management-645 Standard for specific details appropriate for the wildlife specie(s) of interest. All conservation practices are located in FOTG – Section IV – Conservation Practices. However, the designs of windbreaks for other purposes can be modified to make the practice more beneficial to wildlife while still addressing the original windbreak purposes. Considerations for improving the wildlife value of windbreaks include, but are not limited to:

1. Provide dense areas (thickets) of suckering shrubs or conifers, especially spruce and juniper for winter thermal protection.
2. Choose a variety of plants that will provide food throughout the growing season, especially during mid and late winter. Refer to Tree and Shrub Characteristics for individual species value as a food source.
3. Using tall grasses, standing corn, trees or shrubs, establish a snow trap 50-100 feet upwind to prevent snow from covering the food sources and shelter areas.
4. Add additional rows that provide food or cover on the lee side of the planting.
5. Add a secondary windbreak to protect food and cover from storms from the south or east.
6. Connect isolated plantings by providing travel corridors of 3-4 rows of trees/shrubs between established woody plantings.

For Boundary Delineation

Adhere to all appropriate Setbacks, All Windbreaks, on page 3 of this document when using trees or shrubs to delineate property boundaries.

When using trees or shrubs to delineate field boundaries, be aware of the impact that the mature plant might have on toolbar spacings, machinery operation, or adjacent fences. Avoid creating a future nuisance for the landowner.

Any within-row spacing is appropriate for this purpose. See Table 1. Be aware of how different spacings affect snow distribution and depth, timeliness of field operations, summer breezes, crop protection, moisture harvest, etc.

Boundary plantings can be made more valuable for wildlife by adding additional rows, alternating compatible species within the row, and/or using a variety of plants valuable to wildlife. See Table 2.

For Reducing Chemical Drift

Windbreaks reduce chemical drift hazards in two ways - by reducing the wind velocities across the field where the chemicals are applied and by intercepting chemicals that have moved off site onto the leaves, twigs, and bark of the windbreak plants.

The minimum requirement for this purpose is one row of shrubs, deciduous trees or conifers. Use the appropriate within-row spacing found in Table 1. Where appropriate, use the tallest trees appropriate for the site. Tall trees can intercept more of the laterally moving air mass. Multiple rows of tall trees provide additional benefits since they provide more surface area that can intercept drift.

When installing a system of belts to reduce drift, space each belt at 10 times the expected 20-year tree height. Spacings between belts may be decreased downward to fit even multiples of toolbar widths.

Encourage landowners to use methods and machinery that minimize drift, thereby reducing the amount of chemical moving offsite that must be trapped by the windbreak.

The most difficult part of designing windbreaks for reducing chemical drift is determining what species of tree or shrub will be resistant to the chemical drift 20 years from now. Based on nearly 50 years of herbicide application in North Dakota, phenoxy-type herbicides have been the most damaging to trees. Conifers are most resistant to these types of herbicides, except during periods of rapid, succulent growth.

For Irrigation Efficiency

Windbreaks can improve irrigation efficiency by reducing evaporation at the sprinkler head, reducing evaporation from the plants and soil surface and by reducing transpiration through the plant. Plantings of tall trees just outside the arc of the sprinklers can provide some of the benefits listed, as long as they intercept the troublesome winds.

Another way to address irrigation efficiency is by installing a system of narrow shrub rows that are short enough to allow the sprinklers to pass overhead. These shrub rows can reduce transpiration from the growing crop and provide a microclimate that yields greater production. Preliminary data would indicate that economically the shrub rows would use about the same amount of water that would be saved by the growing crop. Benefits to the crop primarily accrue through stress reduction on the growing crop, protection during critical stages, and erosion reduction.

Aesthetics

Aesthetics are in the eye of the beholder. Use any of the spacings listed in Table 1. Be alert to the effects the windbreak will have on snowdrift locations and depths; alterations of airflow; impacts on visibility, especially at roads; and maintenance requirements of the planting design.

Refer to Tree and Shrub Characteristics for individual species characteristics.

Carbon Storage

Carbon sequestration can be realized through several different mechanisms; cessation of soil tillage, accumulation of carbon in roots and upper tree material, and accumulation of a duff layer. Generally speaking, maximum carbon sequestration can be expected through:

- Close row spacings maximizing plants per acre without unduly causing plant stress that would lead to early mortality. Use the minimum between-row and within-row spacing from Table 1. When different species require different spacings, use the larger of the minimum spacings.
- Establishing long-lived trees.
- Planting trees that will grow large with extensive and deep root systems.
- Harvest of woody material for lumber or fossil fuel substitution.

For maximum carbon storage, minimize amount of tillage within the planting to that necessary for establishment.

For long-term carbon sequestration, establish and maintain adequate firebreaks to prevent catastrophic loss of the planting.

Composition

For sustainability and long-term effectiveness, try for a diversity of species within the planting, and where compatible with plant forms and owner objectives, within the row. Refer to table 2 for acceptable plant alternation schemes.

At a minimum, no more than two rows within any windbreak system shall be of the same species, unless site conditions limit the number of available species.

For multirow plantings, consider at least one or more rows of conifers.

Often a single species will be planted in each row. Generally, this makes subsequent maintenance and renovation easier. However, single-row, single-species plantings are considerably more prone to failure from drought, disease, and/or insects.

Mixing compatible species within the row can reduce the severity and spread of some insect and disease infestations. Refer to Table 2 for acceptable plant alterations. Aside from potential benefits, such mixing will usually complicate the management of the windbreak.

Appropriate selections of species and spacings can allow a planting to meet multiple purposes at the same time.

For most situations a shrub or conifer will be used in the most windward row of a multiple row planting to provide additional snow (moisture) for the growing plants within the planting and to "park" the snowdrift in an area that is out of the way.

Species selection that allows for the production of nuts and fruits for human consumption, woody materials such as grape vines for floral arrangements, nutraceuticals, or other agroforestry products are appropriate for windbreaks, where production of these products does not hinder the primary purpose of the windbreak.

Refer to Design Purposes, pages 5-9, for considerations specific to each purpose that may affect composition of the planting.

Design Spacing

<u>In-Row Spacing</u>

Refer to Table 1 for in-row spacing of the appropriate type of plant to meet a particular purpose.

<u>Between-Row Spacing</u>

To provide adequate growing space, between-row spacings shall be at least 1½ times the within-row spacing for each type of plant, or wide enough to meet the minimum square footage per plant, except for twin-row high-density windbreaks. Use the wider determination when two adjacent rows each have different spacings. Ex: When a tree is adjacent to a shrub, use 1½ times the tree spacing. See table 1 for general within-row spacings.

Several species require specific row spacing recommendations due to rapid growth rates and form. Rows of conifers and deciduous trees should not be established within 25 feet of cottonwoods, hybrid poplars, and tree willows nor should they be alternated with these species within the row. Rows of conifers and deciduous trees should not be established within 20 feet of Siberian elm.

Closer spacing can increase disease potential and cause pines to self-prune lower limbs. Between-row spacings can be modified upward to fit machinery widths. Row spacings wider than 30 feet are usually inappropriate for the species suited to North Dakota. Obviously, this prohibition does not apply to the area between twin-row pairs, snow traps, etc.

Wider spacings are permissible and will usually provide better growing conditions for the tree but will increase the time before canopy closure, if closure happens at all. Canopy closure in the eastern part of the State can be fairly effective at controlling unwanted herbaceous vegetation. In the western part of the State, moisture stress and the presence of bromegrass and quackgrass limits the effectiveness of canopy closure as a weed control method.

If spacings must be increased because of landowner desires or to provide adequate growing space, it is best to increase the between-row spacing rather than the within-row spacing. Closer within-row spacing, as recommended in Table 1, will provide quicker closure and more effective barrier to the wind.

Table 1: In-row Spacing by Plant Type for Specific Purposes (feet)

(Assumes vigorously growing, single row of species type listed.)

Purpose	Suckering Shrubs	Non - Suckering Shrubs	Short / Medium Decid-uous Trees	Tall Decid-uous Trees**	Spruce	Junipers Cedars Arbor-vitaes	Larches	Pines
Snow Control / Stoppage, Noise Barriers Carbon Storage 80% + Density	3 – 6	3 - 4	Not with one row	Not with one row	8 - 14	6 - 10	Not with one row	8 -14
Snow Spreading 35 -60% Density	Not Suitable	5 - 8	6 - 10	10 - 16	Not Suitable	Not Suitable	10 - 14	10 - 16
Erosion Control, Intercepting Chemical Drift 40 - 70% Density	4 – 8	4 - 6	6 - 10	8 - 14	8 - 16	6 - 10	8 - 12	10 - 16
Traditional Crop Protection 40 - 70% Density	4 – 8	4 - 6	6 - 10	8 - 14	8 - 16	6 - 10	8 - 12	10 - 16
Specialty Crop Protection, Visual Screens 60 - 80% Density	3 – 6	3 - 4	5 - 8	8 - 14	8 - 12	6 - 10	8 - 12	8 - 14
Livestock Protection 60 - 80% Density	3 – 6	Not with one row	Not with one row	Not with one row	8 - 14	6 - 10	8 - 12	8 - 14
Building Site Protection, Visual Screens 60 - 80% Density	3 – 6	Not with one row	Not with one row	Not with one row	8 - 14	6 - 10	8 - 12	8 - 14
Minimum Square Footage Per Plant*	15	15	80	144	144	144	144	192

* The minimum square footage per plant means that a design using a minimum within-row spacing will often require a wider between-row spacing in order to ensure enough growing space for each plant. Adequate growing space per plant will maintain a healthy, vigorously growing plant, with a reduced chance of disease incidence, and a strong likelihood that lower limbs will be maintained throughout the life of the planting.

** Rows of conifers or deciduous trees should not be planted within 25 feet of cottonwoods, hybrid poplars or tree willows, nor should these plants be alternated within the row.

These within-row and between-row spacings are specific to the varied purposes of windbreaks only. Other forestry practices such as riparian forest buffers and tree/shrub establishment, etc. will likely have different spacing requirements.

Within-Row Plant Alternation

To meet landowner needs, to improve aesthetics or function, or to reduce disease potential, compatible plants may be alternated within the row. Such a planting scheme increases the complexity of subsequent maintenance operations. See Table 2 for acceptable alternations.

Table 2 - Acceptable Plant Alterations Within The Row

	Short Shrubs ≤ 6' tall	Tall Shrubs >6'	Small/medium deciduous trees < 25'	Tall Deciduous Trees ≥ 25'	Pines	Larches * or Spruces	Juniper or Redcedar
Short Shrubs < 6' tall	YES	INSERT	INSERT	INSERT	NO	NO	NO
Tall Shrubs ≥ 6 feet tall	INSERT	YES	INSERT	INSERT	NO	NO	NO
Small Deciduous Trees < 25'	INSERT	INSERT	YES	NO	NO	NO	NO
Tall Deciduous Trees ≥ 25'	INSERT	INSERT	NO	YES	NO	NO	NO
Pines	NO	NO	NO	NO	YES	NO	NO
Larches * or Spruces	NO	NO	NO	NO	NO	YES	YES
Juniper or Redcedar	NO	NO	NO	NO	NO	YES	YES

Legend:

Yes = Using the within-row spacings from Table 1, replace every other plant with another plant of similar size and type. Ex: A green ash windbreak designed with 12 feet between plants could be altered to become a green ash, bur oak, hackberry windbreak with 12 feet between plants

Insert = Using Table 1 above, select the appropriate between-plant spacing for the tallest plant of the intended alternation scheme. (Select the upper end of the spacing range.) Plant the shorter plant midway between the tall plants. Ex: A green ash planting designed with 12 feet between trees could be altered to become a green ash, caragana, green ash, lilac planting with 6 feet between plants.

No = The listed alternation scheme is not acceptable due to incompatible plant characteristics that could affect form, survival, filling in, shade tolerance, disease etc.

Note: When determining whether a species is short or tall, refer to the maximum height listed in Tree and Shrub Characteristics.

***** When alternating larch, ensure landowner is aware that this species loses its needles in the fall. This attribute will result in a windbreak with apparently dead trees throughout the fall and winter.

Specialty Designs

Twin-row, High-density Windbreaks

Each pair of twin rows will be planted to the same species.

Twin-row, high-density windbreaks for snow control/stoppage and livestock/building site protection shall consist of at least three pairs of twin-rows. The most windward row of the most windward pair must be at least 200' from the area needing protection. See Figure 8.

Within-row spacing for each pair of a twin-row, high-density windbreak will generally be the smallest value from Table 1 for the species type to be planted. Spacing between rows within each pair shall be the same as the within-row spacing. See Figure 9. Spacing between paired rows shall be 30-50 feet.

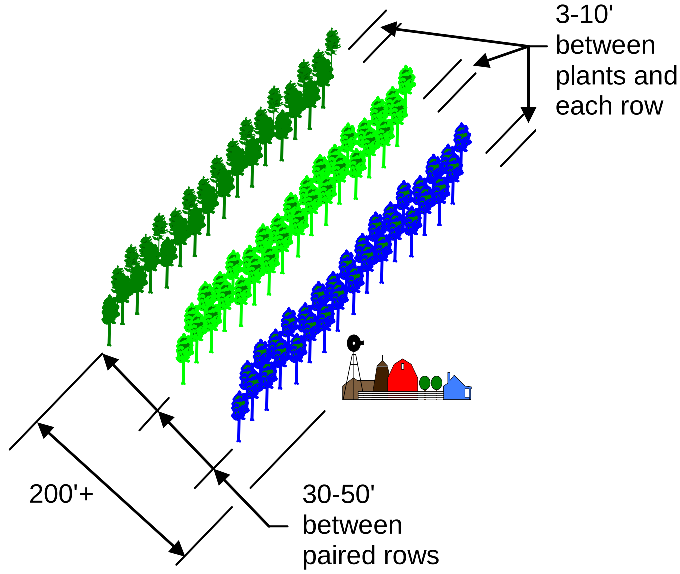


Figure 9: Twin-Row, High-density Windbreak

Windbreak Stubs for Snow Control

To reduce end effects- where existing windbreaks are creating unwanted snowdrifts on roads or other areas needing protection- establish short windbreak stubs. These 300-400' stubs shall consist of 1-3 rows designed as a snow stoppage windbreak (See Table 1) and oriented perpendicular to the problem legs of the existing windbreak. See Figure 10.

For non-cropland sites, the stubs may be planted immediately adjacent to the existing tree rows. With no access gaps, the stubs may be placed as close as 200 feet from the near edge of the area needing protection.

For cropland sites, leave a 50-80 foot machinery access gap between the existing trees and the new trees. When access gaps are a part of the design, the stub rows should be located 400 feet from the near edge of the area needing protection. Access gaps may be incorporated into designs on non-cropland also, based on landowner desires, but the greater setback distance will apply. See Figure 10.

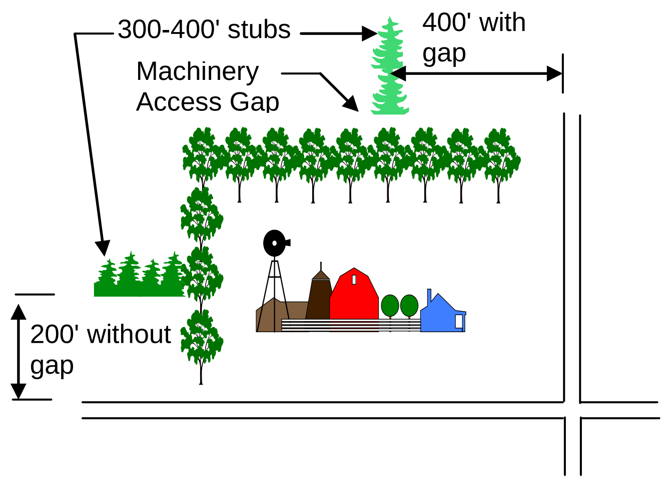


Figure 10: Windbreak Stubs for Snow Control

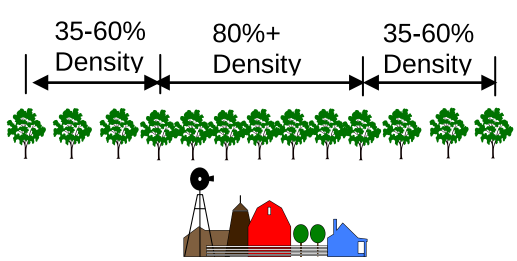


Figure 11: Feathered Windbreak Ends to Reduce End Effect Drifting

Alternative End Effect Reduction

Another way to minimize adverse effects (snow drifts and increased wind velocities) around the ends of dense windbreaks is to change the design of the last 200' from a snow stoppage windbreak to a snow-spreading windbreak. See Figure 11 for details.

Temporary Windbreaks

For more immediate protection, temporary windbreaks shall be planted at the time the main windbreak is established. Temporary windbreaks will consist of a twin-row high density planting. To be effective, temporary windbreaks must grow at least 1 foot per year faster than the fastest growing species within the main windbreak.

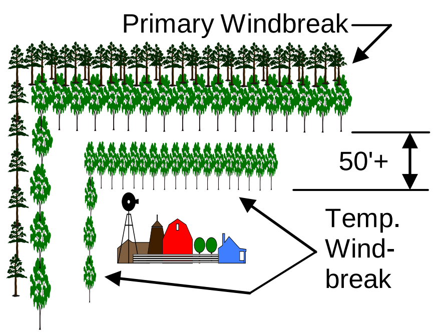


Figure 12: Temporary Windbreaks

Temporary windbreaks may only be used to supplement a properly designed and located primary windbreak. They do not count towards the minimum number of row requirements. See Figure 12 for one possible location.

Locate temporary windbreaks at least 50 feet windward or leeward from the primary windbreak to allow access for harvest or removal. Be alert to how a temporary windbreak will affect snow deposition. Leeward locations will protect the area quicker but may cause problems with snow deposition. Windward locations will eliminate snow problems, but may be too far away to provide protection to the building site any sooner than would the primary windbreak.

Temporary windbreaks are inappropriate if anticipated growth rates of the species in the temporary windbreak do not exceed 2 feet per year on the proposed site. Refer to Tree and Shrub Characteristics for growth rates of individual species. In areas of reduced growth rates, constructed temporary windbreaks may be an appropriate solution.

Effective temporary windbreak designs will often be a twin-row, high-density planting of hybrid poplars or some other fast growing tree or shrub. Once the main windbreak is up and functioning, usually after 10-20 years, the temporary windbreak can be harvested or removed. Properly managed twin-row plantings of poplars can yield a large amount of good quality lumber or firewood.

OPERATION AND MAINTENANCE

Weed Control

To determine an appropriate form of weed control refer to Tree Care and Management, pages 10-14

Replanting

Any tree or shrub that fails within three years should be replaced with a similar plant. Replants shall maintain the intended function of the planting and be compatible with soils and climate. Growth rates of replants (within 3 years) are usually such that little, if any, size difference is noted after 10 years.

After three years a windbreak/shelterbelt shall have at least 85% of the trees planted in a healthy condition with no two adjacent plants missing.

Disease, Insects, Weather and Animals

To determine ways to prevent or control damage due to disease, insects, weather or animals, refer to Tree Care and Management pages 14-16. These pages also list several links that provide more in-depth guidance.

Fire Protection

Windbreaks can be damaged or destroyed by wildfires. In some situations, windbreaks can aggravate the fire risk to a building site. Refer to Firebreak-394 for information on constructing and maintaining effective firebreaks.

OPERATION AND MAINTENANCE FOR LANDOWNERS

To guide landowners in operation and management of their windbreak, provide a copy of pages 11-19 of Tree Care and Management or University of Nebraska pamphlet "Windbreak Management" http://www.ianr.unl.edu/pubs/Forestry/ec1768.htm.

OPTIONAL INFORMATION FOR LANDOWNER USE

1. How Windbreaks Work http://www.ianr.unl.edu/pubs/Forestry/ec1763.htm
2. Windbreak Establishment http://www.ianr.unl.edu/pubs/Forestry/ec1764.htm
3. Windbreaks in Sustainable Ag http://www.ianr.unl.edu/pubs/Forestry/ec1772.htm
4. Windbreaks and Wildlife http://www.ianr.unl.edu/pubs/Forestry/ec1771.htm
5. Windbreaks for Rural Living http://www.ianr.unl.edu/pubs/Forestry/ec1767.htm
6. Windbreaks for Livestock Operations http://www.ianr.unl.edu/pubs/Forestry/ec1766.htm
7. Windbreaks for Snow Management http://www.ianr.unl.edu/pubs/Forestry/ec1770.htm
8. Windbreak Management http://www.ianr.unl.edu/pubs/Forestry/ec1768.htm
9. Windbreak Renovation, http://www.unl.edu/nac/brochures/ec1777/ec1777.pdf
10. Field Windbreaks http://www.ianr.unl.edu/pubs/Forestry/ec1778.htm
11. Fruit Bearing Shrubs for Multi-Use Shelterbelts and Orchards http://www.agr.gc.ca/pfra/shbpub/fruitshr.htm

Exhibit 6-7: Conservation Tree/shrub Plantings Suitability Groups for Kansas

CONSERVATION TREE/SHRUB PLANTINGS SUITABILITY GROUPS FOR KANSAS

INTRODUCTION

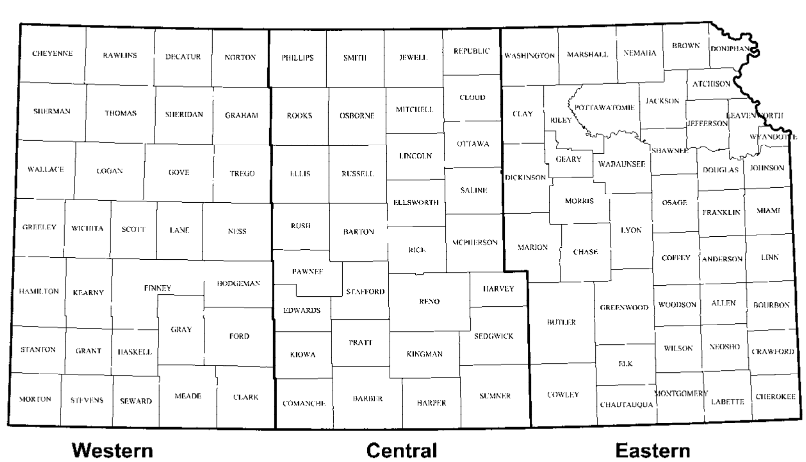
The purpose of this document is to provide guidance for tree and shrub adaptability based on soils. Each tree or shrub species has climatic and physiographic limitations. Within these parameters, a tree or shrub may be well or poorly adapted because of soil characteristics. Additionally, some introduced species may pose a problem because of spreading (by seed or root suckering) or displacing native species. Care should be taken to select materials adapted to the specific planting site and will address the identified resource concern. The species listed within the Conservation Tree/Shrub Plantings and Attributes (Attachment 2) are for conservation tree plantings. Refer to Kansas Forest Service (KFS) preferred tree lists located at http://www.kansasforests.org/pubs/community/index.shtml for Trees recommended for urban or landscape plantings

Windbreak Suitability Groups (Attachment 3) have been developed considering individual species performance under specific conditions of soil, climate, physiography, and management. These groups provide a guide for species best adapted for the soils within your county and for predicting height, growth, and effectiveness. They may be used when selecting woody plants for windbreaks, wildlife plantings, riparian buffers, reforestation, other environmental plantings, recreation, landscaping, wetland restoration or enhancement, and critical area plantings.

A number of attributes are included in the table for each species. These attributes were rated subjectively and assigned a relative value to further assist those unfamiliar with individual species characteristics or desirability for the intended use.

Explanation of Terms for Conservation Tree/Shrub Plantings and Attributes Table:
Species are grouped by plant type (shrubs, deciduous, and conifer) and arranged in alphabetical order by common name.

Kansas Tree/Shrub Zones



1. Suitability Group - A windbreak suitability value given to each soil that reflects soil productivity. Explanation of the Conservation Tree and Shrub Suitability Groups can be found in the National Forestry Manual, Section 537.22(1). Identify soil in the planting site to determine suitability group value. A designation of Not Suited (NS) means that the tree/shrub is not suited for that zone.

2. Average Height 20 Years - Heights represent expected performance of the individual plant species.

3. Growth Rate - Represented by a value relating to plant growth. F=Fast, M=Medium, S=Slow.

4. Native Species - N=Native to Kansas, I=Introduced to Kansas

5. Windbreak Value - H=High, M=Medium, L=Low. A general rating (H, M, L) of species for windbreaks rated on their ability to provide a useful component in the windbreak. An H rating would indicate that the trees or shrubs are capable of developing a row that is uniform, dense, or tall enough to provide the windbreak component for which it is planned.

6. Wildlife Value - A general rating of H, M, or L of a plant's composite of food and cover values for wildlife. Criteria include basal area, season of growth, longevity of fruit, and suitability for nests. Species with an H rating would provide food and cover for many wildlife species.

7. Lumber Products - Y=Yes, N=No. A rating of Y indicates that the species may have commercial value as timber.

8. Fuelwood Product - A Y rating indicates that the species has fuelwood value.

9. Drought Tolerance - The plant's capability to grow in droughty or dry soil conditions. H=Plant can withstand or has physiology to survive droughty periods, M=Some tolerance to drought or dry conditions, L=Little or no tolerance for dry soil conditions.

10. Soil Texture - Adaptation to different soil textures. 1=Fine textured soil, 2=Medium textured soil, 3=Coarse texture soils.

11. Soil Saturation - The plant's capability to grow in saturated soil conditions. H=Plant can withstand saturated soil conditions, M=Some tolerance to saturated conditions, L=Little tolerance of water-saturated soil, N=No tolerance to water saturation.

12. Salinity Tolerance - The plant's ability to tolerate soil salinity. H=Can tolerate high levels of salinity, M=Some tolerance to salinity, L=Little tolerance to salinity, N=No tolerance to salinity.

13. pH Range - The range in soil pH values that the plant species can be expected to grow successfully.

Soil Suitability Groups

Suitability Group 1

Description - These are deep, well drained to somewhat poorly, drained soils that receive beneficial moisture from favorable landscape positions, flooding, runoff from adjacent land, or they have a beneficial seasonal high water table during the spring. Soils within this group are generally fine sandy loam to silty clay loam.

Limitations - High pH will have an effect on the selection of species on some soils in this group. Competition from grass and weeds is the principal concern in establishing the managing trees and shrubs. Occasionally, somewhat poorly drained soils may have excessive water for some species.

Suitability Group 2

Description - Soils in this group are deep, poorly drained or very poorly drained, and excessively wet or ponded during the spring or overflow periods. Wetness limits the selection of species suitable for planting on these soils and may reduce the growth rate.

Limitations - Wetness, high pH, and drainage will have an effect on the selection of tree and shrub species for soils in this group. Competition from grass and weeds is the principal concern in establishing and managing trees and shrubs. Spring planting may be delayed because of wet conditions. Soil blowing is a concern on the sandy and organic soils.

Suitability Group 3

Description - Soils in this group are deep, well drained, loamy-textured soils with moderate and moderately slow permeability on uplands.

Limitations - Competition from grass and weeds is the principal concern in establishing and managing trees and shrubs on these soils. Water erosion is a concern on the gently sloping to moderately steep areas.

Suitability Group 4

Description - Soils are moderately deep to very deep and have loamy surface textures with clayey subsoils, have slow or very slow permeability, and occur on uplands.

Limitations - High clay content and water availability have an effect on the selection of tree and shrub species for these soils. Competition from grass and weeds is the principal concern in establishing and managing trees and shrubs. Water erosion is a concern on the gently sloping to moderately steep areas.

Suitability Group 5

Description - Soils in this group are deep with loamy and sandy texture. This group typically includes soils that normally have adequate soil moisture.

Limitations - Competition from grass and weeds and abrasion from soil blowing are the principal concerns in establishing and managing trees and shrubs on these soils.

Suitability Group 6

Description - Soils are well drained, mostly loamy textures, and moderately deep over sand, gravel, bedrock, and other layers that can severely restrict root growth. Soils have low or moderate available water capacity.

Limitations - Droughtiness will have an effect on the selection of tree and shrub species for use on these soils. Competition from grass and weeds is the principal concern in establishing and managing trees and shrubs. Water erosion is a concern on gently sloping to moderately steep areas. Supplemental watering and/or weed fabric barrier may be needed for establishment.

Suitability Group 7

Description - Soils in this group are deep, excessively to moderately well drained, sandy in texture, typically have low or very low available water-holding capacity, and do not normally have adequate moisture.

Limitations - Drought conditions and abrasion from soil blowing are the principal concerns in establishing and managing trees and shrubs on these soils. Specialized site preparation (due to hummocky sand that is subject to blowouts) and specialized planting methods (vegetation between rows is normally left undisturbed) are needed to establish trees and shrubs. Supplemental watering and/or weed fabric barrier may be essential for successful establishment.

Suitability Group 8

Description - Soils are calcareous at or near the surface. They do not receive beneficial moisture from run-in, flooding, or seasonal high water tables.

Limitations - High calcium content and competition from grass and weeds are the principal concerns in establishing the managing trees and shrubs on these soils. Water erosion is a concern on gently sloping to moderately steep areas.

Suitability Group 9

Description - Soils are affected by salinity and/or sodicity.

Limitations - Concentrations of salt and/or restrictive layers will severely affect the establishment, vigor, and growth of trees and shrubs on these soils.

Suitability Group 10

Description - Soils have one or more characteristics such as soil depth, texture, drainage, available water capacity, slope, or salts which severely limit planting, survival, or growth of trees and shrubs.

Limitations - Soils are usually not recommended for farmstead and feedlot windbreaks, field windbreaks, and plantings for recreation and wildlife. However, onsite investigations may reveal that tree and shrub plantings can be made with special treatments (hand-planting, scalp planting, specialized site preparation, drainage, or other specialized treatments). The selection of species must be tailored to the soil conditions existing at each site. **Limiting conditions and the specialized treatments required to overcome these limitations must be documented on the planting plan.**

Attachment 2 to Forestry Technical Note No. KS-10
Dated May 16, 2007

Conservation Tree/Shrub Plantings and Attributes

Tree/Shrub	Suitability Group			Average Height (feet) 20 yrs.			Attributes						Soil Adaptation				
Adapted Species	1. Eastern Zone	1. Central Zone	1. Western Zone	2. Eastern Zone	2. Central Zone	2. Western Zone	3. Growth Rate	4. Native Species	5. Windbreak Value	6. Wildlife Value	7. Lumber Products	8. Fuelwood Product	9. Drought Tolorance	10. Texture	11. Soil Saturation	12. Salinity Tolerance	13. pH Range
Shrubs																	
Blackhaw	1, 3-6	NS	NS	6-8	NS	NS	S	N	L	H	N	N	M	1, 2	N	N	4.8-7.5
Buttonbush	1, 2	1, 2	1, 2	12-15	8-12	6-8	M	N	L	M	N	N	M	1,2,3	H	L	5.3-8.5
Cherry, Choke	1, 3-8	1, 3-7	1, 3-7	12-14	10-12	6-10	F	N	H	H	N	N	H	1,2,3	M	H	5.2-8.4
Cherry, Sand (Prunus besseyii)	1, 3	1, 3	1, 3	4-6	4-6	4-6	S	N	M	H	N	N	H	2, 3	N	N	5.9-7
Cotoneaster, Peking	1, 3-6	1, 3-6	1, 3-6	6-10	6-8	5-7	M	I	H	H	N	N	H	1,2,3	N	H	5.5-7.5
Currant, Golden	1, 3-8	1, 3-8	1, 3-8	3-5	3-5	3-5	M	N	H	H	N	N	H	2	N	N	6-8
Dogwood, Redosier	1, 3-5	1, 3-5	1, 3-5	6-8	6-8	6-8	F	I	M	M	N	N	L	1,2,3	H	M	4.8-7
Dogwood, Roughleaf or Gray	1, 3-6	1, 3-5	1, 3-5	6-8	6-8	6-8	F	N	H	M	N	N	H	1, 2	L	L	4.5-7.5
Elderberry	1, 3	NS	NS	5-7	NS	NS	F	N	L	H	N	N	M	2	N	N	5-7
Euonymus, Eastern Wahoo	1, 3-4	1	NS	6-8	6-8	NS	M	N	L	M	N	N	M	1,2,3	N	N	6.1-7.8
Euonymus, Winterberry	1, 3-5	1, 3-5	NS	12-18	12-16	NS	F	I	H	L	N	N	M	1,2,3	N	L	4.7-7.5
Forsythia	1, 3-5	1, 3-5	1, 3-5	6-8	6-8	6-8	F	I	M	M	N	N	M	1,2,3	N	L	4.7-7.5
Hazel, American (hazelnut)	1, 3-5	NS	NS	3-5	NS	NS	M	N	L	H	N	N	L	2, 3	M	N	5-7
Honeysuckle, Freedom 1/	NS	NS	1-6,8,9	NS	NS	6-8	F	I	H	H	N	N	M	1,2,3	N	N	6-7.5
Indigobush (Amorpha fuiticosa)	2	2	2	4-6	4-6	4-6	M	N	L	L	N	N	L	1,2,3	M	M	5-8.5
Lilac	1, 3-5	1, 3-5	1.3-5,9	8-10	8-10	6-8	S	I	H	M	N	N	H	1,2,3	N	L	5.8-7.8
New Mexico Forestiera	NS	NS	1, 3-6	NS	NS	6-8	M	N	H	H	N	N	H	1,2,3	N	M	5-7.5
Peashrub (Caragana), Siberian	1, 3-5	1, 3-5	1, 3-5	12-14	10-12	6-10	F	I	H	M	N	N	H	2, 3	L	M	6-9
Plum, American	1,3-6,8	1, 3-5	1, 3-5	8-10	6-8	6-8	M	N	H	H	N	N	M	2, 3	M	L	5-7
Plum, Sandhill	1,3-7,9	1,3-5,7	1,3-5,7	6-8	6-8	4-6	M	N	H	H	N	N	H	2, 3	L	L	5-7.5
Russian Almond	NS	1, 3-6	1, 3-6	NS	3-5	3-5	M	I	H	M	N	N	H	1,2,3	N	N	5-7.5
Saltbush, Fourwing	9	9	1,3-7,9	6-8	4-6	4-6	S	N	H	H	N	N	H	1,2,3	N	H	6.6-9
Sumac, Fragrant	1, 3-8	1, 3-8	1, 3-8	5-8	5-8	4-7	M	N	H	H	N	N	H	1,2,3	L	L	5-8

Conservation Tree/Shrub Plantings and Attributes

Tree/Shrub	Suitability Group			Ave. Height (feet) 20 yrs.			Attributes						Soil Adaptation				
Adapted Species	1. Eastern Zone	1. Central Zone	1. Western Zone	2. Eastern Zone	2. Central Zone	2. Western Zone	3. Growth Rate	4. Native Species	5. Windbreak Value	6. Wildlife Value	7. Lumber Products	8. Fuelwood Product	9. Drought Tolorance	10. Texture	11. Saturation	12. Salinity Tolerance	13. pH Range
Deciduous Trees																	
American Hop Hornbeam	1	NS	NS	13-18	NS	NS	S	N	L	M	N	Y	L	2, 3	L	N	4-7.4
Ash, Green	1-5	1, 2	1, 2	28-32	24-28	24-26	F	N	H	M	Y	Y	M	1,2,3	H	L	5-8
Baldcypress	1-5	1, 2	1, 2	15-20	15-20	15-18	M	I	L	M	Y	Y	M	1,2,3	H	N	4.5-6
Basswood, American	1-5	NS	NS	26-30	NS	NS	M	N	M	M	Y	Y	M	2, 3	L	N	4.5-7.5
Birch, River	1, 2	NS	NS	35-50	NS	NS	F	N	L	L	Y	Y	L	1, 2	L	L	3-6
Catalpa, Northern	1, 3-6	1, 3-6	1, 3-6	26-28	26-28	24-26	F	I	M	H	Y	Y	H	2, 3	M	L	5.3-7
Cherry, Black	1	NS	NS	26-30	NS	NS	F	N	L	M	Y	Y	M	2, 3	N	N	5-7.5
Coffeetree, Kentucky	1, 3-6	1, 3-6	1, 2	26-28	26-28	24-26	M	N	M	M	Y	Y	M	1,2,3	M	M	4.8-7.5
Cottonwood, Eastern	1, 2	1, 2	1, 2	55-65	50-60	45-55	F	N	H	H	Y	Y	M	1,2,3	H	L	5.5-7.5
Elm, Lacebark	1, 3-8	1, 3-8	1, 3-5	24-28	22-26	20-24	F	I	H	M	N	Y	H	1,2,3	N	N	4.8-7
Elm, Siberian	NS	NS	1, 3-8	NS	NS	25-28	F	I	H	L	Y	Y	M	1,2,3	N	N	5.5-8
Hackberry	1-5	1-5	1	28-30	26-28	29-26	F	N	H	H	Y	Y	H	1,2,3	M	M	4.5-8
Hawthorn	1, 3-6	1, 3-6	1, 3-6	20-24	20-24	18-22	M	N	M	H	N	Y	H	1, 2	N	N	4.5-7.2
Hickory	1-5	NS	NS	24-30	NS	NS	S	N	M	H	Y	Y	M	1,2,3	M	N	4-7.4
Honeylocust	3-8	3-8	3-8	30-36	28-32	26-28	F	N	H	M	Y	Y	H	1,2,3	H	L	6-8
Locust, Black	3-8	3-8	NS	26-30	24-26	NS	F	N	M	M	N	Y	M	1,2,3	L	N	4.8-7.5
Maple, Silver	1-3	1, 2	NS	36-38	32-36	NS	F	N	M	M	Y	Y	M	1,2,3	H	L	4-6.5
Maple, Sugar	1, 3-5	NS	NS	24-30	NS	NS	S	N	M	M	Y	Y	L	2, 3	L	N	3.7-7.5
Mulberry, Red/White 2/	1-6	1-8	1-8	20-22	20-22	18-20	M	N/I	H	H	Y	Y	H	1,2,3	M	M	5-8
Oak, White	1	NS	NS	24-28	NS	NS	S	N	H	H	Y	Y	M	2, 3	L	N	4.5-6.8
Oak, Black	1, 3-6	NS	NS	26-30	NS	NS	M	N	M	H	Y	Y	M	1,2,3	L	N	4.5-6.8.
Oak, Bur	1-8	1-8	1-5	24-28	24-26	24-26	S	N	H	H	Y	Y	H	1,2,3	H	L	4.5-8
Oak, Chinquapin	1, 3-6	1, 3-6	NS	24-28	22-26	NS	M	N	M	H	Y	Y	H	2	N	N	6.5-8
Oak, English	3-5	1, 3-5	1, 3-5	40-60	40-60	30-50	M	I	M	H	Y	Y	M	1, 2	M	L	4.5-7
Oak, Northern Red	1, 3-5	1	NS	60-75	55-70	NS	M	Y	M	H	Y	Y	M	1, 2	M	N	4.5-6.5

Conservation Tree/Shrub Plantings and Attributes

Tree/Shrub	Suitability Group			Ave. Height (feet) 20 yrs.			Attributes						Soil Adaptation				
Adapted Species	1. Eastern Zone	1. Central Zone	1. Western Zone	2. Eastern Zone	2. Central Zone	2. Western Zone	3. Growth Rate	4. Native Species	5. Windbreak Value	6. Wildlife Value	7. Lumber Products	8. Fuelwood Product	9. Drought Tolorance	10. Texture	11. Saturation	12. Salinity Tolerance	13. pH Range
Oak, Pin	1-5	1, 2	NS	26-28	24-26	NS	F	N	H	H	Y	Y	M	1, 2	Y	N	4.5-6.5
Oak, Sawtooth	1, 3-5	1, 3-5	NS	26-30	24-28	NS	M	I	H	H	N	Y	M	1,2,3	N	N	4.9-7.0
Oak, Shumard	1, 3-5	1, 3-5	NS	26-30	24-28	NS	M	N	H	H	Y	Y	M	1,2,3	N	N	5.5-7.5
Oak, Swamp White	1-5	1	NS	24-28	24-26	NS	F	N	H	H	Y	Y	M	1,2,3	M	N	4.3-6.5
Osage Orange	1-9	1-9	1-9	18-22	18-22	16-20	M	I	H	M	N	Y	H	2, 3	M	L	4.5-8
Pawpaw	1, 2	1, 2	NS	18-22	15-18	NS	M	N	L	M	N	N	L	2, 3	L	N	5.1-7.2
Pecan	1-5	NS	NS	26-30	NS	NS	S	N	M	H	Y	Y	M	1,2,3	H	N	4.5-7.5
Persimmon	1, 3-5	NS	NS	20-25	NS	NS	M	N	H	H	Y	Y	M	1,2,3	N	L	4-7
Redbud, Eastern	1, 3-6	1, 3-5	1, 3	14-18	10-14	7-10	M	N	M	M	N	N	M	1, 2	N	N	4.5-7.5
Soapberry, Western	1, 3-6	1, 3-6	1, 3-6	22-28	22-26	18-22	M	N	M	M	N	Y	H	2, 3	N	N	5-7
Sycamore, American	1, 2	1, 2	NS	32-36	30-34	NS	F	N	L	M	Y	Y	M	2, 3	H	N	4.9-6.5
Walnut, Black	1, 3	1	1	26-28	24-26	18-22	M	N	H	H	Y	Y	M	2	N	N	5.5-7.5
Willow	1, 2	1, 2	1, 2	25-30	22-28	18-22	F	N	L	M	Y	Y	L	2.3	H	N	6-8
Conifer Trees																	
Arborvitae, Oriental	1-5	1-5	NS	15-20	14-18	NS	F	I	H	M	N	N	M	1,2,3	N	M	4.7-6.8
Juniper, Chinese	1, 3-7	1, 3-7	1, 3-7	15-20	15-20	15-20	F	I	N	M	N	N	M	1,2,3	N	Y	4.8-8
Juniper, Rocky Mountain	NS	NS	1, 3-9	NS	NS	14-18	M	I	H	H	N	N	H	2,3	N	N	5-8
Pine, Austrian	1, 3-7	1, 3-7	1, 3-5	24-28	20-24	18-22	M	I	H	M	N	N	M	2	N	Y	6.5-7.5
Pine, Eastern White	1, 3-5	NS	NS	30-34	NS	NS	F	I	H	M	Y	N	L	2	N	N	4-6.5
Pine, Ponderosa	1, 3-8	1, 3-8	1, 3-8	18-22	16-20	14-18	M	I	H	M	Y	N	H	2,3	N	N	6-7
Pine, Southwestern White	1, 3-5	1, 3-5	1, 3-5	18-22	16-20	14-18	M	I	H	M	N	N	H	2,3	N	Y	5-7.5
Redcedar, Eastern	1, 3-9	1, 3-9	1, 3-9	14-18	12-15	10-12	M	N	H	H	Y	N	H	1,2,3	N	N	4.7-8

Footnote:
1/ Freedom Honeysuckle is a introduced shrub that can become invasive in some locations.
2/ White mulberry is a introduced tree that can become invasive in some locations.

Exhibit 6-8: Conservation Tree/shrub Plantings Suitability Groups for Nebraska

Table of Contents

continued… Plants recommended for each CTSG	Each table lists species adapted to each CTSG by vegetative zone, including 20-year heights and mature height/spread	CTSG 9L p. 92 CTSG 9W p. 93 CTSG 10 p. 94 pp. 95 - 104
Summary - List of Attributes by Species for Conservation Tree/Shrub Plantings in Nebraska	Includes a complete listing of tree and shrub species and their attributes. This list can be used to select species based on their attributes and the purpose of the planting (e.g., shade tolerance, flooding tolerance, wildlife value, density, wood products, and suckering, other attributes/concerns).	

Each field office/DC shall list individual soils that are included in each CTSG for your service area. It is recommended that this task be accomplished using the reports in Web Soil Survey, under the Soil Data Explorer tab. The following table shows where these reports are located in Web Soil Survey.

Soil Interpretation	Map or Table Name	Tab of Soil Data Explorer	Menu	Map (M) or Table (T)	User Options		Notes
					Minor Soils	Depth Range	
Windbreaks	**Windbreaks and Environmental Plantings**	Soil Reports	Soil Erosion	T	●		Lists Tree and Shrub Species By Soil
	Conservation Tree and Shrub Group	Suitabilities and Limitations for Use	Land Classifications	M,T			Rates Dominant Soil In Map Unit
	Conservation Tree and Shrub Group	Soil Reports	Land Classifications	T	●		Rates Individual Soils in Map Unit

Conservation Tree/Shrub Groups (CTSGs)

Introduction

A Conservation Tree/Shrub Group (CTSG) is a physiographic unit or area having similar climatic and edaphic or soils-related characteristics that control the selection and height growth of trees and shrubs. Each Conservation Tree/Shrub Group is based on two soil-related elements: 1) Major Land Resource Area (13 in NE), and 2) Soil Group (22 in NE).

1) Major Land Resource Area (MLRA) refines the list of woody plant species selected and adapted to a specified geographic area with similarities in climate. See USDA Agricultural Handbook 296 (2006) for a definition of a MLRA: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053624.

   States can further subdivide a MLRA by varying elevations (i.e., hardiness zones) and diverse ranges of average annual precipitation that influence species selection and performance.

2) Soil Group further refines the list of woody plants based on groupings of soil-related conditions. Rather than try to correlate plant data for each and every soil component, a component is evaluated against criteria and placed in one of the 22 Nebraska soil groups. Woody plants are then correlated to a specific soil group within the identified MLRA. If needed, local custom criteria can be used to override the calculated soil group, as well as recognize additional local soil groups.

The correlation and display of adapted woody species, height performance, other attributes, and associated practices and measures using the CTSG system need to be clearly understood by clients. The performance of species is expressed as the expected height at a base age (usually 20 years in continental U.S. and Alaska and 10 years for tropical and subtropical areas). Other attributes may be correlated to each species, such as longevity, wildlife value, crown shape and spread. In addition to height performance and other attributes, the CTSG, MLRA, and soil group may be used to determine facilitating practices and measures that can enhance survival and growth of woody species for correlated soil components. For example, a soil component in Soil Group 7 (sandy) in an agricultural area in MLRA 67A will likely have blowing sand that will damage new seedlings in a zone of low precipitation. Permanent irrigation (i.e., Irrigation System – Micro-Irrigation, 441) and moisture-conserving "weed barrier" (i.e., Mulching, 484) in combination with small physical barriers on the windward side of planted seedlings (e.g., straw bales or snow- fence) could offer mitigating actions to insure better survival and establishment.

States are responsible for developing CTSG interpretations for MLRAs that occur wholly within their state. For MLRAs that cross state boundaries, the individual state with the greatest extent of the MLRA is responsible for developing CTSG interpretations but must coordinate with adjacent states having the MLRA. States make periodic reviews and updates to such displays so that information and data are current in section II of the eFOTG, the Web Soil Survey, and other applicable documents. Although the CTSG designation is very helpful in conservation planning, it does not override the need for on-site evaluation for properly selecting trees and shrubs and estimating design heights and other planning requirements (190-V-NFM, Dec. 15, 2008).

All soil series mapped in the state have been placed with similar soils into one of the 22 CTSGs. Refer to Conservation Tree/Shrub Group Descriptions for a brief description of the characteristics of each soil group. Each tree or shrub species has certain climatic and physiographic limits. Within these parameters trees and shrubs may be well or poorly suited because of climate, site and soil characteristics. These 22 groups are derived from splitting out additional soil characteristics, such as calcareousness, dryness, soil texture, soil depth, water holding capacity, depth to water table, salinity, and pH. Individual species performance will vary under specified conditions of climate, physiography, and management. Factors such as weed competition, moisture conservation, spacing, and arrangement must also be considered.

A map of Nebraska Vegetation Zones is included for your reference. It may also be found in the Nebraska Field Office Technical Guide, Section I-Maps. Each county in Nebraska is included in one of four vegetative zones, based on precipitation ranges. Because vegetative zones are large, climatic differences within a zone should also be considered when recommending species. Some species adapted to the eastern end of a zone may not be as adequately adapted to the western end due to rainfall generally varying from “more” in the east to “less” in the west.

This information provides guidance for selecting species best suited within each vegetative zone for each of the 22 groups of soils. It can also be used for predicting survival, height, growth, species attributes and effectiveness for the purpose of the planting. It can be used to select plants for windbreaks, riparian plantings, recreation and wildlife plantings, ornamental or environmental plantings, reforestation, and critical area plantings.

The expected 20-year tree or shrub height and height/spread at maturity is listed in individual tables by CTSG and vegetative zone. This information should be employed when determining: the spacing and placement of tree/shrub plantings, the area to be protected by the windbreak, the species components, the effectiveness of the planting purpose, and other planting design considerations.

Named varieties of plants cooperatively released through the NRCS/USDA Plant Materials Program have been included in the tables. These varieties have proven superior and should be used when they are available. Native plant species should receive higher preference than non-native (introduced) species when planning a tree or shrub planting.

