AERO: a wind erosion modeling framework with applications to monitoring data

Brandon L. Edwards, Nicholas P. Webb, Sarah E. McCord

USDA-ARS Jornada Experimental Range, Las Cruces, NM,USA

USDA Agricultural Research Service

NM STATE UNIVERSITY

The JORNADA Rangeland Research Programs

National Wind Erosion Research Network
http://winderosionnetwork.org

What is AERO?

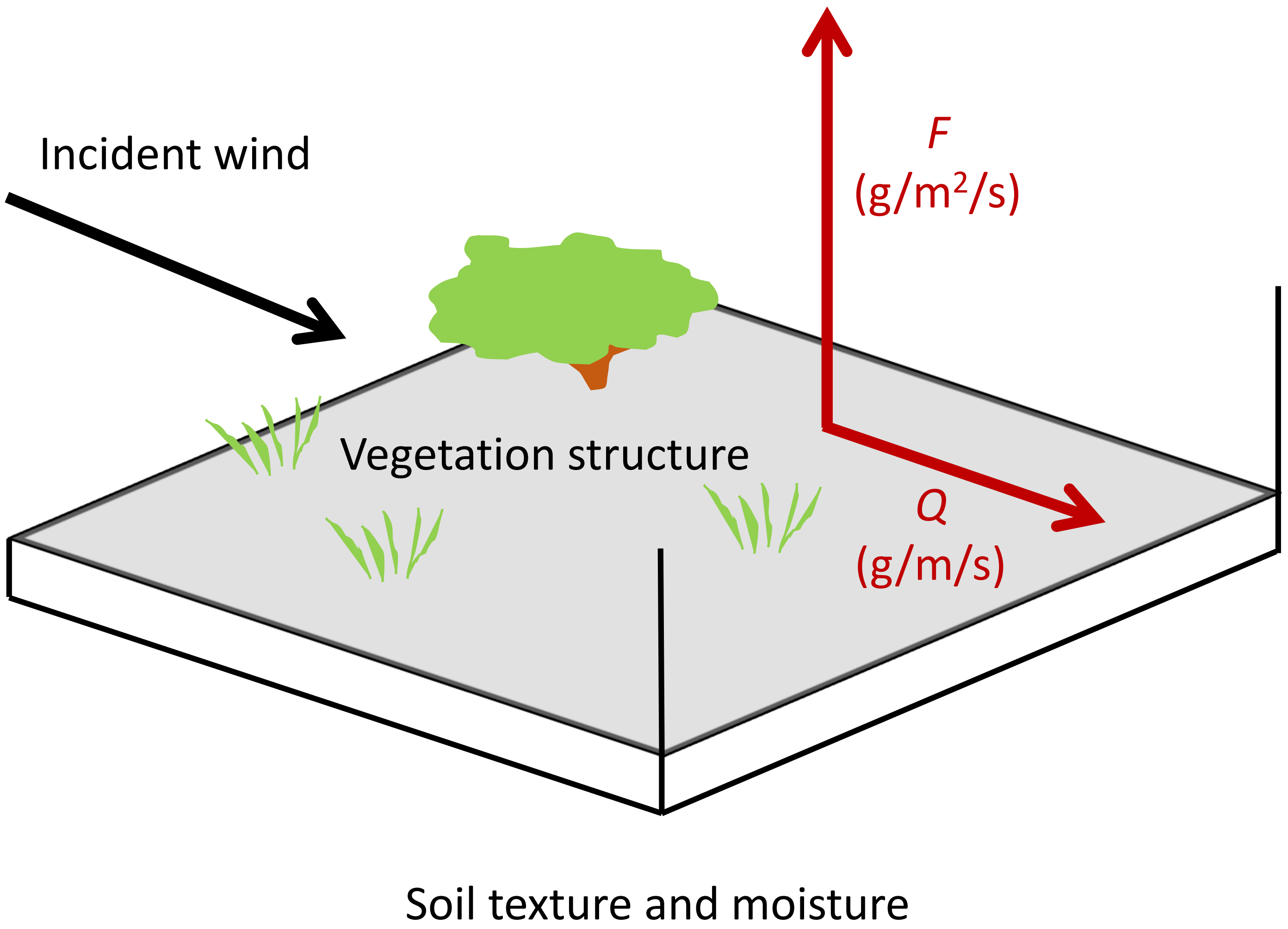
- The Aeolian Erosion Model (AERO) is an aeolian transport and dust emission modeling environment
- Developed to provide a decision-support tool for land managers in addition to a platform for basic research on aeolian processes
- Simulates size-resolved horizontal and vertical mass flux on the plot scale from user inputs of meteorological, soil and vegetation data
- AERO addresses the need for a generalizable wind erosion model that can be applied across different land cover settings

Motivation for development

- Non-standardized methods restrict analyses across US land use and management systems
- Field monitoring and research often use sampling designs that lack statistical rigor (frequently n = 1) and provide insufficient coverage for broad scale assessments
- Models not tested across land use and land cover types – model uncertainty unknown
- Clear need for a generalizable model with sufficient accuracy or precision that can leverage current monitoring data

Design considerations

- Generalizable - mechanistic
- Readily available/easily measured inputs
- Results applicable/meaningful on scales relevant to current management frameworks



Conceptual diagram of AERO model structure. AERO uses inputs of wind, soil and vegetation conditions to calculate horizontal and vertical mass flux.

Model design

Physically based models of aeolian transport inherently describe grain-scale processes

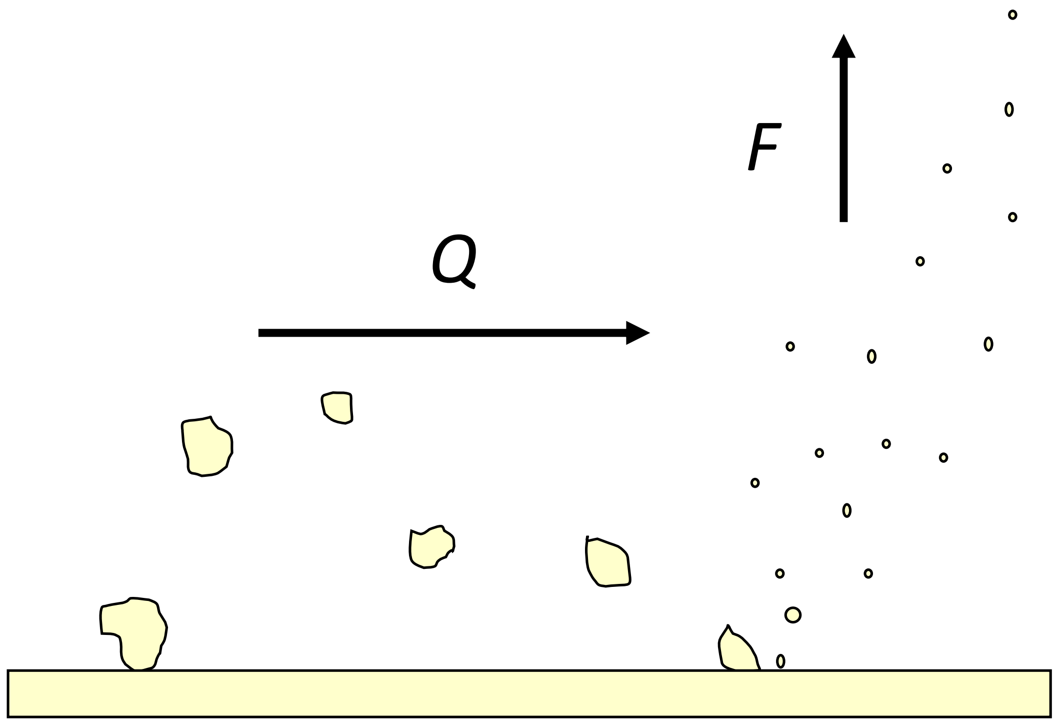
AERO calculates threshold friction velocity, horizontal flux and vertical flux at this scale over a distribution of grain sizes

