



**SOUTHERN ROCKIES**  
Landscape Conservation Cooperative

# **New Tools for Assessing Land-use Impacts on Colorado Plateau Landscapes**

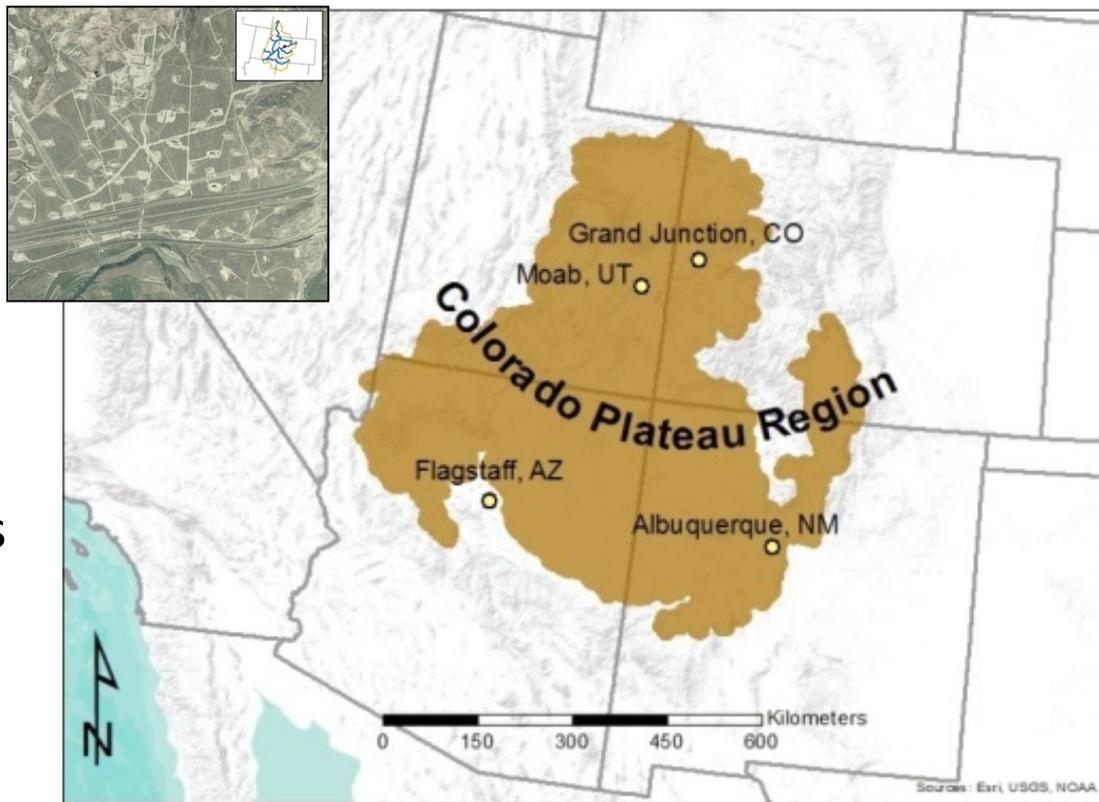
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USGS Southwest Biological Science Center

Co-authors: Miguel Villarreal and Travis Poitras  
USGS Western Geographic Science Center

# New Tools for Assessing Land-use Impacts on Colorado Plateau Landscapes

## Webinar outline:

- Background on oil & gas development
- Challenges to management
- New USGS effort
- ART toolset
- Application of ART to oil & gas
- Next steps & future directions



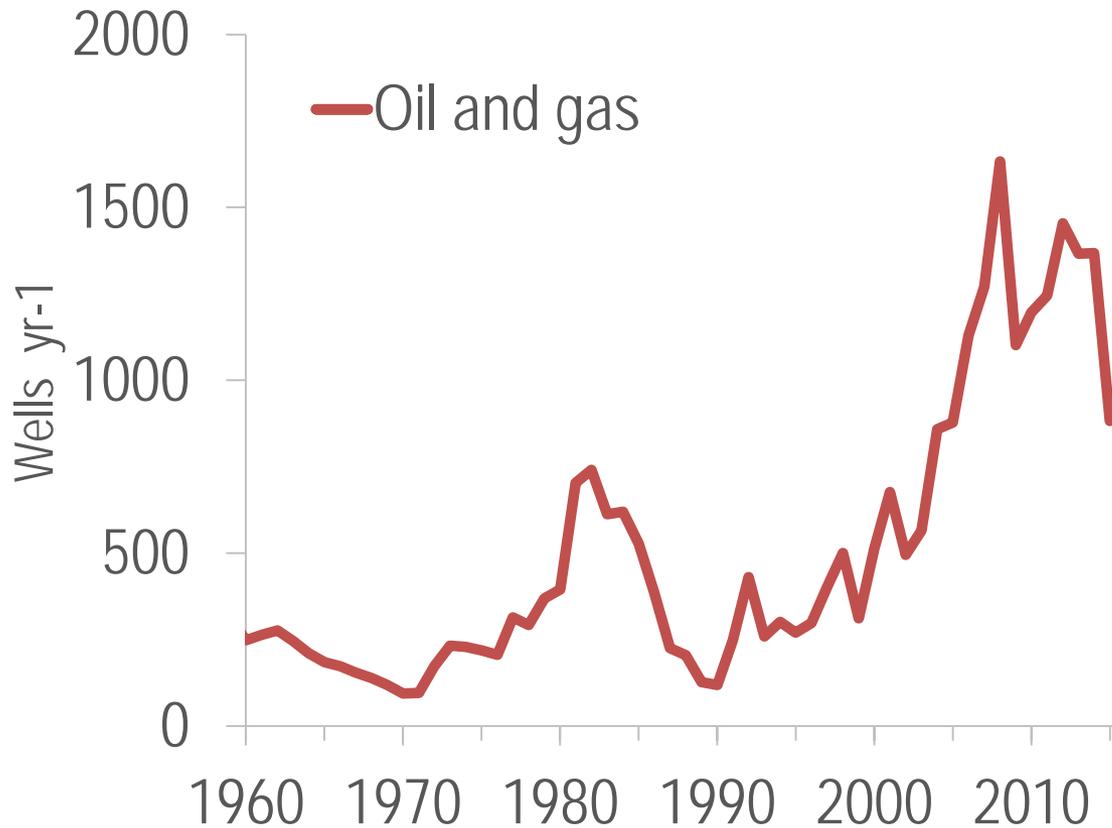
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# Recent trends in oil & gas development



Data demonstrating the rapid growth of energy development as regional land-uses. Shown are total annual oil and/or gas wells drilled per year in Utah.

Utah Department of Natural Resources. Oil and Gas GIS Data Layer: Oil and Gas Wells  
<http://gis.utah.gov/data/energy/oil-gas/>. Accessed: (7/1/2015).