SOIL NAMES ALPHABETICALLY

Component Name	CTSG	phase
Ackmore	1	
Aksarben	4	
Albaton	2K	
Albaton variant	2K	
Albinas	6	
Alcester	3	
Alda	1S	
Alda	10	channeled, frequently flooded
Alice	5	
Alliance	5	
Almeria	10	
Altvan	6	
Angora	3	
Anselmo	5	
Anselmo	3	very fine sandy loam
Aowa	1	
Aowa	10	channeled, frequently flooded
Arvada	10	
Ascalon	5K	
Ashollow	8	
Ashollow	10	> 30 percent slopes
Badland	10	
Bahl	4CK	
Baltic	2K	
Bankard	10	
Bankard variant	10	
Barney	10	
Barney variant	10	
Bayard	5	
Bazile	5	
Beckton	9W	
Belfore	3	
Benfield	10	
Benkelman	1	
Betts	8	
Betts	10	> 30 percent slopes
Bigbend	10	
Bigwinder	1S	
Birdwood	10	
Blackloup	10	
Blackwood	3	
Blake	1	
Blanche	6	
Blencoe	2	
Blendon	5	
Blendon variant	5	
Blownout land	10	
Blueridge	10	
Blyburg	3	
Boel	1S	
Boel	10	channeled, occasionally flooded
Boelus	5	
Bolent	2	
Bolent	10	channeled, occasionally flooded

SOIL NAMES ALPHABETICALLY

Boone	10	
Boyd	10	
Bridget	3	
Bristow	10	
Broadwater	10	
Brocksburg	6	
Brownson	10	
Brunswick	7	
Buffington	4	
Bufton	4	
Burchard	3	
Busher	5	
Bushman	5K	
Butler	2	
Calamus	7	
Calamus	10	channeled, occasionally flooded
Calco	2	
Campus	6	
Canlon	10	
Canyon	10	
Carr	1	
Caruso	2	
Caruso variant	6	
Cass	5	
Cass	10	channeled, frequently flooded
Cass variant	5	
Chappell	6	
Chase	2	
Cheyenne	6	
Clamo	2	
Clarno	2	
Clawhammer	10	
Coleridge	1	
Colfer	7	
Colo	2	
Colo	10	channeled, frequently flooded
Coly	8	
Coly	10	> 30 percent slopes
Contrary	3	
Cooper	1	
Cortland	5	
Cozad	3	
Cozad	9L	saline-alkali
Cozad variant	3	
Craft	8	
Craft	10	channeled, frequently flooded
Craft	9L	
Creighton	3	
Crete	4	
Crete variant	9L	
Crofton	8	
Crofton	10	
Crowther	10	
Cullison	10	
Cutcomb	10	

SOIL NAMES ALPHABETICALLY

Dailey	7	
Dankworth	7	
Darr	6	
Deroin	3	
Detroit	4	
Dickinson	5	
Dix	10	
Doger	7	
Doughboy	8	
Dow	3	
Draknab	5	
Duda	10	
Dudley	9L	
Dunday	7	
Dunn	5	
Duroc	3	
Dwyer	7	
Eckley	10	
Edalgo	10	
Els	1S	
Els	1SK	calcareous
Elsmere	1S	
Elsmere	1SK	calcareous
Eltree	3	
Enning	10	
Epping	10	
Eudora	1	
Filbert	2	
Filley	5	
Fillmore	10	
Fillmore	2	drained
Fillmore variant	10	
Fishberry	10	
Fluvaquents	10	
Fluvaquents, loamy	10	
Fluvaquents, sandy	10	
Fluvaquents, silty	10	
Fonner	6	
Fonner variant	6	
Fontanelle	2	
Forney	2K	
Gannett	10	
Gannett variant	10	
Gates	3	
Gates	10	> 30 percent slopes
Gavins	10	
Gayville	9L	
Gayville variant	9L	
Geary	3	
Geary variant	3	
Gering	9L	
Gibbon	2	
Gibbon	9L	saline-alkali
Gibbon variant	2	
Gilliam	1	

SOIL NAMES ALPHABETICALLY

Glenberg	5K	
Glenberg	10	channeled, frequently flooded
Goshen	3	
Gosper	1	
Gosper	9L	saline-alkali
Gothenburg	10	
Grable	5K	
Grable variant	5K	
Graybert	3	
Grigston	3	
Gullied land	10	
Gus	10	
Gymer	4	
Hadar	5	
Haigler	9L	
Hall	3	
Harney	3	
Hastings	3	
Hastings variant	3	
Haverson	8	
Haxtun	5	
Haynie	8	
Haynie	10	channeled, occasionally flooded
Haynie variant	8	
Hedville	10	
Hemingford	5	
Hennings	5	
Hennings	7	loamy fine sands
Hersh	5	
Hersh	7	loamy fine sands
Hersh	10	> 30 percent slopes
Hisle	10	
Histosols	10	
Hobbs	1	
Hobbs	10	channeled, frequently flooded
Hoffland	10	
Holder	3	
Holder variant	3	
Holdrege	3	
Holdrege variant	3	
Holly Springs	10	
Holt	7	
Holt variant	7	
Hord	3	
Hord variant	3	
Humbarger	3	
Humbarger variant	3	
Ida	8	
Ida	10	> 30 percent slopes
Imlay	10	
Inavale	7	
Inavale	10	channeled, frequently flooded
Inglewood	7	
Inglewood	10	channeled, occasionally flooded
Interior	10	

SOIL NAMES ALPHABETICALLY

Ipage	7	
Janise	9W	
Jankosh	9W	
Jansen	6	
Jansen variant	6	
Janude	3	
Jayem	5	
Jayem	7	loamy fine sands
Johnstown	3	
Josburg	3	
Judson	3	
Kadoka	6D	
Kanorado	4CK	
Keith	3	
Keith variant	9L	
Kenesaw	3	
Kennebec	1	
Kennebec	10	channeled, frequently flooded
Kenridge	1	
Keota	10	
Keota	8	
Keya	3	
Kezan	2	
Kezan	10	channeled, frequently flooded
Kipson	10	
Kipson variant	10	
Kuma	3	
Kyle	4C	
Labu	4C	
Labu	10	> 30 percent slopes
Laird	10	
Lamo	1K	
Lamo variant	1K	
Lancaster	6D	
Lancaster variant	6D	
Las	1SK	
Las Animas	1SK	
Las Animas	10	channeled, frequently flooded
Lawet	1K	
Lawet	9L	
Lawet variant	3	
Leisy	3	
Lemoyne	5	
Leshara	1	
Lewellen	9W	
Lex	1SK	
Lex	9W	saline-alkali
Lex variant	1SK	
Lexsworth	9W	
Libory	1	
Lisco	10	
Lockton	1S	
Lodgepole	10	
Lohmiller	10	channeled, frequently flooded
Lohmiller	4K	

SOIL NAMES ALPHABETICALLY

Longford	4	
Longpine	10	
Loretto	3	
Lossing	1K	
Loup	2	
Loup	10	frequently ponded
Lute	9W	
Luton	2K	
Lynch	10	
Mace	6D	
Malcolm	3	
Malmo	4C	
Manter	5	
Manvel	8	
Mariaville	10	
Marlake	10	
Marshall	3	
Maskell	3	
Massie	10	
Mayberry	4C	
McCash	3	
McConaughy	3	
McCook	8	
McCook	10	channeled, occasionally flooded
McCook variant	8	
McCuligan	2K	
McGrew	1K	
McGrew	9W	saline-alkali
McKelvie	7	
McKelvie	10	
McPaul	1	
Meadin	10	
Meckling	1K	
Medihemists	10	
Melia	3	
Merrick	3	
Minatare	10	
Minnequa	9L	
Minnequa	10	saline-alkali
Mitchell	8	
Mitchell variant	8	
Modale	1	
Monona	3	
Monona	10	> 30 percent slopes
Monona variant	3	
Moody	3	
Morrill	3	
Morrill variant	3	
Moville	1	
Muir	3	
Mullen	5	
Munjor	5K	
Munjor	10	channeled, frequently flooded
Munjor variant	5K	
Muscotah	2	

SOIL NAMES ALPHABETICALLY

Napa	10	
Napier	3	
Nenzel	7	
Nimbro	8	
Niobrara	10	
Nishna	2K	
Nodaway	1	
Nodaway	10	channeled, frequently flooded
Nora	3	
Nora variant	3	
Norrest	4	
Norway	10	
Norwest	1K	
Novina	1	
Nuckolls	3	
Nuckolls variant	3	
Obert	10	
Obert	2K	
Oglala	3	
Olbut	9W	
Olmitz	3	
Olney	5K	
Omadi	1	
Onawa	1	
Onawet	2K	
O'Neill	6	
Onita	4	
Ord	1S	
Ord variant	1S	
Orella	10	
Orpha	7	
Orpha	10	> 30 percent slopes
Ortello	5	
Ortello	7	loamy fine sands
Orwet	2	
Otero	8	
Otero variant	8	
Otoe	4C	
Overlake	5	
Ovina	1	
Owego	2K	
Padonia	4C	
Pahuk	7	
Paka	10	> 30 percent slopes
Paka	3	
Pathfinder	9L	
Pawnee	4C	
Pawnee variant	4C	
Percival	1K	
Phiferson	6DK	
Phiferson	10	> 30 percent slopes
Pierre	4C	
Pivot	7	
Pivot	10	> 17 percent slopes
Platte	1S	

SOIL NAMES ALPHABETICALLY

Platte	10	channeled, frequently flooded
Pohocco	3	
Pohocco	10	> 30 percent slopes
Ponca	3	
Ponderosa	5	
Ponderosa	3	very fine sandy loam
Ponderosa	10	> 30 percent slopes
Promise	4C	
Ralton	6K	
Redstoe	10	
Ree	3	
Reliance	4K	
Richfield	3	
Ringgold	5	
Riverwash	10	
Rock outcrop	10	
Ronson	10	
Rosebud	6D	
Rosebud	10	> 17 percent slopes
Roxbury	1	
Rusco	2	
Rusco variant	2	
Rushcreek	6K	
Salix	1K	
Salmo	9W	
Salmo	10	channeled, frequently flooded
Saltillo	10	
Saltine	10	
Samsil	10	
Sanborn	10	
Sandose	5	
Sansarc	10	
Sarben	10	> 30 percent slopes
Sarben	5	
Sarben	7	loamy fine sands
Sardak	7	
Sarpy	7	
Satanta	3	
Satanta	6	gravelly substratum
Savo	4	
Schamber	10	
Scott	10	
Scott variant	10	
Scoville	5	
Scroll	6K	
Selia	10	
Shale outcrop	10	
Sharpsburg variant	10	
Shelby	3	
Shelby	10	> 30 percent slopes
Shell	1	
Shell variant	3	
Shingle	8	
Sidney	5K	
Silver Creek	9W	

SOIL NAMES ALPHABETICALLY

Simeon	7	
Skilak	9L	
Skilak	10	> 17 percent slopes
Slickspots	10	
Smithland	1	
Sogn	10	
Solomon	2	
Steinauer	8	
Steinauer	10	> 30 percent slopes
Sulco	8	
Sulco	10	> 30 percent slopes
Sully	8	
Talmo	10	
Tassel	10	
Thirtynine	3	
Thurman	7	
Ticonic	5	
Tieville	2	
Tomek	3	
Trent	3	
Tripp	3	
Tryon	2	
Tryon	10	frequently ponded
Tuthill	5	
Udarents	10	
Udorthents	10	
Uly	3	
Uly	10	> 30 percent slopes
Uly variant	3	
Ulysses	3	
Urban land	10	
Ustipsamments	10	
Ustorthents	10	
Valent	7	
Valent	10	> 30 percent slopes
Valentine	7	
Valentine	10	> 30 percent slopes
Verdel	4C	
Verdigre	4	
Vetal	5	
Wabash	2	
Wakeen	6D	
Wakeen	10	> 17 percent slopes
Wakeen variant	6D	
Wann	1S	
Wann	10	channeled, occasionally flooded
Wann	9L	saline-alkali
Wann variant	1S	
Wann variant	9L	saline-alkali
Wathena	1S	
Waubonsie	1	
Wewela	7	
Whitelake	10	
Wildhorse	10	
Wood River	9L	saline-alkali

SOIL NAMES ALPHABETICALLY

Wood River	10	
Woodbury	2	
Woodly	3	
Wymore	4C	
Yockey	10	
Yockey	9W	saline-alkali
Yutan	3	
Zoe	9W	
Zook	2	

SOIL NAMES BY GROUP NUMBER

Component Name	CTSG	Phase
Ackmore	1	
Aowa	1	
Benkelman	1	
Blake	1	
Carr	1	
Coleridge	1	
Cooper	1	
Eudora	1	
Gilliam	1	
Gosper	1	
Hobbs	1	
Kennebec	1	
Kenridge	1	
Leshara	1	
Libory	1	
McPaul	1	
Modale	1	
Moville	1	
Nodaway	1	
Novina	1	
Omadi	1	
Onawa	1	
Ovina	1	
Roxbury	1	
Shell	1	
Smithland	1	
Waubonsie	1	
Blencoe	2	
Bolent	2	
Butler	2	
Calco	2	
Caruso	2	
Chase	2	
Clamo	2	
Clarno	2	
Colo	2	
Filbert	2	
Fillmore	2	drained
Fontanelle	2	
Gibbon	2	
Gibbon variant	2	
Kezan	2	
Loup	2	
Muscotah	2	
Orwet	2	
Rusco	2	
Rusco variant	2	
Solomon	2	
Tieville	2	
Tryon	2	
Wabash	2	
Woodbury	2	
Zook	2	
Alcester	3	

SOIL NAMES BY GROUP NUMBER

Angora	3	
Anselmo	3	very fine sandy loam
Belfore	3	
Blackwood	3	
Blyburg	3	
Bridget	3	
Burchard	3	
Contrary	3	
Cozad	3	
Cozad variant	3	
Creighton	3	
Deroin	3	
Dow	3	
Duroc	3	
Eltree	3	
Gates	3	
Geary	3	
Geary variant	3	
Goshen	3	
Graybert	3	
Grigston	3	
Hall	3	
Harney	3	
Hastings	3	
Hastings variant	3	
Holder	3	
Holder variant	3	
Holdrege	3	
Holdrege variant	3	
Hord	3	
Hord variant	3	
Humbarger	3	
Humbarger variant	3	
Janude	3	
Johnstown	3	
Josburg	3	
Judson	3	
Keith	3	
Kenesaw	3	
Keya	3	
Kuma	3	
Lawet variant	3	
Leisy	3	
Loretto	3	
Malcolm	3	
Marshall	3	
Maskell	3	
McCash	3	
McConaughy	3	
Melia	3	
Merrick	3	
Monona	3	
Monona variant	3	
Moody	3	
Morrill	3	

SOIL NAMES BY GROUP NUMBER

Morrill variant	3	
Muir	3	
Napier	3	
Nora	3	
Nora variant	3	
Nuckolls	3	
Nuckolls variant	3	
Oglala	3	
Olmitz	3	
Paka	3	
Pohocco	3	
Ponca	3	
Ponderosa	3	very fine sandy loam
Ree	3	
Richfield	3	
Satanta	3	
Shelby	3	
Shell variant	3	
Thirtynine	3	
Tomek	3	
Trent	3	
Tripp	3	
Uly	3	
Uly variant	3	
Ulysses	3	
Woodly	3	
Yutan	3	
Aksarben	4	
Buffington	4	
Bufton	4	
Crete	4	
Detroit	4	
Gymer	4	
Longford	4	
Norrest	4	
Onita	4	
Savo	4	
Verdigre	4	
Alice	5	
Alliance	5	
Anselmo	5	
Bayard	5	
Bazile	5	
Blendon	5	
Blendon variant	5	
Boelus	5	
Busher	5	
Cass	5	
Cass variant	5	
Cortland	5	
Dickinson	5	
Draknab	5	
Dunn	5	
Filley	5	
Hadar	5	

SOIL NAMES BY GROUP NUMBER

Haxtun	5	
Hemingford	5	
Hennings	5	
Hersh	5	
Jayem	5	
Lemoyne	5	
Manter	5	
Mullen	5	
Ortello	5	
Overlake	5	
Ponderosa	5	
Ringgold	5	
Sandose	5	
Sarben	5	
Scoville	5	
Ticonic	5	
Tuthill	5	
Vetal	5	
Albinas	6	
Altvan	6	
Blanche	6	
Brocksburg	6	
Campus	6	
Caruso variant	6	
Chappell	6	
Cheyenne	6	
Darr	6	
Fonner	6	
Fonner variant	6	
Jansen	6	
Jansen variant	6	
O'Neill	6	
Satanta	6	gravelly substratum
Brunswick	7	
Calamus	7	
Colfer	7	
Dailey	7	
Dankworth	7	
Doger	7	
Dunday	7	
Dwyer	7	
Hennings	7	loamy fine sands
Hersh	7	loamy fine sands
Holt	7	
Holt variant	7	
Inavale	7	
Inglewood	7	
Ipage	7	
Jayem	7	loamy fine sands
McKelvie	7	
Nenzel	7	
Orpha	7	
Ortello	7	loamy fine sands
Pahuk	7	
Pivot	7	

SOIL NAMES BY GROUP NUMBER

Sarben	7	loamy fine sands
Sardak	7	
Sarpy	7	
Simeon	7	
Thurman	7	
Valent	7	
Valentine	7	
Wewela	7	
Ashollow	8	
Betts	8	
Coly	8	
Craft	8	
Crofton	8	
Doughboy	8	
Haverson	8	
Haynie	8	
Haynie variant	8	
Ida	8	
Keota	8	
Manvel	8	
McCook	8	
McCook variant	8	
Mitchell	8	
Mitchell variant	8	
Nimbro	8	
Otero	8	
Otero variant	8	
Shingle	8	
Steinauer	8	
Sulco	8	
Sully	8	
Alda	10	channeled, frequently flooded
Almeria	10	
Aowa	10	channeled, frequently flooded
Arvada	10	
Ashollow	10	> 30 percent slopes
Badland	10	
Bankard	10	
Bankard variant	10	
Barney	10	
Barney variant	10	
Benfield	10	
Betts	10	> 30 percent slopes
Bigbend	10	
Birdwood	10	
Blackloup	10	
Blownout land	10	
Blueridge	10	
Boel	10	channeled, occasionally flooded
Bolent	10	channeled, occasionally flooded
Boone	10	
Boyd	10	
Bristow	10	
Broadwater	10	
Brownson	10	

SOIL NAMES BY GROUP NUMBER

Calamus	10	channeled, occasionally flooded
Canlon	10	
Canyon	10	
Cass	10	channeled, frequently flooded
Clawhammer	10	
Colo	10	channeled, frequently flooded
Coly	10	> 30 percent slopes
Craft	10	channeled, frequently flooded
Crofton	10	
Crowther	10	
Cullison	10	
Cutcomb	10	
Dix	10	
Duda	10	
Eckley	10	
Edalgo	10	
Enning	10	
Epping	10	
Fillmore	10	
Fillmore variant	10	
Fishberry	10	
Fluvaquents	10	
Fluvaquents, loamy	10	
Fluvaquents, sandy	10	
Fluvaquents, silty	10	
Gannett	10	
Gannett variant	10	
Gates	10	> 30 percent slopes
Gavins	10	
Glenberg	10	channeled, frequently flooded
Gothenburg	10	
Gullied land	10	
Gus	10	
Haynie	10	channeled, occasionally flooded
Hedville	10	
Hersh	10	> 30 percent slopes
Hisle	10	
Histosols	10	
Hobbs	10	channeled, frequently flooded
Hoffland	10	
Holly Springs	10	
Ida	10	> 30 percent slopes
Imlay	10	
Inavale	10	channeled, frequently flooded
Inglewood	10	channeled, occasionally flooded
Interior	10	
Kennebec	10	channeled, frequently flooded
Keota	10	
Kezan	10	channeled, frequently flooded
Kipson	10	
Kipson variant	10	
Labu	10	> 30 percent slopes
Laird	10	
Las Animas	10	channeled, frequently flooded
Lisco	10	

SOIL NAMES BY GROUP NUMBER

Lodgepole	10	
Lohmiller	10	channeled, frequently flooded
Longpine	10	
Loup	10	frequently ponded
Lynch	10	
Mariaville	10	
Marlake	10	
Massie	10	
McCook	10	channeled, occasionally flooded
McKelvie	10	
Meadin	10	
Medihemists	10	
Minatare	10	
Minnequa	10	saline-alkali
Monona	10	> 30 percent slopes
Munjor	10	channeled, frequently flooded
Napa	10	
Niobrara	10	
Nodaway	10	channeled, frequently flooded
Norway	10	
Obert	10	
Orella	10	
Orpha	10	> 30 percent slopes
Paka	10	> 30 percent slopes
Phiferson	10	> 30 percent slopes
Pivot	10	> 17 percent slopes
Platte	10	channeled, frequently flooded
Pohocco	10	> 30 percent slopes
Ponderosa	10	> 30 percent slopes
Redstoe	10	
Riverwash	10	
Rock outcrop	10	
Ronson	10	
Rosebud	10	> 17 percent slopes
Salmo	10	channeled, frequently flooded
Saltillo	10	
Saltine	10	
Samsil	10	
Sanborn	10	
Sansarc	10	
Sarben	10	> 30 percent slopes
Schamber	10	
Scott	10	
Scott variant	10	
Selia	10	
Shale outcrop	10	
Sharpsburg variant	10	
Shelby	10	> 30 percent slopes
Skilak	10	> 17 percent slopes
Slickspots	10	
Sogn	10	
Steinauer	10	> 30 percent slopes
Sulco	10	> 30 percent slopes
Talmo	10	
Tassel	10	

SOIL NAMES BY GROUP NUMBER

Tryon	10	frequently ponded
Udarents	10	
Udorthents	10	
Uly	10	> 30 percent slopes
Urban land	10	
Ustipsamments	10	
Ustorthents	10	
Valent	10	> 30 percent slopes
Valentine	10	> 30 percent slopes
Wakeen	10	> 17 percent slopes
Wann	10	channeled, occasionally flooded
Whitelake	10	
Wildhorse	10	
Wood River	10	
Yockey	10	
Lamo	1K	
Lamo variant	1K	
Lawet	1K	
Lossing	1K	
McGrew	1K	
Meckling	1K	
Norwest	1K	
Percival	1K	
Salix	1K	
Alda	1S	
Bigwinder	1S	
Boel	1S	
Els	1S	
Elsmere	1S	
Lockton	1S	
Ord	1S	
Ord variant	1S	
Platte	1S	
Wann	1S	
Wann variant	1S	
Wathena	1S	
Els	1SK	calcareous
Elsmere	1SK	calcareous
Las	1SK	
Las Animas	1SK	
Lex	1SK	
Lex variant	1SK	
Albaton	2K	
Albaton variant	2K	
Baltic	2K	
Forney	2K	
Luton	2K	
McCuligan	2K	
Nishna	2K	
Obert	2K	
Onawet	2K	
Owego	2K	
Kyle	4C	
Labu	4C	
Malmo	4C	

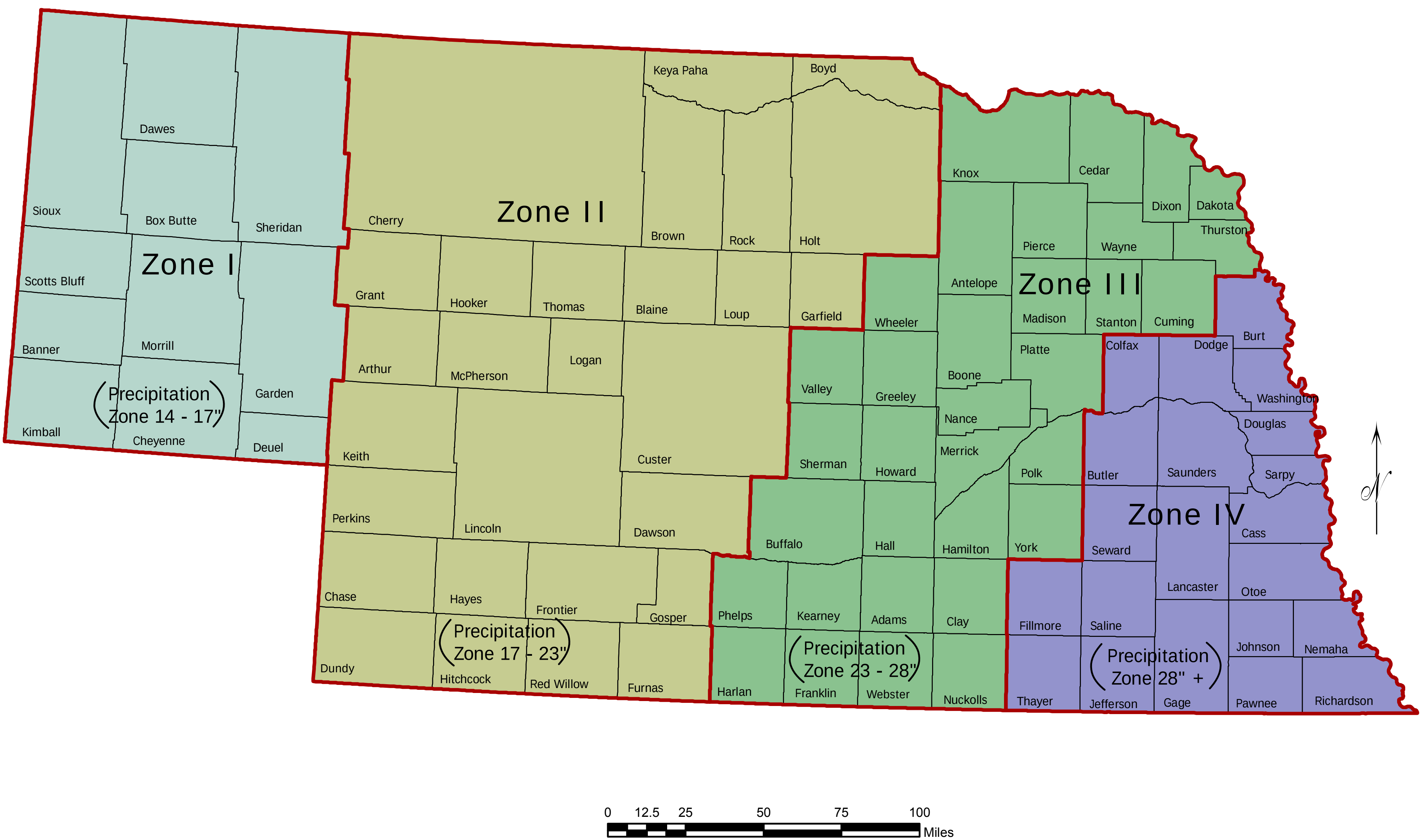
SOIL NAMES BY GROUP NUMBER

Mayberry	4C	
Otoe	4C	
Padonia	4C	
Pawnee	4C	
Pawnee variant	4C	
Pierre	4C	
Promise	4C	
Verdel	4C	
Wymore	4C	
Bahl	4CK	
Kanorado	4CK	
Lohmiller	4K	
Reliance	4K	
Ascalon	5K	
Bushman	5K	
Glenberg	5K	
Grable	5K	
Grable variant	5K	
Munjor	5K	
Munjor variant	5K	
Olney	5K	
Sidney	5K	
Kadoka	6D	
Lancaster	6D	
Lancaster variant	6D	
Mace	6D	
Rosebud	6D	
Wakeen	6D	
Wakeen variant	6D	
Phiferson	6DK	
Ralton	6K	
Rushcreek	6K	
Scroll	6K	
Cozad	9L	saline-alkali
Craft	9L	
Crete variant	9L	
Dudley	9L	
Gayville	9L	
Gayville variant	9L	
Gering	9L	
Gibbon	9L	saline-alkali
Gosper	9L	saline-alkali
Haigler	9L	
Keith variant	9L	
Lawet	9L	
Minnequa	9L	
Pathfinder	9L	
Skilak	9L	
Wann	9L	saline-alkali
Wann variant	9L	saline-alkali
Wood River	9L	saline-alkali
Beckton	9W	
Janise	9W	
Jankosh	9W	
Lewellen	9W	

SOIL NAMES BY GROUP NUMBER

Lex	9W	saline-alkali
Lexsworth	9W	
Lute	9W	
McGrew	9W	saline-alkali
Olbut	9W	
Salmo	9W	
Silver Creek	9W	
Yockey	9W	saline-alkali
Zoe	9W	

NEBRASKA VEGETATIVE ZONES



Natural Resources Conservation Service

Conservation Tree/Shrub Groups (CTSGs)

Descriptions

Group 1 (Wet Favorable)
Soil depth to a restrictive layer is at least 40 inches (100 cm). The depth to a water table during the growing season is at least 1.5 feet (45 cm) but less than 4 feet (120 cm). If the soil is frequently or occasional flooded for 2 or more months during the growing season, with duration of brief, long, or very long, then the depth to a water table during the growing season may exceed 4 feet. The available water capacity is greater than 9 inches (22.5 centimeters). In the upper 12 inches (30 cm) of the soil profile free carbonates do not exceed a concentration of 5 percent calcium carbonate equivalent, the range of pH is between 5.6 and 8.4, and electrical conductivity is 4 mmhos/cm or less.

Subgroup 1K (Wet Favorable-Calcareous)
Soil criteria is the same as Group 1 except:
_ In the upper 12 inches (30 cm) of the soil profile free carbonates range between 5 and 15 percent calcium carbonate equivalent and the range of pH is between 6.5 and 8.4.

Subgroup 1S (Wet Favorable-Droughty)
Soil criteria is the same as Group 1 except:
_ The available water capacity is between 6 and 9 inches (15 and 22.5 cm).

Subgroup 1SK (Wet Favorable-Droughty-Calcareous)
Soil criteria is the same as Group 1 except:
_ The available water capacity is between 6 and 9 inches (15 and 22.5 cm)
_ In the upper 12 inches (30 cm) of the soil profile free carbonates range between 5 and 15 percent calcium carbonate equivalent and the range of pH is between 6.5 and 8.4.

Group 2 (Wet)
Soil depth to a restrictive layer is at least 40 inches (100 cm). The depth to a water table during the growing season is at least 0.5 feet (15 cm) but less than 1.5 feet (45 cm). The available water capacity is greater than 3 inches (8 cm).
In the upper 12 inches (30 cm) of the soil profile free carbonates do not exceed a concentration of 5 percent calcium carbonate equivalent, the range of pH is between 5.6 and 8.4, and electrical conductivity is 4 mmhos/cm or less.

Subgroup 2K (Wet-Calcareous)
Soil criteria is the same as Group 2 except:
_ In the upper 12 inches (30 cm) of the soil profile free carbonates range between 5 and 15 percent calcium carbonate equivalent and the range of pH is between 6.5 and 8.4.

Group 3 (Loamy)
Soil depth to a restrictive layer is at least 40 inches (100 cm). The depth to a water table during the growing season is at least 4 feet (120 cm). If the soil is frequently or occasional flooded with duration of brief, long, or very long, it must be for less than 2 months during the growing season. The available water capacity is at least 9 inches (22.5 cm). In the upper 12 inches (30 cm) of the soil profile free carbonates do not exceed a concentration of 5 percent calcium carbonate equivalent, the range of pH is between 5.6 and 8.4, and electrical conductivity is 2 mmhos/cm or less. The texture is non-clayey between 8 inches (20 cm) and 48 inches (120 cm).

Group 4 (Clayey Favorable)
Soil depth to a restrictive layer is at least 20 inches (50 cm). The depth to a water table during the growing season is at least 4 feet (120 cm). The depth to a water table may be less than 4 feet (120 cm) if it is for less than 2 months during the growing season. The available water capacity is at least 6 inches (15 cm). In the upper 12 inches (30 cm) of the soil profile free carbonates do not exceed a concentration of 5 percent calcium carbonate equivalent, the range of pH is between 5.6 and 8.4, and electrical conductivity is 4 mmhos/cm or less. The texture between 8 inches (20cm) and 20 inches (50 cm) is non-clayey over >35% clay.

Subgroup 4K (Clayey Favorable-Calcareous)
Soil criteria is the same as Group 4 except:
_ In the upper 12 inches (30 cm) of the soil profile free carbonates range between 5 and 15 percent calcium carbonate equivalent and the range of pH is between 6.5 and 8.4.

Subgroup 4C (Clayey)
Soil depth to a restrictive layer is at least 20 inches (50 cm). The depth to a water table during the growing season is at least 4 feet (120 cm). The depth to a water table may be less than 4 feet (120 cm) if it is for less than 2 months during the growing season. The available water capacity is at least 6 inches (15 cm). In the upper 12 inches (30 cm) of the soil profile free carbonates do not exceed a concentration of 5 percent calcium carbonate equivalent, the range of pH is between 5.6 and 8.4, and electrical conductivity is 4 mmhos/cm or less. The whole soil profile is >35% clay, but the 0 to 8 inches (20 cm) can be non-clayey

Subgroup 4CK (Clayey-Calcareous)
Soil criteria is the same as Group 4C except:
_ In the upper 12 inches (30 cm) of the soil profile free carbonates range between 5 and 15 percent calcium carbonate equivalent and the range of pH is between 6.5 and 8.4.

Group 5 (Droughty)
Soil depth to a restrictive layer is at least 40 inches (100 cm). The depth to a water table during the growing season is at least 4 feet (120 cm). If the soil is frequently or occasional flooded with duration of brief, long, or very long, it is for less than 2 months during the growing season. The available water capacity is at between 6 and 9 inches (15 and 23 cm). In the upper 12 inches (30 cm) of the soil profile free carbonates do not exceed a concentration of 5 percent calcium carbonate equivalent, the range of pH is between 5.6 and 8.4, and electrical conductivity is 4 mmhos/cm or less. The whole soil profile is non-sandy or loamy or loamy-skeletal.

Subgroup 5K (Droughty-Calcareous)
Soil criteria is the same as Group 5 except:
_ In the upper 12 inches (30 cm) of the soil profile free carbonates range between 5 and 15 percent calcium carbonate equivalent and the range of pH is between 6.5 and 8.4.

Group 6 (Very Droughty)
Soil depth to a restrictive layer is at least 20 inches (50 cm). The depth to a water table during the growing season is at least 4 feet (120 cm). The depth to a water table may be less than 4 feet (120 cm) if it is for less than 2 months during the growing season. The available water capacity is between 3 and 6 inches (8 and 15 cm). In the upper 12 inches (30 cm) of the soil profile free carbonates do not exceed a concentration of 5 percent calcium carbonate equivalent, the range of pH is between 5.6 and 8.4, and electrical conductivity is 4 mmhos/cm or less. The soil has a non-sandy surface, and is loamy/loamy skeletal over sands/gravels. The drainage class for the soil is excessively, somewhat excessively, or well drained.

Subgroup 6K (Very Droughty-Calcareous)
Soil criteria is the same as Group 6 except:
_ In the upper 12 inches (30 cm) of the soil profile free carbonates range between 5 and 15 percent calcium carbonate equivalent and the range of pH is between 6.5 and 8.4.

Subgroup 6D (Droughty-Moderately deep)
Soil depth to a restrictive layer is between 20 and 40 inches (50 and 100 cm). The depth to a water table during the growing season is at least 4 feet (120 cm). The depth to a water table may be less than 4 feet (120 cm) if it is for less than 2 months during the growing season. The available water capacity is at least 6 inches (15 cm). In the upper 12 inches (30 cm) of the soil profile free carbonates do not exceed a concentration of 5 percent calcium carbonate equivalent, the range of pH is between 5.6 and 8.4, and electrical conductivity is 4 mmhos/cm or less. The soil has a non-sandy surface, and is loamy/loamy skeletal over impervious layer.

Subgroup 6DK (Droughty-Moderately deep-Calcareous)
Soil criteria is the same as Group 6D except:
_ In the upper 12 inches (30 cm) of the soil profile free carbonates range between 5 and 15 percent calcium carbonate equivalent and the range of pH is between 6.5 and 8.4.

Group 7 (Sandy)
Soil depth to a restrictive layer is at least 40 inches (100 cm). The depth to a water table during the growing season is at least 4 feet (120 cm). The depth to a water table may be less than 4 feet (120 cm) if it is for less than 2 months during the growing season. The available water capacity is at least 3 inches (8 cm). In the upper 12 inches (30 cm) of the soil profile free carbonates do not exceed a concentration of 5 percent calcium carbonate equivalent, the range of pH is between 5.6 and 8.4, and electrical conductivity is 2 mmhos/cm or less. All horizons have a sandy texture.

Group 8 (Loamy-Calcareous)
Soil depth to a restrictive layer is at least 40 inches (100 cm). The depth to a water table during the growing season is at least 4 feet (120 cm). The depth to a water table may be less than 4 feet (120 cm) if it is for less than 2 months during the growing season. The available water capacity is at least 9 inches (22.5 cm). In the upper 12 inches (30 cm) of the soil profile free carbonates range between 5 and 15 percent calcium carbonate equivalent, the range of pH is between 6.5 and 8.4, and electrical conductivity is 4 mmhos/cm or less. The texture is non-clayey between 8 inches (20 cm) and 48 inches (120 cm).

Subgroup 9L (Dry-Saline/Alkaline)
Soil depth to a restrictive layer is at least 20 inches (50 cm). The depth to a water table during the growing season is > 1.5 feet (45 cm). The depth to a water table may be less than 1.5 feet (45 cm) if it is for less than 2 months during the growing season. The available water capacity is at least 3 inches (8 cm). In the upper 12 inches (30 cm) of the soil profile, the range of electrical conductivity is between 4 and 16 mmhos/cm. Sodium Adsorption Ratio (SAR) will be > 13. Soil texture will vary, and will be saline and/or sodic.

Subgroup 9W (Wet-Saline/Alkaline)
Soil depth to a restrictive layer[1] is at least 20 inches (50 cm). The depth to a water table during the growing season is between 1.5 and 5 feet (45 and 150 cm). The available water capacity is at least 2 inches (5 cm). In the upper 12 inches (30 cm) of the soil profile electrical conductivity is between 4 and 16 mmhos/cm. Sodium Adsorption Ratio (SAR) will be > 13. Soil texture will vary, and will be saline and/or sodic. These soils are poorly or very poorly drained.

Group 10 (On-site Evaluation)
Soils have one or more characteristics that are severely imitating to the planting and growth of trees and shrubs: soil depth is less than 20 inches (50 cm); available water capacity is less than 3 inches (8.0 cm); depth to a water table during the growing season is less than 0.5 feet (15 cm) or occurs for longer than 3 months during the growing season; in the upper 12 inches (30 cm) of the soil profile free carbonates are greater than 40 percent calcium carbonate equivalent, pH is less than 4.0 or greater than 8.4, electrical conductivity is greater than 16 mmhos/cm, or sodium adsorption ratio is 25 percent or greater. Slopes > 30%. All channeled phases that are frequently or occasionally flooded. Soils that occasionally or frequently pond for long or very long duration.

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
1	CONIFEROUS TREES	Arborvitae, American or Northern White Cedar *Thuja occidentalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	25-30/20	15-20	25-30/20
1	CONIFEROUS TREES	Arborvitae, Oriental 1/ *Thuja orientalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-20/15
1	CONIFEROUS TREES	Baldcypress *Taxodium distichum*	Not Recommended	Not Recommended	20-25	25-30/20	20-25	30-35/20	20-30	40-50/20
1	CONIFEROUS TREES	Fir, Douglas *Pseudotsuga mennziesii*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	30-35/20	20-30	40-50/20
1	CONIFEROUS TREES	Fir, White *Abies concolor*	Not Recommended	Not Recommended	20-25	30-45/30	20-25	30-45/25	20-30	40-50/25
1	CONIFEROUS TREES	Juniper, Rocky Mountain 1/ *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1	CONIFEROUS TREES	Pine, Austrian *Pinus nigra*	5-20	30-50/20-30	15-30	30-55/20	20-30	35-50/20	20-35	40-60/20
1	CONIFEROUS TREES	Pine, Eastern White *Pinus strobus*	Not Recommended	Not Recommended	25-30	35-40/20	20-25	40-50/20	30-35	40-60/20
1	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	15-20	30-40/15	15-20	35-45/15	20-30	35-45/15	20-30	35-45/15-20
1	CONIFEROUS TREES	Pine, Limber 1/ *Pinus flexilis*	10-15	25-40/15	10-15	25-45/15-20	15-20	30-45/15-20	20-25	35-55/15-20
1	CONIFEROUS TREES	Pine, Ponderosa 1/ *Pinus ponderosa*	15-25	30-50/20	15-30	30-55/20	20-30	35-55/20	20-35	40-60/20
1	CONIFEROUS TREES	Pine, Southwestern White 1/ *Pinus strobiformis*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1	CONIFEROUS TREES	Redcedar, Eastern 1/ *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-35/15-20	15-25	30-40/20
1	CONIFEROUS TREES	Spruce, Colorado Blue *Picea pungens*	15-20	25-35/20-30	15-20	30-40/20-30	20-25	30-45/20-30	15-20	40-60/25-30
1	CONIFEROUS TREES	Spruce, Norway *Picea abies*	Not Recommended	Not Recommended	25-30	30-40/20	25-30	30-45/20	25-35	45-60/25

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
1	CONIFEROUS TREES	Spruce, White *Picea glauca* (variety Black Hills)	15-20	25-35/15	20-25	30-40/20	20-25	30-45/20	20-30	30-45/20
1	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	5-10	10-15/10	10-15	10-15/10	10-20	10-20/10
1	DECIDUOUS TREES	Ash, Green 1/, 3/ *Fraxinus pennsylvanica*	15-20	25-35/25	20-25	30-40/30	20-30	35-50/3	25-30	40-60/30-40
1	DECIDUOUS TREES	Aspen, Quaking 1/ *Populus tremuloides*	15-20	30-40	15-20	30-40	15-20	30-40	15-20	30-40
1	DECIDUOUS TREES	Basswood/ Linden, American *Tilia americana*	20-25	30-40/30	20-30	30-40/30	20-30	35-45/30	25-35	50-70/30-40
1	DECIDUOUS TREES	Birch, Paper 4/ *Betula papyrifera*	Not Recommended	Not Recommended	20-30 (Niobrara Valley only)	15-25/45	20-30 15-25/45		20-30	15-25/50
1	DECIDUOUS TREES	Birch, River 4/ *Betula nigra*	Not Recommended	Not Recommended	20-30 (Niobrara Valley only)	15-25/45	20-30 15-25/45		20-30	15-25/50
1	DECIDUOUS TREES	Boxelder *Acer negundo*	15-20	25-35/20	15-20	25-35/20	20-25	30-35/20	20-25	35-40/20
1	DECIDUOUS TREES	Catalpa, Northern 1/ *Catalpa speciosa*	Not Recommended	Not Recommended	25-30	25-30/20	25-30	30-40/20	25-30	40-50/25
1	DECIDUOUS TREES	Cherry, Black *Prunus serotina*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	35-40/20	20-30	30-50/20
1	DECIDUOUS TREES	Cottonwood, Eastern 1/ *Populus deltoides* Recom. cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-85/40	45-55	65-85/40-50	50-60	70-90/40-60
1	DECIDUOUS TREES	Crabapple *Malus sp* . Recom. cultivars: Radiant, Siberian, Midwest 1/, Roselow Sargent	8-12	10-15/15	10-15	10-15/15	10-15	10-15/15	5-20	15-20/15
1	DECIDUOUS TREES	Crabapple, Prairie *Malus ionensis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	5-20	15-20/15	5-20	15-20/15
1	DECIDUOUS TREES	Elm, American 1/ *Ulmus americana*	15-30	15-35/20	15-35	20-40/20	25-40	25-40/20	25-40	55-60/30

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
1	DECIDUOUS TREES	Elm, Siberian 1/ *Ulmus pumila*	15-30	15-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1	DECIDUOUS TREES	Hackberry 1/ *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	20-30	45-55/20	20-30	50-60/30
1	DECIDUOUS TREES	Hawthorn, Cockspur 1/ *Crataegus crusgalli*	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15
1	DECIDUOUS TREES	Hawthorn, Washington1/ *Crataegus phaenopyrum*	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15
1	DECIDUOUS TREES	Hickory, Bitternut *Carya cordiformis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	45-55/20
1	DECIDUOUS TREES	Hickory, Shagbark *Carya ovata*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	45-55/20
1	DECIDUOUS TREES	Honeylocust 1/ *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	25-30	35-45/20	25-35	40-50/25-30
1	DECIDUOUS TREES	Hophornbeam, Eastern *Ostrya virginiana*	Not Recommended	Not Recommended	10-15 15-20/10		10-20	20-25/10	15-20	20-25/10-20
1	DECIDUOUS TREES	Kentucky Coffeetree *Gymnocladus dioicus*	20-25	30-40/15	25-30	30-40/20	25-30	35-45/20	25-30	45-70/25-30
1	DECIDUOUS TREES	Locust, Black 1/, 2/ *Robinia pseudoacacia*	20-25	25-35/15	25-30	25-35/15	25-30	35-45/20	25-30	40-50/20
1	DECIDUOUS TREES	Maple, Amur *Acer ginnala* Recommended cultivar: Flame	10-15	10-15/15	10-15	10-15/15	15-20	15-20/15	15-20	15-20/15
1	DECIDUOUS TREES	Maple, Silver *Acer saccharinum*	25-30	30-40/20-25	25-30	35-45/20-25	30-35	40-60/30-40	35-40	50-70/30-50
1	DECIDUOUS TREES	Maple, Sugar *Acer saccharum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-50/30
1	DECIDUOUS TREES	Mulberry, Red 1/ *Morus rubra*	15-20	15-25/15	15-20	30-35/15-20	20-25	35-40/20	20-25	40-45/25-30
1	DECIDUOUS TREES	Mulberry, Russian or White 1/ *Morus alba var. tatarica*	15-20	15-25/15	15-20	30-35/15-20	20-25	35-40/20	20-25	40-45/25-30

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
1	DECIDUOUS TREES	Oak, Black *Quercus velutina*	Not Recommended	Not Recommended	15-20	35-50/20-25	20-25	40-50/30	25-30	40-60/30-40
1	DECIDUOUS TREES	Oak, Bur 1/ *Quercus macrocarpa*	15-20	25-35/20-25	15-25	30-40/20-30	20-25	45-55/40-50	25-30	60-80/40-60
1	DECIDUOUS TREES	Oak, Chinkapin *Quercus muhlenbergii*	Not Recommended	Not Recommended	15-20	35-50/20-25	20-25	40-50/30	25-30	40-60/30-40
1	DECIDUOUS TREES	Oak, English *Quercus robur*	Not Recommended	Not Recommended	25-35	45-55	25-35	50-60	30-40	55-65
1	DECIDUOUS TREES	Oak, Gambel 1/ *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1	DECIDUOUS TREES	Oak, Northern Red *Quercus rubra*	Not Recommended	Not Recommended	15-20	35-50/20-25	20-25	40-50/30	25-30	40-60/30-40
1	DECIDUOUS TREES	Oak, Pin *Quercus palustris*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	40-60/30-40
1	DECIDUOUS TREES	Oak, Swamp White *Quercus bicolor*	Not Recommended	Not Recommended	15-20 30-40/20		15-25	30-45/20	20-30	40-50/20-30
1	DECIDUOUS TREES	Oak, White *Quercus alba*	Not Recommended	Not Recommended	15-20 35-50/20-25		20-25	40-50/30	25-30	40-60/30-40
1	DECIDUOUS TREES	Osage-orange 1/ *Maclura pomifera*	Not Recommended	Not Recommended	15-20	20-25/15	15-20	25-30/15	15-20	30-40/20-25
1	DECIDUOUS TREES	Pawpaw *Asimina Adans.*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-25/10-20
1	DECIDUOUS TREES	Pear, Chinese (Harbin) *Pyrus ussuriensis* Recommended cultivar: McDermand	Not Recommended	Not Recommended	15-20	15-20/15	15-20	15-25/15	20-25	20-25/15
1	DECIDUOUS TREES	Pecan, Northern *Carya illinoensis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended		60-70 (South of Platte River only)		70-80 (South of Platte River only)
1	DECIDUOUS TREES	Redbud, Eastern 1/ *Cercis canadensis*	Not Recommended	Not Recommended	10-15	10-15/10	10-20	10-15/10	15-20	15-20/10-20
1	DECIDUOUS TREES	Sycamore, American *Platanus occidentalis*	Not Recommended	Not Recommended	30	40/50	30-35	40-45/20	35-40	50-70/30-40

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
1	DECIDUOUS TREES	Walnut, Black *Juglans nigra*	Not Recommended	Not Recommended	20-25	30-40/30	20-25	40-50/30	25-30	40-60/30
1	DECIDUOUS TREES	Willow, Black 1/ *Salix nigra*	20-25	25-35/20	20-25	30-35/20	25-30	30-35/20	25-30	35-50/20
1	DECIDUOUS TREES	Willow, Peachleaf 1/ *Salix amygdaloides*	20-25	20-30/20	20-25	20-30/20	20-25	20-30/20	20-25	20-30/20
1	DECIDUOUS TREES	Willow, White or Golden 1/ *Salix alba* (Cultivars Vitellina or Tristis; often called Golden Willow)	20-30	25-35/20	20-25	30-35/20	25-30	30-35/20	25-30	35-40/20
1	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) 1/ *Juniperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
1	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-10		Not Recommended		Not Recommended		Not Recommended	
1	DECIDUOUS SHRUBS	Blackhaw, Rusty *Vibernum rufidulum*	Not Recommended		Not Recommended		15-20		20-30	
1	DECIDUOUS SHRUBS	Buffaloberry, Silver 1/ *Shepherdia argentea*	5-8		10-12		10-12		10-12	
1	DECIDUOUS SHRUBS	Buttonbush *Cephlanthus occidentalis*	Not Recommended		Not Recommended		Not Recommended		8-10	
1	DECIDUOUS SHRUBS	Cherry, Nanking *Prunus tomentosa*	Not Recommended		4-5		4-5		5-7	
1	DECIDUOUS SHRUBS	Chokeberry, Black *Aronia melanocarpa*	Not Recommended		4-8		5-8		6-8	
1	DECIDUOUS SHRUBS	Chokecherry, Common 1/ *Prunus virginiana*	5-8		6-12		6-12		8-14	
1	DECIDUOUS SHRUBS	Coralberry *Symphoricarpos orbiculatus*	Not Recommended		Not Recommended		2-3		2-3	
1	DECIDUOUS SHRUBS	Cotoneaster, Peking *Cotoneaster acutifolia*	4-5		5-6		5-8		5-10	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
1	DECIDUOUS SHRUBS	Cranberry, Highbush *Viburnum trilobum*	Not Recommended		Not Recommended		6-12		10-12	
1	DECIDUOUS SHRUBS	Currant, Buffalo 1/ *Ribes odoratum*	3-6		3-6		3-6		3-6	
1	DECIDUOUS SHRUBS	Currant, Golden 1/ *Ribes aureum*	2-4		2-4		4-6		4-6	
1	DECIDUOUS SHRUBS	Dogwood, Gray *Cornus racemosa*	4-6		6-8		6-8		6-10	
1	DECIDUOUS SHRUBS	Dogwood, Redosier *Cornus sericea*	5-6		5-7		6-8		8-10	
1	DECIDUOUS SHRUBS	Elderberry *Sambucus canadensis*	Not Recommended		4-6		4-6		4-8	
1	DECIDUOUS SHRUBS	Euonymus, Winterberry *Euonymus bungeanus* Recommended cultivar: Pink Lady Winterberry	5-10		5-10		8-14		8-14	
1	DECIDUOUS SHRUBS	Hazelnut, American *Corylus americana*	Not Recommended		6-8		6-8		6-10	
1	DECIDUOUS SHRUBS	Indigo, False *Amorpha fruiticosa*	4-6		6-8		6-8		8-10	
1	DECIDUOUS SHRUBS	Lilac 1/ *Syringa vulgaris*	5-6		5-6		5-8		6-10	
1	DECIDUOUS SHRUBS	Mahogany, Mountain 1/ *Cercocarpus montana*	5-10		Not Recommended		Not Recommended		Not Recommended	
1	DECIDUOUS SHRUBS	Nannyberry 1/ *Viburnum lentago*	Not Recommended		Not Recommended		15-25		15-25	
1	DECIDUOUS SHRUBS	Peashrub, Siberian 1/ *Caragana arborescens*	3-6		4-8		6-10		8-12	
1	DECIDUOUS SHRUBS	Plum, American 1/ *Prunus americana*	5-7		5-8		5-8		6-10	
1	DECIDUOUS SHRUBS	Rose, Arkansas (Prairie) *Rosa arkansana*	1-2		1-2		1-2		1-2	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
1	DECIDUOUS SHRUBS	Rose, Hansen Hedge *Rosa* Sp. *Rosa rugusa x R. woodsii*	4-6		4-6		4-8		6-8	
1	DECIDUOUS SHRUBS	Rose, Woods *Rosa woodsii*	3-5		3-5		4-5		4-5	
1	DECIDUOUS SHRUBS	Sagebrush, Big *Artemisia tridentata*	3-6		Not Recommended		Not Recommended		Not Recommended	
1	DECIDUOUS SHRUBS	Sagebrush, Silver *Artemisia cana*	3-6		Not Recommended		Not Recommended		Not Recommended	
1	DECIDUOUS SHRUBS	Saltbush, Fourwing 1/ *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	
1	DECIDUOUS SHRUBS	Sandcherry, Western *Prunus besseyi*	2-3		2-3		2-4		3-6	
1	DECIDUOUS SHRUBS	Serviceberry, Saskatoon 1/ *Amelanchier alnifolia (Nutt)*	5-7		5-7		6-10		6-10	
1	DECIDUOUS SHRUBS	Snowberry, Common *Symphoricarpos albus*	Not Recommended		Not Recommended		3-4		3-4	
1	DECIDUOUS SHRUBS	Snowberry, Western *Symphoricarpos occidentalis*	3-4		3-4		3-4		3-4	
1	DECIDUOUS SHRUBS	Sumac, Skunkbush 1/ *Rhus trilobata* Recommended cultivars: Big Horn, Konza Fragrant	3-5		4-6		4-6		4-8	
1	DECIDUOUS SHRUBS	Willow, Sandbar *Salix exigua*	10-15		10-15		10-15		10-15	

1/ Adapted to calcareous soils

2/ Black locust can be severely impacted by insect damage; recommend limiting use to wildlife and pollinator plantings, rather than for windbreaks

3/ Green Ash - only to be used in diverse tree and shrub plantings, **not in windbreaks**

4/ Conservation mulch improves growth and survival

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
1K	CONIFEROUS TREES	Arborvitae, American or Northern White Cedar 1/ *Thuja occidentalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	25-30/20	15-20	25-30/20
1K	CONIFEROUS TREES	Arborvitae, Oriental 1/ *Thuja orientalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-20/15
1K	CONIFEROUS TREES	Juniper, Rocky Mountain 1/ *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1K	CONIFEROUS TREES	Pine, Bristlecone 1/ *Pinus aristata*	5-10	25-30/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1K	CONIFEROUS TREES	Pine, Limber 1/ *Pinus flexilis*	10-15	25-40/15	10-15	25-45/15-20	15-20	30-45/15-20	20-25	35-55/15-20
1K	CONIFEROUS TREES	Pine, Ponderosa 1/ *Pinus ponderosa*	15-25	30-50/20	15-30	30-55/20	20-30	35-55/20	20-35	40-60/20
1K	CONIFEROUS TREES	Pine, Southwestern White 1/ *Pinus strobiformis*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1K	CONIFEROUS TREES	Redcedar, Eastern 1/ *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-35/15-20	15-25	30-40/20
1K	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-110	10-20	10-20/10
1K	DECIDUOUS TREES	Ash, Green 1/, 3/ *Fraxinus pennsylvanica*	15-20	25-35/25	20-25	30-40/30	20-30	35-50/3	25-30	40-60/30-40
1K	DECIDUOUS TREES	Aspen, Quaking 1/ *Populus tremuloides*	15-20	30-40	15-20	30-40	15-20	30-40	15-20	30-40
1K	DECIDUOUS TREES	Catalpa, Northern 1/ *Catalpa speciosa*	Not Recommended	Not Recommended	25-30	25-30/20	25-30	30-40/20	25-30	40-50/25
1K	DECIDUOUS TREES	Cottonwood, Eastern 1/ *Populus deltoides* Recom. cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-85/40	45-55	65-85/40-50	50-60	70-90/40-60
1K	DECIDUOUS TREES	Crabapple *Malus sp .* Recom. cultivars: Radiant, Siberian, Midwest 1/, Roselow Sargent	8-12	10-15/15	10-15	10-15/15	10-15	10-15/15	5-20	15-20/15
1K	DECIDUOUS TREES	Crabapple, Prairie *Malus ionensis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	5-20	15-20/15	5-20	15-20/15
1K	DECIDUOUS TREES	Elm, American 1/ *Ulmus americana*	15-30	15-35/20	15-35	20-40/20	25-40	25-40/20	25-40	55-60/30

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
1K	DECIDUOUS TREES	Elm, Siberian 1/ *Ulmus pumila*	15-30	15-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1K	DECIDUOUS TREES	Hackberry 1/ *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	20-30	45-55/20	20-30	50-60/30
1K	DECIDUOUS TREES	Hawthorn, Cockspur 1/ *Crataegus crusgalli*	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15
1K	DECIDUOUS TREES	Hawthorn, Washington 1/ *Crataegus phaenopyrum*	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15
1K	DECIDUOUS TREES	Honeylocust 1/ *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	25-30	35-45/20	25-35	40-50/25-30
1K	DECIDUOUS TREES	Locust, Black 1/, 2/ *Robinia pseudoacacia*	20-25	25-35/15	25-30	25-35/15	25-30	35-45/20	25-30	40-50/20
1K	DECIDUOUS TREES	Mulberry, Red 1/ *Morus rubra*	15-20	15-25/15	15-20	30-35/15-20	20-25	35-40/20	20-25	40-45/25-30
1K	DECIDUOUS TREES	Mulberry, Russian or White 1/ *Morus alba var. tatarica*	15-20	15-25/15	15-20	30-35/15-20	20-25	35-40/20	20-25	40-45/25-30
1K	DECIDUOUS TREES	Oak, Bur 1/ *Quercus macrocarpa*	15-20	25-35/20-25	15-25	30-40/20-30	20-25	45-55/40-50	25-30	60-80/40-60
1K	DECIDUOUS TREES	Oak, English 1/ *Quercus robur*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-35	50-60	30-40	55-65
1K	DECIDUOUS TREES	Oak, Gambel 1/ *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1K	DECIDUOUS TREES	Osage-orange 1/ *Maclura pomifera*	Not Recommended	Not Recommended	15-20	20-25/15	15-20	25-30/15	15-20	30-40/20-25
1K	DECIDUOUS TREES	Redbud, Eastern 1/ *Cercis canadensis*	Not Recommended	Not Recommended	10-15	10-15/10	10-20	10-15/10	15-20	15-20/10-20
1K	DECIDUOUS TREES	Willow, Black 1/ *Salix nigra*	20-25	25-35/20	20-25	30-35/20	25-30	30-35/20	25-30	35-50/20
1K	DECIDUOUS TREES	Willow, Peachleaf 1/ *Salix amygdaloides*	20-25	20-30/20	20-25	20-30/20	20-25	20-30/20	20-25	20-30/20
1K	DECIDUOUS TREES	Willow, White or Golden 1/ *Salix alba* (Cultivars Vitellina or Tristis; often called Golden Willow)	20-30	25-35/20	20-25	30-35/20	25-30	30-35/20	25-30	35-40/20