Defaults/best methods:

Threshold: Iverson and White 1982

Horizontal flux: Gillette and Passi 1988

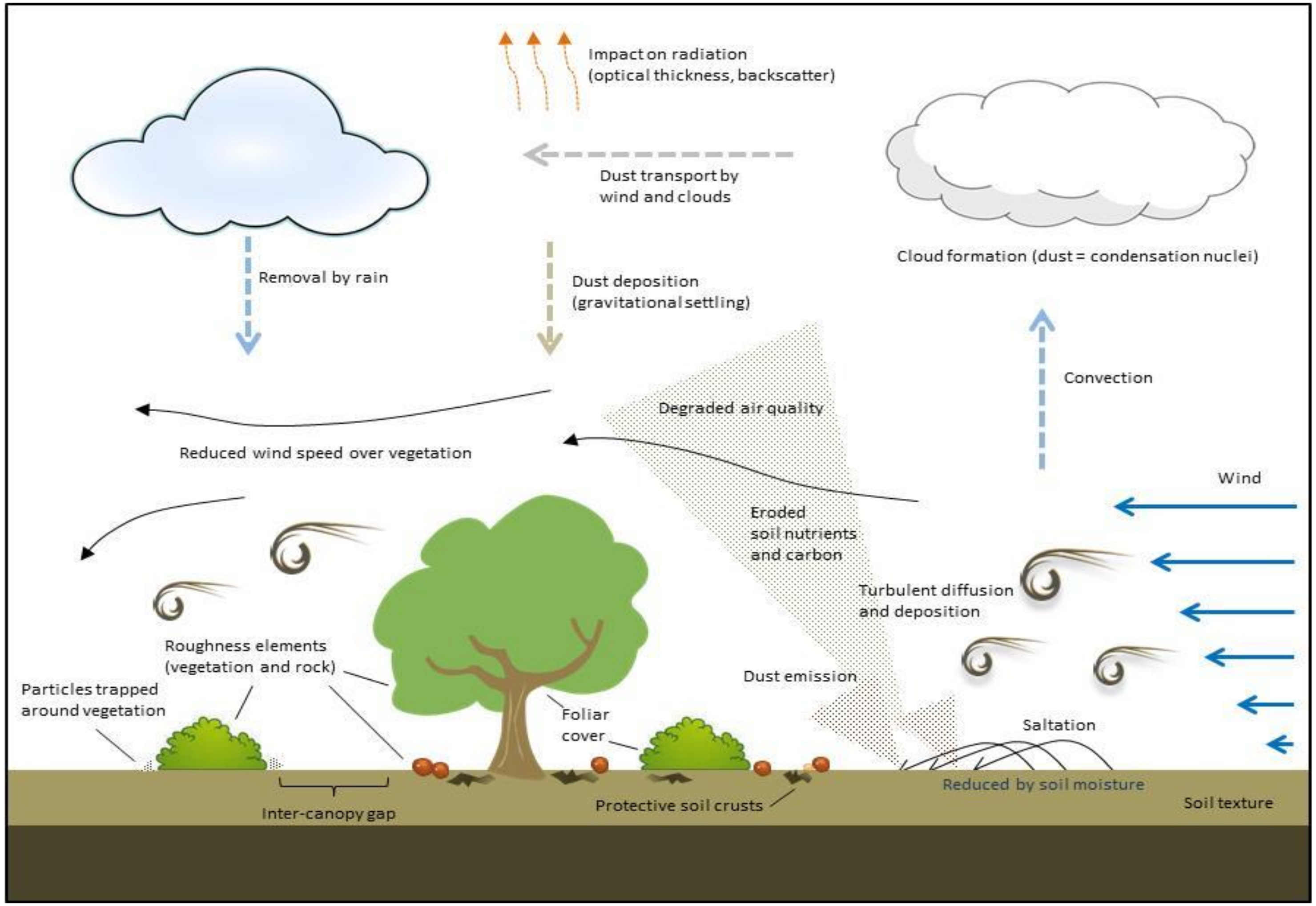
Vertical emission scheme: Shao 2011



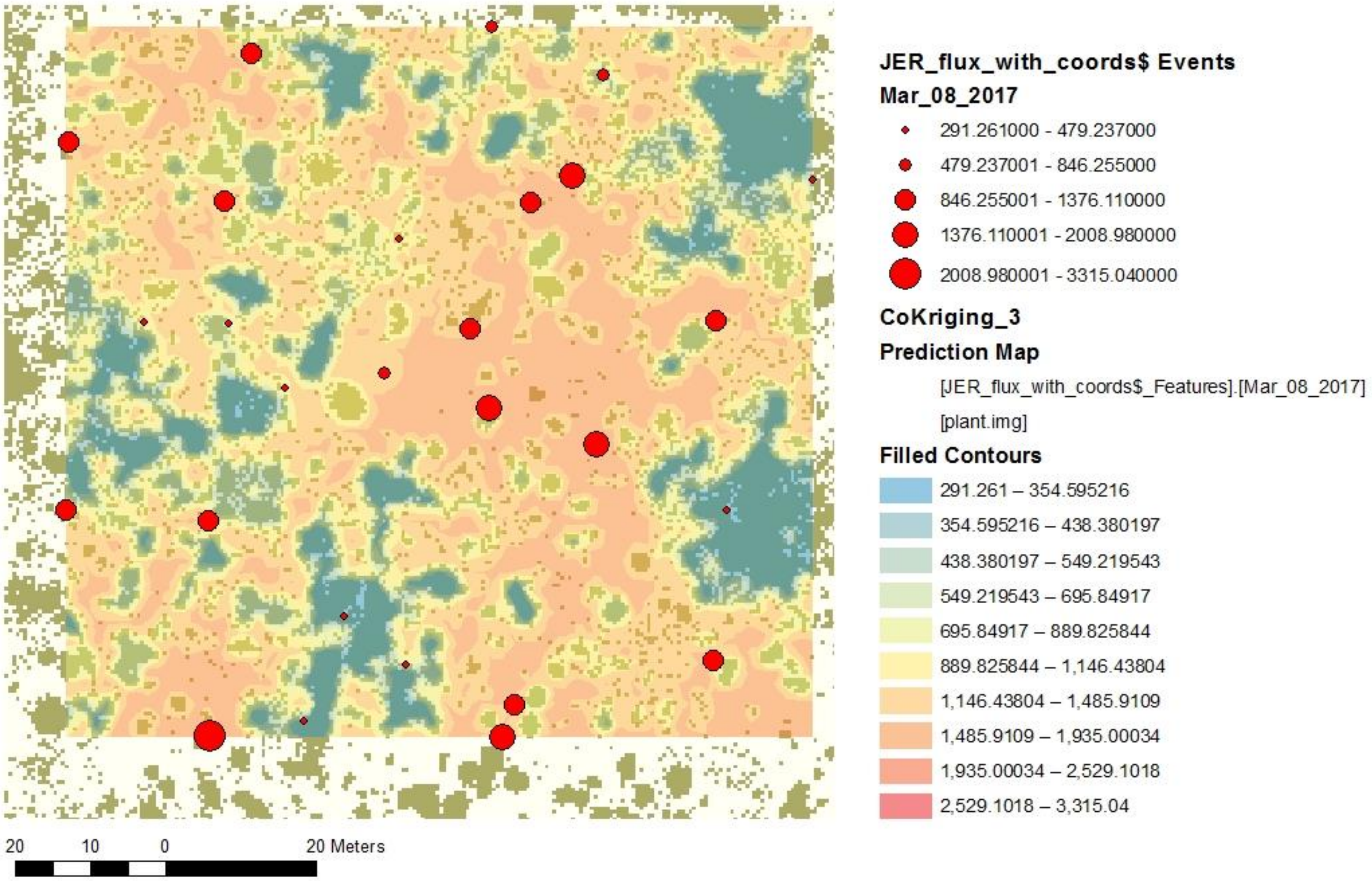
Scaling up to the plot level?