9/24/2006

2006



Image USDA Farm Service Agency

Google earth

10/2/2011

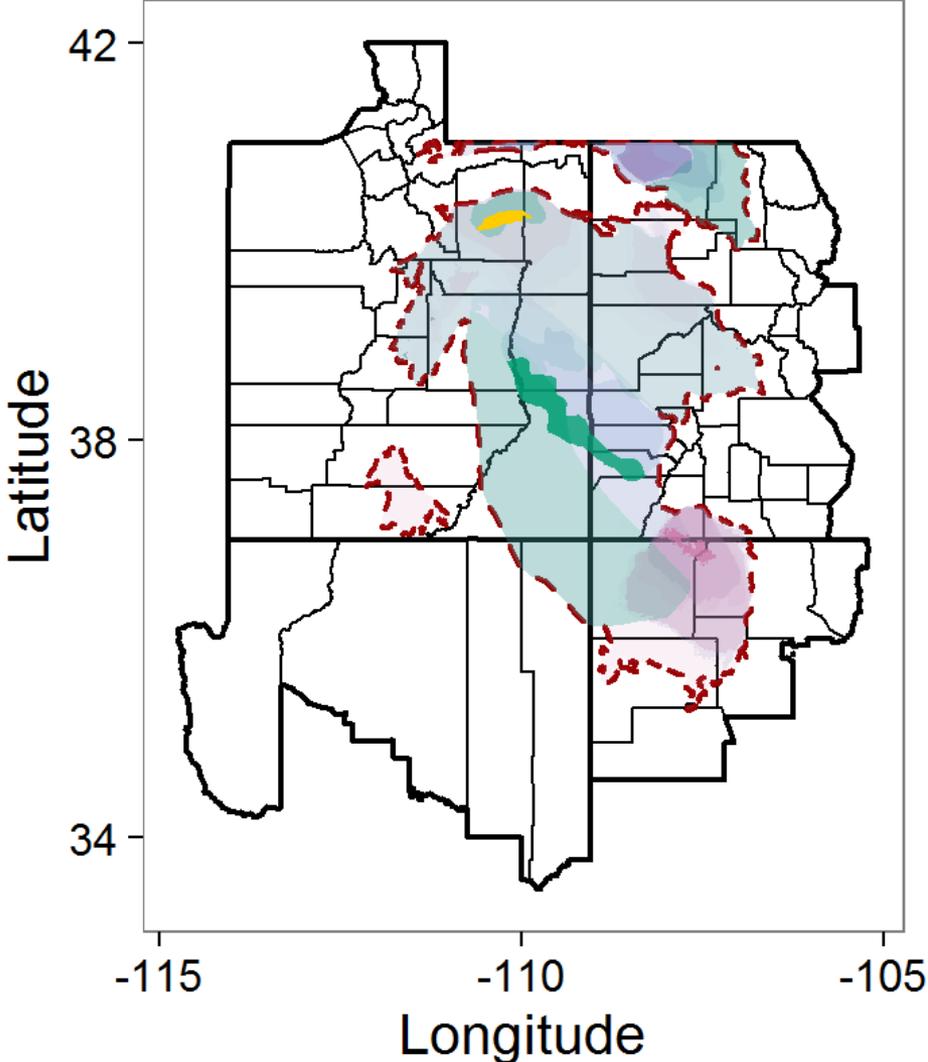
2013

N

Image USDA Farm Service Agency

Google earth

# Future oil & gas development



## Resource Type

- Gas
- NGL
- Oil
- Uteland Butte

## Index Scale

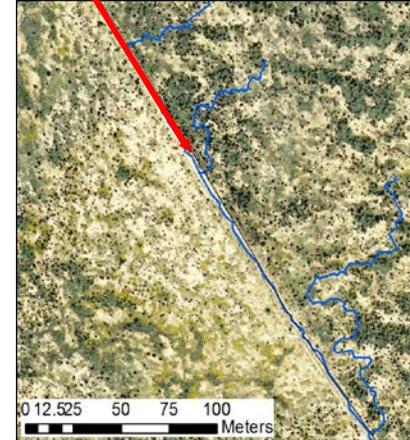
- 0.10
- 0.25
- 0.50
- 1.00

- Assessment Region



# Ecosystem impacts of concern

- Reduced primary productivity and forage production (Allred et al. 2015)
- Visual resources (aesthetics; MLP; BLM 2016)
- Conduit for invasives (Gelbard et al. 2003)
- Surface hydrology and erosion (Duniway & Herrick 2011)
- **Dust**



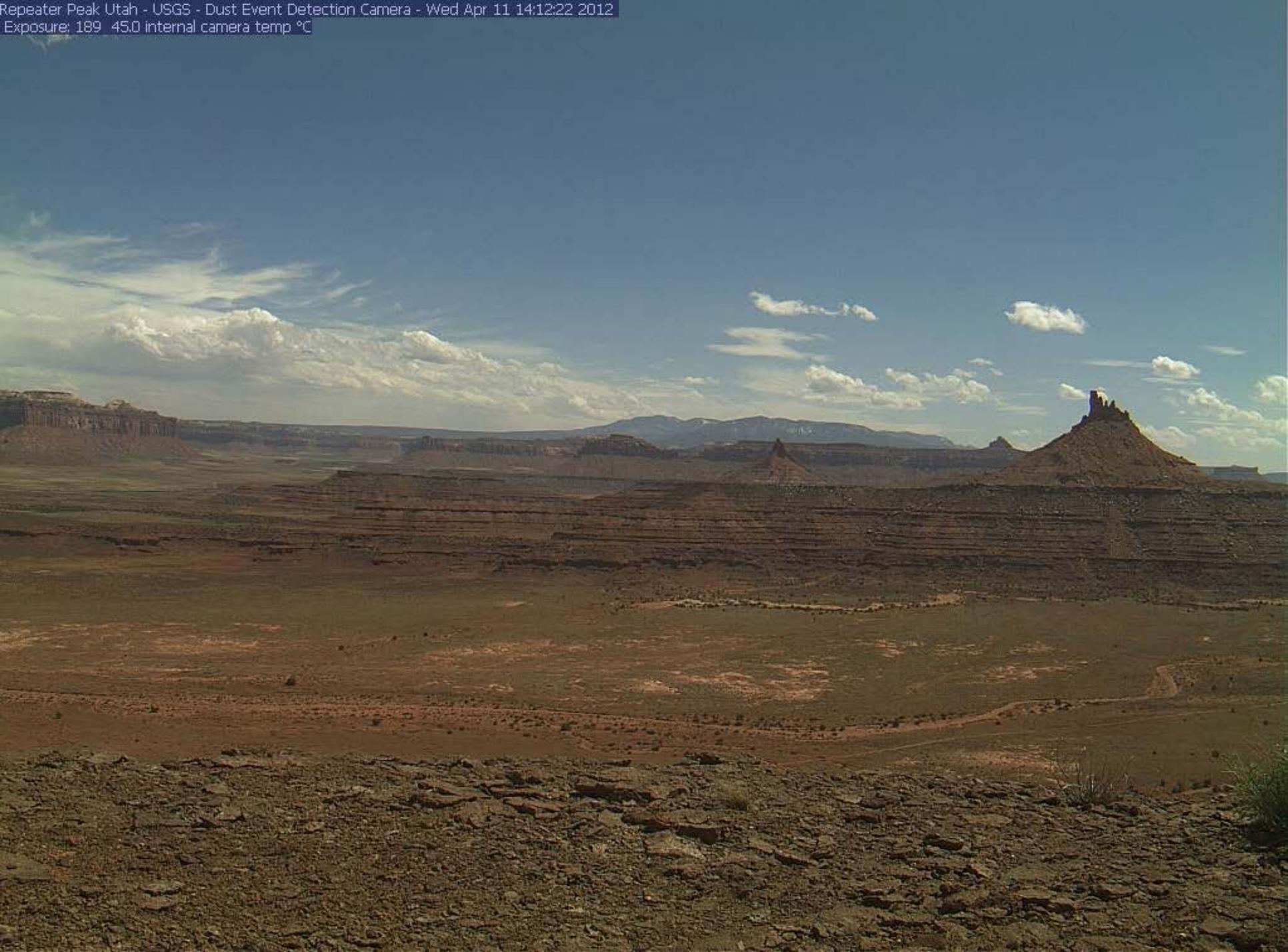
Allred et al. 2015. *Science* **348:401-402**.