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
1K	CONIFEROUS SHRUBS	Juniper, Common 1/ *Juniperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
1K	DECIDUOUS SHRUBS	Antelope Bitterbrush 1/ *Purshia tridentate*	2-10		Not Recommended		Not Recommended		Not Recommended	
1K	DECIDUOUS SHRUBS	Buffaloberry, Silver 1/ *Shepherdia argentea*	5-8		10-12		10-12		10-12	
1K	DECIDUOUS SHRUBS	Chokecherry, Common 1/ *Prunus virginiana*	5-8		6-12		6-12		8-14	
1K	DECIDUOUS SHRUBS	Currant, Buffalo 1/ *Ribes odoratum*	3-6		3-6		3-6		3-6	
1K	DECIDUOUS SHRUBS	Currant, Golden 1/ *Ribes aureum*	2-4		2-4		4-6		4-6	
1K	DECIDUOUS SHRUBS	Lilac 1/ *Syringa vulgaris*	5-6		5-6		5-8		6-10	
1K	DECIDUOUS SHRUBS	Mahogany, Mountain 1/ *Cercocarpus montana*	5-10		Not Recommended		Not Recommended		Not Recommended	
1K	DECIDUOUS SHRUBS	Nannyberry 1/ *Viburnum lentago*	Not Recommended		Not Recommended		15-25		15-25	
1K	DECIDUOUS SHRUBS	Peashrub, Siberian 1/ *Caragana arborescens*	3-6		4-8		6-10		8-12	
1K	DECIDUOUS SHRUBS	Plum, American 1/ *Prunus americana*	5-7		5-8		5-8		6-10	
1K	DECIDUOUS SHRUBS	Saltbush, Fourwing 1/ *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	
1K	DECIDUOUS SHRUBS	Serviceberry, Saskatoon 1/ *Amelanchier alnifolia (Nutt)*	5-7		5-7		6-10		6-10	
1K	DECIDUOUS SHRUBS	Sumac, Skunkbush 1/ *Rhus trilobata* Recommended cultivars: Big Horn, Konza Fragrant	3-5		4-6		4-6		4-8	

1/ Adapted to calcareous soils

2/ Black locust can be severely impacted by insect damage; recommend limiting use to wildlife and pollinator plantings, rather than for windbreaks

3/ Green Ash - only to be used in diverse tree and shrub plantings, **not in windbreaks**

Soils Group	TreeShrub Type	Species	ZONE I 20-YEAR HEIGHT (ft)	ZONE I MATURE HGT/SPREAD (ft)	ZONE II 20-YEAR HEIGHT (ft)	ZONE II MATURE HGT/SPREAD (ft)	ZONE III 20-YEAR HEIGHT (ft)	ZONE III MATURE HGT/SPREAD (ft)	ZONE IV 20-YEAR HEIGHT (ft)	ZONE IV MATURE HGT/SPREAD (ft)
1S	CONIFEROUS TREES	Arborvitae, American or Northern White Cedar *Thuja occidentalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	25-30/20	15-20	25-30/20
1S	CONIFEROUS TREES	Arborvitae, Oriental *Thuja orientalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-20/15
1S	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1S	CONIFEROUS TREES	Pine, Austrian *Pinus nigra*	5-25	30-50/20	15-30	30-520	20-30	35-50/20	20-35	40-60/20
1S	CONIFEROUS TREES	Pine, Eastern White *Pinus strobus*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-25	40-50/20	30-35	40-60/20
1S	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	15-20	25-315	15-20	30-40/15	15-30	30-40/15	20-30	40-415
1S	CONIFEROUS TREES	Pine, Limber *Pinus flexilis*	10-15	25-40/15	10-15	25-415-20	15-20	30-415-20	20-25	35-515-20
1S	CONIFEROUS TREES	Pine, Pinyon [Two needle Pinyon] *Pinus edulis*	5-10	15-20/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1S	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	15-25	30-50/20	15-30	30-520	20-30	35-520	20-35	40-60/20
1S	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-520	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1S	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-215	10-20	20-215	10-25	25-315-20	15-25	30-40/20
1S	CONIFEROUS TREES	Spruce, Colorado Blue *Picea pungens*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	30-420-25	20-30	40-60/25
1S	CONIFEROUS TREES	Spruce, Norway *Picea abies*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	30-420	25-30	45-60/25
1S	CONIFEROUS TREES	Spruce, White *Picea glauca* (variety Black Hills)	15-20	25-315	20-25	30-40/20	20-25	30-420	25-30	30-420
1S	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-110	10-20	10-20/10
1S	DECIDUOUS TREES	Ash, Green 1/ *Fraxinus pennsylvanica*	15-20	25-325	20-25	30-40/30	20-30	35-50/3	25-30	40-60/30-40
1S	DECIDUOUS TREES	Aspen, Quaking *Populus tremuloides*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	20-30	15-20	20-30

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
1S	DECIDUOUS TREES	Basswood/ Linden, American *Tilia americana*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	35-430	25-30	40-50/30
1S	DECIDUOUS TREES	Birch, Paper *Betula papyrifera*	Not Recommended	Not Recommended	20-30 (Niobrara Valley only)	415-25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1S	DECIDUOUS TREES	Birch, River *Betula nigra*	Not Recommended	Not Recommended	20-30 (Niobrara Valley only)	15-25/45	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1S	DECIDUOUS TREES	Boxelder *Acer negundo*	15-20	25-30-20	15-20	25-30/20	20-25	30-35/20	20-25	35-40/20
1S	DECIDUOUS TREES	Catalpa, Northern *Catalpa speciosa*	Not Recommended	Not Recommended	25-30	25-30/20	25-30	30-40/20	25-30	40-50/25
1S	DECIDUOUS TREES	Cottonwood, Eastern *Populus deltoides* Recommended cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-80/40	45-55	65-80/40-50	50-60	70-90/40-50
1S	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	20-25	20-320	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1S	DECIDUOUS TREES	Hackberry *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	20-30	45-50/20	20-30	50-60/30
1S	DECIDUOUS TREES	Hawthorn, Cockspur *Crataegus crusgalli*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	15-20/15	15-20	15-20/15
1S	DECIDUOUS TREES	Hawthorn, Washington *Crataegus phaenopyrum*	Not Recommended	Not Recommended	10-15	15-20/15	10-15	15-20/15	15-20	15-20/15
1S	DECIDUOUS TREES	Honeylocust *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	25-30	35-420	25-35	40-50/25-30
1S	DECIDUOUS TREES	Kentucky Coffeetree *Gymnocladus dioicus*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	35-420	25-30	45-70/25-30
1S	DECIDUOUS TREES	Locust, Black 2/ Robinia pseudoacacia	20-25	25-30/15	25-30	25-30/15	25-30	35-40/20	25-30	40-50/20
1S	DECIDUOUS TREES	Maple, Amur *Acer ginnala* Recommended cultivar:	10-15	10-115	10-15	10-115	15-20	15-20/15	15-20	15-20/15
1S	DECIDUOUS TREES	Maple, Silver *Acer saccharinum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	30-35	40-50/30-40	35-40	50-60/30-40
1S	DECIDUOUS TREES	Mulberry, Red *Morus rubra*	15-20	15-20/15	15-20	30-35/15-20	20-25	35-40/20	20-25	40-45/25-30

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
1S	DECIDUOUS TREES	Mulberry, Russian or White *Morus alba var. tatarica*	15-20	15-20/15	15-20	30-35/15-20	15-20	35-40/20	20-25	40-45/25-30
1S	DECIDUOUS TREES	Oak, Bur *Quercus macrocarpa*	15-20	25-30/15-20	20-25	30-40/20	20-25	35-40/30	25-30	40-60/30-40
1S	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1S	DECIDUOUS TREES	Oak, Swamp White *Quercus bicolor*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-25	30-40/20	25-30	40-50/20-30
1S	DECIDUOUS TREES	Osage-orange *Maclura pomifera*	Not Recommended	Not Recommended	15-20	20-25/15	15-20	25-30/15	15-20	30-35/20-25
1S	CONIFEROUS SHRUBS	Juniper, Common 1/ *Juniperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
1S	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	3-6		3-6		3-6		3-6	
1S	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		2-4		4-6		4-6	
1S	DECIDUOUS SHRUBS	Dogwood, Gray *Cornus racemosa*	Not Recommended		6-8		6-8		6-8	
1S	DECIDUOUS SHRUBS	Dogwood, Redosier *Cornus sericea*	5-6		5-7		6-8		8-10	
1S	DECIDUOUS SHRUBS	Elderberry *Sambucus canadensis*	Not Recommended		4-6		4-6		4-8	
1S	DECIDUOUS SHRUBS	Euonymus, Winterberry *Euonymus bungeanus* Recommended cultivar: Pink Lady Winterberry	6-10		6-10		8-14		8-14	
1S	DECIDUOUS SHRUBS	Indigo, False *Amorpha fruiticosa*	4-6		6-8		6-8		8-10	
1S	DECIDUOUS SHRUBS	Lilac *Syringa vulgaris*	5-6		5-6		5-8		6-10	
1S	DECIDUOUS SHRUBS	Mahogany, Mountain Cercocarpus montana	5-10		Not Recommended		Not Recommended		Not Recommended	
1S	DECIDUOUS SHRUBS	Nannyberry *Viburnum lentago*	Not Recommended		Not Recommended		15-25		15-25	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
1S	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		6-8		6-10		8-10	
1S	DECIDUOUS SHRUBS	Plum, American *Prunus americana*	5-7		5-8		5-8		6-10	
1S	DECIDUOUS SHRUBS	Rose, Arkansas (Prairie) *Rosa arkansana*	1-2		1-2		1-2		1-2	
1S	DECIDUOUS SHRUBS	Rose, Hansen Hedge *Rosa* Sp. *Rosa rugusa x R. woodsii*	4-6		4-6		4-8		6-8	
1S	DECIDUOUS SHRUBS	Rose, Woods *Rosa woodsii*	3-5		3-5		4-5		4-5	
1S	DECIDUOUS SHRUBS	Sagebrush, Big *Artemisia tridentata*	3-6		Not Recommended		Not Recommended		Not Recommended	
1S	DECIDUOUS SHRUBS	Sagebrush, Silver *Artemisia cana*	3-6		Not Recommended		Not Recommended		Not Recommended	
1S	DECIDUOUS SHRUBS	Saltbush, Fourwing Atriplex canescens	2-5		Not Recommended		Not Recommended		Not Recommended	
1S	DECIDUOUS SHRUBS	Sandcherry, Western *Prunus besseyi*	2-3		2-3		2-4		3-6	
1S	DECIDUOUS SHRUBS	Serviceberry, Saskatoon 1/ *Amelanchier alnifolia (Nutt)*	5-7		5-7		6-10		6-10	
1S	DECIDUOUS SHRUBS	Snowberry, Common *Symphoricarpos albus*	Not Recommended		Not Recommended		3-4		3-4	
1S	DECIDUOUS SHRUBS	Snowberry, Western *Symphoricarpos occidentalis*	3-4		3-4		3-4		3-4	
1S	DECIDUOUS SHRUBS	Sumac, Skunkbush 1/ *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		4-6		4-6		4-8	

1/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**

2/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
1SK	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1SK	CONIFEROUS TREES	Pine, Bristlecone *Pinus aristata*	5-10	25-30/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1SK	CONIFEROUS TREES	Pine, Limber *Pinus flexilis*	10-15	25-40/15	10-15	25-40/15-20	15-20	30-40/15-20	20-25	35-50/15-20
1SK	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	15-25	30-50/20	15-30	30-50/20	20-30	35-50/20	20-35	40-60/20
1SK	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-50/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1SK	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-35/15-20	15-25	30-40/20
1SK	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
1K	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-15/10	10-20	10-20/10
1SK	DECIDUOUS TREES	Ash, Green 1/ *Fraxinus pennsylvanica*	15-20	25-325	20-25	30-40/30	20-30	35-50/3	25-30	40-60/30-40
1SK	DECIDUOUS TREES	Aspen, Quaking *Populus tremuloides*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	20-30	15-20	20-30
1SK	DECIDUOUS TREES	Catalpa, Northern *Catalpa speciosa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	30-35/20	15-20	30-35/20
	DECIDUOUS TREES	Cottonwood, Eastern *Populus deltoides* Recommended cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-80/40	45-55	65-80/40-50	50-60	70-90/40-50
1SK	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	15-20	30-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1SK	DECIDUOUS TREES	Hackberry *Celtis occidentalis*	10-15	25-30/20	10-15	25-30/20	10-15	25-30/20	10-15	30-35/30
1SK	DECIDUOUS TREES	Honeylocust *Gleditsia triacanthos*	Not Recommended	Not Recommended	10-15	20-25/15-20	10-15	20-25/20	25-35	40-50/25-30
1SK	DECIDUOUS TREES	Locust, Black 2/ *Robinia pseudoacacia*	Not Recommended	Not Recommended	25-30	25-30/15	25-30	35-40/20	25-30	40-50/20

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
1SK	DECIDUOUS TREES	Oak, Bur *Quercus macrocarpa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	25-30/30	15-20	40-60/30-40
1SK	DECIDUOUS TREES	Oak, English *Quercus robur*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-35	50-60	30-40	55-65
1SK	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
1SK	DECIDUOUS TREES	Osage-orange *Maclura pomifera*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15-20	10-15	30-35/20-25
1SK	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		Not Recommended		Not Recommended		Not Recommended	
1SK	DECIDUOUS SHRUBS	Buffaloberry, Silver *Shepherdia argentea*	5-8		10-12		10-12		10-12	
1SK	DECIDUOUS SHRUBS	Chokecherry, Common *Prunus virginiana*	5-8		6-12		6-12		8-14	
1SK	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	2-4		2-4		3-6		3-6	
1SK	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		2-4		4-6		4-6	
1SK	DECIDUOUS SHRUBS	Lilac *Syringa vulgaris*	5-6		5-6		5-8		6-10	
1SK	DECIDUOUS SHRUBS	Mahogany, Mountain *Cercocarpus montana*	5-10		Not Recommended		Not Recommended		Not Recommended	
1SK	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		6-8		8-10		8-12	
1SK	DECIDUOUS SHRUBS	Plum, American *Prunus americana*	5-7		5-8		5-8		6-10	
1SK	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		4-6		4-6		4-8	

1/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**

2/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I 20-YEAR HEIGHT (ft)	ZONE I MATURE HGT/SPREAD (ft)	ZONE II 20-YEAR HEIGHT (ft)	ZONE II MATURE HGT/SPREAD (ft)	ZONE III 20-YEAR HEIGHT (ft)	ZONE III MATURE HGT/SPREAD (ft)	ZONE IV 20-YEAR HEIGHT (ft)	ZONE IV MATURE HGT/SPREAD (ft)
2	CONIFEROUS TREES	Baldcypress *Taxodium distichum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	30-320	20-30	40-50/20
2	DECIDUOUS TREES	Ash, Green 1/, 4/ *Fraxinus pennsylvanica*	15-20	25-35/25	20-25	30-40/30	20-30	35-50/3	25-30	40-60/30-40
2	DECIDUOUS TREES	Birch, Paper 5/ *Betula papyrifera*	Not Recommended	Not Recommended	20-30 (Niobrara Valley only)	40/15-25	20-30 (Niobrara Valley only)	40/15-25	20-30	50/15-25
2	DECIDUOUS TREES	Birch, River 5/ *Betula nigra*	Not Recommended	Not Recommended	20-30 (Niobrara Valley only)	40/15-25	20-30 (Niobrara Valley only)	40/15-25	20-30	50/15-25
2	DECIDUOUS TREES	Boxelder *Acer negundo*	15-20	25-35/20	15-20	25-35/20	15-20	30-35/20	20-25	35-40/20
2	DECIDUOUS TREES	Cottonwood, Eastern 1/ *Populus deltoides* Recommended cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-80/40	45-55	65-80/40-50	50-60	70-90/40-60
2	DECIDUOUS TREES	Maple, Silver *Acer saccharinum*	Not Recommended	Not Recommended	25-30	35-40/20-25	30-35	40-60/30-40	35-40	50-70/30-50
2	DECIDUOUS TREES	Oak, Pin *Quercus palustris*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	40-60/30-40
2	DECIDUOUS TREES	Oak, Swamp White *Quercus bicolor*	Not Recommended	Not Recommended	15-20	30-40/20	15-25	30-40/20	20-30	40-50/20-30
	DECIDUOUS TREES	Sycamore, American *Platanus occidentalis*	Not Recommended	Not Recommended	30	40/50	30-35	40-45/20	35-40	50-70/30-40
2	DECIDUOUS TREES	Willow, Black 1/ *Salix nigra*	20-25	25-35/20	20-25	30-35/20	25-30	30-35/20-25	25-30	40-60/30
2	DECIDUOUS TREES	Willow, Peachleaf 1/ *Salix amygdaloides*	20-25	20-30/20	20-25	20-30/20	20-25	20-30/20/25	20-25	20-30/30
2	DECIDUOUS TREES	Willow, White or Golden 1/ *Salix alba* (Cultivars Vitellina or Tristis often called Golden Willow)	20-25	25-35/20	20-25	30-35/20	25-30	30-35/20	25-30	35-45/20-25
2	DECIDUOUS SHRUBS	Dogwood, Redosier *Cornus sericea*	5-6		5-7		6-8		8-10	
2	DECIDUOUS SHRUBS	Elderberry *Sambucus canadensis*	Not Recommended		4-6		4-6		4-8	
2	DECIDUOUS SHRUBS	Indigo, False *Amorpha fruiticosa*	4-6		6-8		6-8		8-10	

1/ Adapted to calcareous soils

4/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**.

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
2K	DECIDUOUS TREES	Ash, Green 1/,2/ *Fraxinus pennsylvanica*	15-20	25-35/25	20-25	30-40/30	20-30	35-50/3	25-30	40-60/30-40
2K	DECIDUOUS TREES	Cottonwood, Eastern 1/ *Populus deltoides* Recommended cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-80/40	45-55	65-80/40-50	50-60	70-90/40-60
2K	DECIDUOUS TREES	Sycamore, American *Platanus occidentalis*	Not Recommended	Not Recommended	30	40/50	30-35	40-45/20	35-40	50-70/30-40
2K	DECIDUOUS TREES	Willow, Black 1/ *Salix nigra*	20-25	25-30/20	20-25	30-35/20	25-30	30-35/20	25-30	35-50/20
2K	DECIDUOUS TREES	Willow, Peachleaf 1/ *Salix amygdaloides*	20-25	20-30/20	20-25	20-30/20	20-25	20-30/20	20-25	20-30/20
2K	DECIDUOUS TREES	Willow, White or Golden 1/ *Salix alba* (Cultivars Vitellina or Tristis often called Golden Willow)	20-30	25-30/20	20-25	30-35/20	25-30	30-35/20	25-30	35-40/20

1/ Adapted to calcareous soils

2/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
3	CONIFEROUS TREES	Arborvitae, American or Northern White Cedar *Thuja occidentalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	25-30/20	15-20	25-30/20
3	CONIFEROUS TREES	Arborvitae, Oriental 1/ *Thuja orientalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-20/15
3	CONIFEROUS TREES	Baldcypress *Taxodium distichum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	30-35/20	20-30	40-50/20
3	CONIFEROUS TREES	Fir, Douglas *Pseudotsuga mennziesii*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	30-35/20	20-30	40-50/20
3	CONIFEROUS TREES	Fir, White *Abies concolor*	Not Recommended	Not Recommended	20-25	30-45/30	20-25	30-45/25	20-30	40-50/25
3	CONIFEROUS TREES	Juniper, Rocky Mountain 1/ *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
3	CONIFEROUS TREES	Pine, Austrian *Pinus nigra*	5-20	30-50/20-30	15-30	30-50/20	20-30	35-50/20	20-35	40-60/20
3	CONIFEROUS TREES	Pine, Eastern White *Pinus strobus*	Not Recommended	Not Recommended	25-30	35-40/20	20-25	40-50/20	30-35	40-60/20
3	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	15-20	30-40/15	15-20	35-45/15	20-30	35-45/15	20-30	35-45/15-20
3	CONIFEROUS TREES	Pine, Limber 1/ *Pinus flexilis*	10-15	25-40/15	10-15	25-45/15-20	15-20	30-45/15-20	20-25	35-55/15-20
3	CONIFEROUS TREES	Pine, Pinyon [Two needle Pinyon] *Pinus edulis*	5-10	15-20/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
3	CONIFEROUS TREES	Pine, Ponderosa 1/ *Pinus ponderosa*	15-25	30-50/20	15-30	30-55/20	20-30	35-55/20	20-35	40-60/20
3	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
3	CONIFEROUS TREES	Redcedar, Eastern 1/ *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-35/15-20	15-25	30-40/20
3	CONIFEROUS TREES	Spruce, Colorado Blue *Picea pungens*	15-20	25-35/20-30	15-20	30-40/20-30	20-25	30-45/20-30	15-20	40-60/25-30
3	CONIFEROUS TREES	Spruce, Norway *Picea abies*	Not Recommended	Not Recommended	25-30	30-40/20	25-30	30-40/20	25-35	45-60/25

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
3	CONIFEROUS TREES	Spruce, White *Picea glauca* (variety Black Hills)	15-20	25-35/15	20-25	30-40/20	20-25	30-45/20	20-30	30-45/20
3	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	5-10	10-15/10	10-15	10-15/10	10-20	10-20/10
3	DECIDUOUS TREES	Ash, Green 1/, 3/ *Fraxinus pennsylvanica*	15-20	25-35/25	20-25	30-40/30	20-30	35-45/30	25-30	40-50/30-40
3	DECIDUOUS TREES	Aspen, Quaking 1/ *Populus tremuloides*	15-20	30-40	15-20	30-40	15-20	30-40	15-20	30-40
3	DECIDUOUS TREES	Basswood/ Linden, American *Tilia americana*	15-25	30-40/30	20-30	30-40/30	20-30	35-45/30	25-35	50-70/30-40
3	DECIDUOUS TREES	Birch, Paper 4/ *Betula papyrifera*	Not Recommended	Not Recommended	20-30 (Niobrara Valley only)	15-25/45	20-30 15-25/45		20-30	15-25/50
3	DECIDUOUS TREES	Birch, River 4/ *Betula nigra*	Not Recommended	Not Recommended	20-30 (Niobrara Valley only)	15-25/45	20-30	15-25/45	20-30 15-25/50	
3	DECIDUOUS TREES	Boxelder *Acer negundo*	15-20	25-35/20	15-20	25-35/20	15-20	30-35/20	20-25	35-40/20
3	DECIDUOUS TREES	Catalpa, Northern 1/ *Catalpa speciosa*	Not Recommended	Not Recommended	25-30	25-30/20	25-30	30-40/20	25-30	40-50/25
3	DECIDUOUS TREES	Cherry, Black *Prunus serotina*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	35-40/20	20-30	30-50/20
3	DECIDUOUS TREES	Cottonwood, Eastern 1/ *Populus deltoides* Recommended cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-85/40	45-55	65-85/40-50	50-60	70-90/40-60
3	DECIDUOUS TREES	Crabapple 1/ *Malus sp.* Recommended cultivars: Radiant, Siberian, Midwest, Roselow Sargent	8-12	10-15/15	10-15	10-15/15	10-15	10-15/15	5-20	15-20/15
3	DECIDUOUS TREES	Crabapple, Prairie *Malus ionensis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	5-20	15-20/15 5-20		15-20/15
3	DECIDUOUS TREES	Elm, Siberian 1/ *Ulmus pumila*	15-30	15-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
3	DECIDUOUS TREES	Hackberry 1/ *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	20-30	45-55/20	20-30	50-60/30
3	DECIDUOUS TREES	Hawthorn, Cockspur 1/ *Crataegus crusgalli*	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15
3	DECIDUOUS TREES	Hawthorn, Washington 1/ *Crataegus phaenopyrum*	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15	15-20	15-20/15
3	DECIDUOUS TREES	Hickory, Bitternut *Carya cordiformis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	45-55/20
3	DECIDUOUS TREES	Hickory, Shagbark *Carya ovata*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	45-55/20
3	DECIDUOUS TREES	Honeylocust 1/ *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	25-30	35-45/20	25-35	40-50/25-30
3	DECIDUOUS TREES	Hophornbeam, Eastern *Ostrya virginiana*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-20	20/10	15-20	20-25/10-20
3	DECIDUOUS TREES	Kentucky Coffeetree *Gymnocladus dioicus*	Not Recommended	Not Recommended	25-30	30-40/20	25-30	35-40/20	25-30	45-70/25-30
3	DECIDUOUS TREES	Locust, Black 1/, 2/ *Robinia pseudoacacia*	20-25	25-35/15	25-30	25-35/15	25-30	35-45/20	25-30	40-50/20
3	DECIDUOUS TREES	Maple, Amur *Acer ginnala* Recommended cultivar: Flame	10-15	10-15/15	10-15	10-15/15	15-20	15-20/15	15-20	15-20/15
3	DECIDUOUS TREES	Maple, Silver *Acer saccharinum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	30-35	40-60/30-40	35-40	50-70/30-50
3	DECIDUOUS TREES	Maple, Sugar *Acer saccharum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-50/30
3	DECIDUOUS TREES	Mulberry, Red 1/ *Morus rubra*	15-20	15-25/15	15-20	30-35/15-20	20-25	35-40/20	20-25	40-45/25-30
3	DECIDUOUS TREES	Mulberry, Russian or White 1/ *Morus alba var. tatarica*	15-20	15-25/15	15-20	30-35/15-20	15-20	35-40/20	20-25	40-45/25-30
3	DECIDUOUS TREES	Oak, Black *Quercus velutina*	Not Recommended	Not Recommended	15-20	35-50/20-25	20-25	40-50/30	25-30	40-60/30-40
3	DECIDUOUS TREES	Oak, Bur 1/ *Quercus macrocarpa*	15-20	25-35/20-25	15-25	30-40/20-30	20-25	45-50/40-50	25-30	60-80/40-60

Soils Group	TreeShrub Type	Species	ZONE I 20-YEAR HEIGHT (ft)	ZONE I MATURE HGT/SPREAD (ft)	ZONE II 20-YEAR HEIGHT (ft)	ZONE II MATURE HGT/SPREAD (ft)	ZONE III 20-YEAR HEIGHT (ft)	ZONE III MATURE HGT/SPREAD (ft)	ZONE IV 20-YEAR HEIGHT (ft)	ZONE IV MATURE HGT/SPREAD (ft)
3	DECIDUOUS TREES	Oak, Chinkapin *Quercus muhlenbergii*	Not Recommended	Not Recommended	15-20	35-50/20-25	20-25	40-50/30	25-30	40-60/30-40
3	DECIDUOUS TREES	Oak, English *Quercus robur*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-35	50-60	30-40	55-65
3	DECIDUOUS TREES	Oak, Gambel 1/ Quercus gambelii	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
3	DECIDUOUS TREES	Oak, Northern Red *Quercus rubra*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-50/30	25-30	40-60/30-40
3	DECIDUOUS TREES	Oak, Pin *Quercus palustris*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	40-60/30-40
3	DECIDUOUS TREES	Oak, Swamp White *Quercus bicolor*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-25	30-40/20	20-30	40-50/20-30
3	DECIDUOUS TREES	Oak, White *Quercus alba*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-50/30	25-30	40-60/30-40
3	DECIDUOUS TREES	Osage-orange 1/ *Maclura pomifera*	Not Recommended	Not Recommended	15-20	20-25/15	15-20	25-30/15	15-20	30-40/20-25
3	DECIDUOUS TREES	Pawpaw *Asimina Adans.*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-25/10-20
3	DECIDUOUS TREES	Pear, Chinese (Harbin) *Pyrus ussuriensis* Recommended cultivar: McDermand	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-25/15	20-25	15-25/15
3	DECIDUOUS TREES	Pecan, Northern *Carya illinoensis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended		60-70 (South of Platte River only)		70-80 (South of Platte River only)
3	DECIDUOUS TREES	Redbud, Eastern 1/ *Cercis canadensis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-20	10-15/10	15-20	15-20/10-20
3	DECIDUOUS TREES	Sycamore, American *Platanus occidentalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	30-35	40-45/20	35-40	50-70/30-40
3	DECIDUOUS TREES	Walnut, Black *Juglans nigra*	20-25	30-40/30	20-25	30-40/30	20-25	40-50/30	25-30	40-60/30
3	DECIDUOUS TREES	Willow, Black 1/ *Salix nigra*	Not Recommended	Not Recommended	20-25	30-35/20	25-30	30-35/20	25-30	35-50/20
3	DECIDUOUS TREES	Willow, Peachleaf 1/ *Salix amygdaloides*	Not Recommended	Not Recommended	20-25	20-30/20	20-25	20-30/20	20-25	20-30/20

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
3	DECIDUOUS TREES	Willow, White or Golden 1/ *Salix alba* (Cultivars Vitellina or Tristis often called Golden Willow)	Not Recommended	Not Recommended	20-25	30-35/20	25-30	30-35/20	25-30	35-40/20
3	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		5-10		Not Recommended		Not Recommended	
3	DECIDUOUS SHRUBS	Blackhaw, Nannyberry *Vibernum lentago*	Not Recommended		Not Recommended		6-8		8-12	
3	DECIDUOUS SHRUBS	Buffaloberry, Silver 1/ *Shepherdia argentea*	5-8		10-12		10-12		10-12	
3	DECIDUOUS SHRUBS	Buttonbush *Cephlanthus occidentalis*	Not Recommended		Not Recommended		Not Recommended		8-10	
3	DECIDUOUS SHRUBS	Cherry, Nanking *Prunus tomentosa*	Not Recommended		4-5		4-5		5-7	
3	DECIDUOUS SHRUBS	Chokeberry, Black *Aronia melanocarpa*	Not Recommended		4-5		4-8		6-8	
3	DECIDUOUS SHRUBS	Chokecherry, Common 1/ *Prunus virginiana*	5-8		6-12		6-12		8-14	
3	DECIDUOUS SHRUBS	Coralberry *Symphoricarpos orbiculatus*	Not Recommended		Not Recommended		2-3		2-3	
3	DECIDUOUS SHRUBS	Cotoneaster, Peking *Cotoneaster acutifolia*	4-5		5-6		5-8		5-10	
3	DECIDUOUS SHRUBS	Cranberry, Highbush *Viburnum trilobum*	Not Recommended		Not Recommended		6-12		10-12	
3	DECIDUOUS SHRUBS	Currant, Buffalo 1/ *Ribes odoratum*	3-6		3-6		3-6		3-6	
3	DECIDUOUS SHRUBS	Currant, Golden 1/ *Ribes aureum*	2-4		2-4		4-6		4-6	
3	DECIDUOUS SHRUBS	Dogwood, Gray *Cornus racemosa*	4-6		6-8		6-8		6-8	
3	DECIDUOUS SHRUBS	Dogwood, Redosier *Cornus sericea*	5-6		5-7		6-8		8-10	
3	DECIDUOUS SHRUBS	Elderberry *Sambucus canadensis*	Not Recommended		4-6		4-6		4-8	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
3	DECIDUOUS SHRUBS	Euonymus, Winterberry *Euonymus bungeanus* Recommended cultivar: Pink Lady Winterberry	5-10		5-10		8-14		8-14	
3	DECIDUOUS SHRUBS	Hazelnut, American *Corylus americana*	Not Recommended		Not Recommended		6-8		6-8	
3	DECIDUOUS SHRUBS	Indigo, False *Amorpha fruiticosa*	Not Recommended		Not Recommended		4-6		8-10	
3	DECIDUOUS SHRUBS	Juneberry (Saskatoon Serviceberry) 1/ *Amelanchier alnifolia*	5-7		5-7		6-10		6-10	
3	DECIDUOUS SHRUBS	Lilac 1/ *Syringa vulgaris*	5-6		5-6		5-8		6-10	
3	DECIDUOUS SHRUBS	Mahogany, Mountain 1/ *Cercocarpus montana*	5-10		5-10		Not Recommended		Not Recommended	
3	DECIDUOUS SHRUBS	Peashrub, Siberian 1/ *Caragana arborescens*	6-8		6-8		8-10		8-12	
3	DECIDUOUS SHRUBS	Plum, American 1/ *Prunus americana*	5-7		5-8		5-8		6-10	
3	DECIDUOUS SHRUBS	Rose, Arkansas [prairie rose] *Rosa arkansana*	1-2		1-2		1-2		1-2	
3	DECIDUOUS SHRUBS	Rose, Hansen Hedge *Rosa* Sp. *Rosa rugusa x R. woodsii*	4-6		4-6		4-8		6-8	
3	DECIDUOUS SHRUBS	Rose, Woods' *Rosa woodsii*	3-5		3-5		4-5		4-5	
3	DECIDUOUS SHRUBS	Sagebrush, Big *Artemisia tridentata*	3-6		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	
3	DECIDUOUS SHRUBS	Sagebrush, Silver *Artemisia cana*	3-6		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	
3	DECIDUOUS SHRUBS	Saltbush, Fourwing 1/ *Atriplex canescens*	2-5		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	
3	DECIDUOUS SHRUBS	Sandcherry, Western *Prunus besseyi*	2-3		2-3		2-4		3-6	
3	DECIDUOUS SHRUBS	Snowberry, Common *Symphoricarpos albus*	Not Recommended		Not Recommended		3-4		3-4	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
3	DECIDUOUS SHRUBS	Snowberry, Western *Symphoricarpos occidentalis*	3-4		3-4		3-4		3-4	
3	DECIDUOUS SHRUBS	Sumac, Skunkbush 1/ *RhusTrilobata* Recommended cultivars: Big Horn, Konza Fragrant	3-5		4-6		4-6		4-8	

1/ Adapted to calcareous soils

2/ Black locust can be severely impacted by insect damage; recommend limiting use to wildlife and pollinator plantings, rather than for windbreaks

3/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**

4/ Conservation mulch improves growth and survival

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
4	CONIFEROUS TREES	Arborvitae, American or Northern White Cedar *Thuja occidentalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	25-30/20
4	CONIFEROUS TREES	Arborvitae, Oriental Thuja orientalis	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-20/15
4	CONIFEROUS TREES	Baldcypress *Taxodium distichum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-30	40-50/20
4	CONIFEROUS TREES	Fir, Douglas *Pseudotsuga mennziesii*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	30-35/20	20-30	40-50/20
4	CONIFEROUS TREES	Fir, White *Abies concolor*	Not Recommended	Not Recommended	20-25	30-40/25	20-25	30-40/25	20-30	40-50/25
4	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4	CONIFEROUS TREES	Pine, Austrian *Pinus nigra*	5-25	30-50/20	15-30	30-50/20	20-30	35-50/20	20-35	40-60/20
4	CONIFEROUS TREES	Pine, Eastern White *Pinus strobus*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	30-35	40-60/20
4	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	15-20	25-30/15	15-20	30-40/15	20-30	30-40/15	20-30	35-50/15-20
4	CONIFEROUS TREES	Pine, Limber *Pinus flexilis*	10-15	25-40/15	10-15	25-40/15-20	15-20	30-40/15-20	20-25	35-50/15-20
4	CONIFEROUS TREES	Pine, Pinyon [Two needle Pinyon] *Pinus edulis*	5-10	15-20/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	15-25	30-50/20	15-30	30-50/20	20-30	35-50/20	20-35	40-60/20
4	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-50/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-30/15-20	15-25	30-40/20
4	CONIFEROUS TREES	Spruce, Colorado Blue *Picea pungens*	15-20	25-30/20	15-20	30-40/20	15-25	30-40/20-30	15-30	40-60/25-30
4	CONIFEROUS TREES	Spruce, Norway *Picea abies*	Not Recommended	Not Recommended	25-30	30-40/20	25-30	30-40/20	20-30	45-60/25

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
4	CONIFEROUS TREES	Spruce, White *Picea glauca* (variety Black Hills)	15-20	25-30/15	20-25	30-40/20	20-25	30-40/20	20-30	30-40/20
4	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	5-10	10-15/10	10-15	10-15/10	10-20	10-20/10
4	DECIDUOUS TREES	Ash, Green 1/ *Fraxinus pennsylvanica*	Not Recommended	Not Recommended	15-25	30-40/30	20-30 35-40/30		25-30	40-50/30-40
4	DECIDUOUS TREES	Aspen, Quaking *Populus tremuloides*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	20-30	15-20	20-30
4	DECIDUOUS TREES	Basswood/ Linden, American *Tilia americana*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-30	35-40/30	25-30	50-70/30-40
4	DECIDUOUS TREES	Boxelder *Acer negundo*	15-20	25-30/20	15-20	25-30/20	15-20	30-35/20	20-25	35-40/20
4	DECIDUOUS TREES	Catalpa, Northern *Catalpa speciosa*	Not Recommended	Not Recommended	25-30	25-30/20	25-30	30-40/20	25-30	40-50/25
4	DECIDUOUS TREES	Cherry, Black *Prunus serotina*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	35-40/20	20-30	30-50/20
4	DECIDUOUS TREES	Cottonwood, Eastern *Populus deltoides* Recommended cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-80/40	45-55	65-80/40-50	50-60	70-90/40-50
4	DECIDUOUS TREES	Crabapple *Malus sp .* Recommended cultivars: Radiant, Siberian, Midwest, Roselow Sargent	5-10	10-15/15	10-15	10-15/15	10-15	10-15/15	15-20	15-20/15
4	DECIDUOUS TREES	Crabapple, Prairie *Malus ionensis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	5-15	15-20/15	5-20	15-20/15
4	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	15-30	15-30	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4	DECIDUOUS TREES	Hackberry *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	20-30	45-50/20	20-30	50-60/30
4	DECIDUOUS TREES	Hawthorn, Cockspur *Crataegus crusgalli*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-15/15	10-20	10-20/15
4	DECIDUOUS TREES	Hawthorn, Washington *Crataegus phaenopyrum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-15/15	10-20	10-20/15

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
4	DECIDUOUS TREES	Hickory, Bitternut *Carya cordiformis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	45-50/20
4	DECIDUOUS TREES	Hickory, Shagbark *Carya ovata*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	45-50/20
4	DECIDUOUS TREES	Honeylocust *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	25-30	35-40/20	25-35	40-50/25-30
4	DECIDUOUS TREES	Hophornbeam, Eastern *Ostrya virginiana*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-20	15-20/10-20	10-20	20-25/10-20
4	DECIDUOUS TREES	Kentucky Coffeetree *Gymnocladus dioicus*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	35-40/20	25-30	45-70/25-30
4	DECIDUOUS TREES	Locust, Black 2/ *Robinia pseudoacacia*	20-25	25-30/15	25-30	25-30/15	25-30	35-40/20	25-30	40-50/20
4	DECIDUOUS TREES	Maple, Amur *Acer ginnala* Recommended cultivar: Flame	10-15	10-15/15	10-15	10-15/15	15-20	15-20/15	15-20	15-20/15
4	DECIDUOUS TREES	Maple, Sugar *Acer saccharum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	35-430
4	DECIDUOUS TREES	Mulberry, Red *Morus rubra*	15-20	15-20/15	15-20	30-35/15-20	20-25	35-40/20	20-25	40-45/25-30
4	DECIDUOUS TREES	Mulberry, Russian or White *Morus alba var. tatarica*	15-20	15-20/15	15-20	30-35/15-20	15-20	35-40/20	20-25	40-40/25-30
4	DECIDUOUS TREES	Oak, Black *Quercus velutina*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-60/30-40
4	DECIDUOUS TREES	Oak, Bur *Quercus macrocarpa*	15-20	25-30/15-20	20-25	30-40/20	20-25	35-40/30	20-30	40-60/30-40
4	DECIDUOUS TREES	Oak, Chinkapin *Quercus muhlenbergii*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-50/30	20-25	40-60/30-40
4	DECIDUOUS TREES	Oak, English *Quercus robur*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	30-40	55-65
4	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4	DECIDUOUS TREES	Oak, Northern Red *Quercus rubra*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-60/30-40

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
4	DECIDUOUS TREES	Oak, Swamp White *Quercus bicolor*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-30	40-50/20-30
4	DECIDUOUS TREES	Oak, White *Quercus alba*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-60/30-40
4	DECIDUOUS TREES	Osage-orange *Maclura pomifera*	Not Recommended	Not Recommended	15-20	20-25/15	15-20	25-30/15	15-20	30-35/20-25
4	DECIDUOUS TREES	Redbud, Eastern *Cercis canadensis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	10-15/10	15-20	15-20/10-20
4	DECIDUOUS TREES	Sycamore, American *Platanus occidentalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	30-35	40-45/20	30-40	50-70/30-40
4	DECIDUOUS TREES	Walnut, Black *Juglans nigra*	20-25	30-40/30	20-25	30-40/30	20-25	40-50/30	25-30	40-60/30
4	CONIFEROUS SHRUBS	Juniper, Prostrate *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
4	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		5-10		Not Recommended		Not Recommended	
4	DECIDUOUS SHRUBS	Blackhaw, Nannyberry *Vibernum lentago*	Not Recommended		Not Recommended		6-8		8-12	
4	DECIDUOUS SHRUBS	Buffaloberry, Silver *Shepherdia argentea*	5-8		10-12		10-12		10-12	
4	DECIDUOUS SHRUBS	Cherry, Nanking *Prunus tomentosa*	Not Recommended		4-5		4-5		5-7	
4	DECIDUOUS SHRUBS	Chokeberry, Black *Aronia melanocarpa*	Not Recommended		5-8		4-8		6-8	
4	DECIDUOUS SHRUBS	Chokecherry, Common *Prunus virginiana*	5-8		6-12		6-12		8-14	
4	DECIDUOUS SHRUBS	Coralberry *Symphoricarpos orbiculatus*	Not Recommended		Not Recommended		2-3		2-3	
4	DECIDUOUS SHRUBS	Cotoneaster, Peking *Cotoneaster acutifolia*	4-5		5-6		5-8		5-10	
4	DECIDUOUS SHRUBS	Cranberry, Highbush *Viburnum trilobum*	Not Recommended		Not Recommended		6-12		10-12	
4	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	3-6		3-6		3-6		3-6	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
4	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		2-4		4-6		4-6	
4	DECIDUOUS SHRUBS	Dogwood, Gray *Cornus racemosa*	4-6		6-8		6-8		6-8	
4	DECIDUOUS SHRUBS	Dogwood, Redosier *Cornus sericea*	5-6		5-7		6-8		8-10	
4	DECIDUOUS SHRUBS	Euonymus, Winterberry *Euonymus bungeanus* Recommended cultivar: Pink Lady Winterberry	6-10		6-10		8-14		8-14	
4	DECIDUOUS SHRUBS	Hazelnut, American *Corylus americana*	Not Recommended		Not Recommended		6-8		6-8	
4	DECIDUOUS SHRUBS	Juneberry (Saskatoon Serviceberry) *Amelanchier alnifolia*	5-7		5-7		6-10		6-10	
4	DECIDUOUS SHRUBS	Lilac *Syringa vulgaris*	5-6		5-6		5-8		6-10	
4	DECIDUOUS SHRUBS	Mahogany, Mountain *Cercocarpus montana*	5-10		Not Recommended		Not Recommended		Not Recommended	
4	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		6-8		8-10		8-12	
4	DECIDUOUS SHRUBS	Plum, American *Prunus americana*	5-7		5-8		5-8		6-10	
4	DECIDUOUS SHRUBS	Rose, Arkansas [prairie rose] *Rosa arkansana*	1-2		1-2		1-2		1-2	
4	DECIDUOUS SHRUBS	Rose, Hansen Hedge *Rosa* Sp. *Rosa rugusa x R. woodsii*	4-6		4-6		4-8		6-8	
4	DECIDUOUS SHRUBS	Rose, Woods' *Rosa woodsii*	3-5		3-5		4-5		4-5	
4	DECIDUOUS SHRUBS	Sagebrush, Big *Artemisia tridentata*	3-6		Not Recommended		Not Recommended		Not Recommended	
4	DECIDUOUS SHRUBS	Sagebrush, Silver *Artemisia cana*	3-6		Not Recommended		Not Recommended		Not Recommended	
4	DECIDUOUS SHRUBS	Saltbush, Fourwing *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
4	DECIDUOUS SHRUBS	Sandcherry, Western *Prunus besseyi*	2-3		2-3		2-4		3-6	
4	DECIDUOUS SHRUBS	Snowberry, Common *Symphoricarpos albus*	Not Recommended		Not Recommended		3-4		3-4	
4	DECIDUOUS SHRUBS	Snowberry, Western *Symphoricarpos occidentalis*	3-4		3-4		3-4		3-4	
4	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		4-6		4-6		4-8	

1/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**
2/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
4K	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	CONIFEROUS TREES	Pine, Bristlecone *Pinus aristata*	5-10	25-30/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	CONIFEROUS TREES	Pine, Limber *Pinus flexilis*	10-15	25-40/15	10-15	25-45/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-15/10	10-20	10-20/10
4K	DECIDUOUS TREES	Ash, Green 1/ *Fraxinus pennsylvanica*	Not Recommended	Not Recommended	15-25	30-40/30	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Catalpa, Northern *Catalpa speciosa*	Not Recommended	Not Recommended	25-30	25-30/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Cottonwood, Eastern *Populus deltoides* Recommended cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-85/40	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	15-30	15-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Hackberry *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Honeylocust *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Locust, Black 2/ *Robinia pseudoacacia*	20-25	25-35/15	25-30	25-35/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Mulberry, Red *Morus rubra*	15-20	15-25/15	15-20	30-35/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Mulberry, Russian or White *Morus alba var. tatarica*	15-20	15-25/15	15-20	30-35/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
4K	DECIDUOUS TREES	Oak, Bur *Quercus macrocarpa*	15-20	25-35/15-20	20-25	30-40/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS TREES	Osage-orange *Maclura pomifera*	Not Recommended	Not Recommended	15-20	20-215	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4K	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		5-10		Not Recommended		Not Recommended	
4K	DECIDUOUS SHRUBS	Buffaloberry, Silver *Shepherdia argentea*	5-8		10-12		Not Recommended		Not Recommended	
4K	DECIDUOUS SHRUBS	Chokecherry, Common *Prunus virginiana*	5-8		6-12		Not Recommended		Not Recommended	
4K	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	3-6		3-6		Not Recommended		Not Recommended	
4K	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		2-4		Not Recommended		Not Recommended	
4K	DECIDUOUS SHRUBS	Lilac *Syringa vulgaris*	5-6		5-6		Not Recommended		Not Recommended	
4K	DECIDUOUS SHRUBS	Mahogany, Mountain *Cercocarpus montana*	5-10		Not Recommended		Not Recommended		Not Recommended	
4K	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		6-8		Not Recommended		Not Recommended	
4K	DECIDUOUS SHRUBS	Plum, American *Prunus americana*	5-7		5-8		Not Recommended		Not Recommended	
4K	DECIDUOUS SHRUBS	Saltbush, Fourwing *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	
4K	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		4-6		Not Recommended		Not Recommended	

1/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**
2/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
4C	CONIFEROUS TREES	Baldcypress *Taxodium distichum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-30	40-50/20
4C	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4C	CONIFEROUS TREES	Pine, Austrian *Pinus nigra*	5-25	30-50/20	15-30	30-50/20	20-30	35-50/20	20-35	40-60/20
4C	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	15-20	25-30/15	15-20	30-40/15	20-30	30-40/15	Not Recommended	Not Recommended
4C	CONIFEROUS TREES	Pine, Limber *Pinus flexilis*	10-15	25-40/15	10-15	25-40/15-20	15-20	30-40/15-20	Not Recommended	Not Recommended
4C	CONIFEROUS TREES	Pine, Pinyon [Two needle Pinyon] *Pinus edulis*	5-10	15-20/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4C	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	15-25	30-50/20	15-30	30-55/20	20-30	35-55/20	20-35	40-60/20
4C	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4C	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-35/15-20	15-25	30-40/20
4C	CONIFEROUS TREES	Spruce, Colorado Blue *Picea pungens*	15-20	25-35/20	15-20	30-40/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4C	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	5-10	10-15/10	10-15	10-15/10	10-20	10-20/10
4C	DECIDUOUS TREES	Ash, Green 1/ *Fraxinus pennsylvanica*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-30 35-40/30		25-30	40-50/30-40
4C	DECIDUOUS TREES	Boxelder *Acer negundo*	15-20	25-35/20	15-20	25-35/20	15-20	25-35/20	20-25	35-40/20
4C	DECIDUOUS TREES	Catalpa, Northern *Catalpa speciosa*	Not Recommended	Not Recommended	25-30	25-30/20	25-30	30-40/20	25-30	40-50/25
4C	DECIDUOUS TREES	Cottonwood, Eastern *Populus deltoides* Recommended cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-85/40	45-55	65-85/40-50	Not Recommended	Not Recommended

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
4C	DECIDUOUS TREES	Crabapple *Malus sp.* Recommended cultivars: Radiant, Siberian, Midwest, Roselow Sargent	5-10	10-15/15	10-15	10-15/15	10-15	10-15/15	Not Recommended	Not Recommended
4C	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	15-30	15-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4C	DECIDUOUS TREES	Hackberry *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	20-30	45-55/20	20-30	50-60/30
4C	DECIDUOUS TREES	Hawthorn, Cockspur *Crataegus crusgalli*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-15/15	10-20	10-20/15
4C	DECIDUOUS TREES	Hawthorn, Washington *Crataegus phaenopyrum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-15/15	10-20	10-20/15
4C	DECIDUOUS TREES	Hickory, Bitternut *Carya cordiformis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	45-50/20
4C	DECIDUOUS TREES	Hickory, Shagbark *Carya ovata*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	45-50/20
4C	DECIDUOUS TREES	Honeylocust *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	25-30	35-40/I4420	25-35	40-50/25-30
4C	DECIDUOUS TREES	Hophornbeam, Eastern *Ostrya virginiana*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-20	15-20/10-20	10-20	20-25/10-20
4C	DECIDUOUS TREES	Kentucky Coffeetree *Gymnocladus dioicus*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	35-45/20	25-30	45-70/25-30
4C	DECIDUOUS TREES	Locust, Black 2/ *Robinia pseudoacacia*	20-25	25-35/15	25-30	25-35/15	25-30	35-45/20	25-30	40-50/20
4C	DECIDUOUS TREES	Mulberry, Red *Morus rubra*	15-20	15-25/15	15-20	30-35/15-20	20-25	35-40/20	20-25	40-45/25-30
4C	DECIDUOUS TREES	Mulberry, Russian or White *Morus alba var. tatarica*	15-20	15-25/15	15-20	30-35/15-20	15-20	35-40/20	20-25	40-45/25-30
4C	DECIDUOUS TREES	Oak, Black *Quercus velutina*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-60/30-40
4C	DECIDUOUS TREES	Oak, Bur *Quercus macrocarpa*	15-20	25-35/15-20	20-25	30-40/20	20-25	35-430	20-30	40-60/30-40