AERO uses the Okin 2008 drag partitioning scheme based on vegetation structure to create a distribution of friction velocity values and associated probabilities for a plot

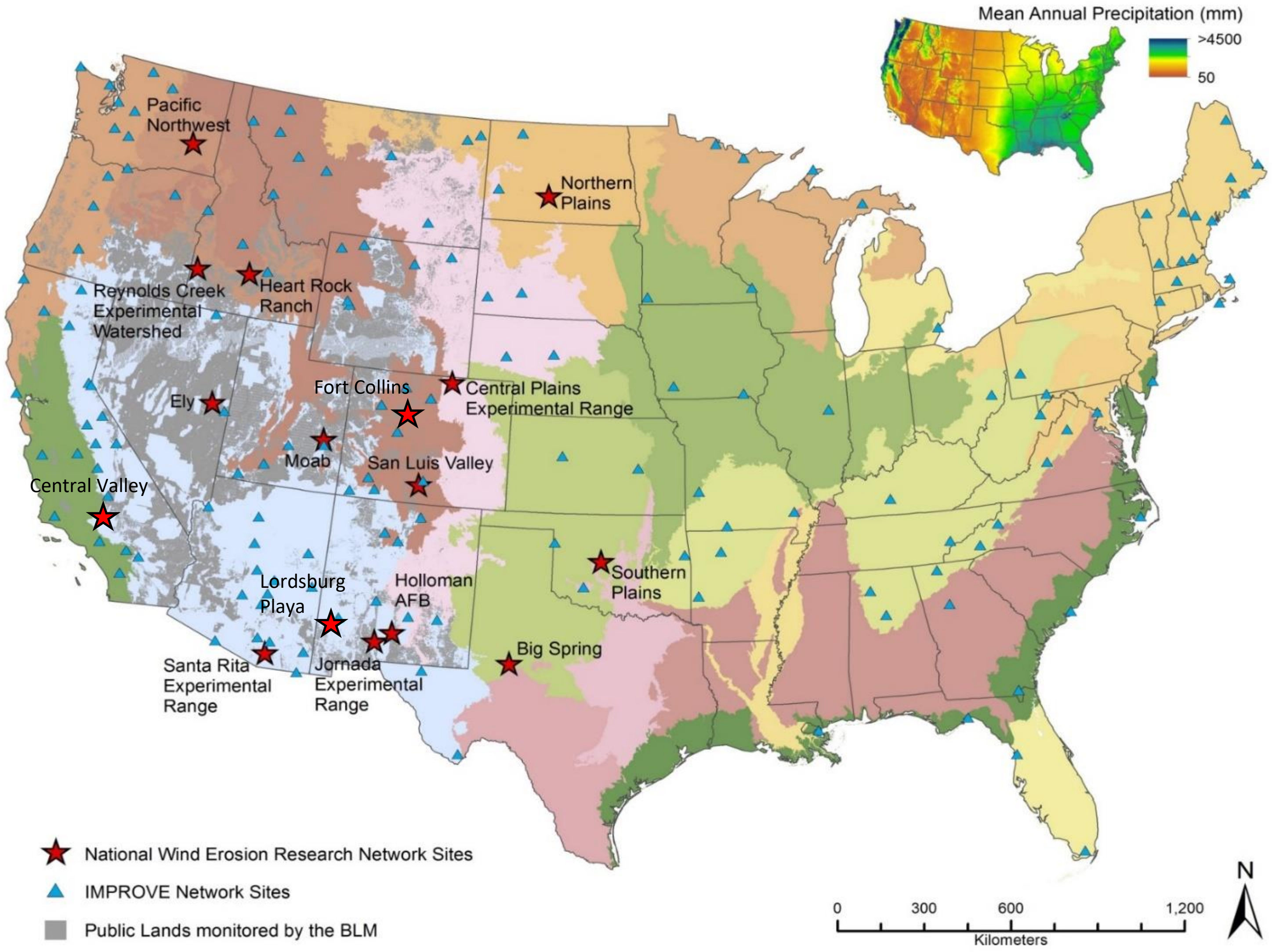
When plot-level probabilities of friction velocity are combined with grain-scale threshold and flux probabilities, transport predictions are scaled upwards to plot-level



March 2017, Jornada experimental range Wind Erosion Network site



National Wind Erosion Research Network sites



Network Objectives:

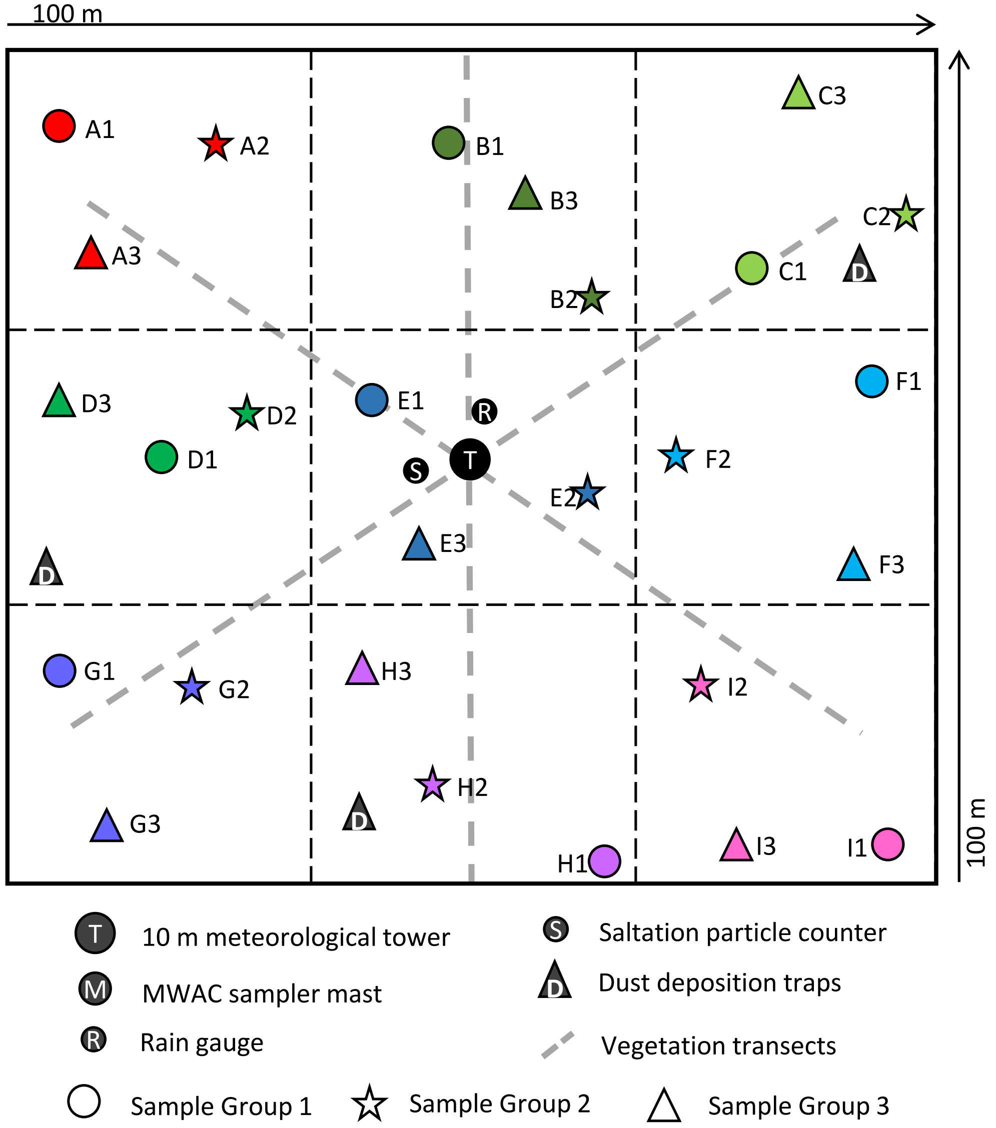
Support research underpinning monitoring, models, and management