Gelbard & Belnap. 2003. *Conservation Biology* **17:420-432**.

Duniway & Herrick. 2011. *Journal of Soil and Water Conservation* **66:31A-36A**.

BLM. 2016. [http://www.blm.gov/ut/st/en/prog/energy/oil\\_and\\_gas/mlp.html](http://www.blm.gov/ut/st/en/prog/energy/oil_and_gas/mlp.html)

Repeater Peak Utah - USGS - Dust Event Detection Camera - Wed Apr 11 14:12:22 2012  
Exposure: 189 45.0 internal camera temp °C



Repeater Peak Utah - USGS - Dust Event Detection Camera - Wed Apr 11 19:12:09 2012  
Exposure: 1200 38.0 internal camera temp °C



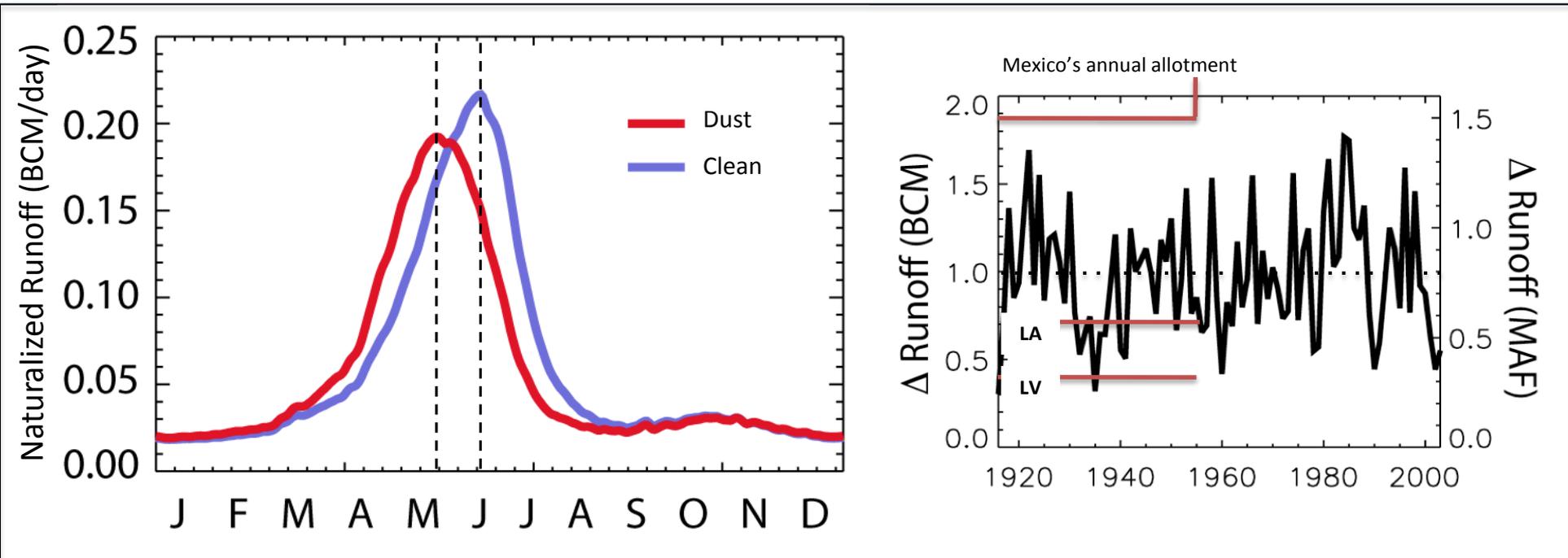


Photo by Chris Landry

© Center for Snow and Avalanche Studies

# Response of Colorado River runoff to dust radiative forcing in snow

Thomas H. Painter<sup>a,b,1</sup>, Jeffrey S. Deems<sup>c,d</sup>, Jayne Belnap<sup>e</sup>, Alan F. Hamlet<sup>f</sup>, Christopher C. Landry<sup>g</sup>, and Bradley Udall<sup>d</sup>