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
4C	DECIDUOUS TREES	Oak, Chinkapin *Quercus muhlenbergii*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-50/30	20-25	40-60/30-40
4C	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4C	DECIDUOUS TREES	Oak, Northern Red *Quercus rubra*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-60/30-40
4C	DECIDUOUS TREES	Oak, Swamp White *Quercus bicolor*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-30	40-50/20-30
4C	DECIDUOUS TREES	Osage-orange *Maclura pomifera*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	25-30/15	15-20	30-320-25
4C	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
4C	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		5-10		Not Recommended		Not Recommended	
4C	DECIDUOUS SHRUBS	Blackhaw, Nannyberry *Vibernum lentago*	Not Recommended		v		6-8		8-12	
4C	DECIDUOUS SHRUBS	Buffaloberry, Silver *Shepherdia argentea*	5-8		10-12		10-12		10-12	
4C	DECIDUOUS SHRUBS	Cherry, Nanking *Prunus tomentosa*	Not Recommended		4-5		4-5		5-7	
4C	DECIDUOUS SHRUBS	Chokeberry, Black *Aronia melanocarpa*	Not Recommended		5-8		4-8		6-8	
4C	DECIDUOUS SHRUBS	Chokecherry, Common *Prunus virginiana*	5-8		6-12		6-12		8-14	
4C	DECIDUOUS SHRUBS	Coralberry *Symphoricarpos orbiculatus*	Not Recommended		Not Recommended		2-3		2-3	
4C	DECIDUOUS SHRUBS	Cotoneaster, Peking *Cotoneaster acutifolia*	4-5		5-6		5-8		5-10	
4C	DECIDUOUS SHRUBS	Cranberry, Highbush *Viburnum trilobum*	Not Recommended		Not Recommended		6-12		10-12	
4C	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	3-6		3-6		3-6		3-6	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
4C	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		2-4		4-6		4-6	
4C	DECIDUOUS SHRUBS	Dogwood, Gray *Cornus racemosa*	4-6		6-8		6-8		6-8	
4C	DECIDUOUS SHRUBS	Dogwood, Redosier *Cornus sericea*	5-6		5-7		6-8		8-10	
4C	DECIDUOUS SHRUBS	Euonymus, Winterberry *Euonymus alatus* Recommended cultivar: Pink Lady Winterberry	6-10		6-10		8-14		8-14	
4C	DECIDUOUS SHRUBS	Hazelnut, American *Corylus americana*	Not Recommended		Not Recommended		Not Recommended		6-8	
4C	DECIDUOUS SHRUBS	Juneberry (Saskatoon Serviceberry) *Amelanchier alnifolia*	5-7		5-7		6-10		6-10	
4C	DECIDUOUS SHRUBS	Lilac *Syringa vulgaris*	5-6		5-6		5-8		6-10	
4C	DECIDUOUS SHRUBS	Mahogany, Mountain *Cercocarpus montana*	5-10		5-10		Not Recommended		Not Recommended	
4C	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		6-8		8-10		8-10	
4C	DECIDUOUS SHRUBS	Plum, American *Prunus americana*	5-7		5-8		5-8		6-10	
4C	DECIDUOUS SHRUBS	Rose, Arkansas [prairie rose] *Rosa arkansana*	1-2		1-2		1-2		1-2	
4C	DECIDUOUS SHRUBS	Rose, Hansen Hedge *Rosa* Sp. *Rosa rugusa x R. woodsii*	4-6		4-6		4-8		6-8	
4C	DECIDUOUS SHRUBS	Rose, Woods' *Rosa woodsii*	3-5		3-5		4-5		4-5	
4C	DECIDUOUS SHRUBS	Sagebrush, Big *Artemisia tridentata*	3-6		Not Recommended		Not Recommended		Not Recommended	
4C	DECIDUOUS SHRUBS	Sagebrush, Silver *Artemisia cana*	3-6		Not Recommended		Not Recommended		Not Recommended	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
4C	DECIDUOUS SHRUBS	Saltbush, Fourwing *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	
4C	DECIDUOUS SHRUBS	Snowberry, Common *Symphoricarpos albus*	Not Recommended		Not Recommended		3-4		3-4	
4C	DECIDUOUS SHRUBS	Snowberry, Western *Symphoricarpos occidentalis*	3-4		3-4		3-4		3-4	
4C	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		4-6		4-6		4-8	

1/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**
2/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
4CK	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	CONIFEROUS TREES	Pine, Bristlecone *Pinus aristata*	5-10	25-30/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	CONIFEROUS TREES	Pine, Limber *Pinus flexilis*	10-15	25-40/15	10-15	25-40/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	15-25	30-50/20	15-30	30-50/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-50/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-215	10-20	20-215	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-15/10	10-20	10-20/10
4CK	DECIDUOUS TREES	Ash, Green 1/ *Fraxinus pennsylvanica*	15-20	25-30/25	15-25	30-40/30	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Catalpa, Northern *Catalpa speciosa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	30-35/20	15-20	30-35/20
4CK	DECIDUOUS TREES	Cottonwood, Eastern *Populus deltoides* Recommended cultivars: Might Mo, Noreaster, Platte	30-55	60-80/40	30-55	65-80/40	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Crabapple Malus sp. Recommended cultivars: Radiant, Siberian, Midwest , Roselow Sargent	5-10	10-115	10-15	10-115	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	15-30	15-320	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Hackberry *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Honeylocust *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Locust, Black 2/ *Robinia pseudoacacia*	20-25	25-30/15	25-30	25-30/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Mulberry, Red *Morus rubra*	15-20	15-20/15	15-20	30-35/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
4CK	DECIDUOUS TREES	Mulberry, Russian or White *Morus alba var. tatarica*	15-20	15-20/15	15-20	30-35/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Oak, Bur *Quercus macrocarpa*	15-20	25-30/15-20	20-25	30-40/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS TREES	Osage-orange *Maclura pomifera*	Not Recommended	Not Recommended	15-20	20-25/G4115	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		Not Recommended		Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Buffaloberry, Silver Shepherdia argentea	5-8		10-12		Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Chokecherry, Common *Prunus virginiana*	5-8		6-12		Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	3-6		3-6		Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		2-4		Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Lilac *Syringa vulgaris*	5-6		5-6		Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Mahogany, Mountain *Cercocarpus montana*	5-10		Not Recommended		Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		6-8		Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Plum, American *Prunus americana*	5-7		5-8		Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Saltbush, Fourwing *Atriplex canescens*	2-5		Not Recommended		Not Recommended	Not Recommended	Not Recommended	Not Recommended
4CK	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		4-6		Not Recommended	Not Recommended	Not Recommended	Not Recommended

1/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**
2/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
5	CONIFEROUS TREES	Arborvitae, American or Northern White Cedar *Thuja occidentalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	25-30/20
5	CONIFEROUS TREES	Arborvitae, Oriental 1/ *Thuja orientalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-20/15
5	CONIFEROUS TREES	Juniper, Rocky Mountain 1/ *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
5	CONIFEROUS TREES	Pine, Austrian *Pinus nigra*	5-25	30-50/20	15-30	30-55/20	20-30	35-50/20	20-35	40-60/20
5	CONIFEROUS TREES	Pine, Eastern White *Pinus strobus*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	40-50/20	30-35	40-60/20
5	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	15-20	25-35/15	15-20	30-40/15	15-30	30-40/15	20-30	40-45/15
5	CONIFEROUS TREES	Pine, Limber 1/ *Pinus flexilis*	10-15	25-40/15	10-15	25-45/15-20	15-20	30-45/15-20	20-25	35-55/15-20
5	CONIFEROUS TREES	Pine, Pinyon [Two needle Pinyon] *Pinus edulis*	5-10	15-20/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
5	CONIFEROUS TREES	Pine, Ponderosa 1/ *Pinus ponderosa*	15-25	30-50/20	15-30	30-55/20	20-30	35-55/20	20-35	40-60/20
5	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
5	CONIFEROUS TREES	Redcedar, Eastern 1/ *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-30/15-20	15-25	30-40/20
5	CONIFEROUS TREES	Spruce, Colorado Blue *Picea pungens*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	30-45/20-25	20-30	40-60/25
5	CONIFEROUS TREES	Spruce, Norway *Picea abies*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	30-45/20	25-30	45-60/25
5	CONIFEROUS TREES	Spruce, White *Picea glauca* (variety Black Hills)	15-20	25-35/15	20-25	30-40/20	20-25	30-45/20	25-30	30-45/20
5	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-15/10	10-20	10-20/10
5	DECIDUOUS TREES	Ash, Green 1/, 3/ *Fraxinus pennsylvanica*	15-20	25-35/25	20-25	30-40/30	20-30	35-45/30	25-30	40-50/30-40
5	DECIDUOUS TREES	Basswood/ Linden, American *Tilia americana*	20-25	30-40/30	25-30	30-40/30	25-30	35-45/30	25-30	40-50/30-40
5	DECIDUOUS TREES	Boxelder *Acer negundo*	15-20	25-35/20	15-20	25-35/20	20-25	30-35/20	20-25	35-40/20
5	DECIDUOUS TREES	Catalpa, Northern 1/ *Catalpa speciosa*	Not Recommended	Not Recommended	25-30	25-30/20	25-30	30-40/20	25-30	40-50/25

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
5	DECIDUOUS TREES	Crabapple 1/ *Malus sp.* Recommended cultivars: Radiant, Siberian, Midwest, Roselow Sargent	10-15	10-15/15	10-15	10-15/15	10-15	10-15/15	15-20	15-20/15
5	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	20-25	20-30/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
5	DECIDUOUS TREES	Hackberry 1/ *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	20-30	45-50/20	20-30	50-60/30
5	DECIDUOUS TREES	Hawthorn, Cockspur 1/ *Crataegus crusgalli*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	15-20/15	15-20	15-20/15
5	DECIDUOUS TREES	Hawthorn, Washington 1/ *Crataegus phaenopyrum*	Not Recommended	Not Recommended	10-15	15-20/15	10-15	15-20/15	15-20	15-20/15
5	DECIDUOUS TREES	Hickory, Bitternut *Carya cordiformis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	45-55/20
5	DECIDUOUS TREES	Hickory, Shagbark *Carya ovata*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	45-55/20
5	DECIDUOUS TREES	Honeylocust 1/ *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	25-30	35-420	25-35	40-50/25-30
5	DECIDUOUS TREES	Kentucky Coffeetree *Gymnocladus dioicus*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	35-45/20	25-30	45-70/25-30
5	DECIDUOUS TREES	Locust, Black 1/, 2/ *Robinia pseudoacacia*	20-25	25-30/15	25-30	25-35/15	25-30	35-45/20	25-30	40-50/20
5	DECIDUOUS TREES	Maple, Amur *Acer ginnala* Recommended cultivar: Flame	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-20/15	15-20	15-20/15
5	DECIDUOUS TREES	Maple, Silver *Acer saccharinum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	30-35	40-60/30-40	35-40	50-70/30-50
5	DECIDUOUS TREES	Maple, Sugar *Acer saccharum*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	40-50/30
5	DECIDUOUS TREES	Mulberry, Red 1/ *Morus rubra*	15-20	15-20/15	15-20	30-35/15-20	20-25	35-40/20	20-25	40-45/25-30
5	DECIDUOUS TREES	Mulberry, Russian or White 1/ *Morus alba var. tatarica*	15-20	15-20/15	15-20	30-35/15-20	15-20	35-40/20	20-25	40-45/25-30
5	DECIDUOUS TREES	Oak, Black *Quercus velutina*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	40-60/30-40
5	DECIDUOUS TREES	Oak, Bur 1/ *Quercus macrocarpa*	15-20	25-30/15-20	20-25	30-40/20	20-25	35-40/30	25-30	40-60/30-40
5	DECIDUOUS TREES	Oak, English *Quercus robur*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	30-40	55-65
5	DECIDUOUS TREES	Oak, Gambel 1/ *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
5	DECIDUOUS TREES	Oak, Northern Red *Quercus rubra*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	40-60/30-40

Soils Group	TreeShrub Type	Species	ZONE I 20-YEAR HEIGHT (ft)	ZONE I MATURE HGT/SPREAD (ft)	ZONE II 20-YEAR HEIGHT (ft)	ZONE II MATURE HGT/SPREAD (ft)	ZONE III 20-YEAR HEIGHT (ft)	ZONE III MATURE HGT/SPREAD (ft)	ZONE IV 20-YEAR HEIGHT (ft)	ZONE IV MATURE HGT/SPREAD (ft)
5	DECIDUOUS TREES	Oak, White *Quercus alba*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	40-60/30-40
5	DECIDUOUS TREES	Osage-orange 1/ *Maclura pomifera*	Not Recommended	Not Recommended	15-20	20-25/15	15-20	25-30/15	15-20	25-30/15
5	DECIDUOUS TREES	Pear, Chinese (Harbin) *Pyrus ussuriensis* Recommended cultivar: McDermand	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-25/15	20-25	20-25/15
5	DECIDUOUS TREES	Sycamore, American *Platanus occidentalis*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	35-40	50-70/30-40
5	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
5	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		Not Recommended		Not Recommended		Not Recommended	
5	DECIDUOUS SHRUBS	Blackhaw, Nannyberry 1/ *Vibernum lentago*	Not Recommended		Not Recommended		6-8		8-12	
5	DECIDUOUS SHRUBS	Buffaloberry, Silver 1/ *Shepherdia argentea*	5-8		10-12		10-12		10-12	
5	DECIDUOUS SHRUBS	Buttonbush *Cephlanthus occidentalis*	Not Recommended		Not Recommended		Not Recommended		8-10	
5	DECIDUOUS SHRUBS	Cherry, Nanking *Prunus tomentosa*	Not Recommended		Not Recommended		4-5		5-7	
5	DECIDUOUS SHRUBS	Chokeberry, Black *Aronia melanocarpa*	Not Recommended		5-8		5-8		5-8	
5	DECIDUOUS SHRUBS	Chokecherry, Common 1/ *Prunus virginiana*	5-8		6-12		6-12		8-14	
5	DECIDUOUS SHRUBS	Coralberry *Symphoricarpos orbiculatus*	Not Recommended		Not Recommended		2-3		2-3	
5	DECIDUOUS SHRUBS	Cotoneaster, Peking *Cotoneaster acutifolia*	4-5		5-6		5-8		5-10	
5	DECIDUOUS SHRUBS	Cranberry, Highbush *Viburnum trilobum*	Not Recommended		Not Recommended		6-8		6-10	
5	DECIDUOUS SHRUBS	Currant, Buffalo 1/ *Ribes odoratum*	3-6		3-6		3-6		3-6	
5	DECIDUOUS SHRUBS	Currant, Golden 1/ *Ribes aureum*	2-4		2-4		4-6		4-6	
5	DECIDUOUS SHRUBS	Dogwood, Gray *Cornus racemosa*	Not Recommended		6-8		6-8		6-8	
5	DECIDUOUS SHRUBS	Dogwood, Redosier *Cornus sericea*	5-6		5-7		6-8		8-10	
5	DECIDUOUS SHRUBS	Elderberry *Sambucus canadensis*	Not Recommended		4-6		4-6		4-8	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
5	DECIDUOUS SHRUBS	Euonymus, Winterberry *Euonymus alatus* Recommended cultivar: Pink Lady Winterberry	5-10		5-10		8-14		8-14	
5	DECIDUOUS SHRUBS	Juneberry (Saskatoon Serviceberry) 1/ *Amelanchier alnifolia*	5-7		5-7		6-10		6-10	
5	DECIDUOUS SHRUBS	Lilac 1/ *Syringa vulgaris*	5-6		5-6		5-8		6-10	
5	DECIDUOUS SHRUBS	Mahogany, Mountain 1/ *Cercocarpus montana*	5-10		Not Recommended		Not Recommended		Not Recommended	
5	DECIDUOUS SHRUBS	Peashrub, Siberian 1/ *Caragana arborescens*	6-8		6-8		6-10		8-10	
5	DECIDUOUS SHRUBS	Plum, American 1/ *Prunus americana*	5-7		5-8		5-8		6-10	
5	DECIDUOUS SHRUBS	Rose, Arkansas (Prairie Rose) *Rosa arkansana*	1-2		1-2		1-2		1-2	
5	DECIDUOUS SHRUBS	Rose, Hansen Hedge Rosa Sp. *Rosa rugusa x R. woodsii*	4-6		4-6		4-8		6-8	
5	DECIDUOUS SHRUBS	Rose, Woods *Rosa woodsii*	3-5		3-5		4-5		4-5	
5	DECIDUOUS SHRUBS	Sagebrush, Big *Artemisia tridentata*	3-6		Not Recommended		Not Recommended		Not Recommended	
5	DECIDUOUS SHRUBS	Sagebrush, Silver *Artemisia cana*	3-6		Not Recommended		Not Recommended		Not Recommended	
5	DECIDUOUS SHRUBS	Saltbush, Fourwing *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	
5	DECIDUOUS SHRUBS	Sandcherry, Western *Prunus besseyi*	2-3		2-3		2-4		3-6	
5	DECIDUOUS SHRUBS	Snowberry, Common *Symphoricarpos albus*	Not Recommended		Not Recommended		3-4		3-4	
5	DECIDUOUS SHRUBS	Snowberry, Western *Symphoricarpos occidentalis*	3-4		3-4		3-4		3-4	
5	DECIDUOUS SHRUBS	Sumac, Skunkbush 1/ *Rhus trilobata* Recommended cultivars: Big Horn, Konza Fragrant	3-5		4-6		4-6		4-8	

1/ Adapted to calcareous soils

2/ Black locust can be severely impacted by insect damage; recommend limiting use to wildlife and pollinator plantings, rather than for windbreaks

3/ Green Ash - only to be used in diverse tree and shrub plantings; not windbreaks

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			0-YEAR	MATURE	0-YEAR	MATURE	0-YEAR	MATURE	0-YEAR	MATURE
			HEIGHT (ft)	HGTSPREAD (ft)	HEIGHT (ft)	HGTSPREAD (ft)	HEIGHT (ft)	HGTSPREAD (ft)	HEIGHT (ft)	HGTSPREAD (ft)
5K	CONIFEROUS TREES	Juniper, Rocky Mountain 1/ *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
5K	CONIFEROUS TREES	Pine, Limber 1/ *Pinus flexilis*	10-15	25-40/15	10-15	25-45/15-20	15-20	30-45/15-20	20-25	35-55/15-20
5K	CONIFEROUS TREES	Pine, Ponderosa 1/ *Pinus ponderosa*	15-25	30-50/20	15-30	30-45/20	20-30	35-520	20-35	40-60/20
5K	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
5K	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-35/15-20	15-25	30-40/20
5K	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-15/10	10-20	10-20/10
5K	DECIDUOUS TREES	Ash, Green 1/, 2/ *Fraxinus pennsylvanica*	10-15	20-25/20	10-15	20-25/20	10-15	20-25/20	10-15	
5K	DECIDUOUS TREES	Aspen, Quaking 1/ *Populus tremuloides*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	30-40	15-20	30-40
5K	DECIDUOUS TREES	Catalpa, Northern 1/ *Catalpa speciosa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-30	30-40/20	25-30	
5K	DECIDUOUS TREES	Crabapple 1/ *Malus sp.* Recommended cultivars: Radiant, Siberian, Midwest, Roselow Sargent	10-15	10-15/15	10-15	10-15/15	10-15	10-15/15	15-20	15-20/15
5K	DECIDUOUS TREES	Elm, Siberian 1/ *Ulmus pumila*	15-20	30-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
5K	DECIDUOUS TREES	Hackberry 1/ *Celtis occidentalis*	10-15	25-30/20	20-25	40-50/20	10-15	25-30/20	10-15	30-35/30
5K	DECIDUOUS TREES	Hawthorn, Cockspur 1/ *Crataegus crusgalli*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	15-20/15	15-20	15-20/15
5K	DECIDUOUS TREES	Hawthorn, Washington 1/ *Crataegus phaenopyrum*	Not Recommended	Not Recommended	10-15	15-20/15	10-15	15-20/15	15-20	15-20/15
5K	DECIDUOUS TREES	Honeylocust 1/ *Gleditsia triacanthos*	Not Recommended	Not Recommended	20-30	30-40/20	20-30	30-40/20	25-35	40-50/25-30
5K	DECIDUOUS TREES	Locust, Black 1/, 3/ *Robinia pseudoacacia*	20-25	25-35/15	25-30	25-315	25-30	35-45/20	25-30	40-50/20

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			0-YEAR	MATURE	0-YEAR	MATURE	0-YEAR	MATURE	0-YEAR	MATURE
			HEIGHT (ft)	HGTSPREAD (ft)	HEIGHT (ft)	HGTSPREAD (ft)	HEIGHT (ft)	HGTSPREAD (ft)	HEIGHT (ft)	HGTSPREAD (ft)
5K	DECIDUOUS TREES	Mulberry, Red 1/ *Morus rubra*	15-20	15-215	15-20	30-35/15-20	20-25	35-40/20	20-25	40-425-30
5K	DECIDUOUS TREES	Mulberry, Russian or White 1/ *Morus alba var. tatarica*	15-20	15-215	15-20	30-35/15-20	15-20	35-40/20	20-25	40-425-30
5K	DECIDUOUS TREES	Oak, Bur 1/ *Quercus macrocarpa*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
5K	DECIDUOUS TREES	Oak, Gambel 1/ *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
5K	DECIDUOUS TREES	Osage-orange 1/ *Maclura pomifera*	Not Recommended	Not Recommended	15-20	20-25/15	15-20	25-30/15	15-20	30-35/20-25
5K	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
5K	DECIDUOUS SHRUBS	Antelope Bitterbrush 1/ *Purshia tridentate*	2-3		Not Recommended		Not Recommended		Not Recommended	
5K	DECIDUOUS SHRUBS	Blackhaw, Nannyberry 1/ *Vibernum lentago*	Not Recommended		Not Recommended		6-8		8-12	
5K	DECIDUOUS SHRUBS	Buffaloberry, Silver 1/ *Shepherdia argentea*	5-8		10-12		10-12		10-12	
5K	DECIDUOUS SHRUBS	Chokecherry, Common 1/ *Prunus virginiana*	5-8		5-8		6-12		8-14	
5K	DECIDUOUS SHRUBS	Currant, Buffalo 1/ *Ribes odoratum*	2-4		3-6		3-6		3-6	
5K	DECIDUOUS SHRUBS	Currant, Golden 1/ *Ribes aureum*	2-4		2-4		4-6		4-6	
5K	DECIDUOUS SHRUBS	Juneberry (Saskatoon Serviceberry) 1/ *Amelanchier alnifolia*	5-7		5-7		6-10		6-10	
5K	DECIDUOUS SHRUBS	Lilac 1/ *Syringa vulgaris*	5-6		5-6		5-8		6-10	
5K	DECIDUOUS SHRUBS	Peashrub, Siberian 1/ *Caragana arborescens*	6-8		6-8		8-10		8-10	
5K	DECIDUOUS SHRUBS	Plum, American 1/ *Prunus americana*	5-7		5-8		5-8		6-10	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			0-YEAR	MATURE	0-YEAR	MATURE	0-YEAR	MATURE	0-YEAR	MATURE
			HEIGHT (ft)	HGTSPREAD (ft)	HEIGHT (ft)	HGTSPREAD (ft)	HEIGHT (ft)	HGTSPREAD (ft)	HEIGHT (ft)	HGTSPREAD (ft)
5K	DECIDUOUS SHRUBS	Saltbush, Fourwing 1/ *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	
5K	DECIDUOUS SHRUBS	Sumac, Skunkbush 1/ *Rhus trilobata* Recommended cultivars: Big Horn, Konza Fragrant	3-5		4-6		4-6		4-8	

1/ Adapted to calcareous soils

2/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**

3/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
6	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6	CONIFEROUS TREES	Pine, Austrian *Pinus nigra*	10-15	20-25/20	15-20	20-25/20	15-20	25-35/20	20-25	30-40/20
6	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	10-15	20-25/15	10-15	20-25/15	15-25	25-30/15	15-25	25-30/15
6	CONIFEROUS TREES	Pine, Limber *Pinus flexilis*	10-15	25-40/15	10-15	25-45/15-20	15-20	30-45/15-20	20-25	35-55/15-20
6	CONIFEROUS TREES	Pine, Pinyon [Two needle Pinyon] *Pinus edulis*	5-10	15-20/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	15-25	30-50/20	15-30	30-55/20	20-30	35-55/20	20-35	40-60/20
6	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-35/15-20	15-25	30-40/20
6	DECIDUOUS TREES	Catalpa, Northern *Catalpa speciosa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	30-35/20	15-20	30-35/20
6	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	15-30	15-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6	DECIDUOUS TREES	Hackberry *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	20-30	45-55/20	20-30	50-60/30
6	DECIDUOUS TREES	Honeylocust *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	25-30	35-45/20	25-35	40-50/25-30
6	DECIDUOUS TREES	Locust, Black 2/ *Robinia pseudoacacia*	20-25	25-35/15	25-30	25-35/15	25-30	35-45/20	25-30	40-50/20
6	DECIDUOUS TREES	Mulberry, Red *Morus rubra*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15	10-15	20-25/15
6	DECIDUOUS TREES	Mulberry, Russian or White *Morus alba var. tatarica*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15	10-15	20-25/15
6	DECIDUOUS TREES	Oak, Bur *Quercus macrocarpa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15	10-15	20-25/15
6	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
6	DECIDUOUS TREES	Osage-orange *Maclura pomifera*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-30/15	15-20	30-35/20-25
6	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
6	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		2-3		Not Recommended		Not Recommended	
6	DECIDUOUS SHRUBS	Buffaloberry, Silver *Shepherdia argentea*	5-8		10-12		10-12		10-12	
6	DECIDUOUS SHRUBS	Chokecherry, Common *Prunus virginiana*	5-8		6-12		6-12		8-14	
6	DECIDUOUS SHRUBS	Coralberry *Symphoricarpos orbiculatus*	Not Recommended		Not Recommended		2-3		2-3	
6	DECIDUOUS SHRUBS	Cotoneaster, Peking *Cotoneaster acutifolia*	4-5		5-6		5-8		5-10	
6	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	3-6		3-6		3-6		3-6	
6	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		2-4		4-6		4-6	
6	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		6-8		6-10		8-10	
6	DECIDUOUS SHRUBS	Rose, Arkansas [prairie rose] *Rosa arkansana*	1-2		1-2		1-2		1-2	
6	DECIDUOUS SHRUBS	Rose, Hansen Hedge *Rosa* Sp. *Rosa rugusa x R. woodsii*	4-6		4-6		4-8		6-8	
6	DECIDUOUS SHRUBS	Rose, Woods' *Rosa woodsii*	3-5		3-5		4-5		4-5	
6	DECIDUOUS SHRUBS	Sagebrush, Silver *Artemisia cana*	3-6		Not Recommended		Not Recommended		Not Recommended	
6	DECIDUOUS SHRUBS	Saltbush, Fourwing *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	
6	DECIDUOUS SHRUBS	Sandcherry, Western *Prunus besseyi*	2-3		2-3		2-4		3-6	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
6	DECIDUOUS SHRUBS	Snowberry, Common *Symphoricarpos albus*	Not Recommended		Not Recommended		2-3		2-3	
6	DECIDUOUS SHRUBS	Snowberry, Western *Symphoricarpos occidentalis*	2-3		2-3		2-3		2-3	
6	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		4-6		4-6		4-8	

1/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**

2/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
6K	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6K	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	10-15	20-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-25	25-30/15
6K	CONIFEROUS TREES	Pine, Limber Pinus flexilis	10-15	25-40/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	35-55/15-20
6K	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	15-25	30-50/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-35	40-60/20
6K	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6K	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-25	30-40/20
6K	DECIDUOUS TREES	Catalpa, Northern *Catalpa speciosa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	30-35/20
6K	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	15-30	15-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6K	DECIDUOUS TREES	Hackberry *Celtis occidentalis*	15-20	30-40/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-30	50-60/30
6K	DECIDUOUS TREES	Honeylocust *Gleditsia triacanthos*	15-25	30-40/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	25-35	40-50/25-30
6K	DECIDUOUS TREES	Locust, Black 1/ *Robinia pseudoacacia*	20-25	25-35/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6K	DECIDUOUS TREES	Mulberry, Red *Morus rubra*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15
6K	DECIDUOUS TREES	Mulberry, Russian or White *Morus alba var. tatarica*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15
6K	DECIDUOUS TREES	Oak, Bur *Quercus macrocarpa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15
6K	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6K	DECIDUOUS TREES	Osage-orange *Maclura pomifera*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	30-35/20-25
6K	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	4-7	4-7/15

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
6K	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		Not Recommended		Not Recommended		Not Recommended	
6K	DECIDUOUS SHRUBS	Buffaloberry, Silver *Shepherdia argentea*	5-8		Not Recommended		Not Recommended		10-12	
6K	DECIDUOUS SHRUBS	Chokecherry, Common *Prunus virginiana*	5-8		Not Recommended		Not Recommended		8-14	
6K	DECIDUOUS SHRUBS	Cotoneaster, Peking *Cotoneaster acutifolia*	4-5		Not Recommended		Not Recommended		5-10	
6K	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	3-6		Not Recommended		Not Recommended		3-6	
6K	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		Not Recommended		Not Recommended		4-6	
6K	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		Not Recommended		Not Recommended		8-10	
6K	DECIDUOUS SHRUBS	Saltbush, Fourwing *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	
6K	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		Not Recommended		Not Recommended		4-8	

1/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
6D	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6D	CONIFEROUS TREES	Pine, Austrian *Pinus nigra*	Not Recommended	Not Recommended	15-20	20-25/20	15-20	25-35/20	20-25	30-40/20
6D	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	10-15	20-25/15	10-15	20-25/15	15-25	25-30/15	15-25	25-30/15
6D	CONIFEROUS TREES	Pine, Limber *Pinus flexilis*	10-15	25-40/15	10-15	25-45/15-20	15-20	30-45/15-20	20-25	35-55/15-20
6D	CONIFEROUS TREES	Pine, Pinyon [Two needle Pinyon] *Pinus edulis*	5-10	15-20/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6D	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	15-25	30-50/20	15-30	30-55/20	20-30	35-55/20	20-35	40-60/20
6D	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6D	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-35/15-20	15-25	30-40/20
6D	DECIDUOUS TREES	Aspen, Quaking *Populus tremuloides*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	20-30	15-20	20-30
6D	DECIDUOUS TREES	Catalpa, Northern *Catalpa speciosa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	30-35/20	15-20	30-35/20
6D	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	15-30	15-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6D	DECIDUOUS TREES	Hackberry *Celtis occidentalis*	15-20	30-40/20	20-25	40-50/20	20-30	45-55/20	20-30	50-60/30
6D	DECIDUOUS TREES	Honeylocust *Gleditsia triacanthos*	15-25	30-40/20	20-30	30-40/20	25-30	35-45/20	25-35	40-50/25-30
6D	DECIDUOUS TREES	Locust, Black 1/ *Robinia pseudoacacia*	20-25	25-35/15	25-30	25-35/15	25-30	35-45/20	25-30	40-50/20
6D	DECIDUOUS TREES	Mulberry, Red *Morus rubra*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15	10-15	20-25/15
6D	DECIDUOUS TREES	Mulberry, Russian or White *Morus alba var. tatarica*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15	10-15	20-25/15
6D	DECIDUOUS TREES	Oak, Bur *Quercus macrocarpa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15	10-15	20-25/15

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
6D	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6D	DECIDUOUS TREES	Osage-orange *Maclura pomifera*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-30/15	15-20	30-35/20-25
6D	DECIDUOUS TREES	Pear, Harbin *Pyrus ussuriensis* Recommended cultivar: McDermand	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	15-20/15	20-25	20-25/15
6D	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
6D	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		2-3		Not Recommended		Not Recommended	
6D	DECIDUOUS SHRUBS	Buffaloberry, Silver *Shepherdia argentea*	5-8		10-12		10-12		10-12	
6D	DECIDUOUS SHRUBS	Chokecherry, Common *Prunus virginiana*	5-8		6-12		6-12		8-14	
6D	DECIDUOUS SHRUBS	Coralberry *Symphoricarpos orbiculatus*	Not Recommended		Not Recommended		2-3		2-3	
6D	DECIDUOUS SHRUBS	Cotoneaster, Peking *Cotoneaster acutifolia*	4-5		5-6		5-8		5-10	
6D	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	3-6		3-6		3-6		3-6	
6D	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		2-4		4-6		4-6	
6D	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		6-8		6-10		8-10	
6D	DECIDUOUS SHRUBS	Rose, Arkansas [prairie rose] *Rosa arkansana*	1-2		1-2		1-2		4-7	
6D	DECIDUOUS SHRUBS	Rose, Hansen Hedge *Rosa* Sp. *Rosa rugusa x R. woodsii*	4-6		4-6		4-8		4-8	
6D	DECIDUOUS SHRUBS	Rose, Woods' *Rosa woodsii*	3-5		3-5		4-5		4-9	
6D	DECIDUOUS SHRUBS	Sagebrush, Silver *Artemisia cana*	3-6		Not Recommended		Not Recommended		Not Recommended	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
6D	DECIDUOUS SHRUBS	Saltbush, Fourwing *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	
6D	DECIDUOUS SHRUBS	Sandcherry, Western *Prunus besseyi*	2-3		2-3		2-4		3-6	
6D	DECIDUOUS SHRUBS	Snowberry, Common *Symphoricarpos albus*	Not Recommended		Not Recommended		2-3		2-3	
6D	DECIDUOUS SHRUBS	Snowberry, Western *Symphoricarpos occidentalis*	2-3		2-3		2-3		2-3	
6D	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		4-6		4-6		4-8	

1/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)	20-YEAR HEIGHT (ft)	MATURE HGT/SPREAD (ft)
6DK	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	10-15	20-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	CONIFEROUS TREES	Pine, Limber *Pinus flexilis*	10-15	25-40/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	15-25	30-50/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	15-30	15-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	5-10	15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS SHRUBS	Antelope Bitterbrush *Purshia tridentate*	2-3		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS SHRUBS	Buffaloberry, Silver *Shepherdia argentea*	5-8		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS SHRUBS	Chokecherry, Common *Prunus virginiana*	5-8		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS SHRUBS	Cotoneaster, Peking *Cotoneaster acutifolia*	4-5		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	3-6		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS SHRUBS	Saltbush, Fourwing *Atriplex canescens*	2-5		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
6DK	DECIDUOUS SHRUBS	Sandcherry, Western *Prunus besseyi*	2-3		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
6DK	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
7	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
7	CONIFEROUS TREES	Pine, Austrian *Pinus nigra*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-20	25-35/20	20-25	30-40/20
7	CONIFEROUS TREES	Pine, Bristlecone *Pinus aristata*	5-10	20-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
7	CONIFEROUS TREES	Pine, Jack *Pinus banksiana*	10-15	20-25/15	10-15	20-25/15	15-25	25-30/15	15-25	25-30/15
7	CONIFEROUS TREES	Pine, Limber *Pinus flexilis*	5-10	15-20/10	5-10	15-20/10	10-15	20-30/20	15-20	25-35/20
7	CONIFEROUS TREES	Pine, Pinyon [Two needle Pinyon] *Pinus edulis*	5-10	15-20/15-20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
7	CONIFEROUS TREES	Pine, Ponderosa *Pinus ponderosa*	10-20	30-40/20	10-20	30-45/20	20-30	35-45/20	20-35	35-45/20
7	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	10-20	30-40/20	10-20	30-45/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
7	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	10-25	20-25/15	10-25	25-35/15-20	15-25	25-35/20
7	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-20	10-20/10
7	DECIDUOUS TREES	Elm, Siberian *Ulmus pumila*	15-20	30-35	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
7	DECIDUOUS TREES	Hackberry *Celtis occidentalis*	10-15	25-30	10-15	25-30	10-15	25-30	10-15	30-35
7	DECIDUOUS TREES	Honeylocust *Gleditsia triacanthos*	Not Recommended	Not Recommended	10-15	20-25	10-15	20-25	25-35	40-50/25-30
7	DECIDUOUS TREES	Locust, Black 1/ *Robinia pseudoacacia*	20-25	25-35/15	25-30	25-35/15	25-30	35-45/20	25-30	40-50/20
7	DECIDUOUS TREES	Mulberry, Red *Morus rubra*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	20-25/15
7	DECIDUOUS TREES	Mulberry, Russian or White *Morus alba var. tatarica*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	20-25	20-25/15
7	DECIDUOUS TREES	Oak, Bur *Quercus macrocarpa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	25-35/20-30	15-20	30-40
7	DECIDUOUS TREES	Oak, Gambel *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
7	DECIDUOUS TREES	Osage-orange *Maclura pomifera*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	30-35/20-25
7	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15
7	DECIDUOUS SHRUBS	Buffaloberry, Silver *Shepherdia argentea*	5-8		10-12		10-12		10-12	
7	DECIDUOUS SHRUBS	Chokecherry, Common *Prunus virginiana*	5-8		6-12		6-12		8-14	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
7	DECIDUOUS SHRUBS	Currant, Buffalo *Ribes odoratum*	2-4		2-4		2-4		2-4	
7	DECIDUOUS SHRUBS	Currant, Golden *Ribes aureum*	2-4		2-4		4-6		4-6	
7	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		6-8		8-10		8-10	
7	DECIDUOUS SHRUBS	Plum, American *Prunus americana*	5-7		5-8		5-8		6-10	
7	DECIDUOUS SHRUBS	Rose, Arkansas [prairie rose] *Rosa arkansana*	1-2		1-2		1-2		1-2	
7	DECIDUOUS SHRUBS	Rose, Hansen Hedge *Rosa* Sp. *Rosa rugusa x R. woodsii*	4-6		4-6		4-8		6-8	
7	DECIDUOUS SHRUBS	Rose, Woods' *Rosa woodsii*	3-5		3-5		4-5		4-5	
7	DECIDUOUS SHRUBS	Sandcherry, Western *Prunus besseyi*	2-3		2-3		2-4		3-6	
7	DECIDUOUS SHRUBS	Snowberry, Western *Symphoricarpos occidentalis*	2-3		2-3		2-3		2-3	
7	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		4-6		4-6		4-8	

1/ Black Locust - for wildlife and pollinators (refer to table 11)

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
8	CONIFEROUS TREES	Juniper, Rocky Mountain 1/ *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
8	CONIFEROUS TREES	Pine, Bristlecone *Pinus aristata*	5-10	25-30/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
8	CONIFEROUS TREES	Pine, Limber 1/ *Pinus flexilis*	10-15	25-40/15	10-15	25-45/15-20	15-20	30-45/15-20	20-25	35-55/15-20
8	CONIFEROUS TREES	Pine, Ponderosa 1/ *Pinus ponderosa*	15-25	30-50/20	15-30	30-55/20	20-30	35-55/20	20-35	40-60/20
8	CONIFEROUS TREES	Pine, Southwestern White *Pinus strobiformis*	15-25	30-50/20	15-30	30-55/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended
8	CONIFEROUS TREES	Redcedar, Eastern 1/ *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-35/15-20	15-25	30-40/20
8	DECIDUOUS TREES	Apricot, Manchurian *Prunus armeniaca*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	10-15/10	10-20	10-20/10
8	DECIDUOUS TREES	Ash, Green 1/, 2/ *Fraxinus pennsylvanica*	10-15	20-25/20	10-15	20-25/20	10-15	20-25/20	10-15	25-30/20-25
8	DECIDUOUS TREES	Aspen, Quaking 1/ *Populus tremuloides*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	20-30	15-20	20-30
8	DECIDUOUS TREES	Catalpa, Northern 1/ *Catalpa speciosa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	15-20	30-35/20	15-20	30-35/20
8	DECIDUOUS TREES	Elm, Siberian 1/ *Ulmus pumila*	15-20	30-35/20	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended	Not Recommended
8	DECIDUOUS TREES	Hackberry 1/ *Celtis occidentalis*	10-15	25-30/20	10-15	25-30/20	10-15	25-30/20	10-15	30-35/30
8	DECIDUOUS TREES	Honeylocust 1/ *Gleditsia triacanthos*	Not Recommended	Not Recommended	10-15	20-25/15-20	10-15	20-25/20	25-35	40-50/25-30
8	DECIDUOUS TREES	Oak, Bur 1/ *Quercus macrocarpa*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	25-35/30	15-20	40-60/30-40
8	DECIDUOUS TREES	Oak, Gambel 1/ *Quercus gambelii*	5-10	15-20	10-15	25	Not Recommended	Not Recommended	Not Recommended	Not Recommended
8	DECIDUOUS TREES	Osage-orange 1/ *Maclura pomifera*	Not Recommended	Not Recommended	Not Recommended	Not Recommended	10-15	20-25/15-20	10-15	30-35/20-25
8	CONIFEROUS SHRUBS	Juniper, Common (Prostrate) *Juiperus communis*	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15	4-7	4-7/15

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
8	DECIDUOUS SHRUBS	Antelope Bitterbrush 1/ *Purshia tridentate*	2-3		Not Recommended		Not Recommended		Not Recommended	
8	DECIDUOUS SHRUBS	Buffaloberry, Silver 1/ *Shepherdia argentea*	5-8		10-12		10-12		10-12	
8	DECIDUOUS SHRUBS	Chokecherry, Common 1/ *Prunus virginiana*	5-8		6-12		6-12		8-14	
8	DECIDUOUS SHRUBS	Currant, Buffalo 1/ *Ribes odoratum*	2-4		2-4		3-6		3-6	
8	DECIDUOUS SHRUBS	Currant, Golden 1/ *Ribes aureum*	2-4		2-4		4-6		4-6	
8	DECIDUOUS SHRUBS	Lilac 1/ *Syringa vulgaris*	5-6		5-6		5-8		6-10	
8	DECIDUOUS SHRUBS	Mahogany, Mountain 1/ *Cercocarpus montana*	5-10		5-10		Not Recommended		Not Recommended	
8	DECIDUOUS SHRUBS	Peashrub, Siberian 1/ *Caragana arborescens*	6-8		6-8		8-10		8-10	
8	DECIDUOUS SHRUBS	Plum, American 1/ *Prunus americana*	5-7		5-8		5-8		6-10	
8	DECIDUOUS SHRUBS	Sumac, Skunkbush 1/ *Rhus trilobata* Recommended cultivars: Big Horn, Konza Fragrant	3-5		4-6		4-6		4-8	

1/ Adapted to calcareous soils

2/ Green Ash - only to be used in diverse tree and shrub plantings; **not windbreaks**

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
9L	CONIFEROUS TREES	Juniper, Rocky Mountain *Juniperus scopulorum*	10-20	15-25/15	10-20	15-25/15	Not Recommended	Not Recommended	Not Recommended	Not Recommended
9L	CONIFEROUS TREES	Redcedar, Eastern *Juniperus virginiana*	10-20	20-25/15	10-20	20-25/15	10-25	25-35/15-20	15-25	30-40/20
9L	DECIDUOUS TREES	Boxelder *Acer negundo*	15-20	25-35/20	15-20	25-35/20	15-20	30-35/20	20-25	35-40/20
9L	DECIDUOUS SHRUBS	Buffaloberry, Silver *Shepherdia argentea*	5-8		10-12		10-12		10-12	
9L	DECIDUOUS SHRUBS	Peashrub, Siberian *Caragana arborescens*	6-8		6-8		8-10		8-10	
9L	DECIDUOUS SHRUBS	Sagebrush, Big *Artemisia tridentata*	3-6		Not Recommended		Not Recommended		Not Recommended	
9L	DECIDUOUS SHRUBS	Sagebrush, Silver *Artemisia cana*	3-6		Not Recommended		Not Recommended		Not Recommended	
9L	DECIDUOUS SHRUBS	Saltbush, Fourwing *Atriplex canescens*	2-5		Not Recommended		Not Recommended		Not Recommended	
9L	DECIDUOUS SHRUBS	Sumac, Skunkbush *Rhus trilobata* Recommended cultivars: Big horn, Konza fragrant	3-5		4-6		4-6		4-8	

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
9W	Trees/shrubs not recommended on this site									

Group 9W = Wet - Saline/Alkaline soils

Soils Group	TreeShrub Type	Species	ZONE I		ZONE II		ZONE III		ZONE IV	
			20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE	20-YEAR	MATURE
			HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)	HEIGHT (ft)	HGT/SPREAD (ft)
10	**Site Visit Required**									

Note: Site visit required before any species can be recommended due to soil limitations, such as soil depth, texture, drainage, channeled phases, available water capacity, slope or salts which severely limit planting, species selection, survival or growth of trees and shrubs. Recommend checking with local forester for technical assistance.

Summary - List of Attributes by Species for Conservation Tree/Shrub Plantings in Nebraska

Coniferous Trees	PLANTS Database Symbol	Native by Vegetative Zones I, II, III, or IV N = Not Native	Shade Tolerance (1)	Flood Tolerance (2)	Wildlife Value (3)				Windbreak Density (4)		Products (5)	Root Suckering (6) N = No, Y = Yes	Comments (7)
					Use Groups	Function	Rating	Season	Summer	Winter			
Arborvitae, American or Northern White Cedar (***Thuja occidentalis***)	THOC2	N	L	M	SB	C	L	N/A	H	H	F	N	Native to Great Lakes region and Northeastern US. Prefers moist, fertile soils. Subject to winter burn. Plantings limited to eastern Nebraska. Height 20-30 ft.
Arborvitae, Oriental (***Platycladus orientalis***)	PLOR80	N	M	M	SB	C	L	N/A	H	H	F, B	N	Winter hardiness questionable in Vegetative Zone III (seed source important). Prefers moist, well-drained soils. Possible substitute for eastern redcedar in windbreaks. Plantings limited to eastern Nebraska. Height to 20 ft.
Baldcypress (***Taxodium distichum***)	TADI2	N	M	H	SB	C	L	N/A	M	L	L	N	Deciduous conifer - rust fall color and loses needles in fall. Prefers acid soils; tolerates slightly alkaline soils. Drought tolerant. Winter hardiness questionable in Vegetative Zone III. Height to 60 ft.
Fir, Douglas (***Pseudotsuga menziesii)***	PSME	N	M	L	SB	B	M	F	H	H	C, L	N	Delicate; protect from strong winds. Uses include wildlife habitat - seed source is important for songbirds. Height to 60 ft.
Fir, White (***Abies concolor***)	ABCO	N	H	L	SB	B	M	F	H	H	C	N	Delicate. Uses include wildlife habitat - seed source important for songbirds. Height to 60 ft.
Juniper, Rocky Mountain (***Juniperus scopulorum***)	JUSC2	I, II	M	L	SB GB	B	H	F/W	H	H	C, S	N	Cercospora a problem in eastern Nebraska. Only female plants produce seeds. Adapted to wide range of soil types. Drought tolerant. Use in windbreaks and wildlife habitat. Height to 40 ft.
Pine, Austrian (***Pinus nigra***)	PINI	N	L	L	SB GB	B	M	F/W	M	M	C	N	Affected by dothistroma and tip blight; moderately susceptible to pine wilt disease. Adapted to range of pH and soils. Drought tolerant. Use for windbreaks and wildlife habitat. Height to 50 ft.
Pine, Bristlecone ***(Pinus aristata)***	PIAR	N	L	L	SB	C	L	N/A	M	M		N	Does not thrive in humid eastern prairies; susceptible to dothistroma and tip blight. Lives longer in dry climates; hardy and long-lived on sunny, dry, infertile sites. Height to 20 ft.
Pine, Eastern White ***(Pinus strobus)***	PIST	N	M	L	SB	C	L	N/A	M	M	C, L, B	N	Needs protection from winds; avoid use in outside rows. Fine needles in clusters of five. Height to 60 ft.
Pine, Jack (***Pinus banksiana***)	PIBA2	N	L	L	SB	C	L	N/A	M	M		N	Moderately susceptible to pine wilt disease. Possible substitute for eastern redcedar in windbreaks. Adapted to range of pH and soils - including very sandy soils. Drought tolerant. Native to Great Lakes region and Canada. Height to 60 ft.
Pine, Limber (***Pinus flexilis***)	PIFL2	I	L	L	SB	C	L	N/A	M	M	F	N	Susceptible to dothistroma needle blight and blister rust. Slow growing. Windbreak species in Zone I. Native population in Kimball Co. Excellent for wildlife plantings. Use in multirow windbreaks only. Height to 50 ft.
Pine, Pinyon (Two Needle) (***Pinus edulis***)	PIED	N	L	L	SB GB	B	H	F	H	H	C, P, F, E1	N	Slow growing. Excellent winter hardiness, drought resistant and tolerant of alkaline soils. Excellent species for wildlife. Pine 'nut' edible by wildlife and humans. Height to 30 ft.
Pine, Ponderosa (***Pinus ponderosa***)	PIPO	I, II, III	L	L	SB GB	B	H	F/W	M	M	C, L, P, F, B	N	Susceptible to tip blight/Zimmerman moth. Use for windbreaks and wildlife habitat. Wild turkey utilize seed source. Prefers acid soils; tolerates low fertility and drought. Height to 50 ft.

Summary - List of Attributes by Species for Conservation Tree/Shrub Plantings in Nebraska

Coniferous Trees	PLANTS Database Symbol	Native by Vegetative Zones I, II, III, or IV N = Not Native	Shade Tolerance (1)	Flood Tolerance (2)	Wildlife Value (3)				Windbreak Density (4)		Products (5)	Root Suckering (6) N = No, Y = Yes	Comments (7)
					Use Groups	Function	Rating	Season	Summer	Winter			
Pine, Southwestern White (***Pinus strobiformis***)	PIST3	N	L	L	SB	C	L	N/A	M	M	C, F	N	Native to Arizona, New Mexico, and Mexico. Susceptible to dothistroma needle blight and blister rust. Faster growing than limber pine. Use as windbreak species in southwestern NE only. Seed source should be from elevations above 7600 ft. Height to 110 ft.
Redcedar, Eastern (***Juniperus virginiana***)	JUVI	I, II, III, IV	M	M	SB GB	B	H	F/W	H	H	P, S, L	N	Invasive in grasslands in eastern and central Nebraska; only female plants produce seeds. Reliable windbreak species. Cercospora can be a problem. Height to 50 ft.
Spruce, Colorado Blue (***Picea pungens***)	PIPU	N	M	L	SB	B	M	F/W	H	H	C	N	Color range from green to blue. Uses include windbreaks and wildlife habitat. Height to 60ft.
Spruce, Norway (***Picea abies***)	PIAB	N	M	L	SB	B	M	F/W	H	H		N	Long, banana shaped cones. Uses include windbreaks and wildlife habitat. Height to 60 ft.
Spruce, White (***Picea glauca***) (recommended Black Hills variety ***(Picea glauca densata)***)	PIGL PIGLD	N	M	L	SB	C	L	N/A	H	H		N	Small cones. Most tolerant spruce tree for wind, cold, heat, and drought. Height to 40 ft.

(1) Shade Tolerance - adaptation for underplantings (H = high, M = medium, L = low)

(2) Flood Tolerance - relative value in riparian locations (H = high tolerance of frequent Flood with poor drainage, M - medium tolerance to Flood and needs good drainage, L = low tolerance of Flood)

(3) Wildlife Value - Use Groups: SM = small mammals, LM = large mammals, SB = song birds, GB = game birds, MB = moths/butterflies; Function: F = food, C = cover, B = both; Rating: H = high value on a long-term use, M = high value on a seasonal basis, L = value on a limited, short-term basis; Season when food is available: Sp =Spring, Su = Summer, F = Fall, W = Winter, N/A = Not Applicable

(4) Windbreak Density - Summer = comparable protection from wind; Winter = comparable protection from wind and snow drifting; H = high, M = medium, L = low

(5) Products - C = Christmas trees, P = posts, S = shavings, L = lumber, F = firewood, B = biomass, E1 = edible directly off the plant, E2 = edible if processed

(6) Root Suckering - comparable aggressiveness to root sprout, N = No, Y = Yes

(7) Comments - check with your local forester or natural resource professional for other possible considerations

Summary - List of Attributes by Species for Conservation Tree/Shrub Plantings in Nebraska

Deciduous Trees	PLANTS Database Symbol	Native by Vegetative Zones I, II, III, or IV N = Not Native	Shade Tolerance (1)	Flood Tolerance (2)	Wildlife Value (3)				Windbreak Density (4)		Products (5)	Root Suckering (6) N = No, Y = Yes	Comments (7)
					Use Groups	Function	Rating	Season	Summer	Winter			
Apricot, Manchurian (***Prunus armeniaca***)	PRAR3	N	L	L	SM SB	F	M	Su	M	L	E2	N	Native of China. Cultivated for fruit. Varieties _mandshurica_ Maxim. and _sibirica L._ are hardy with potential ornamental value in the northern Great Plains. Prefers sun; pH and soil adaptable. Autumn foliage golden. Use native fruit-bearing species in unaltered habitats. Songbirds attracted to fruit. Height to 30 ft.
Ash, Green (***Fraxinus pennsylvanica***)	FRPE	I, II, III, IV	M	H	SM SB	B	H	Sp-F	M	L	F, L	N	Highly susceptible to Emerald Ash Borer that will kill infected trees. Susceptible to native ash borers when young. Historically was widely used in shelterbelt plantings. Currently recommended for use in diverse tree plantings and wildlife plantings only; **not for windbreaks**. Height to 70 ft.
Aspen, Quaking (***Populus tremuloides***)	POTR5	I, II	L	L	GB LM	B	H	All	M	L		Y	Suckers when mature to form aspen grove. Buds and catkins eaten by birds; leaves and twigs provide big game browse. Height to 60 ft.
Basswood/Linden, American (***Tilia americana***)	TIAM	III, IV	H	M	SB MB	B	M	Su/F	M	L	L	N	Native to eastern NE, west to Cherry County along the Niobrara River, and west to Morse Bluff on the Platte River. Also native from the eastern portions of the Dakotas, KS, and OK to the Atlantic Coast from NC to ME. Prefers sun to partial shade, deep, moist fertile soils; pH adaptable. Drought tolerant. Grows best on well watered, partially shaded sites protected from desiccating winds. Flowers used extensively by bees. Used as carving wood. Height to 70 ft.
Birch, Paper (***Betula papyrifera***)	BEPA	II	M	L	SB LM	B	M	F/W	M	L		N	Native along Niobrara Valley. Bark is white and peeling Buds and twigs used to a limited degree by songbirds and deer, respectively. Short life span. Bronze birch borer a problem. Height to 50 ft.
Birch, River ***(Betula nigra)***	BENI	N	M	M	SB LM	F	L	F/W	M	L		Y	Suitable for Vegetative Zone IV on moist soils. Bark has salmon pink shades. Height to 40 ft.
Boxelder (***Acer negundo***)	ACNE2	I, II, III, IV	L	H	SM SB	B	H	Sp-F	M	L		N	Short-lived tree with multiple trunk form. Provides good cavities for wildlife shelter. Hardy on poor sites; common in riparian areas. Songbirds attracted to seeds. Height to 50 ft.
Catalpa, Northern (***Catalpa speciosa***)	CASP8	IV	L	M	MB SB	C	L	N/A	M	L	F	N	Large leaves; white flowers; long seed pods. Susceptible to ash borers. Height to 60 ft.
Cherry, Black (***Prunus serotina***)	PRSE2	III, IV	L	L	SB SM	B	H	Su	M	L	L, E2	N	Native to eastern Nebraska; prefers moist fertile soils on bottomlands. Valuable timber species. Height to 60 ft.
Cottonwood, Eastern or Plain ***(Populus deltoides)*** Recommended cultivars: Might Mo, Noreaster, Platte	PODE3	I, II, III, IV	L	H	SM SB	B	H	F/W	M	L	B, L, S	N	Nebraska state tree. Susceptible to Cytospora canker on uplands. Prefers moist soils, especially along rivers and streams. Wildlife use twigs as browse when young and is a good den tree when mature. Height to 80 ft.