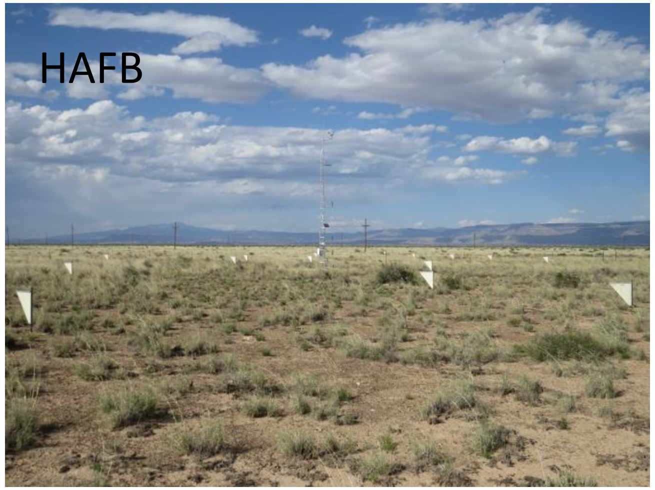
Improve availability of decision-support tools for managers/agencies

Facilitate collaboration to increase impact of science, planning and policy

USDA Agricultural Research Service NRCS Natural Resources Conservation Service USGS science for a changing world The Nature Conservancy

Network standard methods protocol





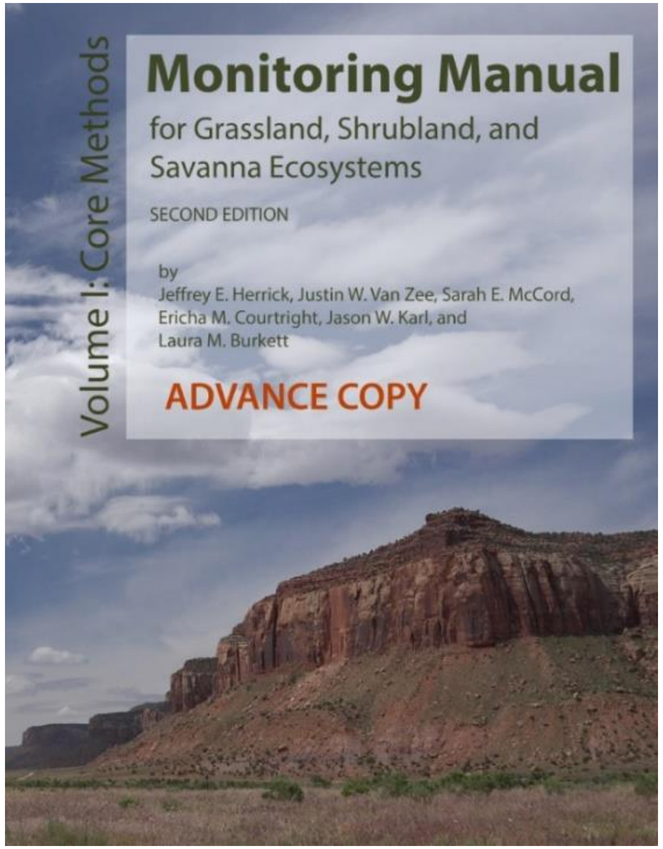
Standardization of methods and data analysis is important for cross-site assessments of wind erosion controls and processes

Model software structure: open source, customizable, flexible

- Coded in Python as a framework with separate modules for calculation methods
- Simulations can be run for a single set of conditions, time series of conditions, conditions over space, or a time series of conditions over space
- Selects available calculation methods depending on user selected order and suitability of inputs
- Key variables can be input as scalars, defined by descriptive statistics, supplied as probability distributions, or remote sensing-derived inputs and atmospheric data from the Weather Research and Forecasting (WRF) weather prediction model

Model inputs: core methods

- AERO was developed for compatibility with US Bureau of Land Management Assessment, Inventory and Monitoring (AIM) and National Resources Conservation Service National Resources Inventory (NRI) monitoring data collected using core methods
- Since 2003, the two programs have sampled at >50,000 locations using standardized methods consisting of 4 core indicators



Soil pits provide soil structure and surface soil texture information.

Line-point intercept provides fractional cover estimates

Vegetation height measurements provide mean vegetation height for use in drag partitioning scheme

Canopy gap measurements describe the distribution of vegetation/ bare ground across plots

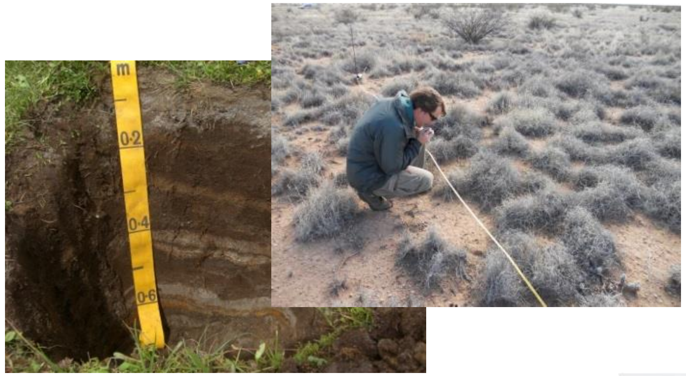
Model inputs: meteorological conditions

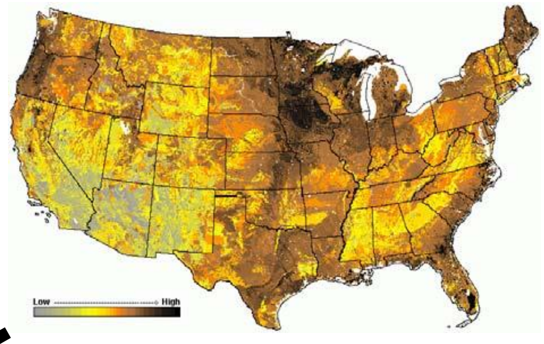
- Observations
  - Compare specific plot-level scenarios across conditions
- Time series of observations
  - Event-based investigations
- PDF based on location
  - Regional assessments
- Spatial or WRF input
  - Regional scenarios with variable conditions, e.g. surface moisture

AERO implementation with NRI, LMF and AIM data

NRI, LMF,
AIM Data

(DIMA,
TerrADat)