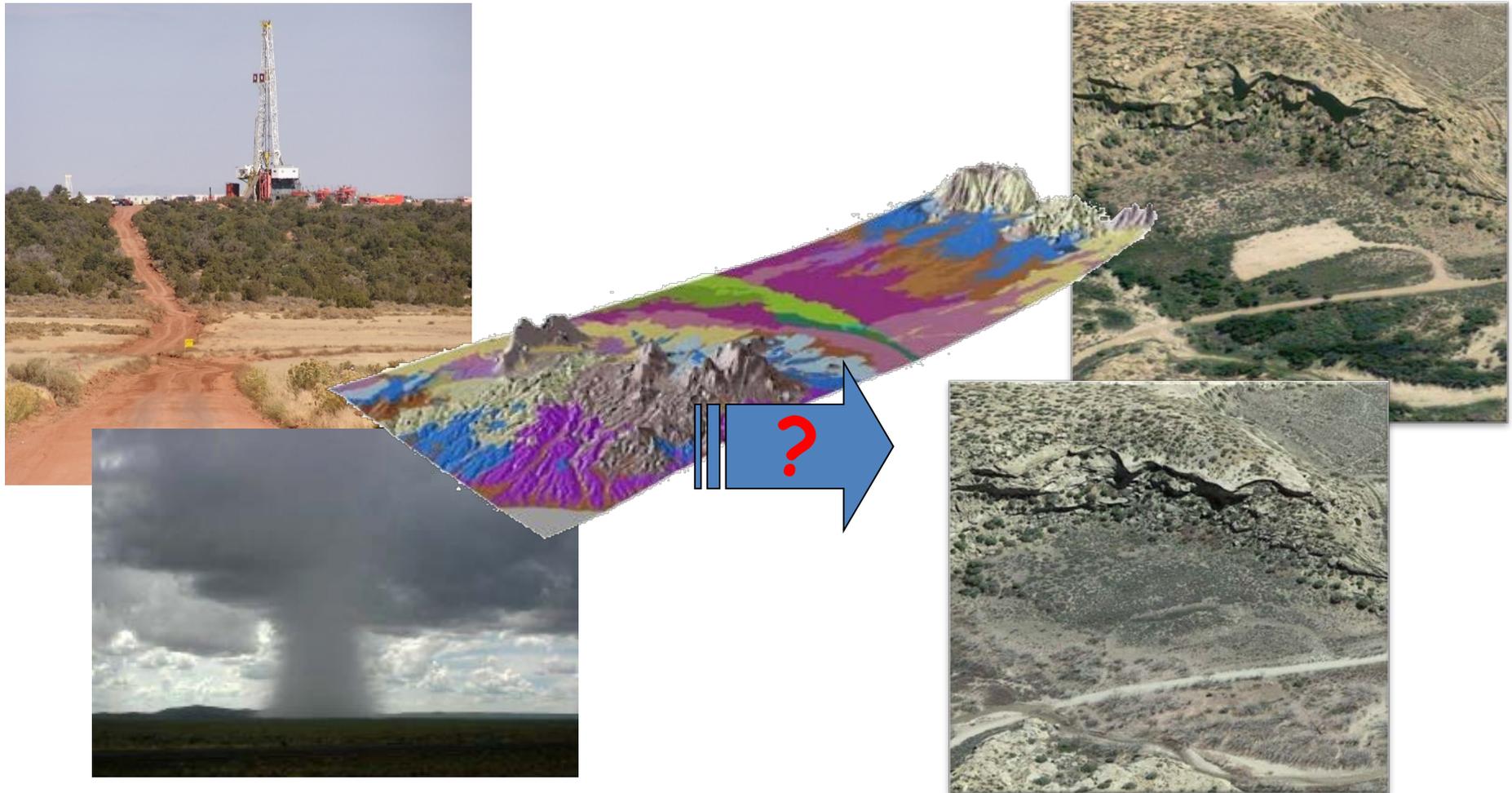
Pre 2009 dusty conditions:

- 3 week earlier peak
- 5% less **annual** runoff

5% is:

- 2x Las Vegas' allocation
- 18 months of L.A.'s use
- ½ Mexico's allocation

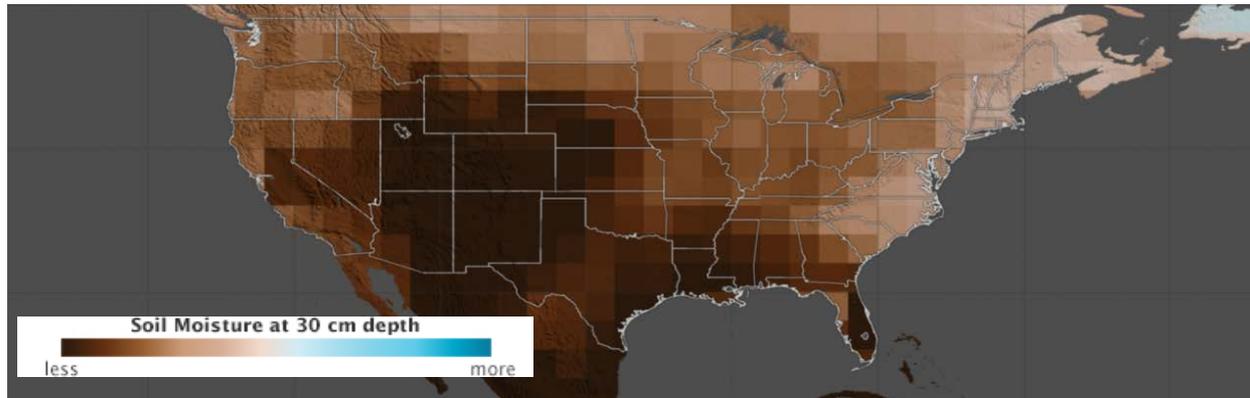
# Heterogeneity in impacts due to the soil-geomorphic template





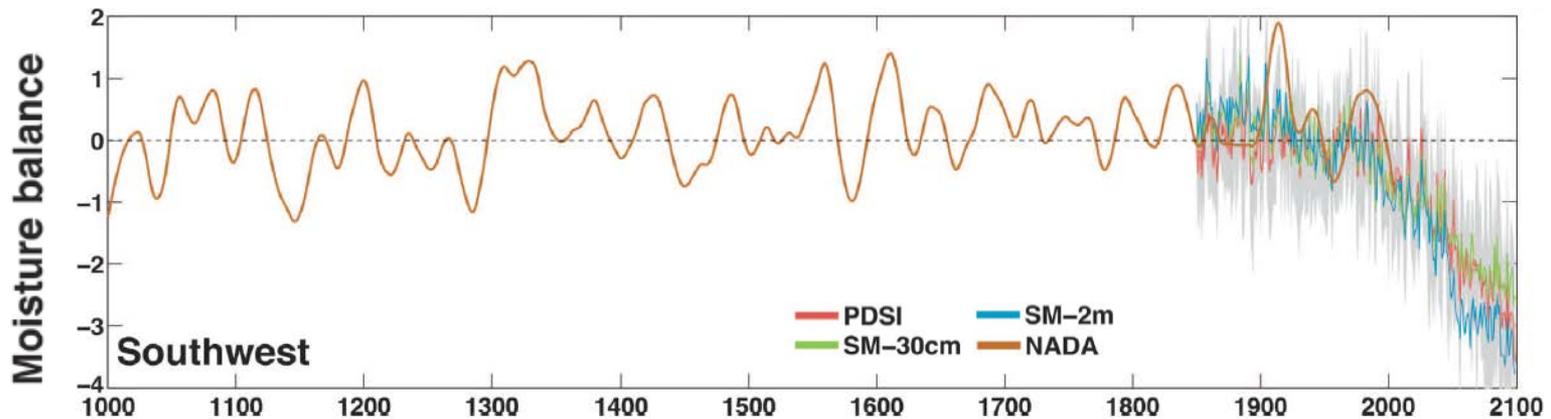
# Drier & warmer future...