Summary - List of Attributes by Species for Conservation Tree/Shrub Plantings in Nebraska

Deciduous Trees	PLANTS Database Symbol	Native by Vegetative Zones I, II, III, or IV N = Not Native	Shade Tolerance (1)	Flood Tolerance (2)	Wildlife Value (3)				Windbreak Density (4)		Products (5)	Root Suckering (6) N = No, Y = Yes	Comments (7)
					Use Groups	Function	Rating	Season	Summer	Winter			
Crabapple (***Malus sp*.**) (Siberian crab is ***M. baccata***; Sargent crab is ***M. sargentii***)	MABA	N	L	L	SB SM	B	M	Su/F	M	L		N	Countless crabapple hybrids and varieties exist with varying characteristics. Radiant is a 25-30 ft. pink-flowered cultivar of Siberian that is susceptible to scab. Midwest is a 15-25 ft. white-flowered cultivar of Siberian. Roselow is a white-flowered, 6-8 ft., shrub-like cultivar of Sargent.
Crabapple, Prairie (***Malus ionensis***)	MAIO	IV	L	L	SB SM	B	H	Su/F	M	L		Y	Species is native to extreme eastern Nebraska. Susceptible to cedar-apple rust. Fruit is small, hard, and green. Suckering roots form thickets. Height to 20 ft.
Elm, American (***Ulmus americana***)	ULAM	I, II, III, IV	M	M	SB SM	B	M	Sp	M	L	F, L	N	Not recommended because of susceptibility to Dutch Elm Disease. Red or slippery elm (*Ulmus rubra*) may be a suitable native substitute. Height to 70ft.
Elm, Siberian (***Ulmus pumila***)	ULPU	N	M	L	SB	B	L	Sp	M	L	F, L	N	Invasive into grasslands and disturbed areas by seedling establishment. **Recommended for Veg. Zone I only**. Strongly suggest seeking alternate species for Veg. Zones II, III, and IV. Often mistakenly called Chinese elm. Seeds eaten by songbirds. Height to 80 ft.
Hackberry (***Celtis occidentalis***)	CEOC	I, II, III, IV	H	M	SB SM	B	H	Su	M	L	F, L	N	Common windbreak species; adapted to wide range of soils. Susceptible to herbicide drift. Nipple gall common on leaves. Songbirds eat seeds. Height to 70 ft.
Hawthorn, Cockspur (***Crataegus crusgalli***)	CRCR2	N	L	L	SB SM	B	H	F/W	M	L		N	Native to eastern US. Sharp thorns on some varieties. Red fruits persist into winter. Height to 20 ft.
Hawthorn, Washington (***Crataegus phaenopyrum***)	CRPH	N	L	M	SB SM	B	H	F/W	M	L		N	Common conservation species. Often thorny. Red berries persist into winter. Possible rust problems. Height to 30 ft.
Hickory, Bitternut (***Carya cordiformis***)	CACO15	III, IV	M	M	SM SB	B	H	F	M	L	F	N	Native to eastern Nebraska in association with oaks. Slow growing. Bark is smooth. Nut is bitter. Height to 80 ft.
Hickory, Shagbark (***Carya ovata***)	CAOV2	IV	M	L	SM SB	B	H	F	M	L	L, F, E2	N	Native to Missouri River bluff woodlands. Extremely slow growing. Bark forms large plates when mature. Nut is edible but extraction is difficult. Height to 80 ft.
Honeylocust ***(Gleditsia triacanthos)***	GLTR	III, IV	L	M	LM SM	F	M	Su-F	M	L	F, L	Y	Nitrogen fixing legume. Common windbreak tree. Seeds eaten by small mammals; pods eaten by cattle. Possible thorns. Potentially invasive in grasslands in eastern Nebraska. Height to 60 ft.
Hophornbeam, Eastern or Ironwood (***Ostrya virginiana***)	OSVI	III, IV	H	L	SM SB	B	M	Su	M	L	F	N	Difficult to obtain as nursery stock. Small tree with very dense wood. Understory species that does well in shady conditions. Height to 40 ft.
Kentucky Coffeetree (***Gymnocladus dioicus***)	GYDI	III, IV	L	L	SB	C	L	N/A	M	L		Y	Nitrogen fixing legume. Prefers moist fertile soils but adapted a wide range. Drought resistant. Possible toxicity of seeds to humans. Nonaggressive root suckering. Height to 60 ft.
Locust, Black (***Robinia pseudoacacia***)	ROPS	N	L	L	SB	C	L	N/A	M	L	P, F	Y	Nitrogen fixing legume. Problems with locust borer. Bark and seeds may be toxic. Aggressive root suckering; potentially invasive due to spontaneous root suckers causing clonal spread. Height to 60 ft.

Summary - List of Attributes by Species for Conservation Tree/Shrub Plantings in Nebraska

Deciduous Trees	PLANTS Database Symbol	Native by Vegetative Zones I, II, III, or IV N = Not Native	Shade Tolerance (1)	Flood Tolerance (2)	Wildlife Value (3)				Windbreak Density (4)		Products (5)	Root Suckering (6) N = No, Y = Yes	Comments (7)
					Use Groups	Function	Rating	Season	Summer	Winter			
Maple, Amur (***Acer ginnala***) (recommended cultivar: Flame)	ACGI	N	M	M	SB	B	H	Su-W	M	L		N	Small tree or large shrub form. Beautiful autumn color. Seeds eaten by songbirds and twigs browsed by deer. Height to 15 ft.
Maple, Silver (***Acer saccharinum***)	ACSA2	III, IV	M	H	SM SB	B	M	Sp/Su	M	L	B, F	Y	Narrow crotch angles may produce mutliple stems; susceptible to wind breakage. Nonaggressive root suckering. Fastest growing maple. Common in riparian areas. Height to 60 ft.
Maple, Sugar (***Acer saccharum***)	ACSA3	N	M	M	SM SB	B	M	Sp/Su	M	L	F, L, E2	Y	Orange/red fall color. Winter hardiness questionable in northern Nebraska. Sap is source of maple syrup. Nonaggressive root suckering. Height to 60 ft.
Mulberry, Red (***Morus rubra***)	MORU2	IV	H	L	SB SM	B	H	Sp	M	L	F, P, E1, E2	N	Native to southeast Nebraska. Leaves often not lobed compared to white mulberry and all fruits mature purple to black. Only female plants produce seeds. Height to 50 ft.
Mulberry, Russian or White (***Morus alba var. tatarica***)	MOAL	N	H	L	SB SM	B	M	Sp	M	L	E1, E2	N	Hybridizes with red mulberry in the wild. Leaves often lobed compared to red mulberry and some fruits mature as white. Only female plants produce seeds. Height to 40 ft.
Oak, Black (***Quercus velutina***)	QUVE	IV	M	L	SM GB	B	H	F	M	L	F	N	Natural site is typically rocky, sandy to clay soil on a dry upland. Approaches northern red oak stature on fertile, bottomland soil. Autumn foliage red, leaves persist through winter. Grows best on sunny site in fertile, moist soil, neutral to acidic. Height to 50 ft.
Oak, Bur (***Quercus macrocarpa***)	QUMA2	I, II, III, IV	M	L	SM GB	B	H	F	M	L	F, L	N	Drought tolerant. Prefers sunny site; pH and soil adaptable. Tolerates occasional poor drainage and inundation. Round, wide spreading crown. Name from bur-like fringe located around rim of acorn cup. Ranges from south central Canada throughout the Great Plains states. Lacks bright fall color. Drops leaves after first sharp freeze. Height to 75 ft.
Oak, Chinkapin (***Quercus muhlenbergii***)	QUMU	IV	L	L	SM GB	B	H	F	M	L	F	N	Drought tolerant. Prefers sunny site; pH and soil adaptable. Generally grown on well-drained sites, from streambanks to dry ridges, with a preference for soils of limestone origin. Seldom found on acidic soils. Sweet acorns were consumed by Native Americans and are excellent wildlife food. Rounded crown. Ranges from central TX and OK to eastern KS and the northeastern U.S. Does not display bright fall colors. Height to 60 ft.
Oak, English (***Quercus robur***)	QURO2	N	M	L	SM GB	B	H	F	M	L	F, L	N	Native to Europe, East Asia, and North Africa, resulting is extensive genetic variability. Recognized by long-stalked acorns. Drought tolerant. Prefers sunny site; pH and soil adaptable. Height to 65 ft.

Summary - List of Attributes by Species for Conservation Tree/Shrub Plantings in Nebraska

Deciduous Trees	PLANTS Database Symbol	Native by Vegetative Zones I, II, III, or IV N = Not Native	Shade Tolerance (1)	Flood Tolerance (2)	Wildlife Value (3)				Windbreak Density (4)		Products (5)	Root Suckering (6) N = No, Y = Yes	Comments (7)
					Use Groups	Function	Rating	Season	Summer	Winter			
Oak, Gambel (***Quercus gambelii***)	QUGA	I	L	L	SM GB	B	H	F	M	L		N	Suitable for small spaces and dry sites. Ranges from dry foothills, canyons, and lower slopes of mountains of NV, UT, CO, AZ, NM, and fringes of adjoining states and Mexico. Locally known as scrub oak due to slow growth and tendency to form thickets. Acorns are excellent wildlife food. Crown is narrow and sparse. Wood is hard, heavy and close grained. Prefers sunny sites; pH and soil adaptable; drought tolerant. Height to 20 ft.
Oak, Northern Red (***Quercus rubra***)	QURU	IV	M	L	SM GB	B	H	F	M	L	F, L	N	Native to states east of the Great Plains; grows on eastern fringes of the Plains. Acorns valuable wildlife food. Is a substitute for pin oak in many situations with less chance of becoming chlorotic on calcareous soils. Produces strong, hard wood used in flooring, furniture, veneer, and interior finishing. Rounded spreading crown. Reddish autumn color. Grows best in sun. Prefers fertile, moist soils, neutral to acidic. Drought tolerant. Height to 70 ft.
Oak, Pin (***Quercus palustris***)	QUPA2	N	L	H	SM GB	B	H	F	M	L	F	N	Native to the U.S. from eastern KS to the Atlantic coast and from TN to southern MI. Acorns valuable wildlife food. Grows naturally on poorly drained, claypan soils and withstands short periods of flooding. Iron chlorosis and growth stunting are problems if planted in calcareous soils. Prefers sun to partial shade, fertile, moist, neutral to acidic soils. Pyramidal crown. Variable autumn foliage from green to shades of yellow and red. Does not produce high quality lumber due to many small persistent branches. Height to 60 ft.
Oak, Swamp White (***Quercus bicolor***)	QUBI	N	M	H	SM GB	B	H	F	M	L	F	N	Occurs naturally in lowlands and swamp edges from IA to MO eastward to the Atlantic coast. Easily mistaken for bur oak or white oak due to leaf similarities. It Has long and slender-stalked acorns similar to English oak. Prefers sun and moist, fertile, neutral to acidic soils. Tolerates compact soils high in clay. Rounded crown. Autumn foliage from subdued brownish yellows and reds, often persistent through winter. Acorns valuable wildlife food. Wood is heavy, strong, hard, moderately durable. Height to 60 ft.
Oak, White ***(Quercus alba)***	QUAL	IV	M	L	SM GB	B	H	F	M	L	F, L	N	Native to southern MN, IA, south into eastern TX and all states to the east. Desirable windbreak tree in Zone IV because leaves tend to persist throughout winter. Round crown. Durable wine red autumn foliage. Acorns provide wildlife food. Prefers sun, fertile, moist, neutral to acidic soils. Can be found on upland sites within its native range. Drought tolerant. Height to 70 ft.
Osage-orange (***Maclura pomifera***)	MAPO	N	L	M	SB GB	B	M	Su/F	M	L	P, F	N	Extremely hard, durable wood for posts. Large 'hedge apple' fruit; seeds eaten by quail/squirrels. Not very winter hardy. Invasive into grasslands in southeast NE. Height to 40 ft.
Pawpaw ***(Asimina Adans)***	ASIMI	IV	H	L	SM SB	F	L	Su	M	L	E2	N	Recommended only in southeast Nebraska. Potential medicinal use. Fruit can be consumed by humans. Height to 25 ft.

Summary - List of Attributes by Species for Conservation Tree/Shrub Plantings in Nebraska

Deciduous Trees	PLANTS Database Symbol	Native by Vegetative Zones I, II, III, or IV N = Not Native	Shade Tolerance (1)	Flood Tolerance (2)	Wildlife Value (3)				Windbreak Density (4)		Products (5)	Root Suckering (6) N = No, Y = Yes	Comments (7)
					Use Groups	Function	Rating	Season	Summer	Winter			
Pear, Chinese (Harbin) (***Pyrus ussuriensis***) (recommended cultivar: McDermand)	PYUS2	N	L	L	SM SB	B	L	Su/F	M	L		N	Slow growth but well adapted to northern prairie climate. White flowers; reddish fall leaf color; round greenish-yellow to light brown fruit. Height to 30 ft.
Pecan, Northern ***(Carya illinoensis)***	CAIL2	N	L	L	SM SB	B	H	F	M	L	L, E1, E2	N	Use northern seed source or hardy cultivars. Excellent nut species and valuable timber species. Suitable to southeast Nebraska (southern half of Veg. Zone 4 only). Height to 80 ft.
Redbud, Eastern (***Cercis canadensis***)	CECA4	IV	H	L	SB MB	F	M	F	L	L		N	Winter hardiness is questionable (seed source important). Susceptible to 2,4-D herbicide. Beautiful early spring flowers. Height to 30 ft.
Sycamore, American (***Platanus occidentalis***)	PLOC	IV	L	H	SB SM	C	L	N/A	M	L	B, L	N	Anthracnose disease is a potential problem. Prefers deep, moist rich soils found in bottomlands. Height to 80 ft.
Walnut, Black (***Juglans nigra***)	JUNI	III, IV	L	L	SM	F	H	F	M	L	L, F, E2	N	Sensitive to broadleaf herbicides. Green husk on nut turning dark brown at maturity. Needs well-drained soils. Most valuable of timber trees. Height to 70 ft.
Willow, Black ***(Salix nigra)***	SANI	III, IV	L	H	SB GB LM	B	H	F/W	M	L	B	N	Native only to extreme eastern Nebraska. Often confused with peachleaf willow. Short-lived species. Buds and twigs consumed by various wildlife species. Cytospora canker on upland sites. Height to 60 ft.
Willow, Peach Leaf (***Salix amygdeloides***)	SAAM2	I, II, III, IV	L	H	SB GB LM	B	H	F/W	M	L		N	Native across Nebraska - especially central and west. Similar to black willow but leaves are slightly wider and whitish on underside. Buds and twigs consumed by various wildlife species. Used by cavity nesting birds. Height up to 60 ft.
Willow, White (or Golden) (***Salix alba***) (Cultivars Vitellina or Tristis often called Golden Willow)	SAAL2	N	L	H	SB SM	C	L	N/A	M	L		N	Grows well in wet sites and may colonize naturally along streams and in wetlands. Tristis is the most hardy cultivar. Cytospora canker on upland sites. Height to 60 ft.

(1) **Shade Tolerance** - adaptation for underplantings (H = high, M = medium, L = low)

(2) **Flood Tolerance - relative value in riparian locations (H = high tolerance of frequent Flood with poor drainage, M - medium tolerance to Flood and needs good** drainage, L = low tolerance of Flood)

(3) **Wildlife Value - Use Groups:** SM = small mammals, LM = large mammals, SB = song birds, GB = game birds, MB = moths/butterflies; Function: F = food, C = cover, B = both; Rating: H = high value on a long-term use, M = high value on a seasonal basis, L = value on a limited, short-term basis; Season when food is available: Sp =Spring, Su = Summer, F = Fall, W = Winter

(4) **Windbreak Density** - Summer = comparable protection from wind; Winter = comparable protection from wind and snow drifting; H = high, M = medium, L = low

(5) **Products - C = Christmas trees, P = posts, S = shavings, L = lumber, F = firewood, B = biomass, E1 = edible directly off the plant, E2 = edible if processed**

(6) **Root Suckering** - comparable aggressiveness to root sprout, N = No, Y = Yes

(7) **Comments - check with your local forester or natural resource professional for other possible considerations**

Summary - List of Attributes by Species for Conservation Tree/Shrub Plantings in Nebraska

Shrubs	PLANTS Database Symbol	Native by Vegetative Zones I, II, III, or IV N = Not Native	Shade Tolerance (1)	Flood Tolerance (2)	Wildlife Value (3)				Windbreak Density (4)		Products (5)	Root Suckering (6) N = No, Y = Yes	Comments (7)
					Use Groups	Function	Rating	Season	Summer	Winter			
Antelope Bitterbrush ***(Purshia tridentate)***	PUTR2	I	L	L	LM SM	B	H	F/W	M	L		N	Excellent big game browse species and small mammals eat seeds. Height to 3 ft.
Blackhaw, Rusty **(*Viburnum rufidulum)***	VIRU	N	L	L	SB GB	B	H	F	H	M	E1	Y	Habit: shrub, tree, open, irregular, May blossoms, augumn fruits reddish, becoming black, sweet and edible. Drought tolerant in zone 5, pH 5.5-7.0. Use: wildlife habitat, windbreak. Height to 30 ft.
Buffaloberry, Silver **(*Shepherdia argentea*)**	SHAR	I, II, III	L	M	SB GB	B	H	F/W	H	M	E1, E2	Y	Thorny shrub with red-orange fruit. Cold and drought hardy. Minimum spacing 5x5; can be planted in coarse and medium soils. Height 10-12 ft.
Buttonbush ***(Cephalanthus occidentalis)***	CEOC2	IV	L	H	GB	B	L	F	M	L		Y	Recommended only in southeast Nebraska. Seeds eaten by waterfowl. Prefers moist sites. Minimum spacing is 4x4; can be planted in coarse, medium and fine soils. Height 8-12 ft.
Cherry, Nanking **(*Prunus tomentosa*)**	PRTO80	N	L	L	SB SM	B	M	Su	M	L	E1, E2	N	Short-lived <10 years. Early fruit producer of sweet cherries. Minimum spacing 6x6; can be planted in coarse and medium soils. Height 5-7 ft.
Chokeberry, Black **(*Aronia melanocarpa*)**	PHME13	N	L	L	SB LM	B	H	F/W	M	L		Y	Blackish purple fruits persist into winter. Minimum spacing 4x4; can be planted in coarse, medium and fine soils. Height 3-8 ft
Chokecherry, Common **(*Prunus virginiana*)**	PRVI	I, II, III, IV	M	M	SB GB	B	H	Su	H	M	E1, E2	Y	Red fall leaf color. Small dark fruit is bitter without processing. Minimum spacing 4x4; can be planted in coarse, medium and fine soils. Height 8-14 ft.
Coralberry ***(Symphoricarpos orbiculatus)***	SYOR	III, IV	M	M	SB SM	B	H	F/W	M	L		Y	Reddish-pink berries persist into winter. Height 3 ft.
Cotoneaster, Peking **(*Cotoneaster acutifolia*)**	COAC2	N	L	M	MB SB	B	M	F/W	H	M		N	Fire blight possible problem. Minimum spacing 5x5; can be planted in coarse, medium and fine soils. Height 5-10 ft.
Cranberry, American or Highbush **(*Viburnum trilobum*)**	VITR8	N	M	M	SB	B	M	F/W	H	M	E2	N	Bright red berries persist into winter. Makes ruby red jelly/jam. Minimum spacing 6x6; can be planted in coarse, medium and fine soils. Height 10-12 ft.
Currant, Buffalo ***(Ribes odoratum)***	RIAUV	I, II, III, IV	M	L	SB SM	B	M	Su	H	M	E1, E2	Y	Adapted to a variety of sites. Minimum spacing 5x5; can be planted in medium soils. Height 4-6 ft.
Currant, Golden ***(Ribes aureum)***	RIAU	I, II, III, IV	M	L	SB SM	B	M	Su	H	M	E1, E2	Y	Adapted to a variety of sites. Minimum spacing 5x5; can be planted in medium soils. Buffalo currant (*Ribes odoratum*) is a closely related species. Height 4-6 ft.
Dogwood, Gray **(*Cornus racemosa*)**	CORA6	III, IV	H	H	SB	B	H	Su/F	H	M		Y	Understory shrub that grows in full shade to sun. Suckers to form thickets. Minimum spacing 3x3; can be planted in coarse, medium and fine soils. understory shrub. Height 6-10 ft.
Dogwood, Redosier **(*Cornus sericea*)**	COSE16	I, II, III, IV	M	H	SB LM	B	H	F/W	M	L		Y	Red stems in winter. Good riparian buffer species. Provides browse for big game. Minimum spacing 4x4; can be planted in coarse, medium and fine soils. Height 8-10 ft.
Elderberry **(*Sambucus canadensis*)**	SANIC4	III, IV	L	H	MB SB	F	M	Su	H	M	E1, E2	Y	Prefers moist sites. Root sprouts readily; leaves and stems may be toxic. Minimum spacing 5x5; can be planted in medium soils. Height 4-8 ft.

Summary - List of Attributes by Species for Conservation Tree/Shrub Plantings in Nebraska

Shrubs	PLANTS Database Symbol	Native by Vegetative Zones I, II, III, or IV N = Not Native	Shade Tolerance (1)	Flood Tolerance (2)	Wildlife Value (3)				Windbreak Density (4)		Products (5)	Root Suckering (6) N = No, Y = Yes	Comments (7)
					Use Groups	Function	Rating	Season	Summer	Winter			
Euonymus, Winterberry (***Euonymus bungeanus***)	EUBU5	N	M	M	SB	B	L	F/W	M	L	E1	N	Large shrub-small tree form. Bright orange-red seeds in the fall. Cultivar released by Manhattan PMC. Height to 20 ft.
Hazelnut, American (***Corylus americana***)	COAM3	IV	M	M	SB SM	B	H	F	M	L	E1	Y	Susceptible to canker. Nuts enclosed in downy bracts. Minimum spacing 5x5; can be planted in medium and fine soils. Height 6-10 ft.
Indigo, Desert False (***Amorpha fruiticosa)***	AMFR	II, III, IV	L	H	SB	C	L	N/A	M	L		Y	Legume with seed pod. Native along riparian areas and prefers moist soils. Minimum spacing 4x4; can be planted in coarse, medium and fine soils. Height 5-10 ft.
Juniper, Common ***(Juniperus communis)***	JUCO6	I, II	M	L	SM SB	B	M	F/W	M	M		N	Evergreen shrub to small tree. Numerous varieties in several forms (prostrate to upright). Certain varieties subject to bagworms, cercospora. Available from Lawyer Nursery, MT (unknown variety or seed source). Height 3 to 15 ft.
Lilac (***Syringa vulgaris***)	SYVU	N	L	L	SB MB	B	M	Su	H	M		Y	Hardy shrub. Purple flowers result in persistent seed capsule. Powdery mildew a potential problem. Minimum spacing 6x6; can be planted in coarse, medium and fine soils. Height 6-10 ft.
Mahogany, Mountain ***(Cercocarpus montanus)***	CEMOM4	I	L	L	LM	F	H	F/W	M	L		N	Excellent big game browse species. Plumose fruits persist into winter. Drought tolerant. Height 5-10 ft.
Nannyberry ***(Viburnum lentago)***	VILE	III, IV	M	M	SB	B	H	Su	M	L		Y	Small tree or large shrub form. Good for wildlife habitat or windbreaks; drought tolerant; may be confused with Black Haw *(Vibernum rufidulum)*. Height to 25 ft.
Peashrub, Siberian (***Caragana aborescens***)	CAAR18	N	L	L	SB	F	L	F	H	M	B	Y	Legume. Cold and drought hardy. Effective windbreak species. Readily defoliated by grasshoppers. Minimum spacing 5x5; can be planted in medium and fine soils. Height 8-12 ft.
Plum, American (***Prunus americana***)	PRAM	I, II, III, IV	M	M	GB SB	B	H	Su	H	M	E1, E2	Y	Medium pink-red fruits. Widely adapted. Suckers to make dense thickets. Minimum spacing for wildlife 2x2; can be planted in coarse and medium soils. Height 8-12 ft.
Rose, Arkansas ***(Rosa arkansana)***	ROAR3	I, II, III, IV	L	L	GB SB	B	H	F/W	L	L	E2	Y	Also called prairie rose. Height to 2 ft.
Rose, Hansen Hedge (***Rosa sp*.**); (Rosa rugosa x R. woodsii)	ROWOHH	N	L	L	SB MB	B	H	F/W	M	L		Y	Woods or Arkansas Rose preferred on unaltered habitats. Origin might be SDSU selection of Rosa rugosa x Rosa woodsii. Height to 6 ft.
Rose, Woods ***(Rosa woodsii)***	ROWO	I, II, III	L	L	GB SB	B	H	F/W	M	L	E2	Y	Preferred winter food for prairie grouse. Available through some NRDs. Height to 5 ft.
Sagebrush, Big ***(Artemisia tridentata)***	ARTR2	I	L	L	LM SM	B	H	F/W	M	L		N	Excellent big game browse species - maintains leaves in winter for high protein diet. Provides big game fawning habitat. Rodents eat seeds. Height 3-6 ft.
Sagebrush, Silver ***(Artemisia cana)***	ARCA13	I	L	L	LM	B	H	F/W	M	L		N	Excellent big game browse species. Provides cover for big game fawning habitat. Height 2-5 ft.

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					Use Groups	Function	Rating	Season	Summer	Winter			
Saltbush, Fourwing (***Atriplex canescens***)	ATCA2	I	L	L	LM SM	B	M	F/W	M	L		N	Maintains leaves in winter. Seeds are persistent. Limit use to high pH and alkaline soils. Height to 2-5 ft.
Sandcherry, Western (***Prunus besseyi***)	PRPUB	I, II, III	L	L	GB SB SM	F	M	Su	M	L	E1, E2	Y	Early fruit producer of dark sweet cherries. Minimum spacing for wildlife 2x2; can be planted in coarse and medium soils. Height 4-6 ft.
Serviceberry, Saskatoon (***Amelanchier alnifolia***)	AMAL2	I, II, III	H	M	SB LM	B	H	Su	H	M	E1, E2	Y	Native to northern Nebraska. Produces near black, edible fruit. Minimum spacing 5x5; can be planted in coarse, medium, and fine soils. Height 6-12 ft.
Snowberry, Common (***Symphoricarpos albus***)	SYAL	III, IV	M	M	SB SM	B	H	F/W	M	L	Y		Whitish berries persist into winter. Western snowberry (*Symphoricarpos occidentalis*) is a very similar species native to Vegetative Zones I, II, III and IV. Used for windbreaks and wildlife habitat. Height 2-3 ft.
Snowberry, Western (***Symphoricarpos occidentalis***)	SYOC	I, II, III, IV	M	M	SB SM	B	H	F/W	M	L	Y		Potential to spread in rangeland. Whitish berries persist into winter. Common snowberry (*Symphoricarpos albus*) is a very similar species native to Vegetative Zones III and IV. Used for windbreaks and wildlife habitat. Height 2-3 ft.
Sumac, Skunkbush (***Rhus trilobata***) Recommended cultivars: Big horn, Konza fragrant	RHTR	I, II, III, IV	L	L	SM SB	B	M	F/W	M	L		N	Good red fall foliage. Leaves have pungent odor. Red fuzzy seed is persistent and not consumed widely by wildlife. Minimum spacing 4x4; can be planted in coarse and medium soils. Height 4-8 ft.
Willow, Sandbar ***(Salix exigua)*** Interior Rowlee	SAIN3	I, II, III, IV	M	H	LM SB	C	M	N/A	H	M	B	Y	Excellent riparian buffer species. Controls streambank erosion and provides wildlife cover. Height to 15 ft.

(1) Shade Tolerance - adaptation for underplantings (H = high, M = medium, L = low)
(2) Flood Tolerance - relative value in riparian locations (H = high tolerance of frequent Flood with poor drainage, M - medium tolerance to Flood and needs good drainage, L = low tolerance of Flood)
(3) Wildlife Value - Use Groups: SM = small mammals, LM = large mammals, SB = song birds, GB = game birds, MB = moths/butterflies; Function: F = food, C = cover, B = both; Rating: H = high value on a long-term use, M = high value on a seasonal basis, L = value on a limited, short-term basis; Season when food is available: Sp =Spring, Su = Summer, F = Fall, W = Winter, N/A = Not Applicable
(4) Windbreak Density - Summer = comparable protection from wind; Winter = comparable protection from wind and snow drifting; H = high, M = medium, L = low
(5) Products - C = Christmas trees, P = posts, S = shavings, L = lumber, F = firewood, B = biomass, E1 = edible directly off the plant, E2 = edible if processed
(6) Root Suckering - comparable aggressiveness to root sprout, N = No, Y = Yes
(7) Comments - check with your local forester or natural resource professional for other possible considerations

Primary References

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Exhibit 6-9: Colorado Windbreak Suitability Groups

COLORADO WINDBREAK SUITABILITY GROUPS

INTRODUCTION

Windbreak suitability groups are being developed to assist in selecting species best suited for the various soils and for predicting height growth and effectiveness. In this first stage, we have covered Land Resource Areas 67, 69, and 72.

All species of trees and shrubs have climatic and physiographic boundaries. On the eastern plains, this is very apparent, as we are introducing species that are not native to the environment.

The groups were developed by considering individual species performance under the following conditions: soil, climate, physiography, and management which includes species, spacing, and arrangement. They may be used to select species for a variety of purposes including: windbreaks, recreation, wildlife, ornamental, critical area, or reforestation plantings.

All soil series mapped have been placed in 10 groups of similar soils. Groups 1, 2, 4, 5, 6, and 9 have been divided into subgroups. Group 10 contains the soils with restrictive conditions that will require an on-site inspection to determine if a planting is feasible.

The tree or shrub heights listed in the tables show the expected height at 20 years after planting. This information should be used to determine placement of the windbreak, area of protection, and species arrangement.

WINDBREAK SUITABILITY GROUP - INDEX

Soil	Group or Subgroup
Absted	9N
Adena	3
Albinas	3
AIda	1
AIda (saline)	9G
Altvan	6G
Anselmo variant	9N
Apishapa	9G
Arvada	9N
Ascalon	3
Avar	9N
Baca (CL, SICL, VAR)	4C
Baca (L, SIL)	4L
Bainville	10
Bankard	IK
Bayard	5
Beckton	9N
Bernal	10
Bethune	4L
Bijou	5
Bijou (wet)	1
Blakeland	7
Bloom	9G
Boel	1
Bonaccord	4C
Bresser	3
Bridgeport	3
Briggsdale	6R
Buick	3
Bushman	5K
Cadoma	9N
Calkins	1
Campo	4C
Campus	8
Canyon	10
Caruso	1
Cascajo	10
Cass	1
Chappell	6G
Cheyenne	6G
Christianburg	4C
Colby	8
Colombo	8
Concordia	9N

Curabith	6G
Cushman	6R

Dacono	6G
Dailey	7
Dalhart	3
Dawes	4L
Deertrail	9N
Dioxice	8
Dix	10
Dunday	7
Dwyer	7
Dwyer variant	9G

Eastonville	5
Eckley	6G
Edgewater	1
Els	1
Elsmere	1
Epping	10
Escabosa	6R

Firstview	9N
Fondis	4C
Fort Collins	3

Gaynor	4C
Gaynor (gravelly)	4L
Gilcrest	5
Glenburg	lK
Glendive	lK
Goshen	1

Harbord	3
Harvey	5K
Harvey (dry)	8
Haverson	1
Haverson (saline)	9N
Haverson Family	1
Havre	lK
Haxtun	3
Hayford	9G
Heldt	4C
Heldt (SL)	4L
Heldt (alkaline plains, salt flats)	9N
Heldt (salt meadow)	9G
Hoehne	1

Ildefonso	5K

Iliff	4L
Inavale	7
Ipage	1

Julesburg	5

Keith	3
Keota	6R
Keyner	9N
Kim	8
Kimst	8
Kitcarson	1K
Koen	9N
Kornman	lK
Kuma	3
Kutch	4C

Laird	9N
Larimer	6G
Las	lK
Las Animas	9G
Las Animas (non-saline)	lK
Las Variant	2K
Lebsack	9N
Limon	9N
Limon (clayey plains)	4C
Limon (salt meadow)	10
Lincoln	1K
Lismas	10
Little	9N
Little (stoney)	10
Lohmiller	4C
Longmont	9G
Loup	2K
Loveland	lK

Manter	5
Manvel	8
Manzanola (CL)	4C
Manzanola (L, SICL)	4L
Manzanst	4C
McCook	1
McCook Variant	3
Midway	10
Minnequa	8
Mitchell	8
Mosher	9N

Neesapah	5K

Nelson	6R
Nepesta	8
Neville	8
Nihill	10
Norka	3
Nucla	8
Numa	8
Nunn (L, LS, SL)	4L
Nunn (stoney)	10
Nunn (wet)	9N
Nunn variant	9N

Olnest	3
Olney	3
Ordway	9N
Orsa	6G
Osgood	7
Otero	5K

Paoli	5
Peetz	6G
Penrose	10
Platner	4L
Platte	1
Playas	10
Pleasant	10
Pleasant (L)	4C
Potter	10
Pultney	9N

Rago	4L
Rago (flooded)	4L
Razor	4C
Renohill	4L
Renohill (CL, STCL)	4C
Renohill (L, FSL, SL)	6R
Richfield	3
Rizozo	10
Rocky Ford	8
Rosebud	6R
Ryegate	6R

Sampson	3
Samsil	10
Satanta	3
Schamber	10
Shingle	10
Singerton	9N
Slickens	10

Stapleton	6R
Stoneham	3
Stoneham Variant	6R
Sundance	3

Table Mountain	3
Tassel	10
Terry	6R
Thedalund	6R
Tivoli	7
Travessilla	10
Treon	10
Tripp	3
Truckton	5
Tullock	7
Tyrone	9N

Ulm (CL, VAR)	4C
Uim (L, SL)	4L
Ulmet	4L
Ulysses	3

Valent	7
Valent (>9%)	10
Valentine	7
Valentine (>15%)	10
Valmont	4C
Valmont (>5%)	10
Vebar	7
Villegreen	6R
Vona	5

Wages	3
Wann	2K
Weld	4L
Westplain	9G
Wiley	8

Yoder	6G

WINDBREAK SUITABILITY GROUPS

SOIL DESCRIPTION

GROUP

1 Loamy soils (<35% clay content) that are subject to frequent flooding or seasonal high water tables; in the upper l2 inches they lack free carbonates, have a pH less than 7.8 and are non-saline.

1K Loamy soils (<35% clay content) that are subject to frequent flooding or seasonal high water table; in the upper 12 inches they have free carbonates, have a pH of 7.8 to 9.0, or have an electrical conductivity (EC) of less than 4 mmhos/cm

2K Artificially drained phases of very poorly and poorly drained soils; in the upper 12 inches they have free carbonates, have a pH of 7.8 to 9.0 or have an EC of less than 4 mmhos/cm.

3 Moderately well and well drained loamy soils (<35% clay content) and clayey soils with a loamy surface mantle greater than 20 inches with high available water capacities (AWC 7.5"); in the upper 12 inches they lack free carbonates, have a pH less than 7.8 and are non-saline.

4C Somewhat poorly, moderately well, and well drained soils with greater than 35% clay content throughout when mixed to 8 inches.

4L Somewhat poorly, moderately well, and well drained clayey soils with a 4-to-6 inch loamy surface mantel.

5 Moderately well and well drained loamy and loamy-skeletal soils with moderate and moderately high available water capacities (AWC 3.75 to 7.5"); in the upper 12 inches they lack free-carbonates, have a pH less than 7.8, and are non-saline.

5K Moderately well and well drained loamy and loamy-skeletal soils with moderate available water capacities (AWC 5.0 to 7.5"); in the upper 12 inches they have free carbonates, have a pH of 7.8 to 9.0, or have an EC of less than 4 mmhos/cm.

6 Deep, moderately well to excessively drained loamy-skeletal and sandy-skeletal soils with low available water capacities (AWC 2 to 3.75").

6G Deep, moderately well to excessively drained loamy-skeletal and sandy-skeletal soils with low available water capacities (AWC 2 to 3.75"). Moderately deep soils over sand and/or gravel.

6R Deep, moderately well to excessively drained loamy-skeletal and sandy-skeletal soils with low available water capacities (AWC 2 to 3.75"). Moderately deep soils with loamy surface over bedrock or a duripan.

7 Deep soils that are sandy throughout.

8 Moderately well and well drained loamy soils (<35% clay content) with high available water capacities (AWC >7.5"); in the upper 12 inches they have free carbonates, have a pH of 7.8 to 9.0 or have an EC of less than 4 mmhos/cm.

9G Deep soils with a water table within 5 feet of the surface; some are subject to flooding or ponding; in the upper 12 inches they have a pH of greater than 7.8 and an EC of 4-16 mmhos/cm.

9N Deep soils without a water table within 5 feet of the surface and are not subject to flooding or ponding; in the upper 12 inches they have a pH of greater than 7.8 and an EC of 4-16 mmhos/cm.

10 Very shallow and shallow soils; soils with a very low available water capacity (AWC <2"); very poorly and poorly drained soils that are saturated or ponded throughout the growing season; and toxic soils.

Windbreak Suitability Group 1

Description:
Loamy soils (<35% clay content) that are subject to frequent flooding or seasonal high water tables; in the upper 12 inches they lack free carbonates, have a pH less than 7.8 and are non-saline.

Limitations:
Spring planting may be delayed for a short period because of soil wetness.

Soils:

Alda	Goshen
Bijou (wet)	Haverson
Boel	Haverson Family
Calkins	Hoehne
Caruso	Ipage
Edgewater	McCook
Els	Platte
Elsmere	

ADAPTED SPECIES FOR WINDBREAK GROUP 1

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine	10	18	22	30
Blue spruce	14	18	20	29
Douglas-fir	10	12	16	27
Eastern redcedar	15	17	19	23
Pinyon pine				
Ponderosa pine	12	18	22	30
Rocky Mtn. Juniper	10	16	18	24
Scotch pine	10	16	20	30
White fir	10	12	16	27
Deciduous Trees:				
Black Locust	10	15	24	32
Bur oak		12	16	30
Eastern cottonwood	25	30	36	55

Golden willow		15	22	34
Green ash	15	20	22	32
Hackberry	14	18	22	30
Honeylocust	8	15	23	36
Narrowleaf cottonwood				
Osage-orange		10	16	22
Plains cottonwood	25	30	36	55
Russian mulberry	10	12	15	30
Siberian elm	20	27	28	40
Shrubs:				
American plum	7	8	9	12
Amur honeysuckle	3	5	8	11
Antelope bitterbrush				
Autumn olive	6	7	8	14
Basin big sagebrush				
Common chokecherry	7	8	8	14
Fourwing saltbush	4	5	5	8
Hansen rose	3	4	5	8
Lilac	5	7	7	10
Nanking cherry	4	6	7	11
Peking cotoneaster	4	5	7	10
Redosier dogwood	4	5	7	8
Rubber rabbitbrush				
Saskatoon serviceberry		5	6	9
Siberian peabush	7	8	11	15
Silver buffaloberry	7	8	10	12
Skunkbush sumac	5	6	8	10
Tatarian honeysuckle	5	7	8	11
Western sandcherry	3	4	4	4
Woods rose				

Windbreak Suitability Group IK

Description:
Loamy soils (<35% clay content) that are subject to frequent flooding or seasonal high water table; in the upper 12 inches they have free carbonates, have a pH of 7.8 to 9.0 or have an electrical conductivity (EC) of less than 4 mmhos/cm.

Limitations:
Spring planting may be delayed for a short period because of soil wetness. Free carbonates, high pH, and a slight EC affect the selection and growth of species.

Soils:

Bankard	Kornman
Glenburg	Las
Glendive	Las Animas (non-saline)
Havre	Lincoln
Kitcarson	Loveland

ADAPTED SPECIES FOR WINDBREAK GROUP 1K

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine				
Blue spruce	13	17	19	27
Douglas-fir				
Eastern redcedar	15	17	19	23
Pinyon pine				
Ponderosa pine	15	18	20	28
Rocky Mtn. Juniper	10	16	18	22
Scotch pine				
White fir				
Deciduous Trees:				
Black Locust	10	15	24	32
Bur oak		10	15	28
Eastern cottonwood				
Golden willow	15	20	26	34
Green ash	15	20	22	32
Hackberry	14	18	22	30
Honeylocust	14	17	21	30
Narrowleaf cottonwood				
Osage-orange	8	10	12	18
Plains cottonwood	26	30	32	48
Russian mulberry	10	13	18	30
Siberian elm	20	27	28	38
Shrubs:				
American plum	6	7	7	12
Amur honeysuckle				
Antelope bitterbrush				
Autumn olive				
Basin big sagebrush				
Common chokecherry	7	8	8	12
Fourwing saltbush	4	5		
Hansen rose	3	4	5	6
Lilac	5	7	7	10
Nanking cherry	4	6	7	11
Peking cotoneaster	5	6	8	10
Redosier dogwood	4	5	6	7
Rubber rabbitbrush				
Saskatoon serviceberry	4	5	7	9

Siberian peabush	7	9	11	14
Silver buffaloberry	7	8	10	12
Skunkbush sumac	4	6	7	10
Tatarian honeysuckle	5	7	8	11
Western sandcherry	3	4	4	4
Woods rose				

Windbreak Suitability Group 2K

Description:
Artificially drained phases of very poorly and poorly drained soils; in the upper 12 inches they have free carbonates, have a pH of 7.8 to 9.0 or have an EC of less than 4 mmhos/cm.

Limitations:
Spring planting may be delayed because of wet conditions. The degree of wetness and drainage, the calcic horizon, and high pH affect selection of species.

Soils:

Las variant	Wann
Loup	

ADAPTED SPECIES FOR WINDBREAK GROUP 2K

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine				
Blue spruce				
Douglas-fir				
Eastern redcedar	16	17	19	24
Pinyon pine				
Ponderosa pine	13	18	20	24
Rocky Mtn. Juniper	10	15	18	22
Scotch pine				
White fir				
Deciduous Trees:				
Black Locust				
Bur oak		10	15	28
Eastern cottonwood		10	20	52
Golden willow	18	24	28	32
Green ash	14	18	22	30
Hackberry	14	18	22	28

Honeylocust	12	16	20	32
Narrowleaf cottonwood				
Osage-orange	8	10	14	22
Plains cottonwood				42
Russian mulberry	12	15	18	30
Siberian elm	20	27	28	40
Shrubs:				
American plum	6	7	7	12
Amur honeysuckle				
Antelope bitterbrush				
Autumn olive				
Basin big sagebrush				
Common chokecherry	7	8	8	12
Fourwing saltbush	5			
Hansen rose				
Lilac	5	7	7	10
Nanking cherry	4	6	7	11
Peking cotoneaster	3	4	5	10
Redosier dogwood				8
Rubber rabbitbrush				
Saskatoon serviceberry				
Siberian peabush	5	7	7	10
Silver buffaloberry		8	10	11
Skunkbush sumac	4	6	7	10
Tatarian honeysuckle	5	7	8	11
Western sandcherry				
Woods rose				

Windbreak Suitability Group 3

Description:
Moderately well and well drained loamy soils (<35% clay content) and clayey soils with a loamy surface mantle greater than 20 inches with high available water capacities (AWC 7.5"); in the upper 12 inches they lack free carbonates, have a pH less than 7.8, and are non-saline.

Limitations:
Water erosion is a hazard on sloping areas.

Soils:

Adena	Norka
Albinas	Olnest
Ascalon	Olney
Bresser	Richfield
Bridgeport	Sampson
Buick	Satanta
Delhart	Stoneham
Fort Collins	Sundance

Harbord	Table Mountain
Haxtun	Tripp
Keith	Ulysses
Kuma	Wages
McCook variant	

ADAPTED SPECIES FOR WINDBREAK GROUP 3

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine	12	15	19	32
Blue spruce	15	16	18	26
Douglas-fir	10	12	15	31
Eastern redcedar	10	14	16	24
Pinyon pine	9	10	12	16
Ponderosa pine	12	16	19	32
Rocky Mtn. juniper	9	10	13	22
Scotch pine	14	16	17	34
White fir	10	12	15	26
Deciduous Trees:				
Black Locust	10	15	22	23
Bur oak	10	15	18	35
Eastern cottonwood				40
Golden willow		15	22	32
Green ash	12	16	18	30
Hackberry	12	15	18	32
Honeylocust	10	15	22	30
Narrowleaf cottonwood				40
Osage-orange	10	15	18	25
Plains cottonwood				40
Russian mulberry	10	12	15	30
Siberian elm	20	26	29	42
Shrubs:				
American plum		7	8	12
Amur honeysuckle	6	6	7	12
Antelope bitterbrush				
Autumn olive		7	9	16
Basin big sagebrush				
Common chokecherry	7	8	8	11
Fourwing saltbush	5			
Hansen rose	4	5	6	8

Lilac	5	7	7	10
Nanking cherry	4	5	6	9
Peking cotoneaster	4	5	7	10
Redosier dogwood			7	9
Rubber rabbitbrush				
Saskatoon serv,iceberry		4	5	6
Siberian peabush	8	8	9	12
Silver buffaloberry		7	8	11
Skunkbush sumac	4	5	7	9
Tatarian honeysuckle	5	7	8	11
Western sandcherry	3	4	4	4
Woods rose				

Windbreak suitability Group 4C

Description:
Somewhat poorly, moderately well, and well drained soils with greater than 35% clay content throughout when mixed to 8 inches.

Limitations:
High clay content affects selection and growth of species. Extra care is required to insure the soil is firmly packed around the roots during planting. Drought tolerant species should be used.

Soils:

Baca (CL, SICL, VAR)	Lohmiller
Bonaccord	Manzanola (CL)
Campo	Manzanst
Christianburg	Nunn (CL)
Fondis	Pleasant (L)
Gaynor	Razor
Heldt	Renohill (CL, SICL)
Kutch	Ulm (CL, VAR)
Limon (clayey plains)	Valmont

ADAPTED SPECIES FOR WINDBREAK GROUP 4C

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine		10	16	22
Blue spruce				20

Douglas-fir				
Eastern redcedar	8	11	13	20
Pinyon pine				
Ponderosa pine	10	12	14	23
Rocky Mtn. Juniper	9	10	12	20
Scotch pine				21
white fir	10	12	15	26
Deciduous Trees:				
Black Locust	11	13	15	25
Bur oak				
Eastern cottonwood				
Golden willow				32
Green ash	10	12	14	27
Hackberry	10	12	14	26
Honeylocust	13	14	15	25
Narrowleaf cottonwood				
Osage-orange		10	15	20
Plains cottonwood				45
Russian mulberry		10	14	22
Siberian elm	19	21	24	35
Shrubs:				
American plum	5	6	7	10
Amur honeysuckle		4	6	9
Antelope bitterbrush				
Autumn olive		6	7	12
Basin big sagebrush				
Common chokecherry	7	8	8	10
Fourwing saltbush	4			
Hansen rose		3	4	7
Lilac	5	5	6	9
Nanking cherry	4	5	6	9
Peking cotoneaster	3	4	5	8
Redosier dogwood				9
Rubber rabbitbrush				
Saskatoon serviceberry			4	6
Siberian peabush	4	5	6	10
Silver buffaloberry		5	6	10
Skunkbush sumac	4	5	7	10
Tatarian honeysuckle	5	6	7	10
Western sandcherry		2	3	5
Woods rose				

Windbreak suitability Group 4L

Description:
Somewhat poorly, moderately well, and well drained clayey soils with a 4-6 inch loamy surface mantle.

Limitations:

High clay content below the surface mantle affects the selection and growth of species, due to slow water intake and the potential for frost heaving.

Soils:

Baca (L, SL)	Nunn (L, LS, SL)
Bethune	Platner
Daws	Rago
Gaynor (gravelly)	Renohill
Heldt (SL)	Ulm (L, SL)
Iliff	Ulmet
Manzanola (L, SICL)	

ADAPTED SPECIES FOR WINDBREAK GROUP 4L

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine		15	18	26
Blue spruce			16	24
Douglas-fir		12	16	23
Eastern redcedar	10	12	14	21
Pinyon pine		8	10	14
Ponderosa pine	12	15	17	26
Rocky Mtn. Juniper	9	11	13	21
Scotch pine			15	24
White fir		12	16	21
Deciduous Trees:				
Black Locust		16	20	28
Bur oak		12	15	20
Eastern cottonwood				
Golden willow				32
Green ash	13	15	17	30
Hackberry	12	14	16	28
Honeylocust	12	15	18	28
Narrowleaf cottonwood				
Osage-orange	10	14	17	22
Plains cottonwood				43
Russian mulberry	10	12	15	23
Siberian elm	19	24	26	36
Shrubs:				
American plum		7	7	12
Amur honeysuckle	5	6	7	11

Antelope bitterbrush				
Autumn olive	6	8	10	14
Basin big sagebrush				
Common chokecherry	7	8	8	12
Fourwing saltbush	3	3	3	4
Hansen rose	4	5	7	9
Lilac	5	7	7	10
Nanking cherry	3	4	5	8
Peking cotoneaster	3	4	5	8
Redosier dogwood			6	9
Rubber rabbitbrush				
Saskatoon serviceberry			4	6
Siberian peabush	5	7	7	10
Silver buffaloberry		8	10	11
Skunkbush sumac	4	6	7	10
Tatarian honeysuckle	5	7	8	11
Western sandcherry	2	3	4	4
Woods rose				

Windbreak suitability Group 5

Description:
Moderately well and well drained loamy and loamy-skeletal soils with moderate and moderately high available water capacities (AWC 3.75 to 7.5"); in the upper 12 inches they lack free carbonates, have a pH less than 7.8, and are non-saline.

Limitations:
Moderate to moderately high AWC can affect selection and growth of planted material.

Soils:

Bayard	Manter
Bijou	Paoli
Eastonville	Truckton
Gilcrest	Vona
Julesburg	

ADAPTED SPECIES FOR WINDBREAK GROUP 5

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine	12	15	20	31

Blue spruce		12	18	24
Douglas-fir	10	12	18	23
Eastern redcedar	10	12	16	24
Pinyon pine	8	10	12	16
Ponderosa pine	12	17	20	32
Rocky Mtn. juniper	9	11	15	21
Scotch pine		14	19	31
white fir		12	17	26
Deciduous Trees:				
Black Locust	13	18	22	33
Bur oak	10	15	17	35
Eastern cottonwood				42
Golden willow			19	34
Green ash	12	16	18	32
Hackberry	11	16	18	30
Honeylocust	13	16	20	34
Narrowleaf cottonwood				42
Osage-orange	10	15	20	25
Plains cottonwood				47
Russian mulberry		12	15	24
Siberian elm	20	24	26	44
Shrubs:				
American plum	6	7	7	10
Amur honeysuckle	6	8	9	12
Antelope bitterbrush				
Autumn olive				14
Basin big sagebrush				
Common chokecherry	7	8	8	11
Fourwing saltbush				
Hansen rose	5	6	7	11
Lilac	5	6	7	12
Nanking cherry		5	6	11
Peking cotoneaster	3	4	6	9
Redosier dogwood			6	9
Rubber rabbitbrush				
Saskatoon serviceberry			4	6
Siberian peabtrsh	5	7	7	12
Silver buffaloberry		7	8	11
Skunkbush sumac	4	5	6	10
Tatarian honeysuckle	5	7	8	11
Western sandcherry	3	3	4	7
Woods rose				

Windbreak suitability Group 5K

Description:

Moderately well and well drained loamy and loamy-skeletal soils with moderate available water capacities (AWC 5.0 to 7.5"); in the upper 12 inches they have free carbonates, have a pH of 7.8 to 9.0, or have an EC of less than 4 mmhos/cm.

Limitations:
The calcic horizon and high pH in the upper 18 inches and the skeletal soils affect selection of species.

Soils:

Bushman	Neespah
Harvey	Otero
Ildefonso	

ADAPTED SPECIES FOR WINDBREAK GROUP 5K

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine				
Blue spruce				26
Douglas-fir				26
Eastern redcedar	8	10	12	23
Pinyon pine	8	10	11	17
Ponderosa pine	10	12	14	35
Rocky Mtn. Juniper	8	10	12	23
Scotch pine				
White fir				
Deciduous Trees:				
Black Locust				
Bur oak				
Eastern cottonwood				
Golden willow				
Green ash	10	12	14	30
Hackberry			12	25
Honeylocust	12	14	17	29
Narrowleaf cottonwood				42
Osage-orange	14	17	20	35
Plains cottonwood				44
Russian mulberry				
Siberian elm	16	20	23	40
Shrubs:				

American plum	6	7	8	11
Amur honeysuckle	7	7	8	13
Antelope bitterbrush				
Autumn olive	5	6	7	11
Basin big sagebrush	4			
Common chokecherry	5	6	7	9
Fourwing saltbush	4	3		
Hansen rose	5	6	8	11
Lilac	5	6	7	13
Nanking cherry		5	6	8
Peking cotoneaster				
Redosier dogwood	6	6	6	12
Rubber rabbitbrush	4			
Saskatoon serviceberry			4	6
Siberian peabush	6	7	9	15
Silver buffaloberry	5	7	8	12
Skunkbush sumac	5	6	7	10
Tatarian honeysuckle	5	7	9	12
Western sandcherry				
Woods rose				

Windbreak Suitability Group 6G

Description:
Deep, moderately well to excessively drained loamy-skeletal and sandy-skeletal soils with low available water capacities (AWC 2 to 3.75"). Moderately deep soils over and and/or gravel.

Limitations:
Field windbreaks are generally not recommended. Drought tolerance will need to be considerated in species selection.