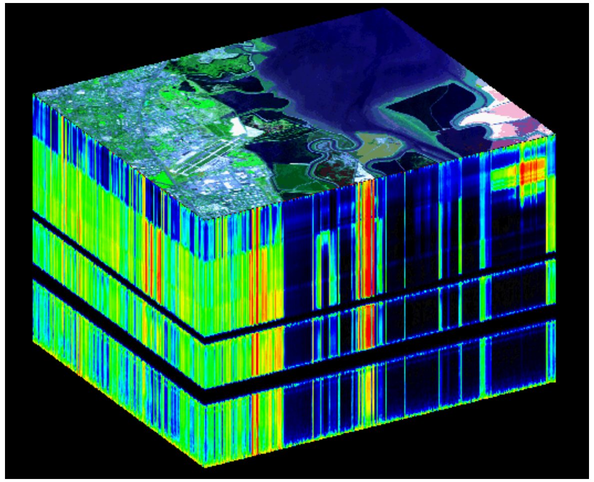


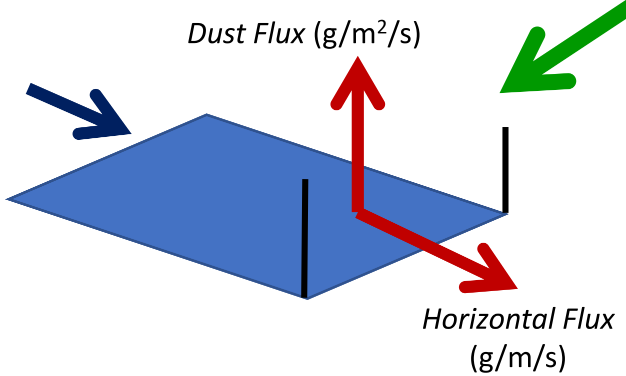


Soil geodatabase providing parameters

Model with user interface

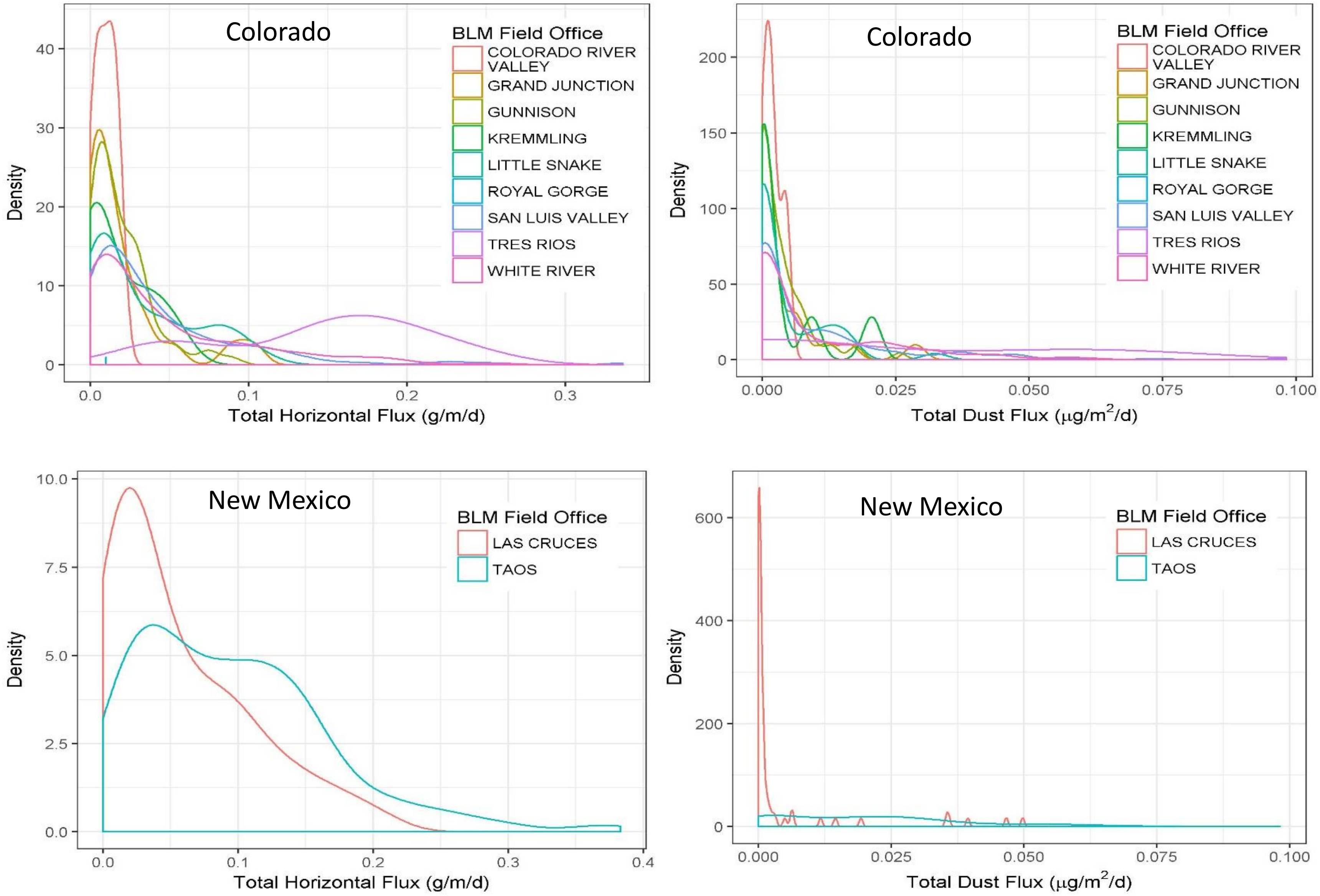
Call atmospheric data by location





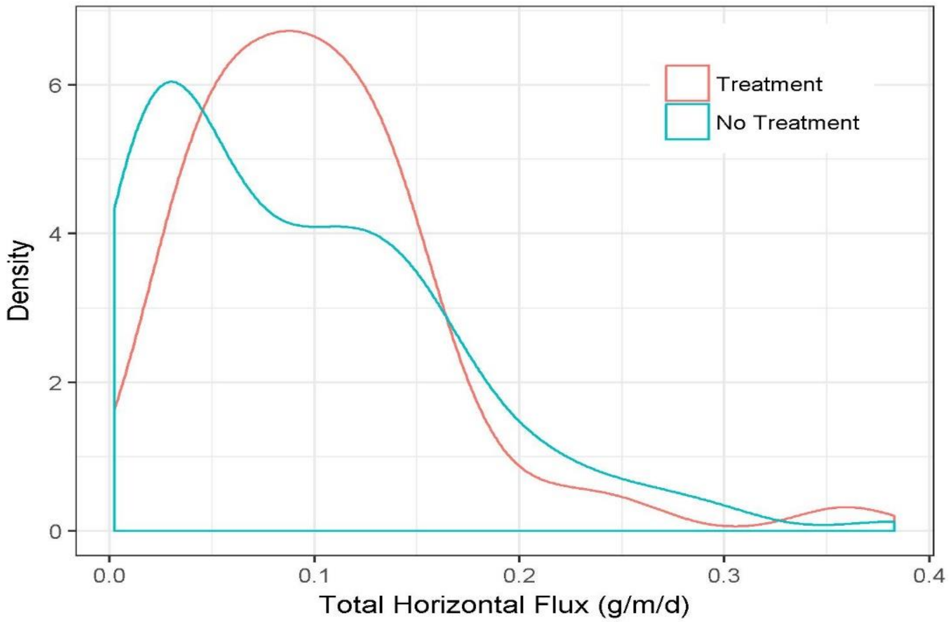
Provide user with estimates of sediment mass fluxes

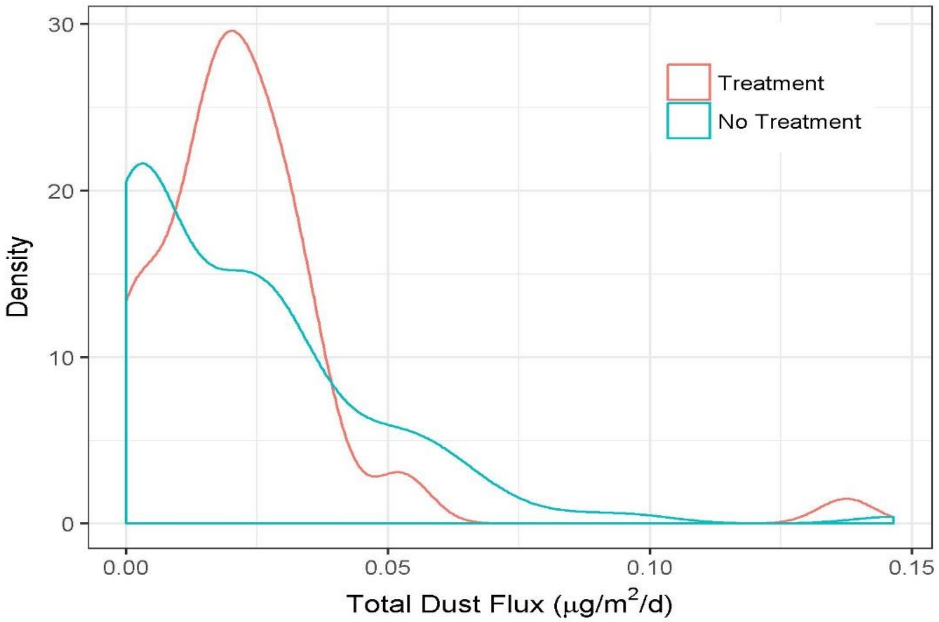
State and regional assessments



Understanding differences in potential fluxes relative to management boundaries is important for identifying land use and management actions that could exacerbate dust emissions.