“**Worst drought** in 1,000 years is predicted for the Southwest US”



Forecast drying will likely increase impacts and complicate management of energy development

NASA Earth Observatory



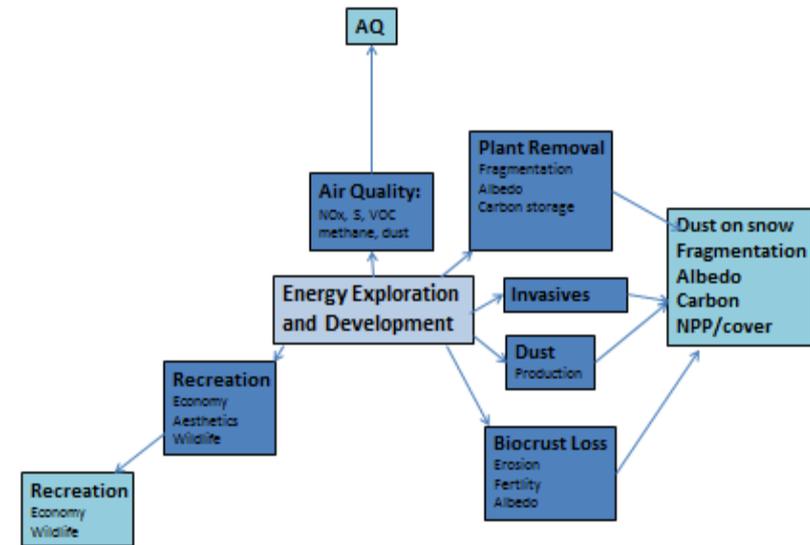
Figured modified from Cook et al. (2015) Science Advances

# Southwest Energy Development & Drought (SWEDD)

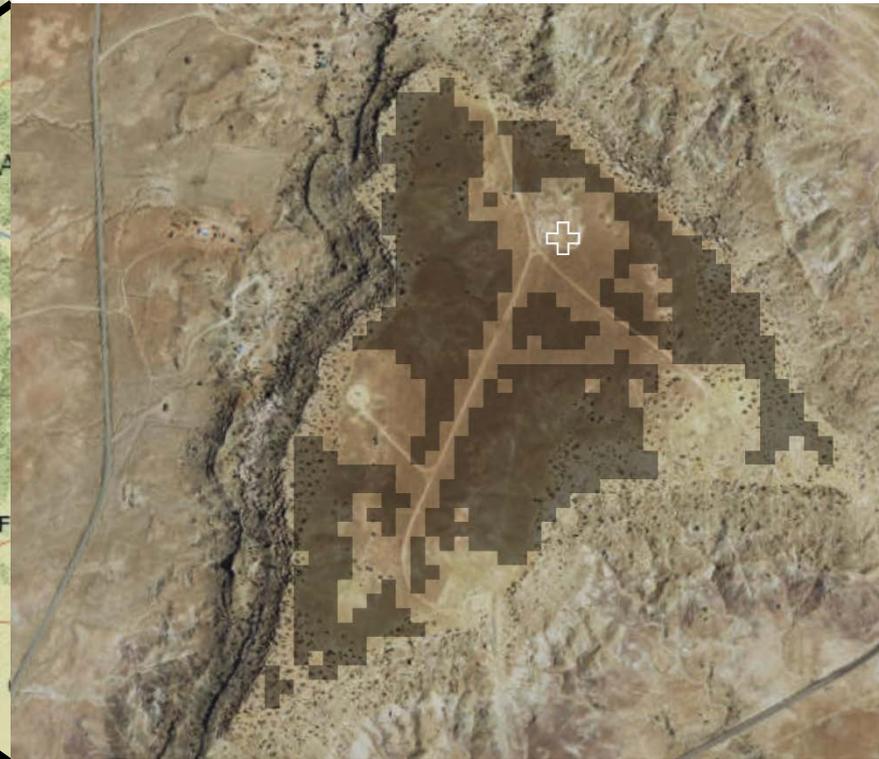
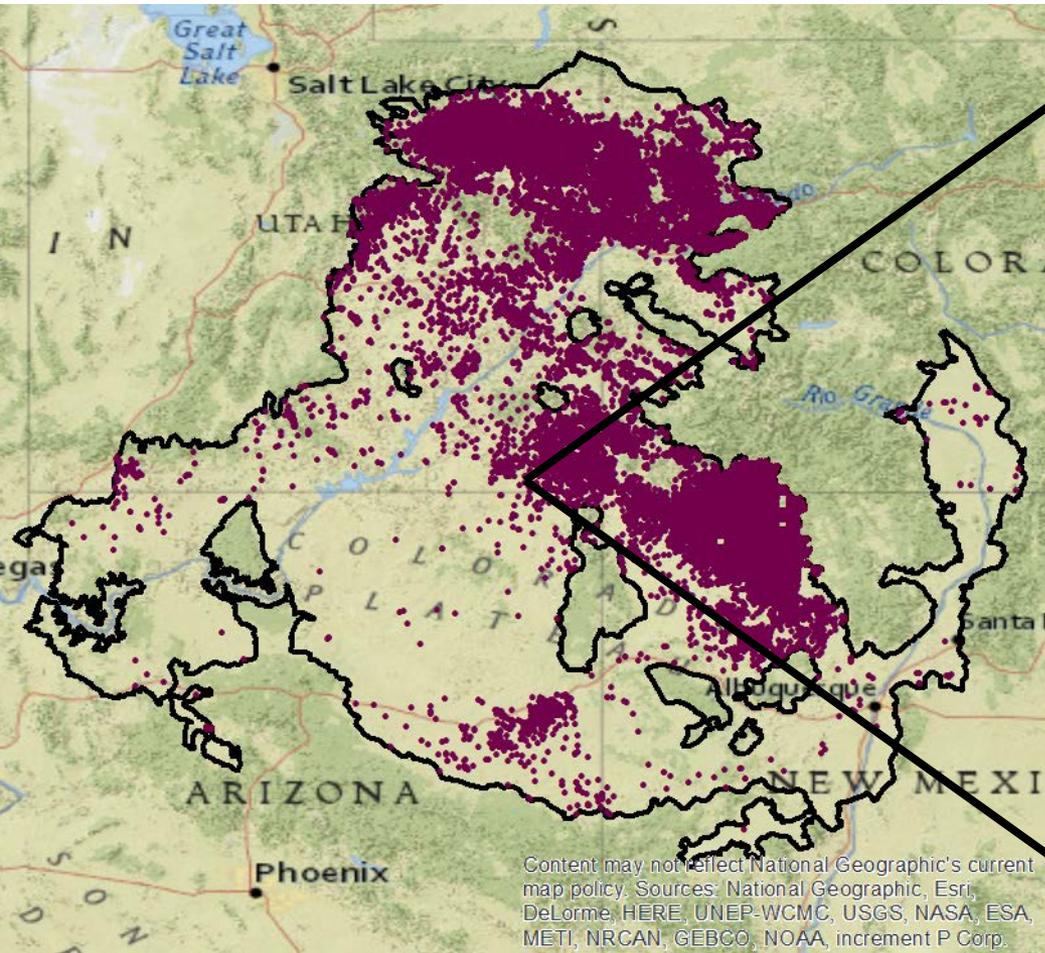
- New multi-center USGS project
  - Southwest Biological Science Center
  - Western Geographic Science Center
  - Western Ecological Research Center
  - Fort Collins Science Center
- Initial efforts focused on the impacts of and restoration from traditional oil and gas activities.
  - **Impacts to social-ecological systems at the plot to regional scale**
  - Rehabilitation of roads and pads
  - Integrated analysis and scenario development