Soils:

Altvan	Eckley
Cass	Larimer
Chappell	Orsa
Curabith	Peetz
Dacono	Yoder

ADAPTED SPECIES FOR WINDBREAK GROUP 6G

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED

Evergreen Coniferous Trees:

Austrian pine		12	14	26
Blue spruce				20
Douglas-fir				
Eastern redcedar	8	10	12	18
Pinyon pine				
Ponderosa pine	12	14	16	26
Rocky Mtn. Juniper	8	10	12	18
Scotch pine	12	14	16	24
White fir				
Deciduous Trees:				
Black Locust		11	15	25
Bur oak				22
Eastern cottonwood				
Golden willow				
Green ash		12	14	26
Hackberry		12	13	24
Honeylocust		13	16	26
Narrowleaf cottonwood				42
Osage-orange				
Plains cottonwood				35
Russian mulberry		11	14	20
Siberian elm	16	20	24	30
Shrubs:				
American plum			6	11
Amur honeysuckle		5	7	9
Antelope bitterbrush	4			
Autumn olive				
Basin big sagebrush	5			
Common chokecherry		6	8	12
Fourwing saltbush	4			
Hansen rose	3	4	5	11
Lilac		4	6	8
Nanking cherry			4	7
Peking cotoneaster		4	5	8
Redosier dogwood				8
Rubber rabbitbrush	4			
Saskatoon serviceberry			4	6
Siberian peabush	5	6	7	8
Silver buffaloberry		5	7	9
Skunkbush sumac		4	6	6
Tatarian honeysuckle	5	6	7	10
Western sandcherry		3	4	6
Woods rose				

Windbreak Suitability Group 6R

Description:
Deep, moderately well to excessively drained loamy-skeletal and sandy-skeletal soils with low available water capacities (AWC 2 to 3.75"). Moderately deep soils with loamy surface over bedrock or a duripan.

Field windbreaks are generally not recommended. Drought tolerance will need to be considered in species selection. When the soil is saturated, a perched water table can occur.

Soils:

Briggsdale	Ryegate
Cushman	Stapleton
Escabosa	Stoneham Variant
Keota	Terry
Nelson	Thedalund
Renohill (L, FSL, SL)	Villegreen
Rosebud	

ADAPTED SPECIES FOR WINDBREAK GROUP 6R

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine	10	14	16	26
Blue spruce				24
Douglas-fir				
Eastern redcedar	8	11	13	20
Pinyon pine	8	9	10	12
Ponderosa pine	12	17	19	26
Rocky Mtn. Juniper	9	11	13	19
Scotch pine		12	15	22
White fir				
Deciduous Trees:				
Black Locust		11	15	25
Bur oak				22
Eastern cottonwood				
Golden willow				30
Green ash	11	13	15	26
Hackberry		12	14	24
Honeylocust		16	18	26
Narrowleaf cottonwood				
Osage-orange		12	16	20

Plains cottonwood				35
Russian mulberry		11	15	22
Siberian elm	19	22	25	31
Shrubs:				
American plum			6	11
Amur honeysuckle		5	7	10
Antelope bitterbrush	3	4		
Autumn olive				
Basin big sagebrush	4	5		
Common chokecherry		6	8	12
Fourwing saltbush				
Hansen rose	3	4	5	7
Lilac		5	6	8
Nanking cherry		4	6	9
Peking cotoneaster		5	6	8
Redosier dogwood			5	8
Rubber rabbitbrush	4			
Saskatoon serviceberry				6
Siberian peabush	5	7	7	10
Silver buffaloberry		7	8	10
Skunkbush sumac	4	5	6	7
Tatarian honeysuckle	5	7	8	10
Western sandcherry	2	3		
Woods rose				

Windbreak Suitability Group 7

Description:
Deep soils that are sandy throughout.

Limitations:
Drought conditions and soil blowing are the principal concerns in the selection and growth of plants. The sandy soil requires specialized site preparation and planting methods to insure establishment. Optimum growth and survival are not expected unless the plantings are irrigated.

Soils:

Blakeland	Tivoli
Dailey	Tullock
Dunday	Valent
Dwyer	Valentine
Inavale	Vebar
Osgood	

ADAPTED SPECIES FOR WINDBREAK GROUP 7

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine	10	12	14	24
Blue spruce				22
Douglas-fir				
Eastern redcedar	8	9	11	20
Pinyon pine	6	8	9	12
Ponderosa pine	10	12	14	23
Rocky Mtn. Juniper	7	9	11	17
Scotch pine		12	13	22
White fir				
Deciduous Trees:				
Black Locust		6	8	19
Bur oak				
Eastern cottonwood				
Golden willow				
Green ash		12	14	30
Hackberry			13	29
Honeylocust		12	15	33
Narrowleaf cottonwood				
Osage-orange		8	10	17
Plains cottonwood				37
Russian mulberry				
Siberian elm		16	19	35
Shrubs:				
American plum			6	13
Amur honeysuckle			7	12
Antelope bitterbrush				
Autumn olive				
Basin big sagebrush				
Common chokecherry			8	10
Fourwing saltbush		5		
Hansen rose	3	4	5	8
Lilac		4	6	11
Nanking cherry		5	6	10
Peking cotoneaster			5	11
Redosier dogwood				8
Rubber rabbitbrush	3	4		
Saskatoon serviceberry				5
Siberian peabush	5	6	8	15
Silver buffaloberry				10
Skunkbush sumac				
Tatarian honeysuckle		5	6	12
Western sandcherry		3	4	4

Woods rose	3	4		

Windbreak suitability Group 8

Description:
Moderately well and well drained loamy soils (<35% clay content) with high available water capacities (AWC> 7.5"); in the upper 12 inches they have free carbonates, have a pH of 7.8 to 9.0, or have an EC of less than 4 mmhos/cm.

Limitations:
Free carbonates and a high pH affect the selection and growth of trees and shrubs.

Soils:

Campus	Minnequa
Colby	Mitchell
Colombo	Nepesta
Dioxice	Neville
Harvey (dry)	Nula
Kim	Numa
Kimst	Rocky Ford
Manvel	Wiley

ADAPTED SPECIES FOR WINDBREAK GROUP 8

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine				24
Blue spruce				
Douglas-fir				
Eastern redcedar	9	10	12	20
Pinyon pine	8	9	11	15
Ponderosa pine	12	14	16	28
Rocky Mtn. Juniper	8	10	12	20
Scotch pine			13	22
White fir				
Deciduous Trees:				
Black Locust		13	16	25
Bur oak	15	17	19	24
Eastern cottonwood				
Golden willow				
Green ash	11	13	14	28

Hackberry		12	15	26
Honeylocust		13	15	28
Narrowleaf cottonwood				
Osage-orange		10	16	22
Plains cottonwood				42
Russian mulberry				
Siberian elm	16	20	23	32
Shrubs:				
American plum			8	11
Amur honeysuckle		3	5	8
Antelope bitterbrush				
Autumn olive				
Basin big sagebrush	4			
Common chokecherry		6	9	12
Fourwing saltbush				
Hansen rose		4	5	8
Lilac	5	6	7	9
Nanking cherry				
Peking cotoneaster				
Redosier dogwood				
Rubber rabbitbrush				
Saskatoon serviceberry				
Siberian peabush	5	6	7	10
Silver buffaloberry	4	5	7	11
Skunkbush sumac	5	6	7	10
Tatarian honeysuckle	5	6	8	11
Western sandcherry				
Woods rose				

Windbreak suitability Group 9G

Description:
Deep soils with a water table within 5 feet of the surface; some are subject to flooding or ponding; in the upper 12 inches they have a pH of greater than 7.8 and an EC of 4-16 mmhos/cm.

Limitations:
High pH and concentrations of salt are the primary hazards and will affect the selection and growth of trees and shrubs. Spring planting may be delayed because of soil wetness.

Soils:

Alda (saline)	Heldt (salt meadow)
Apishapa	Las Animas
Bloom	Longmont
Dwyer variant	Westplain
Hayford	

ADAPTED SPECIES FOR WINDBREAK GROUP 9G

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine				
Blue spruce				
Douglas-fir				
Eastern redcedar		10	12	23
Pinyon pine				
Ponderosa pine				
Rocky Mtn. Juniper	8	10	12	22
Scotch pine				
White fir				
Deciduous Trees:				
Black Locust				
Bur oak				
Eastern cottonwood				
Golden willow	15	19	12	30
Green ash	12	16	18	26
Hackberry				
Honeylocust	15	17	19	26
Narrowleaf cottonwood	10	15	22	35
Osage-orange				
Plains cottonwood	15	22	30	40
Russian mulberry				
Siberian elm	18	22	25	31
Shrubs:				
American plum				
Amur honeysuckle				
Antelope bitterbrush				
Autumn olive				
Basin big sagebrush				
Common chokecherry				
Fourwing saltbush	5	6		
Hansen rose				
Lilac	5	6	7	9
Nanking cherry				
Peking cotoneaster				
Redosier dogwood				
Rubber rabbitbrush	4			
Saskatoon serviceberry				

Siberian peabush	6	7	9	12
Silver buffaloberry		8	9	10
Skunkbush sumac	4	6	7	10
Tatarian honeysuckle	5	7	8	10
Western sandcherry				
Woods rose				

Windbreak Suitability Group 9N

Description:
Deep soils without a water table within 5 feet of the surface and are not subject to flooding or ponding; in the upper 12 inches they have a pH of greater than 7.8 and an EC of 4-16 mmhos/cm.

Limitations:
High pH and concentrations of salt are the primary hazards and will affect the selection and growth of trees and shrubs.

Soils:

Absted	Koen
Anselmo variant	Laird
Arvada	Lebsack
Avar	Limon
Beckton	Litte
Cadoma	Mosher
Concordia	Nunn (wet)
Deertrail	Nunn variant
Firstview	Ordway
Haverson (saline)	Pultney
Heldt (alkaline plains, salt flats)	Singerton
Keynor	Tyrone

ADAPTED SPECIES FOR WINDBREAK GROUP 9N

MEASURED OR ESTIMATED HEIGHT IN FEET AT AGE 20
BY MOISTURE (ANNUAL PRECIPITATION) SUBGROUP

COMMON NAME	12-15”	15-18"	18"+	PERM. IRRIGATED
Evergreen Coniferous Trees:				
Austrian pine				
Blue spruce				
Douglas-fir				
Eastern redcedar	7	8	9	18
Pinyon pine				
Ponderosa pine	10	11	13	22

Rocky Mtn. Juniper	6	7	8	15
Scotch pine				
White fir				
Deciduous Trees:				
Black Locust				
Bur oak				
Eastern cottonwood				
Golden willow				
Green ash	11	13	14	28
Hackberry				
Honeylocust				
Narrowleaf cottonwood				
Osage-orange				
Plains cottonwood				
Russian mulberry				
Siberian elm	11	13	17	30
Shrubs:				
American plum				
Amur honeysuckle				
Antelope bitterbrush				
Autumn olive				
Basin big sagebrush				
Common chokecherry				
Fourwing saltbush	4			
Hansen rose				
Lilac		5	6	9
Nanking cherry				
Peking cotoneaster				
Redosier dogwood				
Rubber rabbitbrush				
Saskatoon serviceberry				
Siberian peabush	5	6	7	11
Silver buffaloberry		5	7	10
Skunkbush sumac	4	5	6	10
Tatarian honeysuckle	4	5	7	10
Western sandcherry				
Woods rose				

Windbreak suitability Group 10

Description:
Very shallow and shallow soils; soils with a very low available water capacity (AWC <2"); very poorly and poorly drained soils that are saturated or ponded throughout the growing season; and toxic soils.

Limitations:

Soils in this group are generally unsuited for windbreaks. On-site investigations should be carried out to determine if special treatments tailored to the existing soil conditions would allow plantings to survive. The selection of species must be tailored to the soil conditions existing at each site.

Soils:

Bainville	Pleasant
Bernal	Potter
Canyon	Rizozo
Casajo	Samsil
Dix	Schamber
Epping	Shingle
Limon (salt meadow)	Slickens
Lismas	Tassel
Little (stoney)	Travessilla
Midway	Treon
Nihill	Valent (>9%)
Nunn (stoney)	Valentine (>15%)
Penrose	Valmont (>5%)
Playas	

Exhibit 6-10: North Dakota NRCS Specification for Renovation of Windbreaks

CONSERVATION PRACTICE SPECIFICATION
Windbreak/Shelterbelt Renovation – 650

When properly applied, windbreak renovation can:

- Restore the function of an existing windbreak
- Modify the function of an existing windbreak
- Increase the health and vigor of selected windbreak plants
- Increase the longevity of a windbreak

Depending upon the renovation method chosen, some or all of the following practice standards or technical documents may be required when developing a windbreak/shelterbelt renovation plan.

- County-specific windbreak suitability groups for each soil type are found in county specific Interpretive Tables in FOTG – Section II – Soil Information.
- "Tree Care and Management" is found in FOTG – Section I – Reference Subjects – Windbreaks and Woodland.
- "Expected 20-Tree Heights" by Windbreak Suitability Groups is found in FOTG – Section II – Windbreaks and Forest.
- "Tree and Shrub Characteristics" is found in FOTG – Section I – Reference Subjects – Windbreaks and Woodland.
- "Tree/Shrub Pruning – 660." All conservation practices are located in FOTG – Section IV – Conservation Practices.
- "Windbreak/Shelterbelt Establishment – 380."

Caution: Several windbreak renovation methods involve substantial soil disturbance at depths below typical agricultural tillage. If the depth of disturbance will exceed 18 inches, notification of various utility companies via the North Dakota One Call System at 1-800-795-0555 is required.

Several of the windbreak renovation methods are considered undertakings per Section 106 of the Federal Historic Preservation Act and will need to be investigated and assessed accordingly.

Detailed purposes, descriptions and techniques for each renovation method are described below. Following the windbreak renovation descriptions and techniques is a symptom key that can be used to determine which renovation method may be most applicable for a particular windbreak.

Windbreak Renovation Purposes

Coppicing can be used to:

Increase windbreak density or hasten within-row closure on newly established shrub rows.
Rejuvenate broken-down shrubs that have become "leggy" but retain a healthy root system.
Rejuvenate many species of deciduous trees that are experiencing top dieback but still have a healthy root system.

Gap Planting can be used to:

Restore windbreak function or effectiveness.

Natural regeneration can be used to:

Maintain age and species diversity.
Maintain or improve windbreak densities.
Maintain or improve windbreaks for wildlife.

Pruning can be used to:

Reduce the density of a windbreak.
Correct improper branching on newly planted stock.
Correct storm, animal, or agricultural damage to trees or shrubs.
Provide agroforestry products.

Root pruning can be used to:

Reduce windbreak competition to crops immediately adjacent to the windbreak.
Provide a temporary zone of reduced competition for replacement trees within or adjacent to an existing windbreak.

Row removal and replacement can be used to:

Remove dead and dying tree and shrub rows.
Provide a site for replacement plantings within an existing windbreak.
Remove part of an even-aged planting to allow for a diversity of age classes.
Provide agroforestry products.
Alter windbreak composition or density.

Shearing can be used to:

Increase windbreak density.
Reduce spread or extent of the windbreak.
Shape the windbreak to meet a specific objective.
Shape conifers for Christmas trees (agroforestry products).

Sod release and management can be used to:

Release trees and shrubs from herbaceous competition.
Extend the life of the windbreak.
Prepare the site for other renovation methods.

Supplemental planting (intra-planting) can be used to:

Improve windbreak density.
Improve species and age class diversity.
Improve wildlife habitat.
Expand a windbreak.

Thinning can be used to:

Alter windbreak density.
Reduce competition to adjacent trees.
Provide agroforestry products.
Manage snow moisture more effectively.

Underplanting (interplanting) can be used to:

Increase species diversity.
Increase windbreak density, especially lower densities.
Improve windbreak characteristics without expanding windbreak acreage.

Windbreak Renovation Descriptions and Techniques

Renovation recommendations will be site-specific to match landowner objectives, site potential, and the composition and condition of the existing windbreak. Some renovation methods may only need to be applied on an infrequent basis, while others will need regular repetition in order to maximize the benefits.

Coppicing

Coppicing is the removal of the top growth on deciduous trees and shrubs in order that the root systems can initiate healthy vigorous sprouting to improve or restore the function of the windbreak. This technique is applicable to most deciduous shrubs and many of the deciduous trees. Care must be taken to prevent injury to stem, root collars and roots. Cuts should be clean with no ragged ends. Bark of the residual stumps should not be damaged or stripped. Do not use rotary mowers, as they do not produce a clean, non-torn cut. The clipping operation should be done in mid to late winter before any leaf emergence.

For newly planted shrubs, 1-2 years old, existing above-ground stems may be cut off at a 6-8 inch height. This will encourage faster row closure and increased density within the planting. A wide variety of tools can be used to cut off above-ground stems including; sickle bar mowers, hedge clippers, etc.

For older shrub rows, coppicing is an effective way to remove the old, "leggy" material that has lost its windbreak effectiveness. The most commonly used tools to remove older stems are chain saws and power pole pruners. When working on larger shrubs try to leave 6-8 inch stumps above the root collar.

For most shrubs with healthy root systems, re-growth the first year will often reach 30-50% of the precut height.

Figure 1 illustrates 3 different phases of a coppiced shrub renovation.

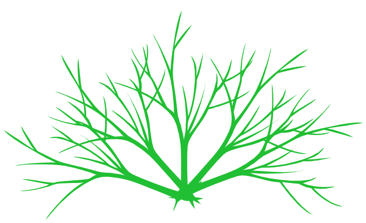


Figure 1a: Leggy, over-mature shrub prior to coppice renovation.

Figure 1b: Top growth removed. 6-8 inch stump remains.

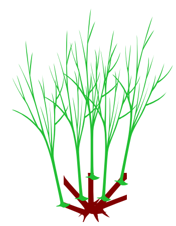


Figure 1c: First year coppice re-growth.

Successful coppicing of older shrubs is dependent upon the shrubs having a reasonably healthy root system. Shrub rows with many gaps, evidence of diseases, and exhibiting minimal annual growth for the past several years may not be suitable candidates for coppice renovation. In these situations coppicing, if used, will need to be supplemented with new plantings.

When using pole pruners or chainsaws, be sure to understand the safe operation requirements of these tools. Wear proper safety equipment. When uncertain of personal skills and abilities, rely on trained professionals to perform the task.

Because of the nature of old shrub rows, chainsaws and pruners will often "bind" in the cut. Using wide loader buckets or other means to take the tension off the stems and "lean" them all one direction will reduce the amount of binding that will occur. Cutting can then proceed on the "up" side of the leaning material. Exercise caution when using saws and pole pruners around tractors and loaders.

Certain deciduous trees exhibit strong tendencies towards coppicing after the main stem has been removed. To determine which species have the greatest chance of being successfully renovated via coppicing, see "Tree and Shrub Characteristics". Deciduous trees shall be cut off to a height of 1-4 inches to encourage a strongly attached sprout arising from the root collar rather than as an advantageous sprout arising from higher locations on the stump.

As with shrub coppicing, care must be taken to prevent injury to the tree stem, root collars and roots. Cuts should be clean with no ragged ends. Bark of the residual stumps should not be damaged or stripped.

Removing the top growth from trees is usually accomplished with chainsaws or specialized tools mounted on skid loaders or tractors. When using chainsaws to fell larger trees, ensure that proper techniques and safety equipment are used. If in doubt, hire someone with the necessary skill, experience, and equipment.

One main difference between coppice regeneration on shrubs versus coppice regeneration on trees is the required maintenance during the first few years after re-growth. In most cases, regenerated trees will require pruning multiple stems to leave only one or two stems per stump prior to the second to fourth growing season.

Select the stem(s) with the best form for the particular species that will meet landowner objectives. Remove remaining sprouts using proper pruning methods. Properly attached sprouts are usually those closest to the ground or arising from the root collar or immediately adjacent roots. Avoid keeping sprouts that are attached high on the stump as they tend to break easily with wind or snow. Waiting a year or two before pruning will allow weather and other site conditions to naturally prune out some of the weaker stems and make it easier to determine which sprouts are the best to leave.

Proper pruning techniques are illustrated and described in "Pruning Trees and Shrubs" http://www.ag.ndsu.edu/pubs/plantsci/trees/h1036.pdf and in Tree/Shrub Pruning - 660.

See figure 2 for illustrations of coppicing deciduous trees.

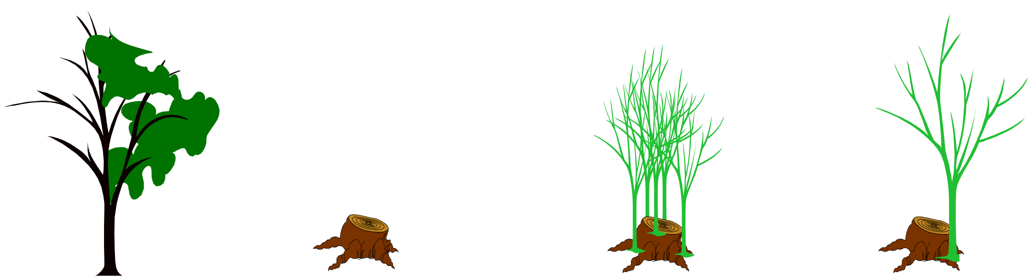


Figure 2a: Tree in a state of decline needing renovation.

Figure 2b: Top removed, leaving 4-6" stump with healthy roots.

Figure 2c: Stump with multiple sprouts first or second year after main tree removal.

Figure 2d: Best sprout selected. Other sprouts pruned in year 3 or 4 after main tree removal.

Gap Planting

Gap planting is the planting of trees or shrubs to fill openings in otherwise healthy windbreaks. Successful gap planting is dependent upon effective weed control, species selection, and water management.

- For all windbreaks needing gap planting:

  Select species appropriate for the soils at the location of the opening in the windbreak. It may have been a soil-related problem that caused the original plants to die.

  Control herbaceous vegetation for one growing season before planting. Be especially diligent in killing perennial sod.

  Establish replacement stock at a spacing appropriate for the species being replanted. See Table 1 of "Windbreak Shelterbelt Establishment" for within-row spacings.

Control weeds after planting with fabric, herbicides, mulch, or tillage. Weed control on plantings to fill gaps is critical since nearby trees and shrubs are competing with the new plant for moisture and nutrients. The newly planted tree or shrub often will not withstand losing additional moisture to weeds. Refer to pages 11-15 of Tree Care and Management for weed control details. Control of aggressive sods and weeds may be needed for many years until replants reach a size to effectively compete with the larger windbreak trees or shrubs.

- For windbreaks less than 5 years old needing gap planting:

  Plant the desired species, either conservation grade stock or larger, at spacings appropriate for the species and the windbreak purpose.

  Refer to pages 3-11 of "Tree Care and Management" for stock handling and planting guidelines.

  Add 10-20 gallons of water every 2 weeks for the first year, when soil around the new plant is dry. Apply in such a way as to thoroughly saturate the root zone of the new tree or shrub.

- For windbreaks over 5 years old

  If site conditions allow, consider root pruning to reduce competition from existing trees or shrubs.

  Pruning or coppicing existing trees may be necessary to reduce shade on new plants.

  Plant new trees or shrubs at a spacing appropriate for each species and windbreak purpose.

  Supplemental water is essential to the successful establishment of replacement trees or shrubs in older windbreaks. Check soil moisture weekly and, provide 20-50 gallons water to each tree or shrub if the soil is dry. Apply in such a way as to thoroughly saturate the root zone of the new tree or shrub.

Natural Regeneration

Natural regeneration is managing the naturally occurring seedlings that develop within the understory of some windbreaks to improve windbreak function. Species such as green ash, basswood, eastern redcedar, honeysuckle, chokecherry, Russian-olive, and buffaloberry will often regenerate naturally within windbreaks.

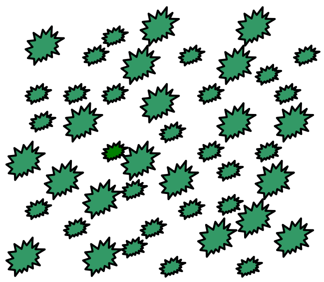
Presence of naturally regenerated trees and shrubs is largely dependent upon the site. Natural regeneration rarely occurs in single-row windbreaks. Full shade, thick sods of grass, or long-term aggressive tillage will often limit the extent of natural regeneration. In North Dakota there is a marked decline in natural regeneration as normal precipitation is reduced from 22 inches to 14 inches from east to west across the state.

Managing natural regeneration usually means thinning competing woody vegetation re-growth in the understory to the desired spacings and controlling herbaceous weeds. Occasionally it involves removing some of the overstory to open the canopy and allow more sunlight to reach the younger plants.

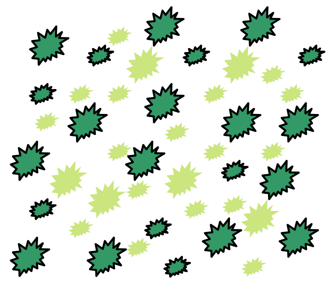
Herbaceous vegetation shall be controlled whenever it begins to adversely affect tree and shrub growth and vigor. Thinning of woody plants can begin once they attain a 3-4 foot height. Plant-to-plant spacings after the thinning operations are dependent upon the purpose of the windbreak.

Generally a residual plant-to-plant spacing of 12-18 feet for large trees, 8-14 feet for medium height trees, and 4-6 feet for the shrub species is appropriate. Mature plant size can be found in "Tree and Shrub Characteristics." These suggested spacings are a bit wider than those for a new windbreak planting, but since thinning operations are so labor intensive, the wider spacings will allow the effects of the thinning to last longer.

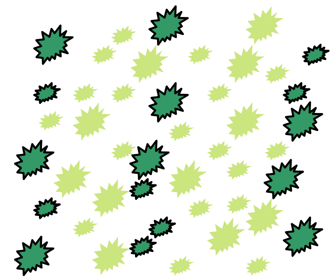
Management of natural regeneration can result in a windbreak that appears to have rows, or it can be managed to look totally natural (no noticeable rows.) See figure 2.



Figurer 2a: Naturally regenerated stand prior to thinning.



Figurer 2b: Naturally regenerated stand, thinned to look natural.



Figurer 2c: Naturally regenerated stand, thinned to rows.

Generally the easiest way to perform a thinning operation in a naturally regenerated windbreak is to walk through the windbreak and mark (with paint or flagging) the plants to be left. Select those plants with the best form for the species that are located approximately where needed to give the desired plant-to-plant spacings. Try to retain a diversity of species when marking for thinning. Remove the remaining plants and saplings.

Removal of unwanted saplings can be done with loppers, axes, chainsaws, powered brush trimmers or pole pruners, etc. In most cases the freshly killed stumps of deciduous species will resprout. To prevent re-sprouting, apply the appropriate herbicide at the correct time. Some herbicides may translocate through root grafts to nearby plants of the same species. Be sure to follow all label directions and precautions. Without chemical stump treatment, thinning operations may have to be performed 2-3 times on the same plant until the residual saplings have attained sufficient height to outgrow the competition.

Where appropriate, consider leaving a few of the larger snags for den trees and roost sites. If compatible with landowner objectives and local ordinances, pruned material could be stacked and left in brush piles for additional wildlife habitat.

<u>Pruning</u>

Pruning is the precise removal of selected branches from trees. For most tree species new tree limbs will not grow from the area pruned, unless pruning was performed incorrectly or the trees were under severe stress. Pruning techniques shall follow the guidance of Tree/Shrub Pruning – 660 or "Pruning Trees and Shrubs."

Pruning to alter windbreak densities will often need to be repeated at a later date to maintain the desired benefits. Remaining tree limbs will often grow (spread) to fill the space left by the pruning.

- Pruning to reduce windbreak density can be done in two ways.

  The first method involves removing all limbs from all trees to a certain height, usually 3-5 feet above the ground. This type of pruning is usually done on field windbreaks to address snow distribution. The result is a windbreak with the same density above the pruned area and essentially no density for the height of the pruning. After a field windbreak has been pruned in this manner, the downwind snowdrift will usually be wider, shallower, and farther away from the tree row. The down side to this method is that the protection to the crop during the growing season will be reduced, especially near the tree row. Wind velocities may be increased somewhat over open field velocities immediately adjacent to the pruned tree row, which may increase wind erosion risks. See figure 3 for the effects of this style of pruning on snow deposition.

The second method involves removing selected limbs throughout the canopy to reduce

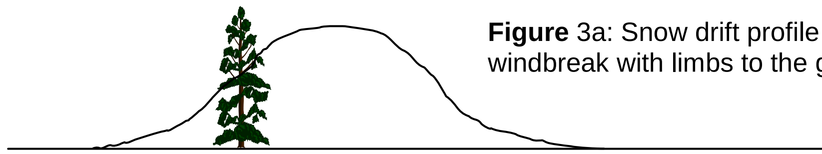


Figure 3a: Snow drift profile behind dense windbreak with limbs to the ground.

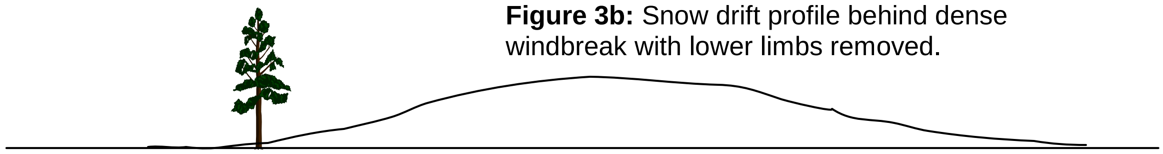


Figure 3b: Snow drift profile behind dense windbreak with lower limbs removed.

overall density of the windbreak to a desired level. This method will look more natural and would be very appropriate where windbreaks are protecting specialty crops that need the proper mix of airflow and protection. It is considerably more labor intensive and would have to be performed more often than the first method.

The zone of protection downwind from a windbreak pruned in this manner would be more uniform than for a windbreak pruned from the bottom up, though snow distribution patterns will be similar.

Best time for either type of pruning is when trees are dormant. (October to February)

Pruning to correct damage or to encourage proper tree form is probably best done whenever the need is noticed. Even though there may be a "best" time to prune, it is usually best to correct problems immediately. If problem-correcting pruning is delayed, the stress to the tree is greater, tree longevity is shortened, and the potential for the operation to be successful is decreased.

Early spring after snow melt is a good time to inspect windbreaks looking for damaged limbs, double leaders and other deformities caused by weather or animals. Using the proper pruning techniques listed at the web sites given above, prune off the damaged parts in a way that encourages rapid callus formation and proper growth forms. Some species, such as green ash, have a strong tendency to form double leaders. Double leaders decrease the longevity and function of the windbreak over time. Pruning to a single leader at the correct time (when limbs are less than one inch in diameter) will result in taller trees that are more wind hardy and will result in fewer limbs falling into adjacent fields. Windbreaks should be examined every year or after every major storm to determine pruning needs.

When scheduling pruning of pine and/or spruce windbreaks, contact local florists, crafters, and others to determine if there is a market for the pruned material. If a market exists for "greens" schedule pruning activities to coincide with market demands.

Root Pruning

Root pruning is a renovation method that severs competing tree roots within the top 18-30" of the soil. Reducing the spread of tree roots reduces the competition to nearby crops or newly planted trees. Root pruning should only be done to one side of a tree or shrub in any given year, to limit the stress to the existing plant.

- Root pruning to reduce crop stress -

  Will usually need to be repeated every 3-4 years to maintain the benefits.

  When performed to reduce crop stress, the root prune line shall be outside the crown drip line of the tree (usually 8-16 feet) to reduce the number and size of tree roots cut and to reduce damage to the tree foliage from the pruning machinery. See figure 3.

For some species of trees, it is best that the root prune line fall within the crop field so that normal cropland tillage or herbicide applications can control the potential re-sprouts from the root pruning.

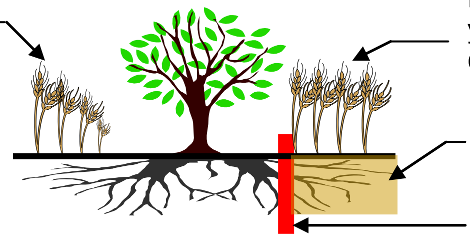


Figure 3: Effects of Root Pruning on Crop Production

- Root pruning to reduce stress to newly planted tree rows. See figure 4.

  Will only provide benefits for 2-3 years.

  The root prune line shall be outside the crown drip line of the tree (8 feet minimum) to reduce the number and size of tree roots cut and to reduce damage to the tree foliage from the pruning machinery.

  Will provide a minimum competition-free zone at least 8 feet wide at planting time.

  Will provide benefits only if adequate weed control is also performed.

  Can increase establishment success when underplanting trees.

  Depending upon species root pruned, root sprouts will need to be controlled.

  Is not as critical if the new tree row is at least 30 feet from the nearest established tree row.

  May be stressful to the remaining windbreak trees.

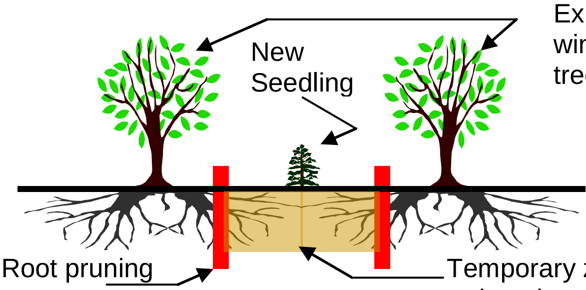


Figure 4: Root pruning to reduce stress on new trees

<u>Row Removal and Replacement</u>

At a minimum this renovation method removes the top growth of dead and dying trees. Traditionally it has often included the removal of stumps and roots and the leveling of the renovation site. Tops may be removed by an assortment of tools and machines such as chainsaws, hydraulic shears, hydraulic saws, PTO-driven saws, dozers, endloaders, etc. Root and stump removal and site leveling are often done with construction equipment or larger agricultural equipment.

In multirow windbreaks where removal and replacement will occur within the windbreak, one additional row will be removed beyond the number of rows to be replaced. Ex: remove 3, plant 2. This requirement is necessary to provide enough growing space for the replacement plantings. This requirement is not necessary in situations, without existing cottonwoods, where existing between-row spacings exceeded 25 feet.

Replacement plants may be planted in, or near the location of the old tree row, or they may be planted in a more distant location as long as the new windbreak(s) protect the same area or acreage.

If new trees or shrubs are to be established in the area of the old windbreak, re-sprouts will be controlled and the site will be fallowed at least one growing season before attempting to plant the new windbreak.

Perennial sod-forming grasses will be controlled for at least one growing season prior to planting the new trees or shrubs.

Tops of American elm and Siberian elm will be disposed of by burning, burying, chipping or debarking to reduce the risk of spreading Dutch elm disease. Elm wood disposal shall occur immediately if removal is during the growing season or before the next growing season if removed during the fall or winter. When this is not possible, disposal should occur within one year after removal.

Other species of woody material may be burned, buried, hauled away or left in piles as long as applicable local and state laws are followed and the disposal method meets landowner objectives. Consider burning, or burying other species if infected with diseases or infested with insects that may spread to nearby trees. Some, but <u>not all</u> of the laws that may apply to row removal and replacement include:

Open burning permit requirements, restrictions and liabilities.

Local ordinances regarding disposal of elm wood.

Potential impacts on cultural resources. NRCS policy lists the procedures to be followed.

Location of buried utilities. NRCS policy lists the procedures to be followed.

In multirow windbreaks where a stand of larger trees will remain after the row removal, consider leaving hollow trees as den sites and a few of the larger dead trees as raptor roost sites.

- Row removal including stumps and roots

  Site will be leveled after removals to allow for planting and maintenance with normally available equipment.

  Planting may be by any method that results in a healthy, vigorously growing tree or shrub. Refer to pages 8-11 of "Tree Care and Management."

  Use extreme caution when replanting sites that have been leveled after stump and root removal. Buried woody debris can be hooked by moving machinery and thrust at people on the tree planter. Ensure protective shields are in place or take other precautions to minimize risks to operators.

- Row removal taking only the tops and leaving the stumps and roots

  Stumps will be left short enough to not impede subsequent management operations.

  Live stumps will be treated with an approved herbicide immediately after cutting to prohibit resprouting. (If resprouting is desired, follow guidance under Coppicing.)

  Planting may be by any method that results in a healthy, vigorously growing tree or shrub. Due to the presence of stumps and roots, planting methods may be limited or must be modified. Often traditional tree planters will function well within a few feet of the stump row, especially when equipped with a coulter. When planting within the old stump rows, hydraulic augers work well to dig the hole, which allows for easy and proper hand planting. See figure 5. Refer to pages 8-11 of "Tree Care and Management." Though the risk of hooking roots that are buried in the soil may be less than on a leveled site, exercise caution and ensure protective shields are in place.

Maintenance operations may have to be modified on sites where new trees have been planted within the old tree row or immediately adjacent to the old tree row. Machine-applied fabric and in-row tillage are often not possible due to the remaining roots and stumps. Hand-placed and pinned fabric, mulching, warm-season grass seedings, herbicides, and careful tillage are alternative weed control methods that are appropriate- depending upon the site.

Continued control of resprouting may be needed for 1-2 years after the initial treatment. Effectiveness of initial treatment is dependent upon species, chemical, time of year, and growth stage of plant.

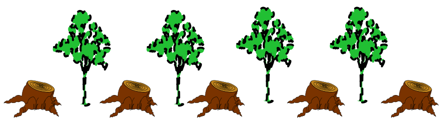


Figure 5a: Replacement trees hand-planted between dead stumps

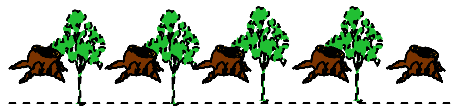


Figure 5b: Replacement trees machine-planted close to dead stumps

Shearing

For reduced stress to the plant, reduced debris needing removal, and to reduce machine and labor requirements, shearing should be done as frequently as needed to refrain from cutting twigs and branches older than two years. If the condition of the windbreak has deteriorated to the point that larger limbs need to be removed, refer to Coppicing or Pruning.

Shearing is most often done on conifers managed for Christmas trees but can be effective on deciduous plants. Deciduous plants will often grow faster and require more frequent shearing. Shearing usually will increase windbreak density, no matter the owner’s objective.

Shearing shall be done with tools that leave a clean, smooth cut. Damage to main stems and root systems will be negligible. Shearing will not be done with side boom rotary mowers, brush cutters, or flails.

When performed on young succulent branches, shearing can be performed with a wide assortment of tools, such as hedge trimmers, sickle-bar mowers, etc. These types of tools provide desirable, clean cuts, but may be damaged if forced to cut older limbs.

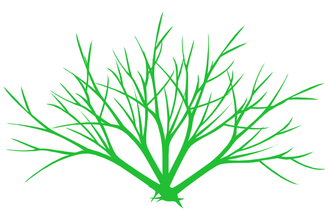


Figure 6a: Shrub with wide spread and tall height

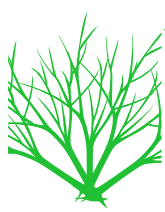


Figure 6b: Shrub sheared to reduce spread

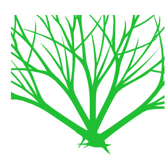


Figure 6c: Shrub sheared to reduce height and spread

- To increase windbreak density

  This application is useful to increase the effectiveness of a windbreak as a visual screen or noise barrier. Final shape and appearance are dependent upon landowner desires and specific plant characteristics.

- To reduce spread or extent of windbreak

  This application can constrain the plants and minimize the amount of land taken out of production. It may also control the tops of windbreaks to allow for effective operations of center-pivot irrigation systems or other uses. See figure 6.

- To shape conifers for Christmas trees or resale.

  Follow the recommendations found in "Christmas Trees, a Management Guide" - Nebraska Cooperative Extension EC 76-1741 http://www.ianr.unl.edu/pubs/Forestry/ec1741.htm#shape or

  "Shearing Recommendations for Christmas Tree Producers" http://web1.msue.msu.edu/aoe/xmas/ncr310.PDF

  When managing a windbreak for Christmas tree production, ensure that the minimum number of trees, and/or tree rows are left to maintain the function of the windbreak. Refer to "Windbreak Shelterbelt Establishment" for the minimum number or rows and trees per row to fulfill a particular function.

Sod Release and Management is the control and management of herbaceous weeds, particularly sod-forming grasses, in order to reduce the stress on windbreak plants and prepare the site for other renovation methods.

- Releasing trees or shrubs from herbaceous competition

  For maximum effectiveness, sod-forming grasses will be controlled as early as possible in their growth stage, consistent with the control method chosen. Generally, the sods will be tilled or mowed or sprayed before the grasses get much taller than 3 inches.

  When using herbicides to control sods and weeds, follow the label directions as they relate to the stage of weed growth for proper application timing. All herbicides will be applied according to label regulations with particular care to minimize damage to trees and shrubs. Several applications may be needed for adequate control. Operations may have to be repeated yearly. Generally, herbicides are most effective in controlling sods when applied to green succulent leaves in late summer or early fall. Many of the effective herbicides work on contact or via translocation. Avoid contact of these products on young bark or green leaves of trees or shrubs. Be alert to potential long-term herbicide buildup.

  If tillage is used, it will not be deeper than 3 inches to minimize root damage. Tillage will not be performed within 1 foot of the trunk of the tree or shrub. Numerous applications (3-6 depending upon yearly moisture and weed species) will be needed each year. Each application runs the risk of mechanically damaging the trees and shrubs.

  If mowing is used it will be applied in such a way as to maximize the stress to the sod while minimizing stress- such as bark injury or soil compaction- to the woody plants. Mow before herbaceous vegetation reaches a 4-inch height and mow as short as possible without damaging the mower. Weather conditions often dictate frequency of mowing.

- Preparing the site for replanting

  The primary purpose of this renovation method is to reduce herbaceous competition on trees and shrubs.

  Guidelines for herbicides and tillage release of sod-bound trees will be followed with the following additional stipulation; Tillage and/or herbicides will be applied in such a way that the sod is completely killed for one growing season before new trees or shrubs are planted. Refer to pages 4-8 of "Tree Care and Management" for site preparation details.

  Mowing **is not** appropriate for this purpose.

Supplemental planting (intra-planting) is nothing more than establishing a new windbreak adjacent to an existing windbreak. Refer to the following tools for specific requirements of designing a supplemental planting.

County-specific windbreak suitability groups for each soil type are found in county specific Interpretive tables in FOTG – Section II – Soil Information.

Estimated 20-year tree heights and determining which tree species are appropriate for planting on which soils can be found in "Expected 20-Year Tree Heights" by Windbreak Suitability Groups, located in FOTG – Section I – Reference Subjects – Windbreaks and Woodland.

Planting stock, stock handling, site preparation, planting techniques, and maintenance details are found in "Tree Care and Management"

Design Requirements to meet a specific purpose are found in "Windbreak Shelterbelt Establishment"

“Tree and Shrub Characteristics”

Newly planted windbreak rows shall be no closer than 40 feet if the nearest adjacent row in the existing planting is a deciduous tree, spruce or suckering shrub.

Newly planted windbreak rows shall be no closer than 20 feet if the nearest adjacent row in the existing planting is a conifer (not spruce) or non-suckering shrub.

Thinning is a method that removes selected plants from a windbreak. Exercise caution when selecting trees to be thinned so that the function of the windbreak is not radically impaired.

Removal can be accomplished with chainsaws, tree spades, handsaws, brush cutters, tree shears, hydraulic saws or some other tool or machine. Rarely will the roots be removed, except in situations where tree spades are used to remove live trees for transplanting. Serious damage to the root systems of remaining trees or shrubs will likely occur if attempts are made to remove the roots of the thinned trees with tools other than a tree spade. (Root damage is still a possibility with a tree spade but the risk is smaller as long as the windbreak is 20 years old or less.)

Tree and shrub tops shall be removed in such a manner that residual stumps and the debris from the thinning operation do not impede subsequent management operations. Tops may be removed from the site, stacked or cut "low and short" and left where they fall. Manage the debris from the thinning in a way that is compatible with landowner objectives.

Debris from Siberian elm or American elm must be chipped, burned or buried to reduce risk of spreading Dutch elm disease. Elm wood disposal shall occur immediately if removal is during the growing season or before the next growing season if removed during the fall or winter. When this is not possible, disposal should occur within one year after removal.

Depending upon the species thinned, stump resprouting may have to be addressed. Repeat thinning operations or treatment with herbicides may be appropriate. Method chosen will depend upon the reason for the thinning. There may be a risk of selected herbicides being translocated from the treated stump to the adjacent tree or shrub via root grafts. Not all species readily develop root grafts. Root grafting does not occur between plants of different species.

- To alter windbreak density

  Ensure that the windbreak maintains enough density to meet the objectives of the landowner after any thinning operation. Depending upon thinning intensity, windbreak function may be reduced for several years after thinning. To reduce this effect do not thin all rows of a multirow windbreak at the same time, or establish new tree or shrub rows several years before thinning.

  Single-row windbreaks

Thinning consists of removing every other plant within the row to reduce density to the desired level. This type of thinning is most often utilized to reduce windbreak density and alter snow distribution patterns. See figure 7. Drift

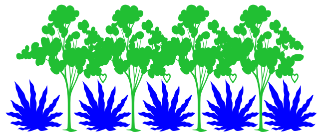


Figure 7a: Dense windbreak before thinning, causing deep snowdrifts.

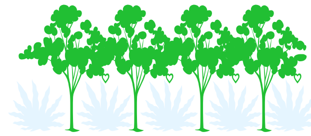


Figure 7b: Dense windbreak after thinning, spreading snow farther across the field.

configurations after thinning will be somewhat similar to figure 3b.

Stump re-sprouts are usually not desirable and shall be controlled. Extensive stump sprouting will often make snow distribution problems worse. If re-sprouts are desirable, refer to coppicing for details on management.

Multi-row windbreaks

Thinning consists of removing every other or every third plant within the selected row(s). It may also be done in such a matter that plant removals from several rows will result in the desired plant-to-plant spacings.

Stump re-sprouts may or may not be a problem. Control re-sprouts, if needed, by herbicides or repeated removals in a way that does not damage the remaining windbreak. If re-sprouts are desirable, refer to coppicing for details on management.

- To reduce competition to adjacent trees

  Thinning consists of removing selected trees or shrubs in a manner that leaves more growing space for each of the remaining trees or shrubs. Thinning may remove every other or every third plant within the selected row. It may also be done in such a matter that plant removals from several rows will result in the desired plant-to-plant spacings. Thinning is a key function in managing natural regeneration. A residual plant-to-plant spacing of 4-6 feet is appropriate for shrubs and 12-18 feet is appropriate for large trees.

  Thinning of conifers shall occur before adjacent tree canopies overlap by more than 2-3 feet throughout ¼ to ½ their height. Extended periods of overlapping limbs throughout much of the canopy will result in dieback of the limbs on conifers and a loss of windbreak function. Timely thinning will prevent such windbreaks from "pruning themselves up" and reduce the likelihood and/or severity of some fungal diseases, especially on spruce.

- To provide agroforestry products

  Depending upon the species and local markets, thinning efforts can be funded in part by the harvest and sale of agroforestry products such as Christmas trees and greens, vines, decorative twigs, or pine straw. Potential for agroforestry markets is dependent upon landowner objectives, presence of markets, and the products to be harvested.

Underplanting

Underplanting is the addition of trees or shrubs under the canopy of an existing windbreak. See figure 8. Often this type of renovation is appropriate for restoring function to a windbreak that has lost density in the lower portion of the canopy. In the absence of row removal and/or extensive pruning, species selected for underplanting shall be selected for a level of shade tolerance appropriate to the level of canopy in the existing windbreak. Refer to "Tree and Shrub Characteristics" to determine shade tolerances of individual species.

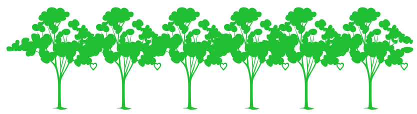


Figure 8a: Windbreak with reduced density in lower crown allowing wind and snow to blow through into areas needing protection.

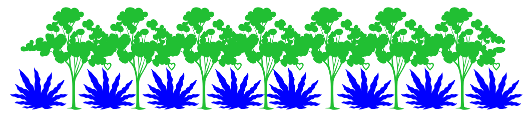


Figure 8b: Windbreak renovated by establishing shade-tolerant trees or shrubs in understory.

Site preparation methods to control herbaceous weeds and sod shall be appropriate for the weed pressure. Sites with sods, deep-rooted legumes, or noxious weeds shall be fallowed for at least one season prior to planting in order to control vegetation and store moisture for the newer plants.

Where room permits, and based on the competitiveness of adjacent tree species, root pruning to provide a zone of reduced competition for several years will benefit the new planting. See root pruning for details.

Species selected for underplanting shall be shade-tolerant and suitable for planting on the soils at the planting site.

KEY TO DETERMINE APPROPRIATE RENOVATION METHOD *

<u>Field Windbreak Key</u>

1. The windbreak forms a complete barrier with no gaps; trees appear healthy and vigorous with few dead branches and no insect or disease problems. No noxious weeds or sod-forming grasses are present. The windbreak is meeting all of landowner objectives. No renovation is needed, continue annual maintenance program.

1. The windbreak appears unhealthy; trees may be overcrowded or protection is not adequate; individual trees are in poor condition with many dead branches. Noxious weeds or sod-forming grasses may be present. Over all, the windbreak fails to meet landowner objectives. Go to 2.

    2. Sod-forming grasses or noxious weeds are present. See Sod Release and Management.

    2. Sod-forming grasses or noxious weeds are not present. Go to 3.

        3. Individual trees in the windbreak appear healthy but there are large gaps (two or more adjacent trees are missing) in the windbreak. See Gap Planting.

        3. There are no large gaps in the windbreak. Go to 4.

            4. The density of the windbreak is low (less than 30 percent), especially in the lower one-third. The windbreak fails to provide sufficient wind erosion control or crop protection. See Underplanting or Supplemental Planting.

            4. The density of the windbreak is high (more than 50 percent) and there is adequate wind erosion control. However, deep snowdrifts form that restrict field access in the spring. See Thinning or Pruning.

            4. The density is about right to meet landowner objectives but there are problems not identified above. Go to 5.

                5. Individual trees have insects or diseases present. Contact a local tree care professional to determine the insect or disease present and the proper treatment. Treat only if necessary.

5. Windbreaks are in good condition and meet landowner's primary objectives but could be improved for wildlife. Consider adding a shrub row or leaving several rows of unharvested crop adjacent to the windbreak for wildlife. See Windbreaks and Wildlife http://www.ianr.unl.edu/pubs/Forestry/ec1771.htm or "Tree and Shrub Characteristics".

5. Windbreaks are in good condition but crop yields next to the windbreak are low. See Root Pruning.

5. Windbreaks are in good condition, but they are over 25 years old and it is time to plan for the future. See Supplemental Planting, Underplanting, or Coppicing.

<u>Farmstead and Livestock Windbreak Key</u>

1. The windbreak appears healthy and vigorous with few dead branches and no insect or disease problems. The trees are well spaced within rows and between rows.

    2. There is a good mix of deciduous and coniferous tree and shrub species; trees are of several ages. No renovation is needed, continue annual maintenance program.

    2. Windbreak is composed of a single species and all trees are approximated the same ages. See Supplemental Planting or Underplanting.

1. The windbreak appears unhealthy; individual trees are in poor condition; density may be too low or too high to meet landowner objectives.

    3. Sod-forming grasses or noxious weeds are present. See Sod Release and Management

    3. Sod-forming grasses or noxious weeds are not present. Go to 4.

        4. Insects or diseases are present. Contact a local tree care professional to determine the insect or disease present and the proper treatment. Treat only if necessary.

        4. Insects or diseases are not present. Go to 5.

            5. Trees are overcrowded. See Thinning.

            5. Trees are not overcrowded; density is low and wind protection is limited. See Coppicing, Underplanting, Natural Regeneration, Shearing, or Supplemental Planting.

*The Field Windbreak Key and the Farmstead and Livestock Windbreak Key were adapted from "Windbreak Renovation" University of Nebraska Cooperative Extension EC 98-1777-x; by Craig Stange, USDA Natural Resources Conservation Service; Jon Wilson and Jim Brandle, University of Nebraska; and Mike Kuhns, Utah State University

Exhibit 7-1: Web Soil Survey Soil Report Information for Selected Practices

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD

ANIONIC POLYACRYLAMIDE (PAM) APPLICATION

CODE 450

Idaho NRCS: Boise, Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
peat or organic matter surface horizons	surface texture
slope	slope
sodium adsorption ratio (SAR)	soil chemical properties
soil texture (surface)	surface texture

Web Soil Survey Related Items	Soil Data Explorer Tab		
	Suitabilities and Limitations	Soil Properties and Qualities	Soil Reports
slope		Soil Qualities and Features: Representative Slope	AOI Inventory: Component Legend
surface texture		Soil Physical Properties: Surface Texture	Soil Physical Properties: Engineering Properties
Sodium adsorption ratio		Soil Chemical properties: Sodium Adsorption Ratio	Soil Chemical Properties

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD
BRUSH MANAGEMENT
CODE 314

Idaho NRCS: Boise, Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
ecological site[1]	ecological site

[1]Ecological site information is available in the Web Soil Survey by clicking on a separate tab, labelled "Ecological Site Assessment", that is located between the Soil Properties and Qualities tab and the Soil Reports tab. **Ecological site information is not available for all soils or for all areas at this time.**

Web Soil Survey Related Items	Soil Data Explorer Tab		
	Suitabilities and Limitations	Soil Properties and Qualities	Soil Reports
ecological site			

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD

CRITICAL AREA PLANTING

CODE 342

Idaho NRCS: Boise Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
erosion from wind and water	erosion factors Kw, Kf, T wind erodibility group wind erodibility index
soil conditions	map unit description

<table>
<tr><th rowspan="2">Web Soil Survey Related Items</th><th colspan="3">Soil Data Explorer Tab</th></tr>
<tr><th>Suitabilities and Limitations</th><th>Soil Properties and Qualities</th><th>Soil Reports</th></tr>
<tr><td rowspan="2">erosion factors:
Kw
Kf
T
wind erodibility group
wind erodibility index</td><td rowspan="2"></td><td rowspan="2">Soil Erosion Factors:
K Factor, Rock Free
K Factor, Whole Soil
T Factor
Wind Erodibility Group
Wind Erodibility Index</td><td>Soil Erosion:
Conservation Planning</td></tr>
<tr><td>Soil Physical Properties:
Physical Soil Properties</td></tr>
<tr><td>map unit description</td><td></td><td></td><td>AOI Inventory:
Map Unit Description (Brief, Generated)</td></tr>
</table>

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD
FORAGE AND BIOMASS PLANTING
CODE 512

Idaho NRCS: Boise, Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
soil condition and landscape position attributes such as:	refer to items listed below
available water holding capacity[1]	available water capacity available water storage available water supply
depth	depth to soil restrictive layer
drainage class	drainage class
flooding	flooding frequency
ponding	ponding frequency
salinity	a concern for some soils in Idaho
slope	slope
soil pH	soil reaction (pH)

[1]Available water capacity (AWC) is given in cm of water per cm or soil (or in per in) for each soil layer. Available water storage and available water supply are calculated as the AWC times the thickness of each soil layer, summed to a specified depth.