Assessing management trade-offs

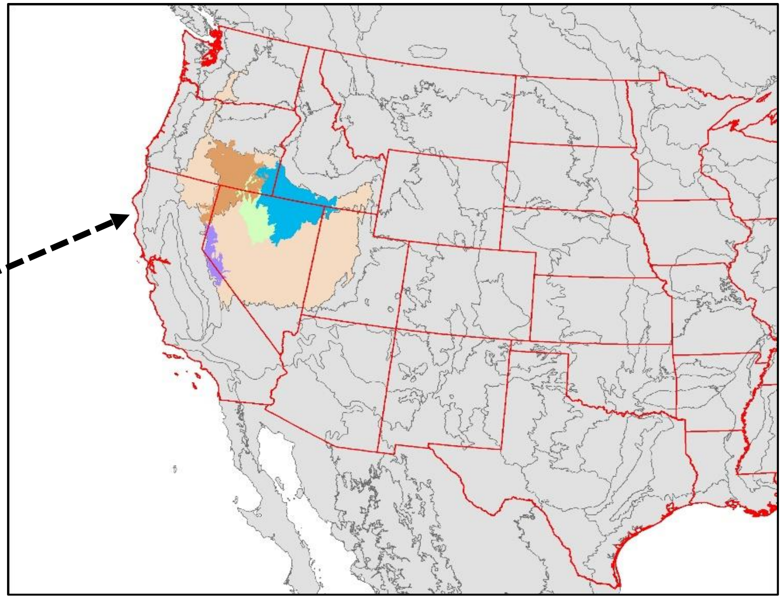


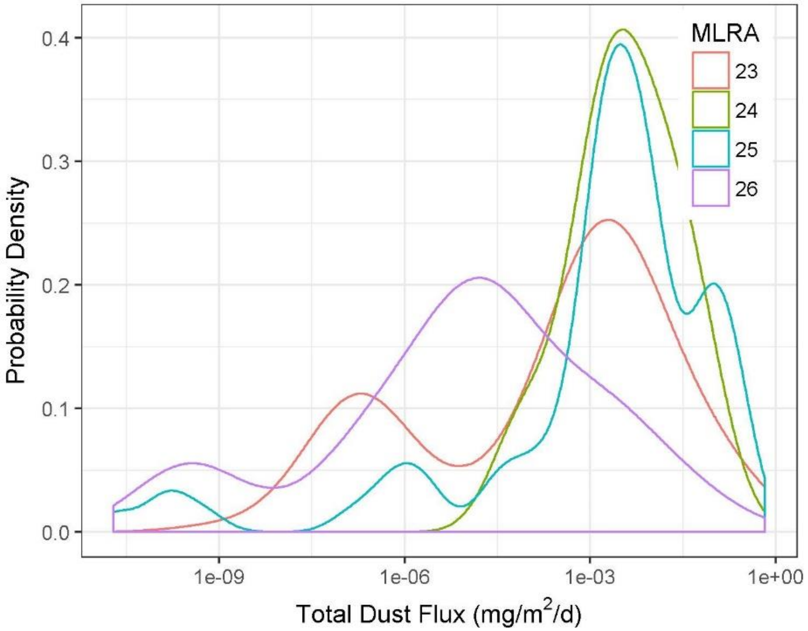


Management actions to benefit one resource may have negative consequences for other biotic and abiotic processes. In New Mexico, shrub removal treatments to benefit wildlife potentially increase dust emissions which could negatively impact regional air quality.

Variability among ecoregions and MLRAs

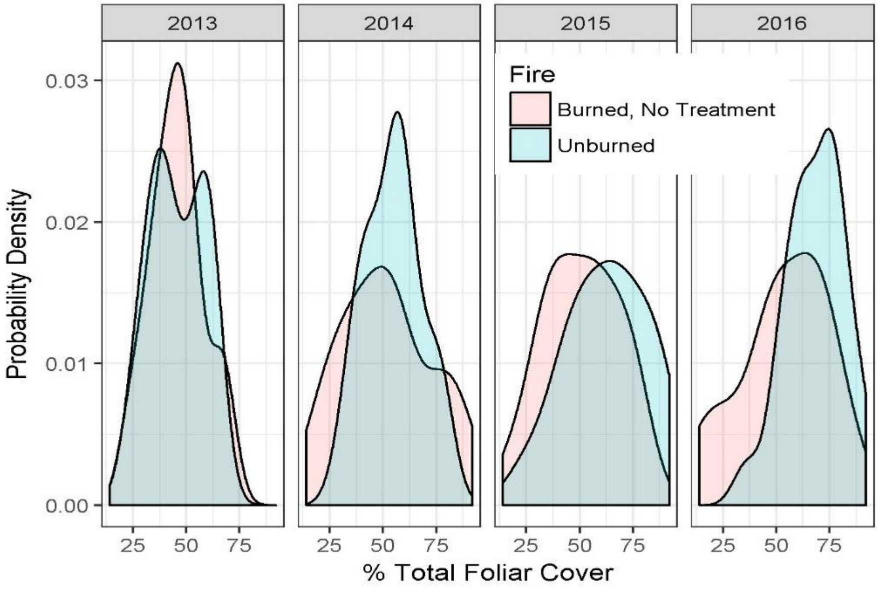
Ecoregion	Total Horizontal Flux *mean*	Total Horizontal Flux *sd*	Total Dust Flux *mean*	Total Dust Flux *sd*	*n*
Arizona/New Mexico Plateau	0.0796	0.0705	0.0180	0.0222	266
Blue Mountains	0.0727	0.0831	0.0160	0.0240	105
Cascades	0.0026	0.0034	0.0002	0.0003	12
Central Basin and Range	0.0844	0.1612	0.0139	0.0465	647
Chihuahuan Desert	0.0561	0.0524	0.0043	0.0111	69
Colorado Plateaus	0.0547	0.0669	0.0097	0.0176	364
Columbia Plateau	0.1642	0.2338	0.0444	0.0697	20
Eastern Cascades Slopes	0.0248	0.0490	0.0038	0.0115	131
Middle Rockies	0.0046	0.0061	0.0006	0.0011	31
Mojave Basin and Range	0.0285	0.0384	0.0034	0.0068	84
Northern Basin and Range	0.1264	0.3015	0.0302	0.1032	741
Northwestern Great Plains	0.0424	0.0746	0.0079	0.0147	64
Snake River Plain	0.2605	0.5686	0.0312	0.0789	26
Sonoran Desert	0.0210	0.0214	0.0009	0.0027	117
Southern Rockies	0.0215	0.0239	0.0043	0.0070	126
Wasatch & Uinta Mountains	0.0436	0.0559	0.0089	0.0182	16
Wyoming Basin	0.0423	0.0486	0.0054	0.0111	307