## Priority Ecosystems Science



# The challenge



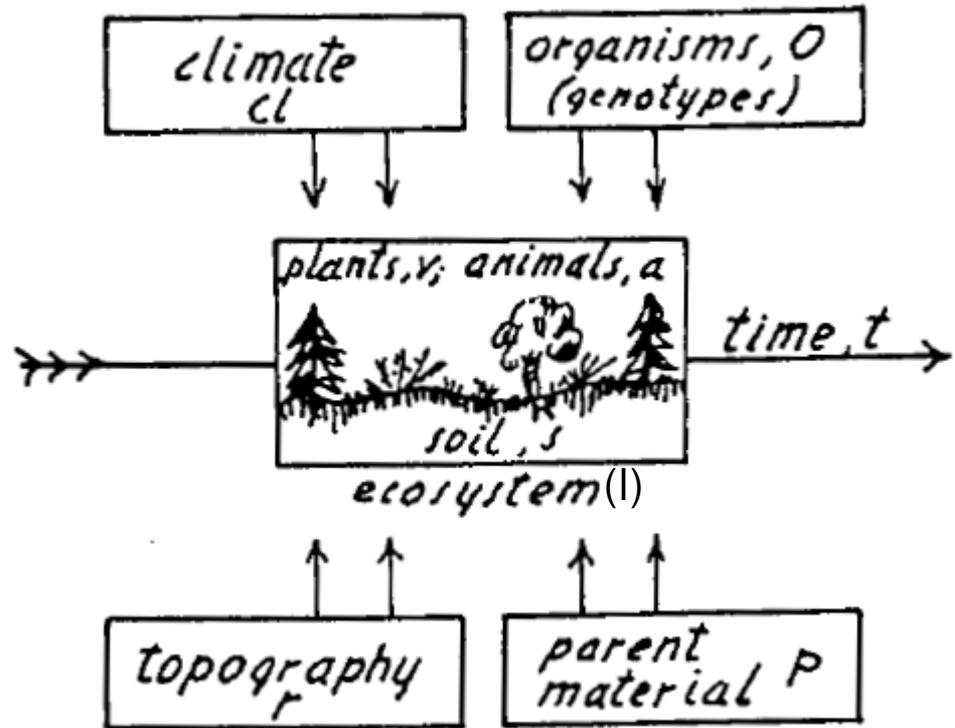
~90,000 oil and gas records on CO Plateau

# The challenge

- Find 'reference' areas that have similar:
  - **ecological potential**
  - history
    - climate
    - management history
- Isolate the disturbance of focus
  - i.e. oil and gas well-pads

# Ecological potential

- Similar
  - Species
    - composition
    - Structure
  - Behavior
    - resistance
    - resilience



1991. Amunson & Jenny. Soil Sci. Vol 151, No. 1  
"The Ecofactorial"

# Ecological potential

- Soils
  - depth
  - texture
  - chemistry

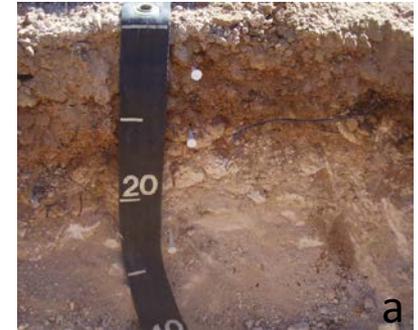
\*Highly tied to geology on plateau



Deep sandy loam



Moderately deep cobbly sandy loam



Shallow loam with strong calcic horizon

a) United States Department of Agriculture, Natural Resources Conservation Service. 2010. Soil Survey of Canyonlands National Park, Utah. Accessible online at: [http://soils.usda.gov/survey/printed\\_surveys/](http://soils.usda.gov/survey/printed_surveys/).

# Ecological potential

- Topography
  - exposure
  - aspect
  - runoff
  - microclimate

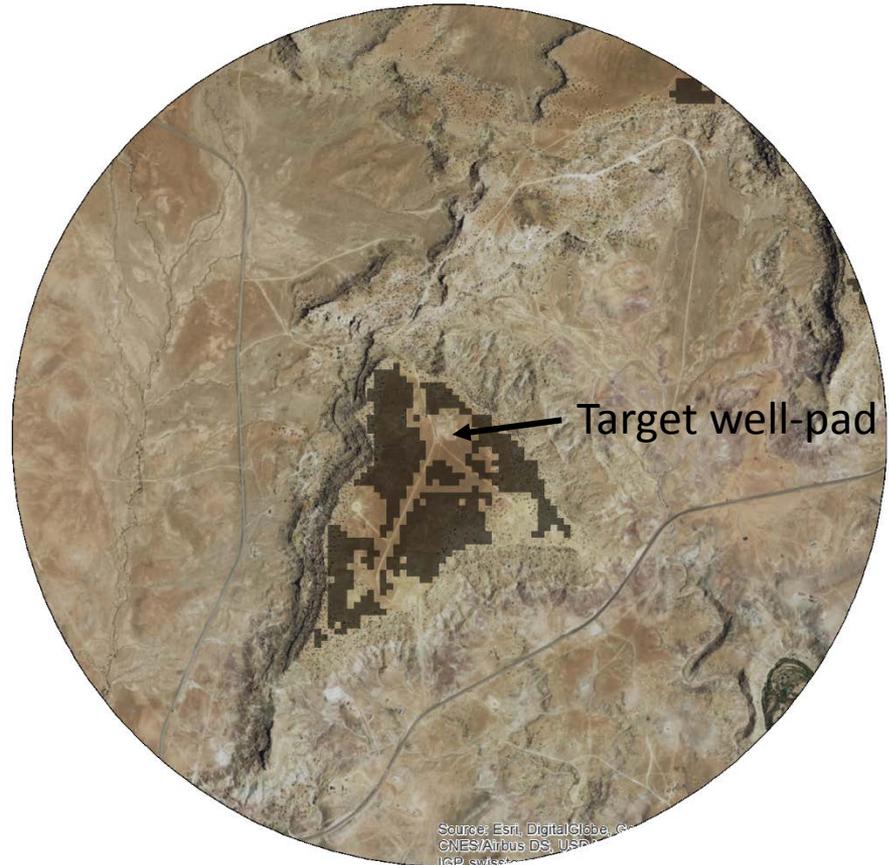


View from La Sal Mountains near Moab, UT.