Web Soil Survey Related Items	Soil Data Explorer Tab		
	Suitabilities and Limitations	Soil Properties and Qualities	Soil Reports
available water capacity		Soil Physical Properties: Available Water Capacity	Soil Physical Properties: Physical Soil Properties
available water storage		Soil Physical Properties: Available Water Storage	
available water supply		Soil Physical Properties: Available Water Supply	
depth to soil restrictive layer		Soil Qualities and Features: Depth to Any Soil Restrictive Layer	Soil Qualities and Features: Soil Features
drainage class		Soil Qualities and Features: Drainage class	
flooding frequency		Water Features: Flooding Frequency Class	Water Features: Water Features
ponding frequency		Water Features: Ponding Frequency Class	
slope		Soil Qualities and Features: Representative Slope	AOI Inventory: Component Legend
soil reaction (pH)		Soil Chemical Properties: pH (1 to 1 Water), EC, SAR	Soil Chemical Properties: Chemical Soil Properties

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD

HEAVY USE AREA PROTECTION

CODE 561

Idaho NRCS: Boise, Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
bearing capacity of the soil	Unified Soil Classification
sites that need drainage	depth to water table drainage class

Web Soil Survey Related Items	Soil Data Explorer Tab		
	Suitabilities and Limitations	Soil Properties and Qualities	Soil Reports
depth to water table		Water Features: Depth to Water Table	Water Features: Water Features
drainage class		Soil Qualities and Features: Drainage Class	
Unified Soil Classification		Soil Qualities and Features: Unified Soil Classification (surface)	Soil Physical Properties: Engineering Properties

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD
HERBACEOUS WEED CONTROL
CODE 315

Idaho NRCS: Boise, Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
ecological site description (ESD)	ecological site[1]
organic matter	organic matter
soil erosion potential	erosion factors Kw, Kf, T
soil map	soil map tab[2]
soil texture	soil texture

Web Soil Survey Related Items	Soil Data Explorer Tab		
	Suitabilities and Limitations	Soil Properties and Qualities	Soil Reports
ecological site[1]			
erosion factors: Kw Kf T		Soil Erosion Factors: K Factor, Rock Free K Factor, Whole Soil T Factor	Soil Erosion: Conservation Planning
			Soil Physical Properties: Physical Soil Properties
organic matter		Soil Physical Properties: Organic Matter	Soil Physical Properties: Physical Soil Properties
		Soil Health: Soil Health – Organic Matter	Soil Health: Soil Health – Organic Matter
soil texture		Soil Physical Properties: Surface Texture	Soil Physical Properties: Engineering Properties

[1]Ecological site information is available in the Web Soil Survey by clicking on a separate tab, labelled “Ecological Site Assessment”, that is located between the Soil Properties and Qualities tab and the Soil Reports tab. Ecological site information is not available for all soils or for all areas at this time.

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv’s) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

[2]A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD
PRESCRIBED BURNING
CODE 338

Idaho NRCS: Boise, Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
ecological sites	ecological site[1]
location of wetlands	hydric soils[2]
soil and site conditions	map unit description

[1]Ecological site information is available in the Web Soil Survey by clicking on a separate tab, labelled "Ecological Site Assessment", that is located between the Soil Properties and Qualities tab and the Soil Reports tab. **Ecological site information is not available for all soils or for all areas at this time.**

[2]Hydric soils are not synonymous with wetlands, but hydric soils are one of the 3 wetland factors/parameters required for an area to be considered a wetland.

Web Soil Survey Related Items	Soil Data Explorer Tab		
	Suitabilities and Limitations	Soil Properties and Qualities	Soil Reports
hydric soils	Land Classifications: Hydric Rating by Map Unit		Land Classifications: Hydric Soils
map unit description			AOI Inventory: Map Unit Description (Brief, Generated)

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD
PRESCRIBED GRAZING
CODE 528

Idaho NRCS: Boise Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
ecological site or forage suitability group	ecological site[1]
flooding	flooding

[1]Ecological site information is available in the Web Soil Survey by clicking on a separate tab, labelled "Ecological Site Assessment", that is located between the Soil Properties and Qualities tab and the Soil Reports tab. **Ecological site information is not available for all soils or for all areas at this time.**

Web Soil Survey Related Items	Soil Data Explorer Tab		
	Suitabilities and Limitations	Soil Properties and Qualities	Soil Reports
flooding		Water Features: Flooding Frequency Class	Water Features: Water Features

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD

RESTORATION AND MANAGEMENT OF RARE OR DECLINING HABITATS

CODE 643

Idaho NRCS: Boise, Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
ecological site Description (ESD)	ecological site[1]

[1]Ecological site information is available in the Web Soil Survey by clicking on a separate tab, labelled "Ecological Site Assessment", that is located between the Soil Properties and Qualities tab and the Soil Reports tab. **Ecological site information is not available for all soils or for all areas at this time.**

Web Soil Survey Related Items	Soil Data Explorer Tab		
	Suitabilities and Limitations	Soil Properties and Qualities	Soil Reports

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD

SILVOPASTURE

CODE 381

Idaho NRCS: Boise, Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
description of the soils	map unit description
ecological sites	ecological site[1]
soil conditions of the site	map unit description
soils map	soil map[2]

Web Soil Survey Related Items	Soil Data Explorer Tab		
	Suitabilities and Limitations	Soil Properties and Qualities	Soil Reports
ecological site[1]			
map unit description			AOI Inventory: Map Unit Description (Brief, Generated)

[1]Ecological site information is available in the Web Soil Survey by clicking on a separate tab, labelled "Ecological Site Assessment", that is located between the Soil Properties and Qualities tab and the Soil Reports tab. Ecological site information is not available for all soils or for all areas at this time.

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

[2]*A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.*

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD
WATER HARVESTING CATCHMENT
CODE 636

Idaho NRCS: Boise, Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
rock outcrops[1]	depth to bedrock (lithic bedrock)

[1]Some small areas of rock outcrop may be designated as spot symbols on the maps in the WSS.

Web Soil Survey Related Items	Soil Data Explorer Tab		
	Suitabilities and Limitations	Soil Properties and Qualities	Soil Reports
depth to bedrock (lithic bedrock)		Soil Qualities and Features: Depth to a Selected Soil Restrictive Layer (lithic bedrock)	Soil Qualities and Features: Soil Features

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Soil Report Considerations for:

CONSERVATION PRACTICE STANDARD
WATERING FACILITY
CODE 614

Idaho NRCS: Boise, Idaho

Soil Concerns Stated in Standard	Web Soil Survey (WSS) Related Items
suitable soils	map unit description

<table>
<tr><th rowspan="2">Web Soil Survey Related Items</th><th colspan="3">Soil Data Explorer Tab</th></tr>
<tr><th>Suitabilities and Limitations</th><th>Soil Properties and Qualities</th><th>Soil Reports</th></tr>
<tr><td>map unit description</td><td></td><td></td><td>AOI Inventory:
Map Unit Description (Brief, Generated)</td></tr>
</table>

Note: The Suitabilities and Limitations, and the Soil Properties and Qualities options in WSS are designed to aggregate data and return a single rating or value for each map unit. The single value is typically either for the surface layer, or it is a weighted average for a specified depth range. This is done to facilitate the creation of a thematic map for the selected item. Representative values (rv's) are used, rather than the range in properties, and depth measurements are generally displayed in centimeters. The Soil Reports option generally provides the range in values for each soil component and depth measurements are generally displayed in inches or feet; however, results are tabular only.

A soil map and map legend of the area can be generated from the WSS through the Soil Map tab. Soil maps were published at certain scales. Site specific practices may require onsite investigation.

Exhibit 8-1: Enhancement Bundle Worksheet

United States Department of Agriculture

CROPLAND ENHANCEMENT BUNDLE

CONSERVATION STEWARDSHIP PROGRAM

B000CPL9

Crop Bundle #9 - "Organic", Wind Erosion

Conservation Practices 340: Cover Crop; 328: Conservation Crop Rotation; 345: Residue and Tillage Management, Reduced Till; 590: Nutrient Management; and an option for 595: Integrated Pest Management or 327: Conservation Cover

APPLICABLE LAND USE: Crop (annual & mixed)

RESOURCE CONCERNS ADDRESSED: Soil Erosion, Soil Quality Degradation, Water Quality Degradation and/or Fish/Wildlife Habitat

BUNDLE LIFE SPAN: 5 years

Enhancement Description

By implementing this combination of enhancements together, a synergy is achieved that should result in more conservation benefits than would be expected from implementing the enhancements individually. Applicants that choose to implement this bundle will receive additional ranking points and a higher payment rate.

Criteria

- All of the component enhancements in the required group, along with one additional component enhancement, must be adopted as shown in the table below.
- If an applicant has already adopted one or more component enhancements within a bundle, the applicant may schedule the bundle as long as the applicant is newly adopting the majority (more than 50 percent) of the component enhancements within the bundle.
- Applicants may choose to adopt a bundle on any portion of the agricultural operation and will be required to install component enhancements on all applicable acres where the bundle is adopted.

CONSERVATION STEWARDSHIP PROGRAM

- The bundle is scheduled in the year in which all component enhancements in the bundle are applied but no later than the third fiscal year of the contract.
- The bundle, once adopted, may continue to be implemented in all subsequent years through the end of the contract.

Documentation and Implementation Requirements

Participant will:

- ☐ Follow the documentation and implementation requirements outlined in the respective enhancement job sheets to document the implementation of each component enhancement in the bundle.
- ☐ Prior to and after implementation, document the planned amount, fields, applied amount and the year each component enhancement in the bundle is applied:

Component Enhancement Code	Tract, Field No. or Name	Planned Amount (units)	Applied Amount (units)	Year(s)
ADOPT ALL REQUIRED COMPONENT ENHANCEMENTS FROM THIS GROUP				
E340102Z				
E328106Z2				
E345106Z				
E590118Z				
ADOPT ONE ADDITIONAL COMPONENT ENHANCEMENT FROM THIS GROUP				
E327136Z1				
E327137Z				
E595116Z				

NRCS Documentation Review:

CONSERVATION STEWARDSHIP PROGRAM

I have reviewed all required participant documentation and have determined the participant has implemented the bundle and met all criteria and requirements.

Participant Name ________________________________ Contract Number ________________

Total Amount Applied _______________________ Fiscal Year Completed ___________

_______________________________________ ________________

NRCS Technical Adequacy Signature Date

Appendix C : NRCS T-Charts for Conservation Practices

Conservation Practice Effects

Alley Cropping (Ac) 311

<u>Definition:</u> Trees or shrubs planted in a set or series of single or multiple rows with agronomic, horticultural crops or forages produced in the alleys between the rows of woody plants.

<u>Major Resource Concerns Addressed:</u> Wind erosion, soil health, wildlife habitat.

<u>Benchmark Condition:</u> Small grain, hay crop rotation.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind and gulley erosion is reduced by vegetation, surface litter, tall vegetation and wind shadow. • Roots and vegetative matter from permanent vegetation increases organic matter. • Root penetration and organic matter helps restore soil structure and reduces compaction. **Water** • Runoff, flooding and ponding are reduced, less runoff with increased water infiltration. • Seasonal high water table and seeps are reduced with greater plant water uptake. • Drifted snow is captured by tree/shrub crowns and deposited between rows. • Tall vegetation reduces wind speeds and evapotranspiration allowing more efficient use of available water. • Trees and shrubs intercept pesticide drift and take up pesticide and nutrient	**Land** • Cultural resources may be adversely effected during tree planting. • Increased complexity of land use, producing two or more crops. • Change to less intense land use, some land converted from crop to tree production. • No additional field equipment required. **Capital** • Site preparation and tree planting costs. • Operation and maintenance costs maintaining vegetation and managing pests. **Labor** • Reduced labor with less intensive agriculture. **Management** • Increase to manage additional farm enterprise. **Risk** • Decrease in farm flexibility while

residues. • Nutrients and pesticides in surface and ground water will decrease as plant vigor improves soil conditions. • Pathogens and chemicals from manure in surface and groundwater will be reduced in sensitive areas. • Sediment in surface water will be reduced. • High water temperature will be reduced. • Petroleum, heavy metals and other pollutants in surface and groundwater will be reduced. Air • Trees provide windbreak and reduce saltating particles. • Vegetation removes CO2 from the air and stores it as carbon in plants and soil. Plants • Crops are sheltered from airborne sediment and chemical drift. • Plant productivity will increase. Animals • Fish, wildlife and livestock habitat, food, water, cover and shelter will improve for some species. • Wildlife habitat continuity (space) will improve, tall vegetation creates vertical habitat structure. • Trees can limit livestock heat stress. Energy • Comparatively energy-efficient. • Potential biofuel production. Human • Increase yields/reduce costs as land becomes more productive. • Create sustainability of natural resources that support your business. • Increase the property value (real estate) of your property.	following designed cropping pattern around perennial plantings. • Cash flow will decrease with less intense agricultural production. • Crops must be adapted and managed to account for use of available water by trees. • Foregone income from lost production or change in seasonal use.

• **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.**	
Net Effect: **Alley Cropping improves soil productivity, reduces erosion at a moderate cost.**	

Commonly Associated Practices: Conservation Crop Rotation, Contour Buffer Strips, Contour Farming, Cover Crop, Forest Stand Improvement, Integrated Pest Management, Multi-Story Cropping, Nutrient Management, Residue and Tillage Management, Mulch Till, Residue and Tillage Management, No Till/Strip Till/Direct Seed, Residue and Tillage Management, Ridge Till, Residue Management, Seasonal, Tree/Shrub Establishment, Tree/Shrub Pruning, Tree/Shrub Site Preparation, Woody Residue Treatment

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Amending Soil Properties with Gypsum Products (Ac) 333

Definition: Using gypsum- (calcium sulfate dihydrate) derived products to change the physical and/or chemical properties of soil.

Major Resource Concerns Addressed: Soil health and plant productivity.

Benchmark Condition: Acidic cropland soil.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill and wind erosion is reduced by improved soil structure. • Organic matter is maintained or increased. • Aluminum toxicity is reduced. **Water** • Runoff, flooding, or ponding is - Improved infiltration. • Use of irrigation water will - Improved infiltration. **Air** • No change. **Plants** • Plant productivity and health will improve with better Ca:Mg ratio for improved nutrient use efficiency. **Animals** • Improved Nutrient use efficiency for livestock feed and forage. **Energy** • No change. **Human**	**Land** • No change to land use **Capital** • Slight increase in materials and annual operation and maintenance costs • No additional equipment required. **Labor** • Minimal change in labor. **Management** • Minimal change in management. **Risk** • No additional risk.

• **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.**	
Net Effect: **Adding gypsum improves soil productivity at a minimal cost.**	

Commonly Associated Practices: Agrichemical Handling Facility, Nutrient Management, Waste Utilization.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Cover (Ac) 327

Definition: Establishing and maintaining permanent vegetative cover

Major Resource Concerns Addressed: Soil Erosion and Water Quality.

Benchmark Condition: Annually tilled highly erodible low productivity cropland.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Increased vegetation and cover will improve infiltration and decrease sheet and rill, wind, and gully erosion. • Streambank, shoreline, and channel erosion is reduced. • Organic matter will increase with residue and root establishment. • Compaction and subsidence is will decrease with fewer field operations. • Concentration of salts or other chemicals is reduced with permanent cover. **Water** • Runoff, flooding, ponding, seeps or seasonal high water table may be reduced with increased water use. • Permanent vegetation can trap snow. • Soil moisture will increase. • Reduced nutrient and pesticide use, less transport to surface and ground water. • Less runoff and infiltration of salts, pathogens and chemicals from manure. • Less sediment in surface water. **Air** • Fewer emissions of particulate matter, permanent vegetation reduces wind erosion and generation of fugitive dust. • Emissions of ozone precursors and CO2	**Land** • Land use will be changed or land taken out of production if cropland is converted to permanent cover. **Capital** • No additional field equipment required. • Materials, seedbed and planting costs. • Annual operation and maintenance costs to maintain vegetation and reduce pests. • Reduced farm income (forgone income). **Labor** • None. **Management** • None. **Risk** • Reduced whole farm flexibility and timing by taking land out of agricultural production. • Reduced or lost crop production. • Reduced cash flow. • Seeps may increase with deeper and more numerous roots and higher soil infiltration rates.

will be reduced with less machinery use. **Plants** • Plant community productivity and health will increase. • Permanent vegetation may slow the spread of noxious weeds. **Animals** • Fish and wildlife habitat, food, cover and shelter will improve. • Fish and wildlife habitat continuity (space) will increase and may be used to connect other cover areas. **Energy** • Less fuel and oil will be used with reduced machinery use. **Human** • Cultural resources may be protected from erosion. • Labor, management and capital will decrease as land is taken out of production. • Reduced time cultivating previous crop. • Create sustainability of natural resources that support farm business. • Increase the property value (real estate). • Create open space and improve habitat for wildlife. • Conserve soil and water for periods of drought and future use. • Prevent off-site negative impacts. • Comply with environmental regulations. • Save time, money and labor. • Promote family health and safety. • Make land more attractive and promote good stewardship. • May be eligible for cost share.	
• Net Effect: Soil health will improve, erosion will be reduced and water quality improved at a significant cost. Profitability will decrease as land is taken out of production.	

Commonly Associated Practices: Brush Management, Critical Area Planting, Fence, Tree/Shrub Establishment, Upland Wildlife Habitat Management

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Conservation Crop Rotation (Ac) 328

<u>Definition:</u> Growing crops in a planned sequence on the same field.

<u>Major Resource Concerns Addressed:</u>

<u>Benchmark Condition:</u>

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • **Reduced sheet, rill, wind and gully erosion by maintaining sufficient canopy and residue cover that reduces soil detachment by water.** • **High residue crops can lead to increased root development and increased soil organic carbon.** • **Deep rooted crops in the rotation may reduce compaction.** • **Soil subsidence may be reduced if rotation addresses drainage.** • **Salt tolerant crops with high transpiration rates can increase salt uptake and reduce salt content in the root zone.** **Water** • **Improved plant uptake may reduce excessive seepage, runoff, flooding, ponding and seasonal high water table.** • **Crop rotation balances available water with crop needs and may reduce total irrigation requirements.** • **Reduced need for pesticide use by breaking pest lifecycles and improve surface and ground water quality.** • **Nitrogen demanding or deep rooted crops can remove excess nitrogen.**	**Land** • **Cultural resources may be harmed if new deep rooted crops are introduced.** • **Land may be utilized more intensely.** • **No change in land in production.** **Capital** • **No additional field equipment required.** • **Crop production costs.** **Labor** • **Additional time cultivating crops.** **Management** • **Increase time managing crop production.** **Risk** • **Decrease in agricultural operation flexibility and timing with required crops in rotation.** • **Forgone income by going to less profitable crops.**

• Legumes in rotation will provide slow release nitrogen and reduce need for additional nitrogen and improve surface and ground water quality. • Reduced erosion and runoff reduces transport of salts, and some crops may accumulate salts, improving water quality. • Depending on crop rotation, less erosion and runoff reduces delivery of sediment and pathogens. **Air** • Crops in the rotation can reduce the generation of fugitive dust. • Vegetation removes CO_2 from the air and stores it in the form of carbon in the plants and soil. **Plants** • Increase in crop yield with improved soil quality, fertility and moisture holding capacity. • Crop selection will be modified to include species better suited to soils and climate. • Crop rotation creates diversity that may reduce weed pressures, break weed life cycles, and provide competition that would slow the spread of noxious plants. **Animals** • Suitable rotations may provide more food, cover and shelter for wildlife. • Increased cover will increase space for wildlife and connect to other cover areas. • Crop rotation may be designed to add forage crops and aftermath grazing for livestock. **Energy** • Legume crops supply nitrogen reducing fertilizer costs. **Human** • Increase yields/reduce costs as land becomes more productive.	

• **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **Cover crop improves soil productivity, reduces erosion at a moderate cost.**	

Commonly Associated Practices: Conservation Cover, Contour Buffer Strips, Cover Crop, Critical Area Planting, Cross Wind Trap Strips, Herbaceous Wind Barriers, Integrated Pest Management, Irrigation Water Management, Mulching, Nutrient Management, Residue and Tillage Management-Mulch Till, Residue and Tillage Management-No Till/Strip Till/Direct Seed, Residue and Tillage Management-Ridge Till, Residue Management-Seasonal, Terrace, Spoil Spreading, Stream Habitat Improvement and Management, Streambank and Shoreline Protection.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Cover Crop (Ac) 340

Definition: Grasses, legumes, and forbs planted for seasonal vegetative cover.

Major Resource Concerns Addressed: Soil Erosion, Water Quality, Plant Productivity.

Benchmark Condition: Cropland, row crops, non-irrigated.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Reduce erosion from wind and water and transport of sediment. • Maintain or increase soil health and organic matter content. • Improve soil moisture use efficiency. • Minimize soil compaction. **Water** • Reduce water quality degradation by utilizing excessive soil nutrients. • Reduce drainage, seepage and soil subsidence. • Increased organic matter will buffer salts. • Reduce runoff and increase infiltration. • Improves infiltration, soil structure, and soil water storage. • Increase soil biological activity. • Reduce runoff and transport of nutrients, pesticides, pathogens and soluble salts. **Air** • Ground cover helps reduce wind erosion and generation of fugitive dust. • Vegetation removes CO2 from the air and stores it in the form of carbon in the plants and soil. **Plants** • Suppress excessive weed pressures and break pest cycles.	**Land** • No change in landuse • Land utilized more intensely **Capital** • Materials & planting costs. • Grass/Legume Seed. • Seeding Operation, No Till/Grass Drill. • Herbicide, ground application. • Mechanical or chemical crop kill. **Labor** • Increase in labor to plant, manage, eliminate crop. **Management** • Increase time managing crop production. **Risk** • Other farm activities delayed while implementing the practice. • In dry climates (<20 inches/year) will compete for crop moisture. • May recruit unwanted wildlife. • May have to convert to shorter season crops in northern latitudes.

• **Improved plant health, productivity and crop yields.** **Animals** • **Increased food and cover for wildlife.** • **Increased space and connectivity for wildlife.** • **Supplemental forage for livestock.** **Energy** • **Cover crops can reduce nitrogen inputs.** **Human** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **Cover crop improves soil productivity, reduces erosion at a moderate cost.**	

Commonly Associated Practices: Conservation Crop Rotation, Integrated Pest Management, Nutrient Management, Residue and Tillage Management, Mulch Till, Residue and Tillage Management, No Till/Strip Till/Direct Seed, Residue and Tillage Management, Ridge Till, Residue Management, Seasonal.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying

a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Cross Wind Ridges (Ac) 588

<u>Definition:</u> Ridges formed by tillage, planting or other operations and aligned across the direction of erosive wind

<u>Major Resource Concerns Addressed:</u> Wind erosion.

<u>Benchmark Condition:</u> Level row-cropland in wind prone area.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Wind Erosion is reduced by adding roughness to the soil. • Reduced wind erosion decreases organic matter loss. **Water** • Reduced wind erosion transport of soil-adsorbed nutrients, pesticides and salts to surface water. • Reduced offsite sediment transport. **Air** • Emissions of Particulate Matter (and precursors) will - Surface roughness oriented perpendicular to the erosive wind direction will reduce wind erosion. **Plants** • Decreased physical plant damage. • Improved crop yields. **Animals** • None. **Energy** • None. **Human** • Reduced time managing sediment.	**Land** • Cultural resources may be protected from erosion. • No change in land use. • Minor amount of land taken out of agricultural production. **Capital** • No additional field equipment required. • Materials & installation cost. • Annual operation and maintenance costs to maintain vegetation and manage pests. • Foregone Income. **Labor** • Increase in tillage operations. **Management** • Increased time managing crop production. **Risk** • Decreased agricultural operation flexibility and timing by taking land out of agricultural production. • Equipment weight during ridge establishment may increase soil compaction is under certain soil moisture conditions.

• **Improved agricultural operation flexibility and timing with protected agricultural land.** • **Reduced labor repairing critical erosion areas and removing sediment.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **Reduced wind erosion, improved plant productivity, at a low cost.**	

Commonly Associated Practices: Cross Wind Trap Strips, Herbaceous Wind Barriers, Residue and Tillage Management, Mulch Till, Residue and Tillage Management, No Till/Strip Till/Direct Seed, Residue and Tillage Management, Ridge Till, Residue Management, Seasonal, Windbreak/Shelterbelt Establishment

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Cross Wind Trap Strips (Ac) 589C

Definition: Herbaceous cover established in one or more strips typically perpendicular to the most erosive wind events.

Major Resource Concerns Addressed: Wind erosion.

Benchmark Condition: Level cropland in wind prone area.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Wind erosion is reduced. • Increase in soil organic matter. **Water** • Reduced wind erosion transport of soil-adsorbed nutrients, pesticides and salts to surface water. • Reduced offsite sediment transport. **Air** • Improved particulate matter air quality. • Vegetation removes CO2 from the air and stores it in the form of carbon in the plants and soil. **Plants** • Decreased physical plant damage. • Improved crop yields. **Animals** • Vegetation provides cover for wildlife. • Feed and forage for livestock. **Energy** • None. **Human** • Reduced time managing sediment. • Improved agricultural operation	**Land** • Cultural resources may be protected from erosion. • No change in land use. • Minor amount of land taken out of agricultural production. **Capital** • No additional field equipment required. • Materials & installation cost. • Annual operation and maintenance costs to maintain vegetation and manage pests. • Foregone Income. **Labor** • Increase in tillage operations. **Management** • Increased time managing crop production. **Risk** • Decreased agricultural operation flexibility and timing by taking land out of agricultural production.

flexibility and timing with protected agricultural land. • **Reduced labor repairing critical erosion areas and removing sediment.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **Reduced wind erosion, improved plant productivity, at a low cost.**	

Commonly Associated Practices: Cross Wind Ridges, Herbaceous Wind Barriers, Residue and Tillage Management, Mulch Till, Residue and Tillage Management, No Till/Strip Till/Direct Seed, Residue and Tillage Management, Ridge Till, Residue Management, Seasonal, Upland Wildlife Habitat Management, Windbreak/Shelterbelt Establishment.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Field Border (Ac) 386

<u>Definition:</u> A stripe of permanent vegetation established at the edge or around the perimeter or a field.

<u>Major Resource Concerns Addressed:</u> Water quality, wildlife habitat.

<u>Benchmark Condition:</u> Cropland field with annually tilled crop.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • **Reduced sheet, rill, wind and gulley erosion if vegetation is planted across the slope.** • **Permanent cover and lack of soil disturbance reduces decomposition of soil organic materials.** • **Compaction is reduced as root penetration and increased organic matter restores soil structure.** **Water** • **Permanent vegetation will reduce runoff and increase infiltration.** • **Borders may attract beneficial insects or trap insect pests, reducing the need for pesticide applications.** • **Nutrients, pesticides, salts, pathogens, manure in surface and ground water will be reduced.** **Air** • **Permanent vegetation around the field edge reduces particulate emissions from vehicle traffic and tillage in the border area.** • **Vegetation removes CO2 from the air and stores it as soil carbon.**	**Land** • **Slight change in land use if cropland converted to border.** • **Minor amount of land taken out of agricultural production.** **Capital** • **No additional field equipment required.** • **Materials & planting costs.** • **Foregone income with land taken out of production.** • **Annual operation and maintenance costs to maintain vegetation and manage pests.** **Labor** • **Slight increase for weed control.** **Management** • **Increased management of crop production.** **Risk** • **Reduced operation flexibility and timing with land taken out of production.**

Plants • **Plants are selected and managed to maintain optimal productivity and health.** • **Vegetation is installed and managed to control undesired species.** **Animals** • **Increased quality and quantity of food, cover and shelter for wildlife.** • **Permanent vegetation may provide added habitat and connectivity for selected wildlife species.** • **Opportunity for feed and forage for livestock.** **Energy** • **None** **Human** • **Historic properties in agricultural context can be protected from erosion by permanent vegetative cover.** • **Slight decrease in labor turning equipment at ends of fields.** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>Net Effect:</u> Improves soil productivity and water quality at a low cost.	

Commonly Associated Practices: Conservation Crop Rotation, Dust Control on Unpaved Roads and Surfaces, Early Successional Habitat Development/Mgt., Residue and Tillage Management, Mulch Till, Residue and Tillage Management, No Till/Strip Till/Direct Seed, Residue and Tillage Management, Ridge Till, Residue Management, Seasonal, Upland Wildlife Habitat Management, Wetland Wildlife Habitat Management.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Field Operations Emissions Reduction (Ac) 376

Definition: Adjusting field operations and technologies to reduce particulate matter (PM) emissions from field operations.

Major Resource Concerns Addressed: Air quality.

Benchmark Condition: Dryland fallow field in winter wheat crop rotation.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Techniques may reduce the potential for sheet, rill and wind erosion. **Water** • None **Air** • Reduced soil and residue particulates in the air with changes in tillage, harvest and other field operations. • Increase carbon sequestration and reduce greenhouse gas emissions. **Plants** • None. **Animals** • None. **Energy** • None. **Human** • Prolong life of above-ground cultural resources. • Prevent off-site negative impacts. • Comply with environmental regulations. • Save time, money and labor. • Promote family health and safety.	**Land** • No change in land use or land in production. **Capital** • Purchase new equipment. • Annual operation and maintenance costs to service and maintain equipment. **Labor** • No change. **Management** • No change. **Risk** • None.

• **Promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>**Net Effect:**</u> **Improved air quality at a moderate cost.**	

Commonly Associated Practices: Conservation Cover, Contour Buffer Strips, Cover Crop, Critical Area Planting, Cross Wind Trap Strips, Herbaceous Wind Barriers, Integrated Pest Management, Irrigation Water Management, Mulching, Nutrient Management, Pumping Plant, Residue and Tillage Management-Mulch Till, Residue and Tillage Management-No Till/Strip Till/Direct Seed, Residue and Tillage Management-Ridge Till, Residue Management-Seasonal, Terrace, Spoil Spreading, Stream Habitat Improvement and Management, Streambank and Shoreline Protection.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Hedgerow Planting (Ac) 422

Definition: **Establishment of dense vegetation in a linear design to achieve a natural resource conservation purpose.**

Major Resource Concerns Addressed: **Wildlife habitat, cover and shelter.**

Benchmark Condition: **Cropland without trees or shrubs.**

Date: **October, 2016** **Developer/Location:** **Hal Gordon, OR**

Positive Effects	Negative Effects
Soil • Reduced wind erosion with dense vegetation trapping saltating particles. • Permanent vegetation increases soil organic matter. • Root development will improve soil structure and porosity and reduce compaction. **Water** • Tall vegetation will trap snow upwind of structures and animal concentration areas, and increase soil moisture. • Reduced pesticide drift and improve water quality. • Borders may attract beneficial insects or trap insect pests which reduce the need for pesticide applications. • Nutrients kept in place with reduced overland flow and wind erosion. • Borders along small streams increases shade and moderates stream temperatures. **Air** • Permanent rows of trees or shrubs can reduce wind erosion and intercept and trap airborne particles. • Vegetation removes CO2 from the air	**Land** • Cultural resources may be impacted during planting. • Change in land use as crop or grazed land is converted to shrub/tree and wildlife use. • Minor amount of land taken out of agricultural production. **Capital** • Some brush management equipment may be required. • Materials & planting costs. • Annual operation and maintenance costs to maintain vegetation and manage pests. **Labor** • Additional labor maintaining hedgerow, reduced time with some land out of crop production. **Management** • Increase in crop production planning and scouting. **Risk** • Reduced agricultural operation flexibility and timing with land taken out of production. • Forgone income as crop land is taken out

and stores it in the form of carbon in the plants and soil. • **Reduced objectionable odors are intercepted.** **Plants** • **Vegetation is installed and managed to control undesired species.** **Animals** • **Selected plants improve food supply, cover, shelter and habitat for fish and wildlife.** • **Hedgerows can provide some shade and protection from wind for livestock.** **Energy** • **No change.** **Human** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	**of production.**
Net Effect: **Improves soil productivity and wildlife habitat at a moderate cost.**	

Commonly Associated Practices: Stripcropping, Tree/Shrub Establishment, Upland Wildlife Habitat Management, Windbreak/Shelterbelt Establishment.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Herbaceous Wind Barriers (Ac) 603

<u>Definition:</u> Herbaceous vegetation established in rows or narrow strips in the field across the prevailing wind direction.

<u>Major Resource Concerns Addressed:</u> Wind erosion.

<u>Benchmark Condition:</u> Cropland in wind erosion area.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Wind Erosion is reduced by stiff stemmed herbaceous vegetation established across the prevailing wind erosion direction by trapping saltating soil particles and sheltering an area down wind. • Soil organic matter increased as wind erosion is reduced. **Water** • Trapped snow can provide additional plant available moisture. • Barriers may attract beneficial insects or trap insect pests which reduce the need for pesticide applications improving water quality. • Reduced wind erosion keeps soil-adsorbed nutrients and sediment in place improving water quality. **Air** • Barriers can reduce wind erosion and particulate emissions. • Vegetation removes CO_2 from the air and stores it in the form of carbon in the plants and soil and reduced soil loss/organic matter **Plants**	**Land** • Vegetative covers may protect near surface or subsurface historic properties. • Minor change in land use as crop is converted to grass/forb production. • Minor amount of land taken out of agricultural production. **Capital** • No additional field equipment required. • Materials & planting costs. • Annual operation and maintenance costs to maintain vegetation and manage pests. **Labor** • Additional labor maintaining wind barriers. **Management** • Increase in crop production planning and field scouting. **Risk** • Reduced agricultural operation flexibility and timing with land taken out of production. • Forgone income with some land taken out of crop production.

• **Increased crop yield with reduced wind erosion.** • **Vegetation is installed and managed to control undesired species.** **Animals** • **Increased quality and quantity of vegetation provides more food, cover, shelter and habitat for wildlife.** **Energy** • **No change.** **Human** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>Net Effect:</u> Improved soil productivity and reduced wind erosion at a moderate cost.	

Commonly Associated Practices: Cover Crop, Residue and Tillage Management, Mulch Till, Residue and Tillage Management, No Till/Strip Till/Direct Seed, Residue and Tillage Management, Ridge Till, Residue Management, Seasonal, Upland Wildlife Habitat Management.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying

a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Mulching (Ft) 484

<u>Definition:</u> Applying plant residues or other suitable materials produced off site, to the land surface

<u>Major Resource Concerns Addressed:</u> Soil productivity.

<u>Benchmark Condition:</u> Depleted intensively farmed row crop land.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • **Reduced sheet, rill, wind, gully and streambank erosion.** • **Increased soil organic matter.** • **Reduced evaporation may reduce salt build-up and added organic matter will buffer salts.** **Water** • **Increased infiltration reduces runoff, flooding and ponding.** • **Increased infiltration and decreased evaporation results in more available water from irrigation and precipitation.** • **Reduced runoff of pesticides, nutrients, salts, sediment, manure, pathogens and other agricultural chemicals improve surface water quality.** **Air** • **Stabilized the soil surface, reducing the generation of particulate matter.** **Plants** • **Improved crop production opportunities.** • **Improve growing conditions and increased plant health and vigor.** • **Thick and/or impenetrable mulch cover can prevent emergence of undesired weed**	**Land** • **Adverse effects on cultural resources possible during planting and/or removal.** • **No change in land use or land in production.** **Capital** • **Mulching equipment and materials.** **Labor** • **Increase in passes over the field.** **Management** • **No Change.** **Risk** • **Increase in pests may reduce crop yield.** • **Increase in seeps and seasonal high water table with increased infiltration.** • **Impervious mulches may increase runoff and surface water quality problems.** • **Increased infiltration negatively effects ground water.**

species. **Animals** • **Mulching enhances wildlife food, cover and shelter.** **Energy** • **None** **Human** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: Improved soil productivity at a low cost.	

Commonly Associated Practices: Contour Farming, Critical Area Planting, Integrated Pest Management, Irrigation Water Management, Nutrient Management.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics

Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Multi-Story Cropping (Ft) 379

Definition: Existing or planted stands of trees or shrubs that are managed as an overstory with an understory of woody and/or non-woody plants that are grown for a variety of products.

Major Resource Concerns Addressed: Soil productivity.

Benchmark Condition: Annual cropland.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, gully and streambank erosion is reduced by vegetation and surface litter reducing raindrop impact, slowing runoff water and increasing infiltration. • Wind erosion is reduced by trees or shrubs creating turbulence, reduced wind velocities and stable areas which stops saltating particles. • Biological activity, root depth/density and organic matter cycling increases. • Compaction is reduced and soil structure improved. • Canopy cover and organic matter provide soil buffer during extended tropical droughts to reduce organic matter oxidation and loss. • Plants may take up some salts, and increased root penetration improves infiltration that may lead to increased leaching. • Water • Runoff, flooding, ponding, high water table and seeps are reduced with increased infiltration, evapotranspiration utilizes water, and increased soil organic matter holds water.	**Land** • Cultural resources may be damaged during tree planting. • Increased intensity of land use, producing two or more crops. **Capital** • Additional field equipment required to produce two crops. • Materials, installation and management costs. **Labor** • Labor for additional field operations. **Management** • Increase in management to take soil test, calibrate equipment and keep records. **Risk** • Reduced agricultural operation flexibility and timing with less annual crop and more perennial vegetation. • Crops must be adapted and managed to account for use of available water by trees. • Changes in stand structure and composition may interrupt continuity of habitat for certain wildlife species.

• **Management of mixed multistoried crops reduces need for chemicals to manage pests. Pesticide degradation may be improved by interception of drift by varied canopy layers. Surface and ground water are improved.** • **Permanent vegetation and soil organisms' uptake nutrients and surface and ground water are improved.** • **Varied canopy layers and surface cover and organic matter increases infiltration and reduces need for irrigation or chemical inputs and reduces harmful pathogens.** • **Reduced sediment-laden runoff from reaching surface water conveyances.** • **Air** • **Permanent vegetation traps air and slows movement of air, reducing wind velocities and wind stress on crops while providing a stable area to intercept air particles.** • **Emissions of greenhouse gases are reduced and stored as carbon.** • **Plants** • **Increase in crop yield with more effective use of nutrients and plant protection.** • **Plants are selected and managed to maintain optimal productivity, health and to control plant pests and undesired species.** • **Management of multiple layers and surface organic matter reduce ladder fuel load buildup.** • **Animals** • **Fish and wildlife habitat, cover and shelter will improve.** • **Changes in stand structure and composition may create habitat diversity and edge conditions favored by some wildlife.** • **Energy** • **No change.** • **Human**	

• **Opportunity to produce two or more sources of income.** • **Decrease in labor with land taken out of annual crop production.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: Improves soil productivity at a moderate cost.	

Commonly Associated Practices: Access Control , , Brush Management, Firebreak, Forage and Biomass Planting, Forest Stand Improvement, Forest Trails and Landings, Herbaceous Weed Control, Integrated Pest Management, Nutrient Management, Tree/Shrub Establishment, Tree/Shrub Pruning, Tree/Shrub Site Preparation, Woody Residue Treatment.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics

Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Residue and Tillage Management, Reduced Till (Ac) 345

Definition: **Managing the amount, orientation and distribution of crop and other plant residue on the soil surface year round while limiting the soil-disturbing activities used to grow and harvest crops in systems where the field surface is tilled prior to planting.**

Major Resource Concerns Addressed: **Soil erosion, water quality, plant productivity.**

Benchmark Condition: **Corn and soybean crop rotation.**

Date: **October, 2016** **Developer/Location:** **Hal Gordon, OR** **Date:** **October, 2016** **Developer/Location:** **Hal Gordon, OR**

Positive Effects	Negative Effects
Soil • Sheet, rill, wind, gully erosion is reduced by increasing residue and reducing soil disturbance. • Improvement in soil health and water holding capacity. • Decreased erosion and less oxidation from lack of soil disturbance will increase or maintain organic matter. • Fewer field operations and less tillage reduce the potential for soil compaction. • Low disturbance and high residue increase organic matter which buffers salts. • Increase in soil carbon. **Water** • Increased infiltration results in more water moving through the profile, reducing runoff, ponding and seasonal high water table. • Increased infiltration and decreased evaporation results in more available water. • Decreased runoff and erosion reduces nutrients, pesticides, salt, pathogens and	**Land** • No change in land in production. • More intensive land use. **Capital** • Additional field equipment required including no-till drill and spray rig. • Increase in pest management costs. • Annual operation, maintenance and replacement costs of new field equipment. **Labor** • None. **Management** • Increase management costs in developing crop, nutrient, pest plans and record keeping. • Steep learning curve first few years. **Risk** • Reduced flexibility when tillage is not available as a management option. • Increase in pesticide use (substitute tillage with chemical pest control). • Increased infiltration reduces the efficiency of flood and furrow irrigation.

sediment to surface waters. • High soil organic carbon may cause microbes to immobilize nutrients to leaching. **Air** • Fewer field operations reduce the generation of particulate matter, ozone precursors and CO_2. **Plants** • Possible increase in crop yields. • Conserving moisture and improving soil conditions improve plant productivity and health. **Animals** • Crop residue provides food, cover, shelter and habitat for wildlife. **Energy** • Fewer passes over the field reduces fuel and oil use. **Human** • Reduction in field labor, fewer passes over the field. • Reduced equipment repairs with fewer passes over the field. • Improved drainage allows working the field earlier and later in field season. • Salvage value of obsolete field equipment. • Increase yields/reduce costs as land becomes more productive. • Create sustainability of natural resources that support your business. • Increase the property value (real estate) of your property. • Create open space and improve habitat for wildlife. • Conserve soil and water for periods of drought and future use. • Prevent off-site negative impacts. • Comply with environmental regulations. • Save time, money and labor. • Promote family health and safety.	• Increased infiltration may increase nutrient, salt and agricultural chemicals leaching to ground water. • High residue on cold and wet soils may delay crop emergence and early growth.

• **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>Net Effect:</u> **Improved soil productivity and improved water quality at a profit.**	

Commonly Associated Practices: Conservation Crop Rotation, Contour Farming, Integrated Pest Management, Irrigation Water Management, Nutrient Management.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Residue and Tillage Management, No Till (Ac) 329

Definition: Managing the amount, orientation and distribution of crop and other plant residue on the soil surface year round, limiting soil-disturbing activities to those necessary to place nutrients, condition residue and plant crops.

Major Resource Concerns Addressed: Soil erosion, water quality, plant productivity.

Benchmark Condition: Small grain and fallow crop rotation.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

<table>
<tr><th>Positive Effects</th><th>Negative Effects</th></tr>
<tr><td>
Soil

Sheet, rill, wind, gully erosion is reduced by increasing residue and reducing soil disturbance.
Improvement in soil health and water holding capacity.
Decreased erosion and less oxidation from lack of soil disturbance will increase or maintain organic matter.
Fewer field operations and less tillage reduce the potential for soil compaction.
Low disturbance and high residue increase organic matter which buffers salts.
Increase in soil carbon.

Water

Increased infiltration results in more water moving through the profile, reducing runoff, ponding and seasonal high water table.
Increased infiltration and decreased evaporation results in more available water.
Decreased runoff and erosion reduces nutrients, pesticides, salt, pathogens and sediment to surface waters.

</td><td>
Land

No change in land in production.
More intensive land use.

Capital

Additional field equipment required including no-till drill and spray rig.
Increase in pest management costs.
Annual operation, maintenance and replacement costs of new field equipment.

Labor

None.

Management

Increase management costs in developing crop, nutrient, pest plans and record keeping.
Steep learning curve first few years.

Risk

Reduced flexibility when tillage is not available as a management option.
Increase in pesticide use (substitute tillage with chemical pest control).
Increased infiltration reduces the efficiency of flood and furrow irrigation.
Increased infiltration may increase nutrient, salt and agricultural chemicals

</td></tr>
</table>

• High soil organic carbon may cause microbes to immobilize nutrients to leaching. **Air** • Fewer field operations reduce the generation of particulate matter, ozone precursors and CO_2. **Plants** • Possible increase in crop yields. • Conserving moisture and improving soil conditions improve plant productivity and health. **Animals** • Crop residue provides food, cover, shelter and habitat for wildlife. **Energy** • Fewer passes over the field reduces fuel and oil use. **Human** • Reduction in field labor, fewer passes over the field. • Reduced equipment repairs with fewer passes over the field. • Improved drainage allows working the field earlier and later in field season. • Salvage value of obsolete field equipment. • Increase yields/reduce costs as land becomes more productive. • Create sustainability of natural resources that support your business. • Increase the property value (real estate) of your property. • Create open space and improve habitat for wildlife. • Conserve soil and water for periods of drought and future use. • Prevent off-site negative impacts. • Comply with environmental regulations. • Save time, money and labor. • Promote family health and safety. • Make land more attractive and promote good stewardship.	leaching to ground water. • High residue on cold and wet soils may delay crop emergence and early growth.

• **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>Net Effect:</u> Improved soil productivity and water quality at a profit.	

Commonly Associated Practices: Conservation Crop Rotation, Contour Farming, Integrated Pest Management, Irrigation Water Management, Nutrient Management

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Stripcropping (Ac) 586

Definition: Growing planned rotations of row crops, forages, small grains, or fallow in a systematic arrangement of equal width strips across a field.

Major Resource Concerns Addressed: Wind erosion.

Benchmark Condition: Level cropland in wind prone area.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind and gulley erosion is reduced when applied on or near the contour. • Perennial crops in the alternating strips can add organic matter to the soil. **Water** • Increased water infiltration and seeps, particularly during fallow periods. • Increased water infiltration which may slightly reduce the potential for flooding or ponding. • Protected strips will capture additional snow, increase infiltration and create excess soil moisture and subsurface water. • Reduced runoff and erosion and soil-attached pesticides, nutrients, salts, manure and pathogens delivered to surface water. • Increased water infiltration could move salts, pesticides, nutrients and other agricultural chemicals to groundwater. **Air** • Vegetated strips provide ground cover and reduces wind erosion.	**Land** • Cultural resources may be protected from erosion. • No change in land use. • Change to less intensive crop production. **Capital** • No additional field equipment required. • Annual operation and maintenance costs to maintain vegetation and manage pests. **Labor** • Increase in labor with more turns at end of rows. **Management** • Increase in developing crop management plan and record keeping. **Risk** • Reduced agricultural operation flexibility and timing when required to follow designed row pattern.

Plants • **Reduced erosion will improve site potential and enhance plant productivity and health.** **Animals** • **Improved fish and wildlife habitat, food, cover and shelter.** **Energy** • **None.** **Human** • **Reduced time managing sediment.** • **Improved agricultural operation flexibility and timing with protected agricultural land.** • **Reduced labor repairing critical erosion areas and removing sediment.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **Reduced wind erosion, improved plant productivity, at a low cost.**	

Commonly Associated Practices: Conservation Crop Rotation, Contour Farming, Diversion, Grassed Waterway, Integrated Pest Management, Nutrient Management, Underground Outlet.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying

a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Surface Roughening (Ac) 609

Definition: Performing tillage operations that create random roughness of the soil surface.

Major Resource Concerns Addressed: Wind erosion.

Benchmark Condition: Level fallow cropland in wind prone area.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Wind erosion is reduced. • Maintained soil organic matter. **Water** • Reduced wind erosion transport of soil-adsorbed nutrients, pesticides and salts to surface water. • Reduced offsite sediment transport. **Air** • Improved particulate matter air quality. • Vegetation removes CO_2 from the air and stores it in the form of carbon in the plants and soil. **Plants** • None. **Animals** • Noon. **Energy** • None. **Human** • Reduced time managing sediment. • Improved agricultural operation flexibility and timing with protected agricultural land. • Reduced labor repairing critical erosion	**Land** • Cultural resources may be protected from erosion. • No change in land use or land taken out of production. **Capital** • No additional field equipment required. • Additional tillage passes over the field. **Labor** • Increase in tillage operations. **Management** • Increased time managing crop production. **Risk** • None.

areas and removing sediment. • Create sustainability of natural resources that support your business. • Increase the property value (real estate) of your property. • Conserve soil and water for periods of drought and future use. • Prevent off-site negative impacts. • Comply with environmental regulations. • Save time, money and labor. • Promote family health and safety. • Make land more attractive and promote good stewardship. • Increased profitability in the long run.	
<u>Net Effect:</u> Reduced wind erosion at a low cost.	

Commonly Associated Practices: Conservation Crop Rotation, Cross Wind Ridges, Cross Wind Trap Strips, Herbaceous Wind Barriers, Integrated Pest Management, Nutrient Management, Residue and Tillage Management-Mulch Till, Residue and Tillage Management-No Till/Strip Till/Direct Seed, Residue and Tillage Management-Ridge Till, Residue Management, Seasonal, Windbreak/Shelterbelt Establishment, Windbreak/Shelterbelt Renovation.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Vegetative Barrier (Ac) 601

Definition: Permanent strips of stiff, dense vegetation established along the general contour of slopes or across concentrated flow areas.

Major Resource Concerns Addressed: Waste runoff, water quality.

Benchmark Condition: Livestock winter feeding and loafing area.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind and gulley erosion is reduced by stiff-stemmed vegetation planted along the contour or across areas of concentrated flow increasing infiltration. **Water** • Reduced runoff and erosion and traps adsorbed pesticides, nutrients and agricultural chemicals. • Soluble organics infiltrate into the soil and may be taken up by plants and soil organisms. • Vegetative barriers capture sediment-bound pathogens and retard pathogen movement, allowing more time for mortality to occur before pathogens can reach water bodies. • Vegetation slows runoff, filters water, and increases infiltration. **Air** • Vegetation removes CO2 from the air and stores it in the form of carbon in the plants and soil. **Plants** • Reduced erosion and improved water	**Land** • Historic properties may be protected by erosion reduction. • Minimal land taken out of agricultural production, some land may be brought into production. **Capital** • No additional field equipment required. • Installation equipment costs. • Materials and planting costs. • Annual operation and maintenance costs to maintain control barrier. **Labor** • Increase in labor to remove sediment and maintain vegetation. **Management** • No Change. **Risk** • Over time salts are collected or redistributed within a field due to seepage, if present.

management creates site conditions favorable to plant health and productivity. **Animals** • **Wildlife habitat/food species can be included in the barrier.** • **The barrier provides cover, space and habitat for some species.** • **Fish and wildlife habitat/water will be improved by the filtering functions of the barriers.** **Energy** • **None** **Human** • **Stabilizing steep land and bringing land into production.** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>Net Effect:</u> Improved water quality and reduced erosion at a moderate cost.	

Commonly Associated Practices: Conservation Crop Rotation, Contour Farming, Integrated Pest Management, Nutrient Management, Residue and Tillage Management-Mulch Till, Residue and Tillage Management-No Till/Strip Till/Direct Seed, Residue and Tillage Management-Ridge Till, Residue Management-Seasonal.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Windbreak/Shelterbelt Establishment (Ac) 380

Definition: **Windbreaks or shelterbelts are single or multiple rows of trees or shrubs in linear configurations.**

Major Resource Concerns Addressed: **Wind erosion, energy savings.**

Benchmark Condition: **Exposed cropland and headquarters.**

Date: **October, 2016** **Developer/Location:** **Hal Gordon, OR**

Positive Effects	Negative Effects
Soil • Sheet, rill and gully erosion is reduced by vegetation across the slope and surface litter reduces erosive water energy. • Wind Erosion is reduced by tall vegetation that creates a wind shadow, reduces erosive wind velocities and provides a stable area which stops saltating particles. • Roots and vegetative matter and its breakdown increases organic matter. • Root penetration and organic matter helps restore soil structure and reduces compaction. **Water** • Reduction in seeps as trees/plants uptake excess water. • Runoff, flooding, or ponding is reduced as trees or shrubs increase infiltration and retard flood water movement. • Water table and soil moisture is restored as plants uptake excess water. • Snow is captured within and downwind of tree/shrub rows increasing soil moisture. • Tall vegetation reduces wind speeds and evapotranspiration allowing more	**Land** • Change in land use and land in production. • Historic landscapes may change. **Capital** • Materials, planting & installation costs. • No additional field equipment required. • Annual operation and maintenance costs to maintain vegetation and manage pests. • Forgone income. **Labor** • Increase in labor during planting. **Management** • Management change from previous crop. **Risk** • None

efficient use of available water. • Sheltered crops intercept pesticide drift. • Plants and soil organisms' uptake nutrients and improve surface and ground water quality. • Vegetation traps sediment preventing it from being deposited elsewhere. **Air** • Reduced particulate emissions associated with wind erosion and filtering particulate matter, CO2 and ammonia from the air. • Vegetation will reduce wind movement and intercept fine particulates, dust and reduce odor. **Plants** • Crops are sheltered from airborne sediment and chemical drift. • Reduced crop damage. • Vegetation is installed and managed to control undesired species. **Animals** • Improved plant diversity and quality and quantity of vegetation provides food, cover and space for wildlife. • Livestock feed and forage in is enhanced by improving the microclimate. • Tall vegetation provides shelter for wildlife and livestock. **Energy** • Reduced heating and cooling around farmsteads. • Potential biomass as fuel source. **Human** • Increase yields/reduce costs as land becomes more productive. • Create sustainability of natural resources that support your business. • Increase the property value (real estate) of your property.	