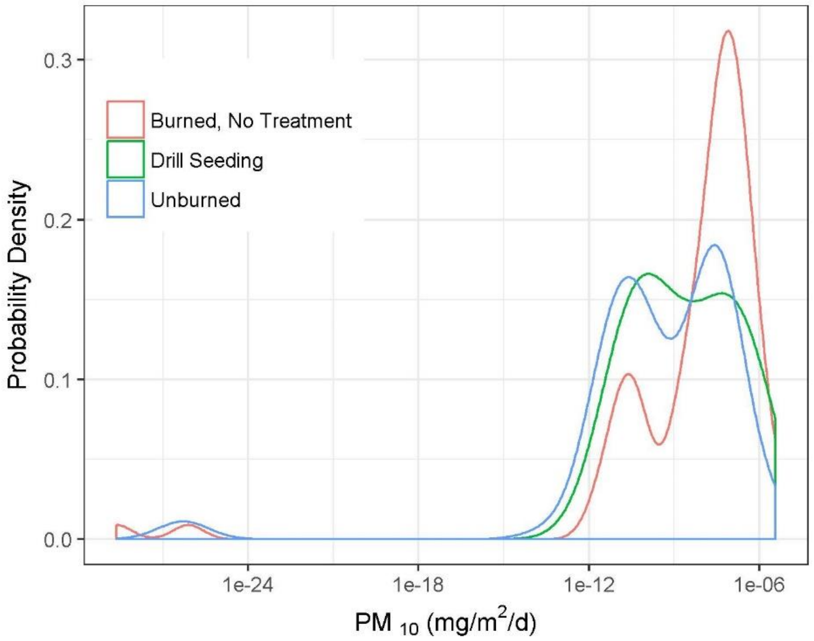




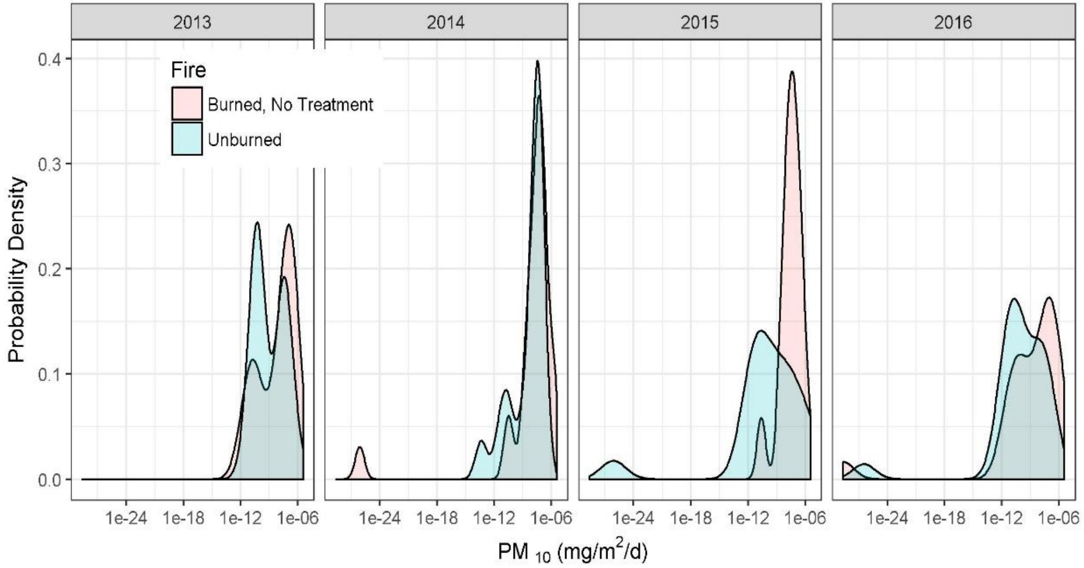
- MLRA 24 (25) is one of the most fire-susceptible MLRAs in the Great Basin.
- Heavy cheatgrass infestation following fire over the last 20 years.
- AERO run on 3,137 AIM plots enables assessment across Ecoregions and MLRAs, including fire effects.

Drought, fire, and management effects

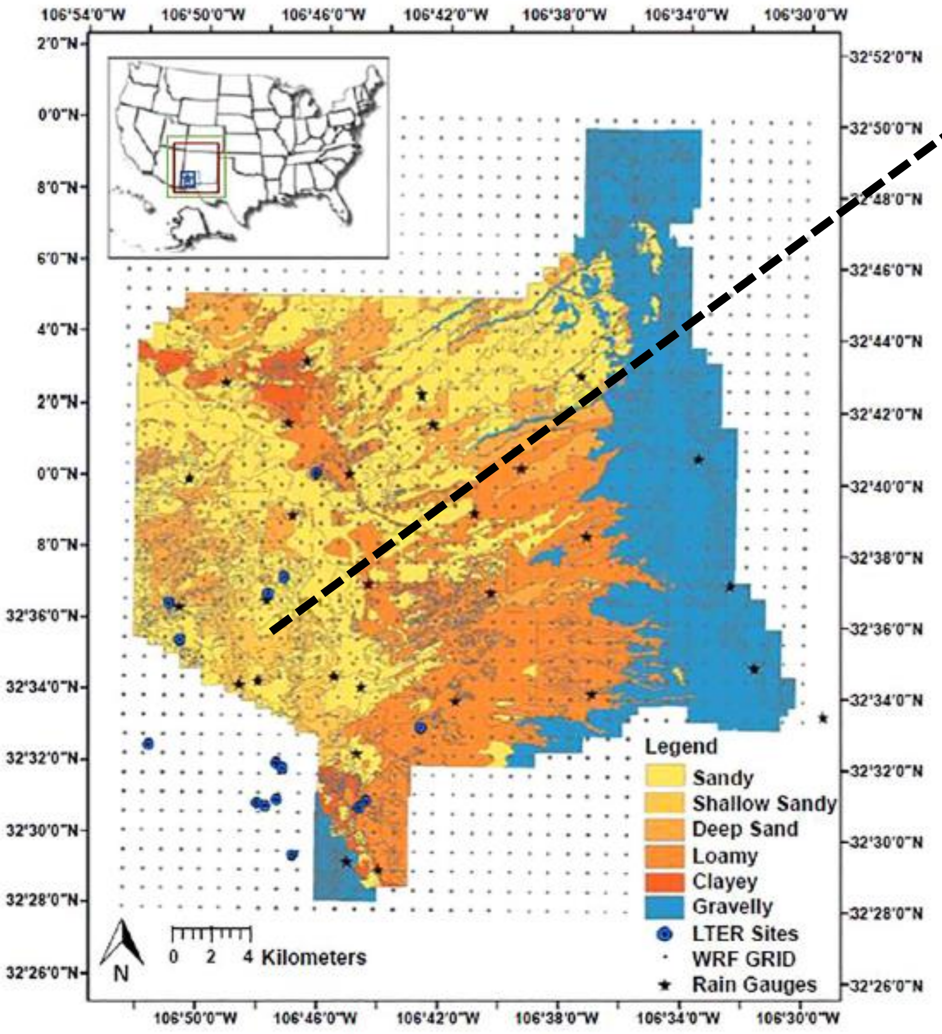




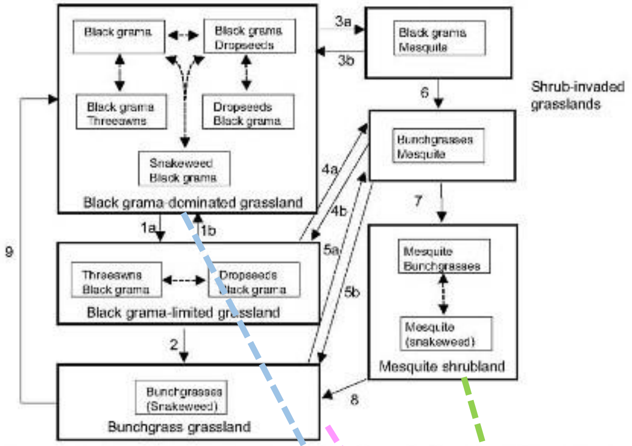
- In 2012 a 250,000 acre fire burnt in California
- Simultaneous severe drought
- BLM responded with drill and aerial seeding treatments to facilitate recovery
- AIM data were collected to monitor fire and treatment effects