# History

- Climate x Management = TRICKY!
- Use 1<sup>st</sup> rule of geography:  
‘...near things are more related than distant things’

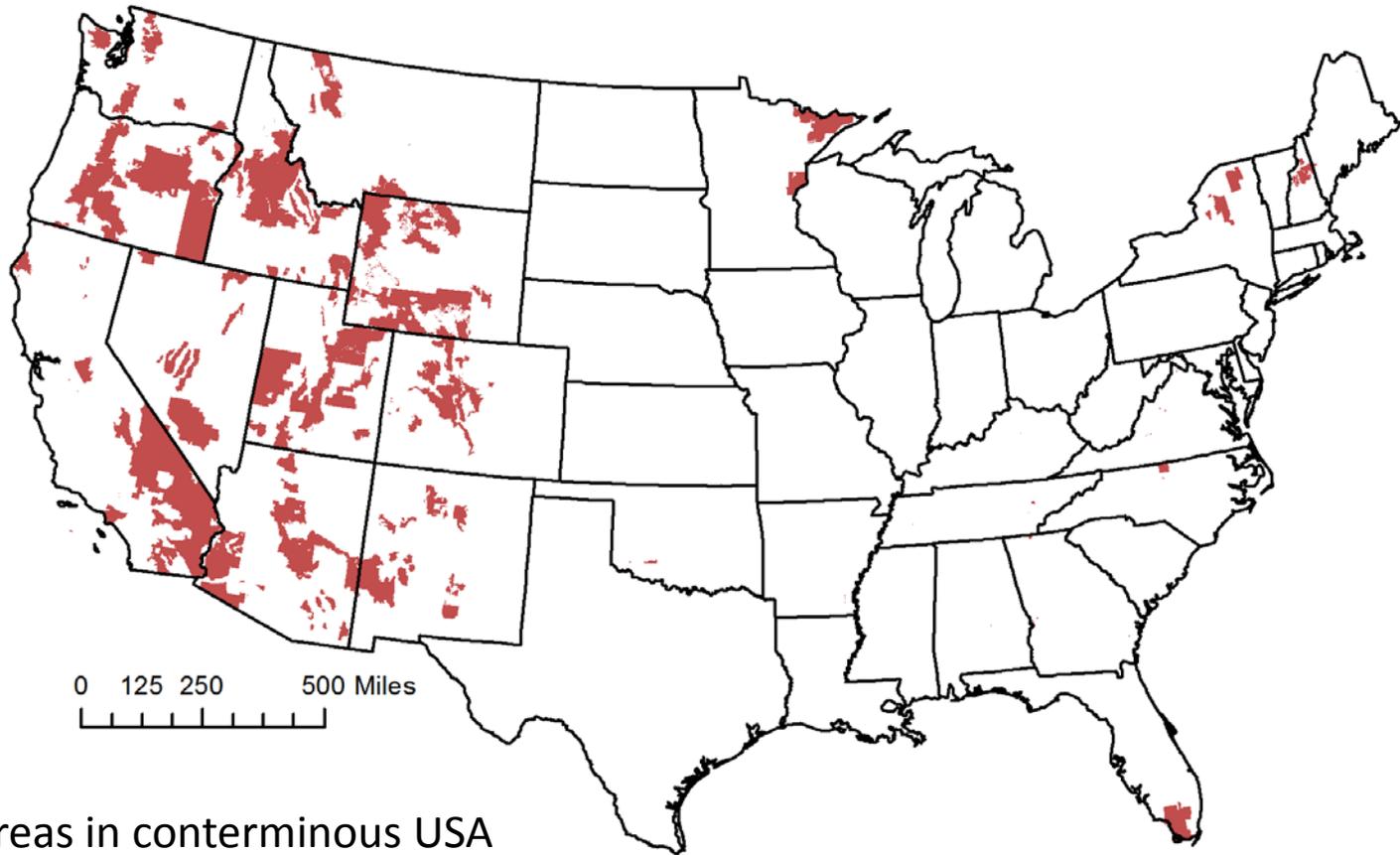
- Neighborhood analysis:
  - Radial 2km
- More specific options:
  - Allotment
  - Management unit
  - Ecological classifications



Source: Esri, DigitalGlobe, GeoEye, IGN, CNES/Airbus DS, USDA, AeroGRID, IGN, swisstopo

# The soil dilemma

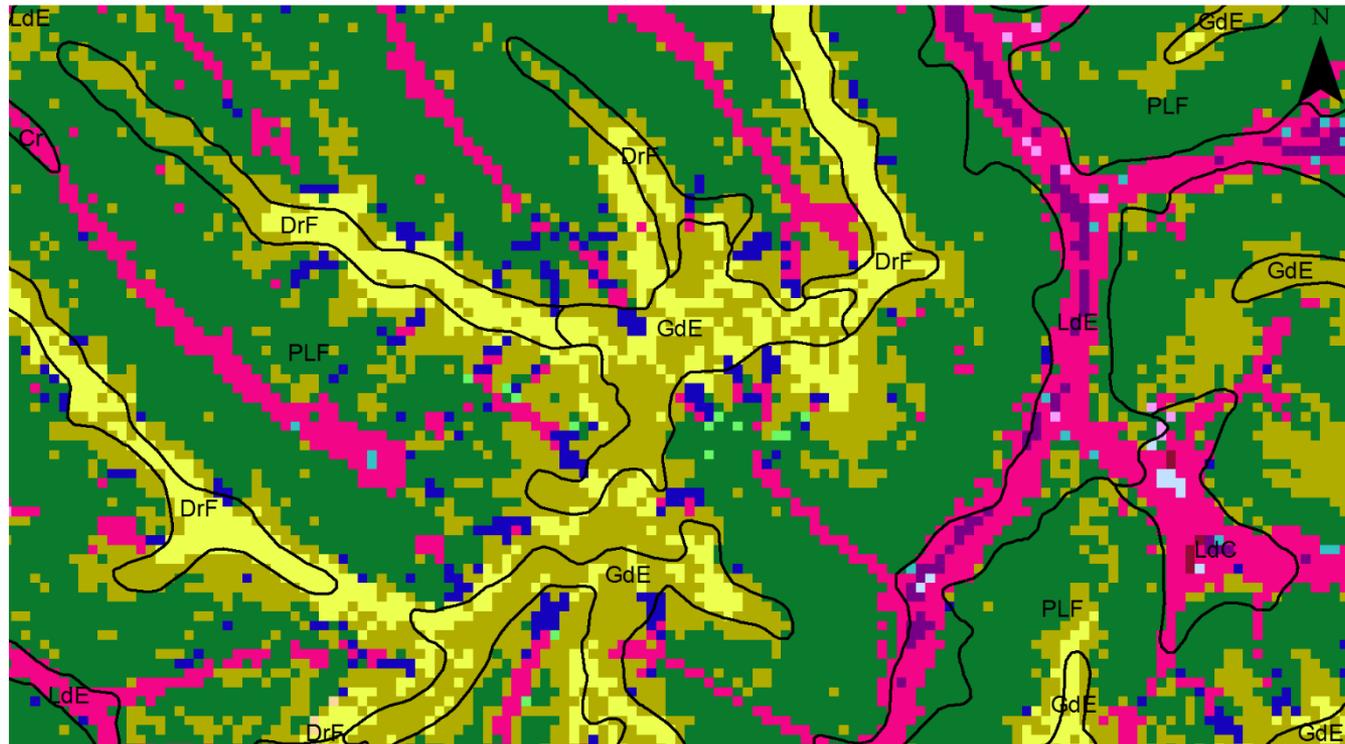
– Need field scale soil map!