• **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.**	
Net Effect: **Reduced wind erosion, improved soil productivity at a moderate cost.**	

Commonly Associated Practices: Access Control , Brush Management, Conservation Crop Rotation, Cover Crop, Cross Wind Trap Strips, Dust Control from Animal Activity on Open Lot Surfaces, Fence, Field Border, Firebreak, Herbaceous Weed Control, Herbaceous Wind Barriers, Integrated Pest Management, Mulching, Residue and Tillage Management-Mulch Till, Residue and Tillage Management-No Till/Strip Till/Direct Seed, Residue and Tillage Management-Ridge Till, Residue Management-Seasonal, Tree/Shrub Establishment, Tree/Shrub Pruning, Tree/Shrub Site Preparation, Upland Wildlife Habitat Management, Watering Facility, Windbreak/Shelterbelt Renovation.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Access Control (Ac) 472

<u>Definition:</u> The temporary or permanent exclusion of animals, people, vehicles, and/or equipment from an area.

<u>Major Resource Concerns Addressed:</u> Soil erosion, streambank protection, wildlife habitat.

<u>Benchmark Condition:</u> Riparian area.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects

Soil

- **Sheet, rill, wind, gully, streambank erosion is reduced by less disturbance of the soil and vegetation.**
- **Organic matter increases.**
- **Soil compaction is reduced.**

Water

- **Runoff, flooding, ponding, seasonal high water table and seeps may be reduced as plant vigor increase water uptake and soil structure improves.**
- **Soil moisture will increase with improved vegetation and soil structure.**
- **Nutrients and pesticides in surface and ground water will decrease as plant vigor improves soil conditions.**
- **Pathogens and chemicals from manure in surface and groundwater will be reduced in sensitive areas.**
- **Sediment in surface water will be reduced.**
- **High water temperature will be reduced.**
- **Petroleum, heavy metals and other pollutants in surface and groundwater will be reduced.**

Air

- **Emissions of particulate matter, ozone**

Negative Effects

Land

- **Land will be taken out of production with a change to less intense land use.**

Capital

- **Reduced use of field equipment.**
- **Forgone income from previous land use.**
- **Annual operation and maintenance costs to maintain control barrier.**

Labor

- **None.**

Management

- **None.**

Risk

- **Agricultural operation flexibility and timing will be limited due to deferred land use, reduced grazing or cropping.**
- **Cash flow will decline, annual costs may be greater than annual benefits.**
- **Profitability will decrease if land is taken out of production.**
- **Wildfire hazard from excessive biomass accumulation may increase.**
- **The threat of noxious and invasive plants may increase.**

precursors and greenhouse gases will be reduced. **Plants** • **Plant community productivity and health will increase by excluding animals, people, and vehicles and encouraging natural revegetation.** • **The threat of noxious and invasive plants may decrease.** **Animals** • **Fish and wildlife habitat, food, water, cover, and shelter will improve for certain wildlife species.** • **Fish and wildlife habitat continuity (space) will improve.** • **Livestock feed, forage and shelter will improve (if utilized in the future).** **Energy** • **Less energy will be expended with reduced land use.** **Human** • **Reduced labor and management.** • **Cultural resources will be protected.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.**	
<u>Net Effect:</u> Access Control improves soil productivity, reduces erosion and protects wildlife in the long term at a moderate cost.	

Commonly Associated Practices: Aquaculture Ponds, Critical Area Planting, Fence, Forage and Biomass Planting, Forest Stand Improvement, Fuel Break, Karst Sinkhole Treatment , Land Reclamation, Abandoned Mined Land, Land Reclamation, Currently Mined Land, Land Reclamation, Landslide Treatment, Multi-Story Cropping, Pond, Prescribed Grazing, Range Planting, Riparian Forest Buffer, Road/Trail/Landing Closure and Treatment, Silvopasture Establishment, Tree/Shrub Establishment, Vegetated Treatment Area , Waste Storage Facility, Waste Treatment Lagoon, Water Well, Water Well Decommissioning, Watering Facility, Wetland Restoration, Windbreak/Shelterbelt Establishment.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Anionic Polyacrylamide (PAM) Erosion Control (Ac) 450

Definition: **Application of water-soluble Anionic Polyacrylamide (PAM) to meet a resource concern.**

Major Resource Concerns Addressed: **Furrow irrigation erosion.**

Benchmark Condition: **Furrow irrigated row crops.**

Date: **October, 2016** **Developer/Location:** **Hal Gordon, OR**

Positive Effects	Negative Effects
Soil • **Sheet, rill, wind and gully erosion is reduced as soil particles coagulate making them less susceptible to detachment from flowing water and wind.** **Water** • **Minimize furrow erosion allowing higher water flow in the furrow that provides more efficient application.** • **Reduced erosion and delivery of sediment-attached nutrients and pesticides to be carried off-site to surface water and infiltrated to ground water.** • **Reduces sediment load to waterways.** **Air** • **Reduce the susceptibility of soil to wind erosion.** **Plants** • **Improved crop yields.** **Animals** • **Water quality improvement to fish and wildlife.** **Energy** • **Reduces seepage losses resulting in**	**Land** • **No change in land in production or land use.** **Capital** • **Materials and some mixing and field application equipment required.** • **No operation and maintenance costs.** **Labor** • **Materials application labor.** **Management** • **Increase in record keeping and developing irrigation schedules.** **Risk** • **No increase in risk.**

reduced energy use for pumping. **Human** • **Less time managing sediment in waterways.** • **Increase furrow irrigation management options.** • **Increased crop yields and reduced erosion and sediment management costs.** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **PAM improves soil productivity, reduces erosion at a low cost.**	

Commonly Associated Practices: Irrigation Canal or Lateral, Irrigation Field Ditch, Irrigation System, Sprinkler, Irrigation System, Surface & Subsurface.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics

Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Brush Management (Ac) 314

<u>Definition:</u> The management or removal of woody (non-herbaceous or succulent) plants including those that are invasive and noxious.

<u>Major Resource Concerns Addressed:</u> Invasive plants, wildlife habitat, soil erosion.

<u>Benchmark Condition:</u> Juniper infested rangeland.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind, gully erosion is reduced with reduced brush canopy and increase in herbaceous ground cover resulting in increased infiltration, reduced overland flow and reduced soil detachment. **Water** • Runoff, flooding and ponding is reduced with increased ground cover. • Increase in soil moisture and plant use efficiency with a decrease in undesirable species. • Reduced sediment in surface water with improved plant cover and less overland flow and runoff. **Air** • Positive long-term carbon sequestration effect from brush management. **Plants** • Brush removal increases desirable plant community health, vigor and biodiversity. • Reduced wildfire hazard and fuel loadings. **Animals** • Improved composition, structure,	**Land** • Cultural resources may be damaged with mechanical treatment. • Land may be utilized more intensely. • Land in production may increase. **Capital** • No additional field equipment required. • Treatment costs (chemical, mechanical, grazing or fire). • Annual operation and maintenance costs may include spot treatment for reinvading brush. **Labor** • None. **Management** • None. **Risk** • Short term foregone income or change in seasonal use if deferred from grazing. • Temporary increase in soil erosion following mechanical treatment. • Pesticides in surface water if used to control brush. • Removal of vegetation by mechanical means or burning can increase short-term particulate matter emissions, CO_2,

amount and availability of plants for food. • Improved fish and wildlife cover/shelter and habitat continuity depending on the amount of brush removed and the enhancement of stand composition and structure. • Increased production of forage that meets nutritional and productive needs for livestock. **Energy** • None **Human** • Reduced time managing unwanted brush and livestock. • Increase yields/reduced costs as land becomes more productive. • Create sustainability of natural resources that support your business. • Increase the property value (real estate) of your property. • Create open space and improve habitat for wildlife. • Conserve soil and water for periods of drought and future use. • Prevent off-site negative impacts. • Comply with environmental regulations. • Save time, money and labor. • Promote family health and safety. • Make land more attractive and promote good stewardship. • May be eligible for cost share. • Increased profitability in the long run.	VOC and/or NOx emissions. • Loss of habitat for some wildlife species.
Net Effect: Improved soil productivity, forage yield, wildlife habitat at a moderate cost.	

Commonly Associated Practices: Early Successional Habitat Development/Mgt., Herbaceous Weed Control, Integrated Pest Management, Nutrient Management, Prescribed Burning, Prescribed Grazing, Riparian Forest Buffer, Upland Wildlife Habitat Management, Woody Residue Treatment.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Critical Area Planting (Ac) 342

Definition: **Establishing permanent vegetation on sites that have, or are expected to have, high erosion rates, and on sites that have physical, chemical or biological conditions that prevent the establishment of vegetation with normal practices.**

Major Resource Concerns Addressed: **Soil erosion and sedimentation.**

Benchmark Condition: **Steep cropland slope above perennial stream.**

Date: **October, 2016** **Developer/Location:** **Hal Gordon, OR**

Positive Effects	Negative Effects
Soil • Sheet, rill, wind, gully and streambank erosion reduced with increased vegetation, cover and stabilization of erosive conditions. • Increase in soil organic matter. • Decrease in soil compaction with increased root growth. • Increased vegetation will increase salt uptake and increased organic matter may tie up salts and other chemicals. **Water** • Growing plants will take up excess water and may reduce seeps, ponding, flooding and high water table with large treatment area. • Reduced soil erosion and sediment-attached nutrients delivered to surface and ground water. • Permanent vegetation will uptake excess nutrients. • Less runoff reduces transport of soluble salts to surface and ground water. **Air** • Permanent cover helps reduce wind erosion and generation of fugitive dust.	**Land** • Historic properties and cultural resources may be protected from erosion. • Change in land use if large areas are planted. • Some land taken out of agricultural production. **Capital** • No additional field equipment required. • Materials & planting costs. • Annual operation and maintenance costs to maintain vegetation and manage pests. • Forgone income. **Labor** • None. **Management** • None. **Risk** • Reduced agricultural operation flexibility and timing by taking land out of production. • Reduced profitability with land taken out of production.

• **Vegetation removes CO_2 from the air and stores it in the form of carbon in the plants and soil.** **Plants** • **Establishment of permanent vegetation may provide competition that would slow the spread of noxious plants.** **Animals** • **Increased quality and quantity of wildlife food, cover, shelter and habitat.** **Energy** • **None.** **Human** • **Reduced labor repairing critical erosion areas and removing sediment.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.**	
<u>Net Effect:</u> Reduced erosion and improved soil quality a moderate cost.	

Commonly Associated Practices: Access Control

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Dust Control on Unpaved Roads and Surfaces (SqFt) 373

Definition: Controlling direct particulate matter emissions produced by vehicle and machinery traffic or wind action from unpaved roads and other surfaces by applying a palliative on the surface.

Major Resource Concerns Addressed: Air Quality

Benchmark Condition: Dusty roads at farm headquarters.

Date: October, 2016 Developer/Location: Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Treatment of unpaved surfaces can help to bind particles, resulting in reduced erosion. • Wind erosion is reduced by treatment of open lots. **Water** • Reduced manure, nutrient, salt, pathogen and other chemical runoff from the open lot surface. **Air** • Reduce particulate matter emissions from vehicle traffic and wind erosion on unpaved roads and surfaces. **Plants** • No effect **Animals** • Improved working conditions and animal health. **Energy** • No effect **Human** • Improved working conditions.	**Land** • No change in land use or land in production. **Capital** • Some application equipment required and purchase materials. • No O&M costs after implementation. **Labor** • Additional labor required to operate dust control equipment. **Management** • Increased management of equipment and record keeping. **Risk** • If road oils are used, nearby surface water may be impacted.

• **Increase the property value (real estate) of your property.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.**	
Net Effect: **Improved air quality at a low cost.**	

Commonly Associated Practices: Critical Area Planting, Dust Control Animals, Heavy Use Area Protection, Irrigation Pipeline, Irrigation Reservoir, Irrigation System, Sprinkler, Livestock Pipeline, Mulching, Pumping Plant, Windbreak/Shelterbelt Establishment.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Forage and Biomass Planting (Ac) 512

<u>Definition:</u> Establishing adapted and/or compatible species, varieties, or cultivars of herbaceous species suitable for pasture, hay, or biomass production.

<u>Major Resource Concerns Addressed:</u> Plant productivity.

<u>Benchmark Condition:</u> Low yield hayland.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Reduced sheet, rill, wind, gully erosion with an increase in vegetative cover. • Improved soil organic matter with enhanced biomass production, root development, litter accumulation, increased biological activity, and reduced tillage (if associated with change in land use). • Reduced soil compaction. **Water** • Reduced runoff, flooding and ponding with an increase in cover and infiltration. • Reduced pesticides, nutrients, pathogens and other agricultural chemicals in surface and ground water. **Air** • Permanent vegetation reduces the potential for generation of particulates by wind erosion. • Vegetation removes CO_2 from the air and stores it in the form of carbon in the plants and soil. **Plants** • Increased crop yield with better plant species mix and plant density.	**Land** • No change in land use if currently hayed/grazed. • Increase in land in production if land is brought into production. **Capital** • No additional field equipment required. • Materials and planting costs. • Annual operation and maintenance costs to maintain vegetation and manage pests. **Labor** • No Change. **Management** • Increased management of crop production. **Risk** • Reduced agricultural operation flexibility, timing and income if converting from annual to perennial crop. • During the establishment period, there may be an increase in soil erosion, depending on seedbed preparation, seeding method, and species planted.

• **Improved plant community structure and composition with adapted and suited plants.** **Animals** • **Planted species may provide food, cover and shelter for certain wildlife species.** • **Plant species will be selected that accommodate seasonal livestock production and nutritional needs.** **Energy** • **Use of biomass as an alternative energy source can greatly reduce the use of fossil fuels.** **Human** • **Improved agricultural operation flexibility and timing with higher quality crop.** • **Decrease in labor from annual cropping.** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>**Net Effect:**</u> **Improves soil productivity and air quality at a low cost.**	

Commonly Associated Practices: Access Control, Conservation Crop Rotation, Forage Harvest Management, Herbaceous Weed Control, Integrated Pest Management, Nutrient Management, Prescribed Grazing, Upland Wildlife Habitat Management.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Grazing Land Mechanical Treatment (Ac) 548

Definition: Modifying physical soil and or plant conditions with mechanical tools by treatment such as; pitting, contour furrowing, and ripping or sub-soiling.

Major Resource Concerns Addressed: Plant productivity.

Benchmark Condition: Rangeland with declining forage production.

Date: October, 2016 Developer/Location: Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Reduced sheet, rill and wind erosion with increased surface roughness and improved vegetation cover that increases infiltration and reduced runoff and soil movement. • Improved plant vigor and productivity increases organic matter. **Water** • Increased infiltration and decreased runoff, ponding and flooding. • Increased water infiltration and improved plant soil moisture. • Reduced nutrients, pathogens and sediment in surface water. **Air** • Emissions of greenhouse gases will - Intensive disturbance of soil can release stored soil carbon as carbon dioxide. **Plants** • Plant productivity, health and vigor will increase. **Animals** • Improved forage and livestock yield with improved soil permeability, infiltration and plant vigor.	**Land** • No change in land use or land in production. **Capital** • No additional field equipment required. • Materials and planting costs. • No additional operation and maintenance costs. **Labor** • No change. **Management** • No change. **Risk** • May have forgone income if land is deferred for one or more years. • Intensive disturbance of soil can release particulate matter into air. • Undesired plants can colonize newly treated disturbed areas.

• **Improved plant production and species diversity.** **Energy** • **No change.** **Human** • **Improved agricultural operation flexibility and timing with an increase in forage productivity and grazing opportunities.** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **Improved soil productivity and forage quality and yield at a moderate cost.**	

Commonly Associated Practices: Forage and Biomass Planting, Integrated Pest Management, Nutrient Management, Prescribed Grazing, Range Planting.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Heavy Use Area Protection (Ac) 561

Definition: The stabilization of areas frequently and intensively used by people, animals or vehicles by establishing vegetation cover, by surfacing with suitable materials, and/or by installing needed structures.

Major Resource Concerns Addressed: Soil health and livestock productivity.

Benchmark Condition: Muddy sacrifice area near water facility on rangeland.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Reduced sheet, rill, wind, gully and streambank erosion with vegetative cover, hard-surfacing, or installing structures to protect the soil. • If vegetation is used to protect the site, organic matter may be increased, if another material is used to protect the site, organic matter will be decreased or unchanged. • The area will be used preferentially and the area adjacent to the site will have less soil compaction. **Water** • Reduced nutrient, pathogen, manure and sediment runoff into surface water as they are collected and disposed. **Air** • Stabilizing high-traffic areas can reduce particulate matter and dust. **Plants** • Use of the protected area will result in less traffic on adjacent areas, resulting in improved plant health. **Animals**	**Land** • Vegetative cover may protect surface or subsurface cultural resources; heavy surface treatment or structures may damage cultural resources. • No change in land use. • Minor amount of land taken out of agricultural production. **Capital** • No additional field equipment required. • Construction costs and materials. • Annual operation and maintenance costs to keep pad clear and surfaced. **Labor** • Reduced time removing debris and managing livestock. **Management** • Increased management of site. **Risk** • Impermeable surfaces will cause increased runoff.

• **Improved livestock health and management.** **Energy** • **None.** **Human** • **Less livestock labor required.** • **Improved opportunities for land use and water management.** • **Increase yields/reduced costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>Net Effect:</u> Improves soil health and livestock productivity at a low cost.	

Commonly Associated Practices: Access Road , Critical Area Planting, Dry Hydrant, Dust Control from Animal Activity on Open Lot Surfaces, Fence, Filter Strip, Nutrient Management, Prescribed Grazing, Roof Runoff Structure, Subsurface Drain, Trails and Walkways, Vegetated Treatment Area , Waste Storage Facility, Waste Transfer, Waste Treatment, Waste Utilization.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Herbaceous Weed Control (Ac) 315

Definition: The removal or control of herbaceous weeds including invasive, noxious and prohibited plants.

Major Resource Concerns Addressed: Plant productivity, wildlife habitat.

Benchmark Condition: Russian knapweed and jointed goatgrass infested pasture.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind, gully erosion is reduced with increased health, vigor and cover of desirable plant species. **Water** • Reduced nutrients and sediment in surface water with improved ground cover reducing overland flow. **Air** • Positive long-term carbon sequestration effect from weed management. **Plants** • Weed removal increases desirable plant community health, vigor and biodiversity. • Increase in forage productivity and grazing opportunities. • Reduced wildfire hazard and fuel loadings. **Animals** • Improved composition, structure, amount and availability of plants for food. • Improved fish and wildlife cover/shelter and habitat continuity depending on the type and amount of weeds removed.	**Land** • Cultural resources may be damaged with mechanical treatment. • Land may be utilized more intensely. • Land in production may increase. **Capital** • No additional field equipment required. • Treatment costs (chemical, mechanical, grazing). • Annual operation and maintenance costs may include spot treatment for reinvading weeds. **Labor** • Additional time controlling weeds. **Management** • Increase in crop production planning and field scouting. **Risk** • Pesticides may be used to control vegetation. • Removal of vegetation by mechanical means or burning can increase short-term particulate matter emissions, CO_2, VOC and/or NO_x emissions. • Loss of habitat for some wildlife species.

• **Increased production of forage that meets nutritional and productive needs for livestock.** **Energy** • **None.** **Human** • **Increase in crop and livestock yields due to reduced weed competition.** • **Reduced time managing unwanted brush and livestock.** • **Increase yields/reduced costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **Improved plant productivity and farm enterprise opportunities at a low cost.**	

Commonly Associated Practices: Critical Area Planting, Early Successional Habitat Development/Mgt., Forage Harvest Management, Forest Stand Improvement, Integrated Pest Management, Land Clearing, Nutrient Management, Prescribed Burning, Prescribed Grazing, Range Planting, Upland Wildlife Habitat Management.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Land Reclamation, Landslide Treatment (Ft) 453

<u>Definition:</u> Managing in-place natural materials, mine spoil (excavated over-burden), mine waste or overburden to reduce down-slope movement.

<u>Major Resource Concerns Addressed:</u> Soil and water quality.

<u>Benchmark Condition:</u> Landslide on steep mined slope resulting from road water run-off.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • **Reduced sheet, rill, wind and gully erosion with the establishment of vegetative cover.** • **Increase in soil organic matter.** **Water** • **Removal of water to stabilize slopes reduces seepage and seasonal high water table.** • **Reduced run-off of pathogens, agricultural chemicals, manure and sediment into surface water.** **Air** • **Increase vegetation removes CO2 from the air and stores it in the form of carbon in the plants and soil.** **Plants** • **Vegetative cover species will be selected and maintained at optimal conditions for the intended purpose.** • **Vegetation is installed and managed to control undesired species.** **Animals** • **Increased quality and quantity of vegetation provides food, cover and shelter for wildlife.**	**Land** • **Cultural resources may be impacted during construction.** • **Land may be brought into production.** **Capital** • **No additional field equipment required.** • **Materials and installation costs.** • **No annual operation and maintenance costs.** **Labor** • **Labor to dispose of spoil material.** **Management** • **Increase in plan development and record keeping.** **Risk** • **None.**

Energy • **None.** **Human** • **Increase in public safety.** • **Increase in crop and livestock production from restoration of previously unproductive areas.** • **Create sustainability of natural resources that support farm business.** • **Increase the property value (real estate).** • **Create open space and improve habitat for wildlife.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **Improved soil productivity and water quality at a significant cost.**	

Commonly Associated Practices: Critical Area Planting, Integrated Pest Management, Land Reclamation, Currently Mined Land, Land Reclamation, Toxic Discharge Control, Nutrient Management, Obstruction Removal, Subsurface Drain, Terrace, Underground Outlet.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Prescribed Burning (Ac) 338

Definition: Controlled fire applied to a predetermined area

Major Resource Concerns Addressed: Noxious weeds, plant and livestock productivity.

Benchmark Condition: Brush and noxious weed infested grazing land.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind and gulley erosion is reduced with improved plant production and vegetative cover. • Improved plant production increases soil carbon. • Organic soils are susceptible to subsistence. **Water** • Runoff, flooding, or ponding is reduced with improved vegetative cover. • Increased plant vigor improves the uptake of nutrients and improves surface and ground water quality. • Improved vegetative cover reduces runoff and sediment into waterways. • Maintain or lower surface water temperatures. **Air** • Increased plant vigor reduces the potential for generation of particulates by wind erosion. • Minimal reduction of ozone precursors through reduced incidence of wildfire. • Short-term increase in ozone precursors (NOx and VOC emissions) during the burn. • Emissions of greenhouse gases and CO2	**Land** • Cultural resources may be affected by burning and mechanical treatment. • Increase in land use, brush/tree areas brought into production. **Capital** • No additional field equipment required, some installation equipment required. • Consultants, permits, safety considerations and implementation. • No operation and maintenance costs, only one-time implementation costs. • Foregone income from lost production or change in seasonal use. **Labor** • No Change. **Management** • Develop fire management plan. **Risk** • Fire hazard to people, structures, crops and livestock. • Burning mineralizes organic materials, may increase salts. • Increase in particulate emissions from the fire.

emissions are decreased with the decreased incidence of wildfire. • Increased plant vigor increases carbon sequestration. • Fire increases smoke, particulates and other objectionable associated odors. **Plants** • Growing conditions are altered to enhance health and productivity of more desirable plants. • Improved management of undesirable vegetation. • Reduced fuel loading and wildfire hazard. **Animals** • Improved livestock distribution, increased forage availability, improved livestock health, extended grazing period, and improved forage production. • A more diverse plant community with adequate food and cover for wildlife. • Restored desired habitat, space and wildlife habitat continuity. • Improved production and quality of desirable forage species. **Energy** • Reduced energy requirements for firefighting and pest control. **Human** • More land management options. • Labor savings managing brush and improved livestock herding. • Increase in wildlife recreational opportunities. • Increase yields/reduce costs as land becomes more productive. • Create sustainability of natural resources that support your business. • Increase the property value (real estate) of your property. • Create open space and improve habitat	• Some shrubs and trees which provide livestock and wildlife shelter are removed from area.

for wildlife. • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>Net Effect:</u> **improves soil productivity, reduces erosion at a moderate cost.**	

Commonly Associated Practices: Access Control , Brush Management, Critical Area Planting, Dust Control on Unpaved Roads and Surfaces, Early Successional Habitat Development/Mgt., Forage and Biomass Planting, Forest Stand Improvement, Forest Trails and Landings, Fuel Break, Herbaceous Weed Control, Integrated Pest Management, Range Planting, Sediment Basin, Silvopasture Establishment, Tree/Shrub Pruning, Tree/Shrub Site Preparation, Woody Residue Treatment.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Prescribed Grazing (Ac) 528

Definition: Managing the harvest of vegetation with grazing and/or browsing animals.

Major Resource Concerns Addressed: Low plant/animal productivity and health.

Benchmark Condition: Native rangeland, poor livestock distribution, low forage yields.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind and gully erosion reduced by improving the health/vigor of plant communities with increased vegetative cover and water infiltration. • Streambanks protected with an increase in riparian vegetation. • Increase in vegetative cover, deeper root systems, increased soil organic material and biological activity, and improved nutrient cycling. • Reduced soil compaction. • Increased cover reduces evaporative salt accumulation. **Water** • Spring and seep flows improved. • Runoff, flooding, or ponding is reduced and infiltration increased with improved vegetative cover. • Soil moisture improved, less irrigation. • Reduced pesticides and fertilizer use with better plant health and vigor, improved surface and ground water. • Reduced risk of movement of pathogens in surface waters with increase in soil microbial activity. • Reduced sediment delivery to surface water.	**Land** • Slight increase in land in production with better livestock distribution. • Protect buried cultural resources. **Capital** • Slight increase in equipment costs, some monitoring equipment may be required (camera, stakes, hoops, clippers, etc.) • Minor increase in annual operation and maintenance costs for herding and forage monitoring. **Labor** • Additional labor herding livestock between pastures. **Management** • Increase in field scouting to determine when to move livestock and manage forage, minerals and water. • Increase record keeping. **Risk** • Possible foregone income from forage deferment during implementation.

• **Reduced surface water temperatures.** **Air** • **Improved vegetative cover reduces the generation of particulates and removes CO2 from the air and stores it as carbon in plants and soil.** • **Objectionable manure odor reduced.** **Plants** • **Improved plant and animal management enhances growing conditions of the desired plant community and reduces noxious and invasive plants.** • **Improved forage yields and access.** • **Reduced fuel loads and wildfire hazard.** **Animals** • **Improved fish and wildlife habitat, cover, shelter, water, habitat continuity and space.** • **Livestock numbers are in balance with feed and forage that meets livestock nutritional and productive needs.** • **Grazing management considers animal shelter throughout the year.** **Energy** • **Opportunity to reduce herding requirements and fuel use.** **Human** • **Improved livestock distribution and management options.** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Promote family health and safety.**	

• **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>Net Effect:</u> improved forage productivity & water quality, reduce erosion at a minor cost.	

Commonly Associated Practices: Access Control , Animal Trails and Walkways, Dust Control from Animal Activity on Open Lot Surfaces, Feed Management, Fence, Forage and Biomass Planting, Heavy Use Area Protection, Integrated Pest Management, Livestock Pipeline, Nutrient Management, Pond, Spring Development, Stream Crossing, Water Well, Watering Facility.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Range Planting (Ac) 550

<u>Definition:</u> Establishment of adapted perennial or self-sustaining vegetation such as grasses, forbs, legumes, shrubs and trees.

<u>Major Resource Concerns Addressed:</u> Soil productivity.

<u>Benchmark Condition:</u> Low productive range land.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • **Sheet, rill, wind, shoreline and gully erosion is reduced with increased vegetative cover.** • **Increase in organic matter and reduced soil compaction with enhanced root development, litter accumulation, and increased biological activity.** • **Site may be planted to adapted species that reduce saline seeps.** **Water** • **Runoff, flooding, ponding, high water table and seeps are reduced with an increase in cover, infiltration and reduced runoff and overland flow.** • **Reduced drifting snow.** • **Reduced runoff, erosion and the delivery of organics and nutrients to surface water.** • **Permanent vegetation will uptake excess nutrients protecting surface and ground water.** • **Planting in recharge areas may reduce movement of salts to seep areas and surface and ground waters.** • **Increased soil microbiological activity will reduce movement of pathogens.**	**Land** • **Cultural resources may be affected by mechanical treatment.** • **No change in landuse if currently grazed, substantial if change from other land use.** **Capital** • **No additional field equipment required.** • **Materials & planting costs.** • **Annual operation and maintenance costs to maintain vegetation and manage pests.** **Labor** • **No change.** **Management** • **No change.** **Risk** • **During the establishment period, there may be a slight to moderate risk of erosion, depending on seedbed preparation, seeding method, and species planted.** • **There may be an increase in seeps because of increased infiltration.** • **Potential for leaching of salt into ground water because of increased infiltration.** • **Short term foregone income from lost production or change in seasonal use.**

• **Reduced runoff and sedimentation.** • **Reduced high water temperature through thermal regulation of gravitational water moving laterally to open water.** **Air** • **Permanent vegetation reduces the potential for generation of particulates by wind erosion.** • **Vegetation removes CO_2 from the air and stores it in the form of carbon in the plants and soil.** **Plants** • **Plants are selected and managed to maintain optimal productivity, health and ecological function.** • **Undesired species are controlled.** **Animals** • **Increase in livestock and wildlife yield from better plant species mix and plant density.** • **Fish and wildlife cover, shelter and habitat are improved.** **Energy** • **No change.** **Human** • **Improved livestock distribution, increased forage availability and management options.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote**	

good stewardship. • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>**Net Effect:**</u> **Improves soil productivity at a moderate cost.**	

Commonly Associated Practices: Access Control, Brush Management, Grazing Land Mechanical Treatment, Prescribed Burning, Prescribed Grazing, Upland Wildlife Habitat Management, Watering Facility.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Restoration and Management of Rare or Declining Habitats (Ac) 543

Definition: Restoring, conserving, and managing unique or diminishing native terrestrial and aquatic ecosystems.

Major Resource Concerns Addressed: Wildlife habitat.

Benchmark Condition: Vernal pool habitat for aquatic invertebrates and waterfowl.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind, gully and streambank erosion is reduced by establishing or improving native vegetative cover. • Improved vegetative cover may increase soil organic matter. However, if prescribed burning is used, removal of vegetation and litter from a site temporarily removes organic material that could have become soil organic matter. **Water** • Improved vegetative cover will reduce runoff and sedimentation. • Restoration of habitat adjacent to streams or water bodies will moderate surface water temperatures. **Air** • Additional vegetation removes CO_2 from the air and stores it in the form of carbon in the plants and soil. **Plants** • Plants are selected and managed to maintain optimal productivity, health and the desired plant community.	**Land** • Cultural resources may be harmed during restoration. • Some land may be taken out of agricultural production. **Capital** • No change in field equipment. • Materials & construction costs. • Annual operation and maintenance costs to clean-out debris, repair and replace structures, maintain vegetation and manage pests. • Foregone income from lost production or change in seasonal use. **Labor** • Increase in labor depends on natural or artificial habitat. **Management** • Develop habitat management plan, field scouting and record keeping. **Risk** • Reduced agricultural operation flexibility and timing with more restricted land use.

• **Vegetation is managed to control undesired species.** **Animals** • **Improved plant diversity and quality and quantity of vegetation provides food, cover, shelter and habitat for wildlife.** • **Declining habitats and space are restored.** • **Additional feed and forage for livestock.** **Energy** • **None** **Human** • **Labor, management and capital will decrease as land is taken out of production.** • **Reduced time cultivating previous crop.** • **Create sustainability of natural resources that support farm business.** • **Increase the property value (real estate).** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>Net Effect:</u> Improved soil productivity and wildlife habitat at a moderate cost.	

Commonly Associated Practices: Access Control , Animal Trails and Walkways, Brush Management, Conservation Cover, Early Successional Habitat Development/Mgt., Fence, Forage and Biomass Planting, Range Planting, Tree/Shrub Establishment, Upland Wildlife Habitat Management, Wetland Wildlife Habitat Management.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Riparian Forest Buffer (Ac) 391

<u>Definition:</u> An area predominantly trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies.

<u>Major Resource Concerns Addressed:</u> Wildlife habitat and streambank erosion.

<u>Benchmark Condition:</u> Degraded riparian area adjacent to cropland.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind and gully erosion is reduced by vegetation and surface litter. • Streambank, shoreline and conveyance channels erosion is reduced. • Root penetration and organic matter will reduce compaction and restore soil structure. • Increased vegetation and organic matter will increase salt uptake tie up salts and other chemicals. **Water** • Trees or shrubs may retard flood water movement from the site. • Seasonal high water table may be reduced as plants take up excess water. • Trees, shrubs and other vegetation may reduce runoff, trap adsorbed pesticides, take up pesticide residues and may intercept pesticide drift. • Plants and soil organisms will utilize nutrients, and the buffer will filter out suspended particles to which nutrients are attached. • Pathogens, agricultural chemicals and manure will be captured and delayed or removed from waterways.	**Land** • Historic properties may be protected from erosion by permanent cover. • Some land may be taken out of agricultural production. **Capital** • No change in field equipment. • Materials, planting and construction costs. • Annual operation and maintenance costs to clean-out debris, repair and replace structures, maintain vegetation and manage pests. **Labor** • None. **Management** • Increase in developing a habitat management plan, field scouting and record keeping. **Risk** • Reduced farm flexibility when land is taken out of production.

• **Sediment, pathogens, chemicals, manure, bio-solids or compost will be captured and delayed from entering waterways.** • **Riparian forest canopy shades streams and rivers, cooling water temperatures.** **Air** • **Vegetation reduces erosive wind velocities and provides a stable area which stops saltating particles.** • **Vegetation removes CO2 from the air and stores it in the form of carbon in the plants and soil.** **Plants** • **Buffer establishment and management creates the desired plant community.** • **Vegetation is installed and managed to control undesired species.** **Animals** • **Improved fish and wildlife habitat, food, continuity, space, cover and shelter for wildlife.** **Energy** • **None.** **Human** • **Decrease in labor with land taken out of production.** • **Reduced labor managing sediment and sloughing shoreline.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for fish and wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.**	

• **May be eligible for cost share.** • **Increased profitability in the long run.** •	
<u>**Net Effect:**</u> **Improve wildlife habitat and water quality at a moderate cost.**	

Commonly Associated Practices: Access Control , Brush Management, Early Successional Habitat Development/Mgt., Field Border, Filter Strip, Firebreak, Fish Passage, Forest Stand Improvement, Grassed Waterway, Herbaceous Weed Control, Integrated Pest Management, Multi-Story Cropping, Nutrient Management, Prescribed Grazing, Recreation Area Improvement, Riparian Herbaceous Cover, Shallow Water Development and Management, Stream Crossing, Stream Habitat Improvement and Management, Streambank and Shoreline Protection, Structure for Water Control, Subsurface Drain, Tree/Shrub Establishment, Tree/Shrub Pruning, Tree/Shrub Site Preparation, Underground Outlet, Upland Wildlife Habitat Management, Wetland Creation, Wetland Enhancement, Wetland Restoration, Wetland Wildlife Habitat Management, Woody Residue Treatment.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Riparian Herbaceous Cover (Ac) 390

Definition: **Grasses, sedges, rushes, ferns, legumes, and forbs tolerant of intermittent flooding or saturated soils, established or managed as the dominant vegetation in the transitional zone between upland and aquatic habitats.**

Major Resource Concerns Addressed: **Wildlife habitat and streambank erosion.**

Benchmark Condition: **Degraded riparian area adjacent to pasture land.**

Date: **October, 2016** **Developer/Location:** **Hal Gordon, OR**

Positive Effects	Negative Effects
Soil • Sheet, rill, wind and gully erosion is reduced by vegetation and surface litter. • Streambank, shoreline and conveyance channels erosion is reduced. • Root penetration and organic matter will reduce compaction and restore soil structure. • Increased vegetation and organic matter will increase salt uptake tie up salts and other chemicals. **Water** • Shrubs may retard flood water movement from the site. • Seasonal high water table may be reduced as plants take up excess water. • Shrubs and other vegetation may reduce runoff, trap adsorbed pesticides, take up pesticide residues and may intercept pesticide drift. • Plants and soil organisms will utilize nutrients, and the buffer will filter out suspended particles to which nutrients are attached. • Pathogens, agricultural chemicals and manure will be captured and delayed or	**Land** • Historic properties may be protected from erosion by permanent cover. • Some land may be taken out of agricultural production. **Capital** • No change in field equipment. • Materials, planting and construction costs. • Annual operation and maintenance costs to clean-out debris, repair and replace structures, maintain vegetation and manage pests. **Labor** • None. **Management** • Increase in developing a habitat management plan, field scouting and record keeping. **Risk** • Reduced farm flexibility when land is taken out of production.

removed from waterways. • **Sediment, pathogens, chemicals, manure, bio-solids or compost will be captured and delayed from entering waterways.** • **Herbaceous cover and shrubs may shade waterways, cooling water temperatures.** **Air** • **Vegetation reduces erosive wind velocities and provides a stable area which stops saltating particles.** • **Vegetation removes CO2 from the air and stores it in the form of carbon in the plants and soil.** **Plants** • **Buffer establishment and management creates the desired plant community.** • **Vegetation is installed and managed to control undesired species.** **Animals** • **Improved fish and wildlife habitat, food, continuity, space, cover and shelter for wildlife.** **Energy** • **None.** **Human** • **Decrease in labor with land taken out of production.** • **Reduced labor managing sediment and sloughing shoreline.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for fish and wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.**	

• **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>**Net Effect:**</u> **Improve wildlife habitat and water quality at a low cost.**	

Commonly Associated Practices: Access Control , Conservation Cover, Fence, Forage and Biomass Planting, Forest Stand Improvement, Herbaceous Weed Control, Integrated Pest Management, Prescribed Grazing, Riparian Forest Buffer, Stream Habitat Improvement and Management, Streambank and Shoreline Protection, Structure for Water Control, Tree/Shrub Establishment, Tree/Shrub Site Preparation, Upland Wildlife Habitat Management.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Road/Trail/Landing Closure and Treatment (Ac) 654

Definition: The closure, decommissioning, or abandonment of roads, trails, and/or landings and associated treatment to achieve conservation objectives.

Major Resource Concerns Addressed: Soil compaction and plant productivity.

Benchmark Condition: High road density on grazing woodlots.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Increased vegetation and cover and stabilization of erosive conditions will improve infiltration, decrease soil detachment by water and reduce erosion, gully formation and streambank erosion. • Increased soil organic matter. • Decrease in soil compaction. • Increased organic matter may tie up salts and other chemicals. **Water** • Hydrologic processes are restored through vegetative and other treatments. • Reduced nutrient, salt, pathogens, agricultural chemicals, manure and sediment delivery to surface and ground water. • Reestablishment of natural hydrology can reduce surface water temperatures. **Air** • Permanent cover and other treatments help reduce wind erosion and wind and traffic generation of fugitive dust. • Vegetation removes CO_2 from the air and stores it in the form of carbon in the plants and soil.	**Land** • Negative if trail is historic and needs maintenance. • Change in land use from roadway to other land use. • Reduced access may reduce land in production. **Capital** • No change in field equipment. • Materials & construction costs. • Operate and maintain water bars, barriers and structures. • Foregone income from lost production or change in seasonal use. **Labor** • Decrease in labor with land taken out of production. **Management** • No change. **Risk** • Decrease in agricultural operation flexibility and timing due to restricting access, reduced grazing or agricultural production options. • Increase in travel costs.

Plants • **Proper plant selection, nutrient modification and management improves plant growth and vigor.** • **Establishment of permanent vegetation provide competition that slows the spread of noxious plants, removes noxious plants and improves plant community** **Animals** • **Increased quality and quantity of vegetation provides more food, cover, shelter and habitat for wildlife.** • **Established vegetation may add forage for domestic animals.** **Energy** • **No change.** **Human** • **Decrease in labor with land taken out of production.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **Improves soil and plant productivity at a moderate cost.**	

Commonly Associated Practices: Access Control , Critical Area Planting, Forest Stand Improvement, Sediment Basin, Structure for Water Control, Upland Wildlife Habitat Management, Woody Residue Treatment.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Silvopasture Establishment (Ac) 381

Definition: An application establishing a combination of trees or shrubs and compatible forages on the same acreage.

Major Resource Concerns Addressed: Soil productivity and livestock habitat.

Benchmark Condition: Sparse woodlot adjacent to pasture land.

Date: October, 2016 Developer/Location: Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind, gully and streambank erosion is reduced by establishing a combination of trees, shrubs and forages which reduce erosion by water. • Permanent vegetation, roots, vegetative matter and livestock waste may increase soil organic matter. • Tree root penetration and organic matter counteracts soil compaction from livestock. • Contaminants taken up by forage plants will be returned to the soil as manure. **Water** • Decrease in runoff, flooding, ponding, seeps and seasonal high water table with increased utilization of soil moisture and evapotranspiration from changes in vegetative structure and composition. • Increase in drifted snow that is captured by tree/shrub crowns and deposited within the forage area. • Trees and shrubs will take up additional pesticide residues and intercept pesticide drift. • Increased nutrients and salt uptake by plants, reducing their movement to	**Land** • Cultural resources may be harmed during earth moving or tree planting. • Change in land use and land in production. **Capital** • Additional field equipment may be required (crop, hay or livestock). • Installation, materials & planting costs. • Annual operation and maintenance costs to maintain vegetation and manage pests. **Labor** • Increase in labor managing tree and crop production. **Management** • Increase time managing crop and tree production. **Risk** • Slight increase in seeps or high water table with increased infiltration, especially during dormant season. • Grazing animals may cause difficulty in scheduling forage irrigations. • Establishment of permanent silvopasture vegetation may negatively impact the native understory plant community.

surface and ground water. • **Captured and delayed pathogen movement and increased pathogen mortality.** • **Reduced sedimentation.** • **Tall vegetation established near surface waters provides shade and reduces water temperatures.** • **Vegetation may take up heavy metals.** **Air** • **Reduced wind velocities, filtering particulates from the air, stopping saltating particles and reduced odor.** • **Increase in storing soil carbon.** • **Tall vegetation slows surface air movement and intercepts and captures airborne particulates.** **Plants** • **Vegetation is installed and managed to control undesired weed species.** • **Overstory trees are spaced and managed to reduce wildfire hazard.** **Animals** • **Changes in structure and composition will have positive effects on food, cover and habitat for certain wildlife species and wildlife.** **Energy** • **Reduced energy use associated with fighting wildfire.** • **Potential biofuel production.** **Human** • **Improved agricultural operation flexibility and timing with diversification of land uses.** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.**	• **Changes in structure and composition will have negative effects on food, cover and habitat for certain wildlife species.**

• **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
<u>Net Effect:</u> Improved soil productivity, livestock and wildlife habitat at a moderate cost.	

Commonly Associated Practices: Access Control , Brush Management, Dust Control from Animal Activity on Open Lot Surfaces, Firebreak, Forage and Biomass Planting, Forest Stand Improvement, Herbaceous Wind Barriers, Livestock Pipeline, Prescribed Burning, Prescribed Grazing, Tree/Shrub Establishment, Tree/Shrub Pruning, Tree/Shrub Site Preparation, Upland Wildlife Habitat Management, Watering Facility, Wetland Wildlife Habitat Management.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Trails and Walkways (Ac) 568

<u>Definition:</u> A pathway for pedestrian, equestrian, bicycle, other off-road modes of recreation travel, farm-workers, construction/maintenance access and small walk behind equipment.

<u>Major Resource Concerns Addressed:</u> Sensitive riparian areas, water quality.

<u>Benchmark Condition:</u> Wet meadow along riparian area near dairy milking parlor.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind, gully and streambank and shoreline erosion is reduced by directing travel away from erosion prone areas. • Controlled traffic confines compaction is to a more limited area. **Water** • Managed foot traffic increases vegetative cover and reduces compaction, runoff, flooding, or ponding. • Trails and Walkways can move traffic away from sensitive riparian areas. • Suspended sediment and turbidity in surface water will decrease due to controlled traffic and reduced erosion. **Air** • Reduced time and travel of motorized vehicles. **Plants** • Trails provide firebreaks and access to sites for fuel reduction activities. **Animals** • By confining animals to a trail they will stay out of the stream and away from wildlife food, cover and shelter sources.	**Land** • Historic properties and cultural resources may be affected by route preparation, construction and by certain operation and maintenance actions. • Minimal land taken out of agricultural production. **Capital** • No additional field equipment required. • Installation equipment and materials. • Annual operation and maintenance costs to maintain pathway, control vegetation and manage pests. **Labor** • No change. **Management** • No change. **Risk** • None.

• **Improved distribution of animals makes forage more readily available to livestock.** • **Provides access to previously inaccessible feeding and watering areas.** **Energy** • **Reduced time and travel of motorized vehicles.** **Human** • **Increase in farm flexibility with improved accessibility.** • **Improved livestock management and health.** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: Improved livestock management, protect sensitive areas, at a moderate cost.	

Commonly Associated Practices: Access Control , Access Road , , Critical Area Planting, Dam, Dam, Diversion, Dike, Diversion, Dust Control on Unpaved Roads and Surfaces, Filter Strip, Heavy Use Area Protection, Mulching, Recreation Area Improvement, Recreation Land Grading and Shaping, Riparian Forest Buffer, Riparian Herbaceous Cover, Upland Wildlife Habitat Management, Water and Sediment Control Basin, Wetland Wildlife Habitat Management.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying

a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Tree/Shrub Establishment (Ac) 612

<u>Definition:</u> Establishing woody plants by planting seedlings or cuttings, direct seeding, or natural regeneration.

<u>Major Resource Concerns Addressed:</u> Plant productivity, unproductive woodlot.

<u>Benchmark Condition:</u> Douglas fir riparian area after wildfire.

<u>Date:</u> October, 2016 <u>Developer/Location:</u> Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Sheet, rill, wind and gully erosion is reduced by vegetation and surface litter. • Establishment of permanent woody vegetation increases root and shoot development and increases soil organic matter. • Root penetration and organic matter helps restore soil structure and reduces compaction. • Woody vegetation takes up limited quantities of salts and other chemicals. **Water** • Deep rooted plants uptake excess water and reduce seeps, ponding, flooding and high water table. • Snow is captured and deposited down wind of planted trees and shrubs. • Adapted and managed vegetative production allows more efficient use of available water. • Trees and shrubs take up pesticide, nutrient and agricultural chemical residues. • Reduces runoff of pesticides, nutrients and agricultural chemicals into surface and groundwater.	**Land** • Change in land use if converting to woodland. • Land taken out of agricultural production. **Capital** • No additional field equipment required. • Materials & planting costs. • Annual operation and maintenance costs to maintain vegetation and manage pests. **Labor** • Increase in labor during planting. **Management** • No change. **Risk** • Reduced farm flexibility by changing to permanent vegetation. • Trees or shrubs may retard flood water movement away from the site.

• **Woody vegetation captures and delays pathogen movement.** • **Near streams and other water bodies, trees and shrubs provide shade to moderate water temperature.** **Air** • **Permanent vegetative cover reduces wind erosion and fugitive dust generation.** • **Vegetation removes CO_2 from the air and stores it in the form of carbon in the plants and soil.** • **Vegetation will reduce wind movement and can intercept odors.** **Plants** • **Plants are selected and managed to maintain optimal productivity and health.** **Animals** • **Plants are chosen and managed to enhance food, cover and shelter for target species.** • **May be used as feed and forage by livestock if the desired trees and shrubs are not harmed.** • **Tall vegetation provides livestock shelter.** **Energy** • **Plantings may reduce need for heating and cooling around farmsteads.** • **Potential biomass fuel production.** **Human** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.**	

• **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.** • **Increased profitability in the long run.**	
Net Effect: **Improved woodland at a moderate cost.**	

Commonly Associated Practices: Conservation Cover, Critical Area Planting, Early Successional Habitat Development/Mgt., Forest Stand Improvement, Forest Trails and Landings, Hedgerow Planting, Integrated Pest Management, Nutrient Management, Riparian Forest Buffer, Sediment Basin, Tree/Shrub Pruning, Tree/Shrub Site Preparation, Upland Wildlife Habitat Management, Windbreak/Shelterbelt Establishment, Windbreak/Shelterbelt Renovation

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Watering Facility (No) 614

Definition: A permanent or portable device to provide an adequate amount and quality of drinking water for livestock and or wildlife.

Major Resource Concerns Addressed: Livestock distribution, water quality and plant productivity.

Benchmark Condition: Uncontrolled in-stream access to watering livestock.

Date: October, 2016 Developer/Location: Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Increased vegetated cover due to better livestock distribution reduces soil and gully erosion. • Streambank, shoreline and water conveyance channel erosion are reduced with reduced animal traffic. **Water** • Increased infiltration due to better vegetative cover, and an increase in seep flow and reduced ponding, flooding and high water table. • When used in place of an in-stream water source, decreased manure deposition in stream. • Better distribution of animals results in less concentration of contaminants entering waterways. • Getting animals out of the stream will keep them cleaner and reduce contact with manure-borne pathogens. • A water development will decrease livestock trampling in wet areas and nearby streams, reducing sediment, turbidity and high stream temperatures. **Air**	**Land** • Possible damage to cultural resources during installation. • Increase in land use intensity if livestock can access additional land. **Capital** • Installation, operation and maintenance equipment required. • Annual operation and maintenance costs include clean-out debris, repair and replace structures and equipment. **Labor** • Increase in labor to maintain structures. **Management** • Develop water management plan. **Risk** • Livestock traffic may increase soil compaction around the practice, but the practice will help reduce excess moisture where traffic occurs.

• **No change.** **Plants** • **Improved livestock distribution improves growth and vigor of plants.** **Animals** • **Supplying water to off-stream locations protects the stream, riparian areas and fish and wildlife habitat.** • **Improved distribution of animals makes forage more readily available to livestock.** **Energy** • **No Change.** **Human** • **More dependable water supply.** • **Improved access to livestock water.** • **Reduce livestock water costs and develop more intensive grazing system.** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.**	
Net Effect: Improves soil and water quality, increases plant productivity, at a low cost.	

Commonly Associated Practices: Critical Area Planting, Dust Control from Animal Activity on Open Lot Surfaces, Dust Control on Unpaved Roads and Surfaces, Fence, Heavy Use Area Protection, Livestock Pipeline, Prescribed Grazing, Spring Development, Upland Wildlife Habitat Management, Water Well.

Note: This worksheet contains general talking points for the conservation planner to discuss with the land user. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied at the field level. Data for the worksheet comes from the land user, conservation planner, technical specialist and local agricultural supply vendors and contractors. See Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.

Conservation Practice Effects

Water Well (Ac) 642

Definition: A hole drilled, dug, driven, bored, jetted or otherwise constructed to an aquifer for water supply.

Major Resource Concerns Addressed: Inadequate livestock water.

Benchmark Condition: Rangeland with poor livestock distribution.

Date: October, 2016 **Developer/Location:** Hal Gordon, OR

Positive Effects	Negative Effects
Soil • Increased vegetative cover due to better distribution of water reduces soil erosion. **Water** • Well will provide a dependable supply of water allowing better management. • Where well flows are used for irrigation, contaminants can be leached below the root zone. • Reduce high water table as water is removed from subsurface water source. **Air** • No Change. **Plants** • Plant productivity and health will improve with increased availability and managed application of irrigation water. **Animals** • Provides dependable water supply to livestock and wildlife in areas where surface water is scant. • Improved distribution of animals makes forage more readily available to livestock. • Wells facilitate the availability and distribution of water.	**Land** • Facilitating practice, may convert to irrigated land or more intensive grazed land. • Significant increase in land in production with irrigation. **Capital** • Install well and associated water management and distribution equipment. • Annual operation and maintenance costs to repair and replace structures and equipment. **Labor** • Increase in labor if bringing more land into production. **Management** • Increase in management and record keeping. **Risk** • In coastal areas pumping fresh groundwater may allow the intrusion of saltwater. • Use of wells to irrigate previously non irrigated land will increase the likelihood of soluble and sediment-attached

Energy • **No change.** **Human** • **Improved options for agricultural production.** • **Reduce irrigation or culinary water costs, develop more intensive agriculture.** • **Increase yields/reduce costs as land becomes more productive.** • **Create sustainability of natural resources that support your business.** • **Increase the property value (real estate) of your property.** • **Create open space and improve habitat for wildlife.** • **Conserve soil and water for periods of drought and future use.** • **Prevent off-site negative impacts.** • **Comply with environmental regulations.** • **Save time, money and labor.** • **Promote family health and safety.** • **Make land more attractive and promote good stewardship.** • **May be eligible for cost share.**	**contaminants moving of-site, probable less contaminants on grazing lands.** • **Where well flows are used for irrigation, contaminants can be leached below the root zone.** • **Increase in energy use.**
Net Effect: **Improved water management and plant productivity, at a moderate cost.**	

Commonly Associated Practices: Irrigation Water Management, Livestock Pipeline, Pumping Plant, Watering Facility.

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Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013) for more information.