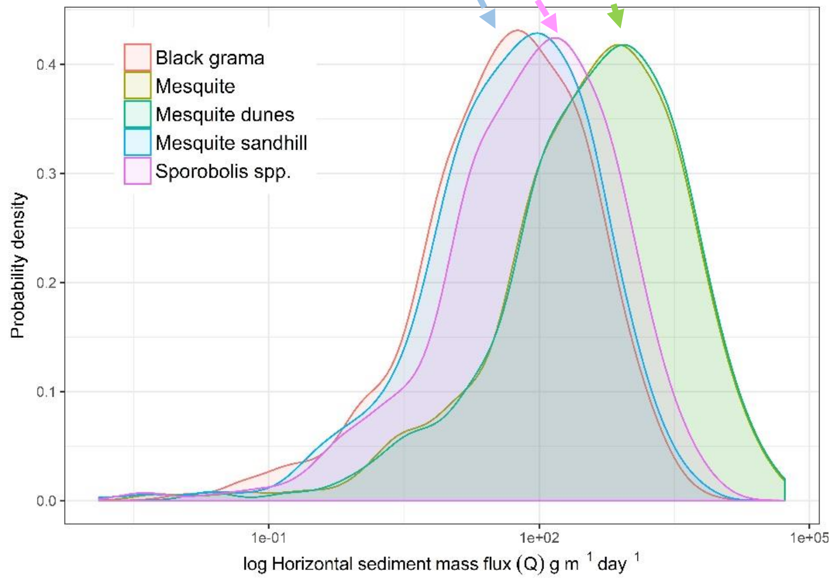
Linking wind erosion to ecological sites



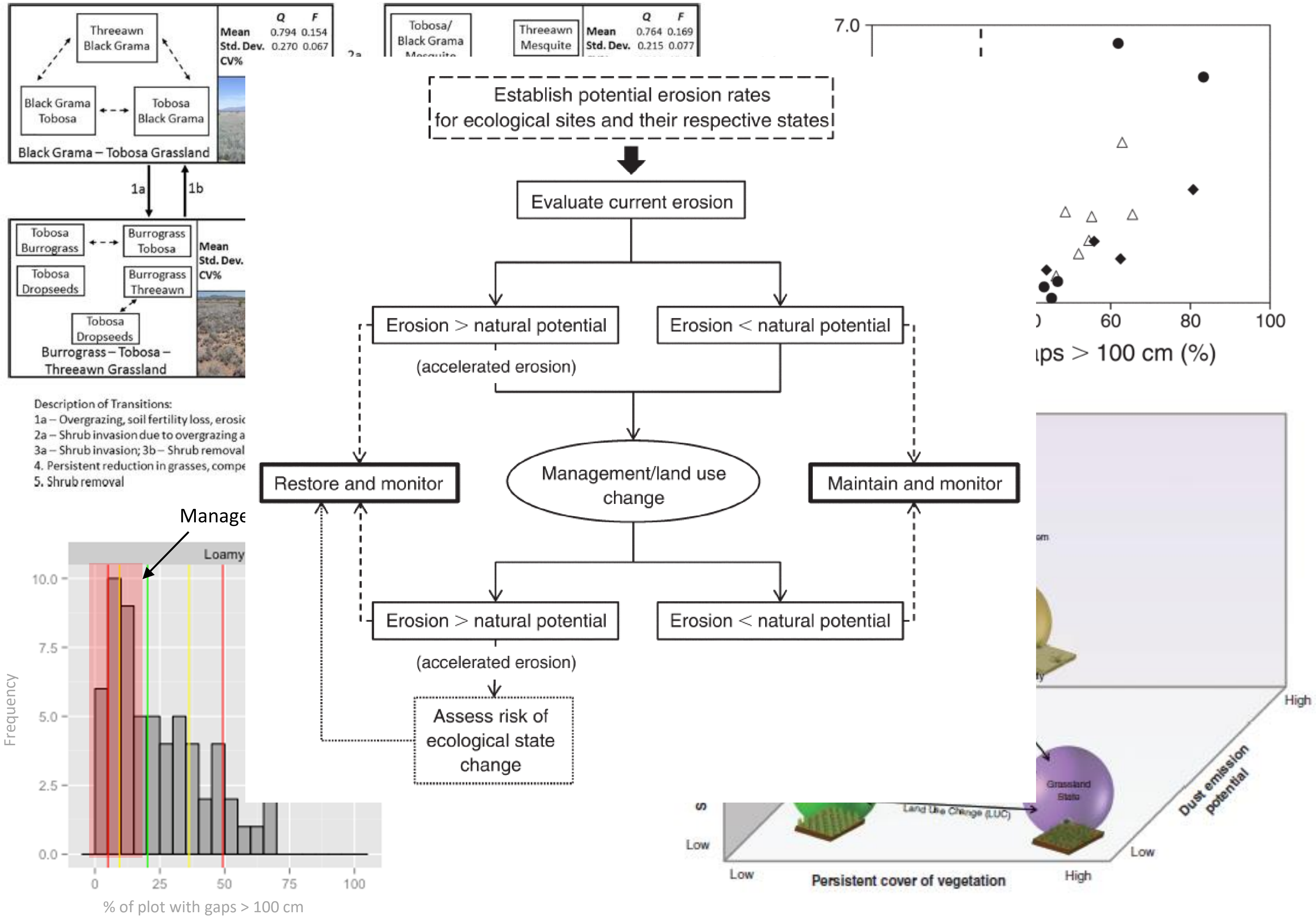
State-Transition model: MLRA 42, SD-2, Upland sandy site group: Shallow sandy



1a. Climate change and/or overgrazing, moderate soil degradation. **1b.** Restoration of soil fertility (if climate not involved)
2. Extinction of black grama, severe soil degradation.
3a. Introduction of mesquite seeds, reduced grass competition, lack of fire. **3b.** Shrub removal, restoration of fuel loads and fire.
4a, 5a. Mesquite invasion. **4b, 5b.** Shrub removal, restoration of fuel loads and fire.
6a. Black grama extinction due to mesquite competition and grazing. **6b.** Shrub control with black grama restoration.
7. Continued grass loss (e.g. overgrazing), inter shrub erosion, soil fertility loss, high soil temperatures, small mammal herbivory. **8.** Dune destruction, mesquite removal, soil stabilization, nutrient addition, seeding during wet periods.
9. Reseeding, replanting with restoration of soil fertility.



Benchmarks and management practices



Where is development currently?

Progress:

Continuing to Build database of meteorological, vegetation and horizontal aeolian transport data for model calibration and refinement

Dust emission measurement capabilities are currently being added

Need:

Improve soil PSD database with representative samples from western US

Directions and goals

- Calibrate model using National Wind Erosion Network (https://winderosionnetwork.org) data
- Produce multi-scale wind erosion assessments (plot to national level) enabling regionalization of research and findings to support management
- Leverage large-scale ecological datasets to evaluate responses to management treatments and changes in land surface conditions
- Link model estimates to IMPROVE/AERONET data to interpret trends
- Incorporate wind erosion information into frameworks to support systems-level analyses of management co-benefits and trade-offs

AERO application to dust mitigation

- Which landscapes are emitting dust, how much, and when?
- How will management activities impact dust emission?
- How is air quality impacted by land condition and management?
- What are the costs, co-benefits and trade-offs for management practices and wind erosion mitigation options?