Areas in conterminous USA  
without field scale soil survey (e.g.  
SSURGO)

# The soil dilemma

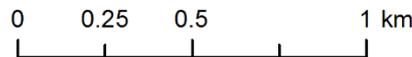
- Soil survey map units can include multiple soils, which often can have different management implications



## SSURGO Map Units

□ MU boundaries

PLF - Pineville-Gilpin-Guyandotte association, very steep, extremely stony  
 GdE - Gilpin-Dekalb complex, 15 to 35 percent slopes, extremely stony  
 DrF - Dekalb-Rock outcrop complex, 35 to 70 percent slopes, extremely stony  
 LdE - Laidig channery silt loam, 15 to 35 percent slopes, extremely stony  
 LdC - Laidig channery silt loam, 3 to 15 percent slopes, extremely stony



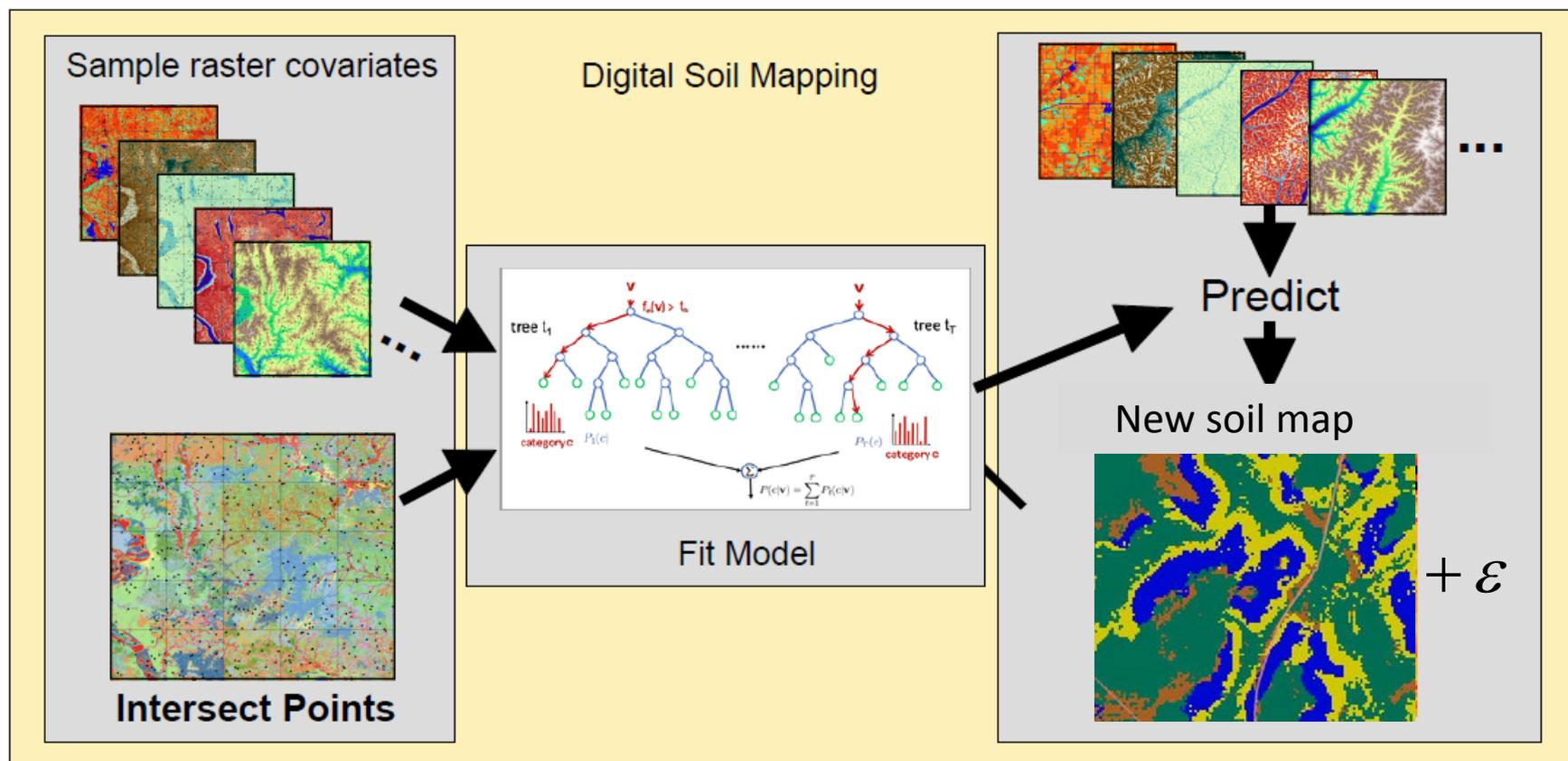
## Disaggregation (SqRt)



From: Nauman, T. W., and J. A. Thompson. 2014. Semi-automated disaggregation of conventional soil maps using knowledge driven data mining and classification trees. *Geoderma* 213:385-399.

# The soil dilemma

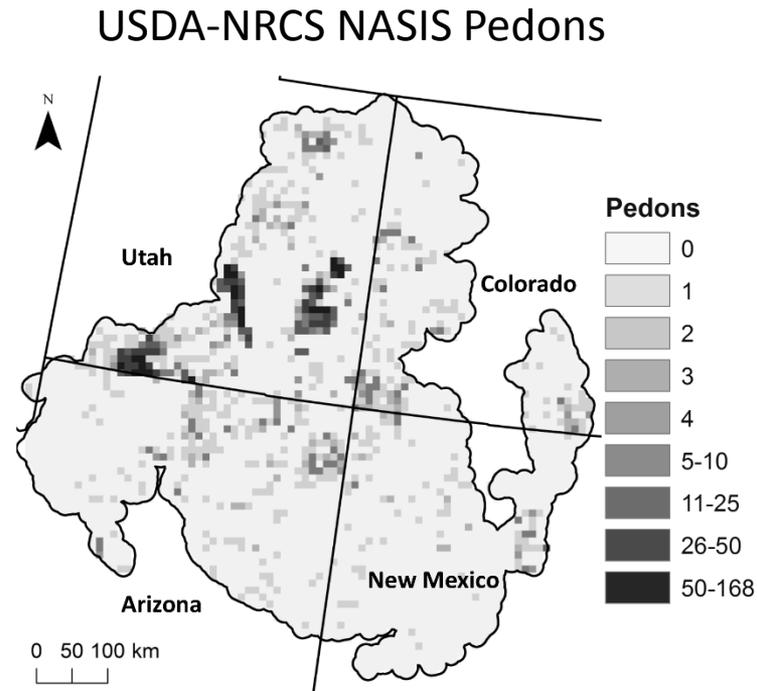
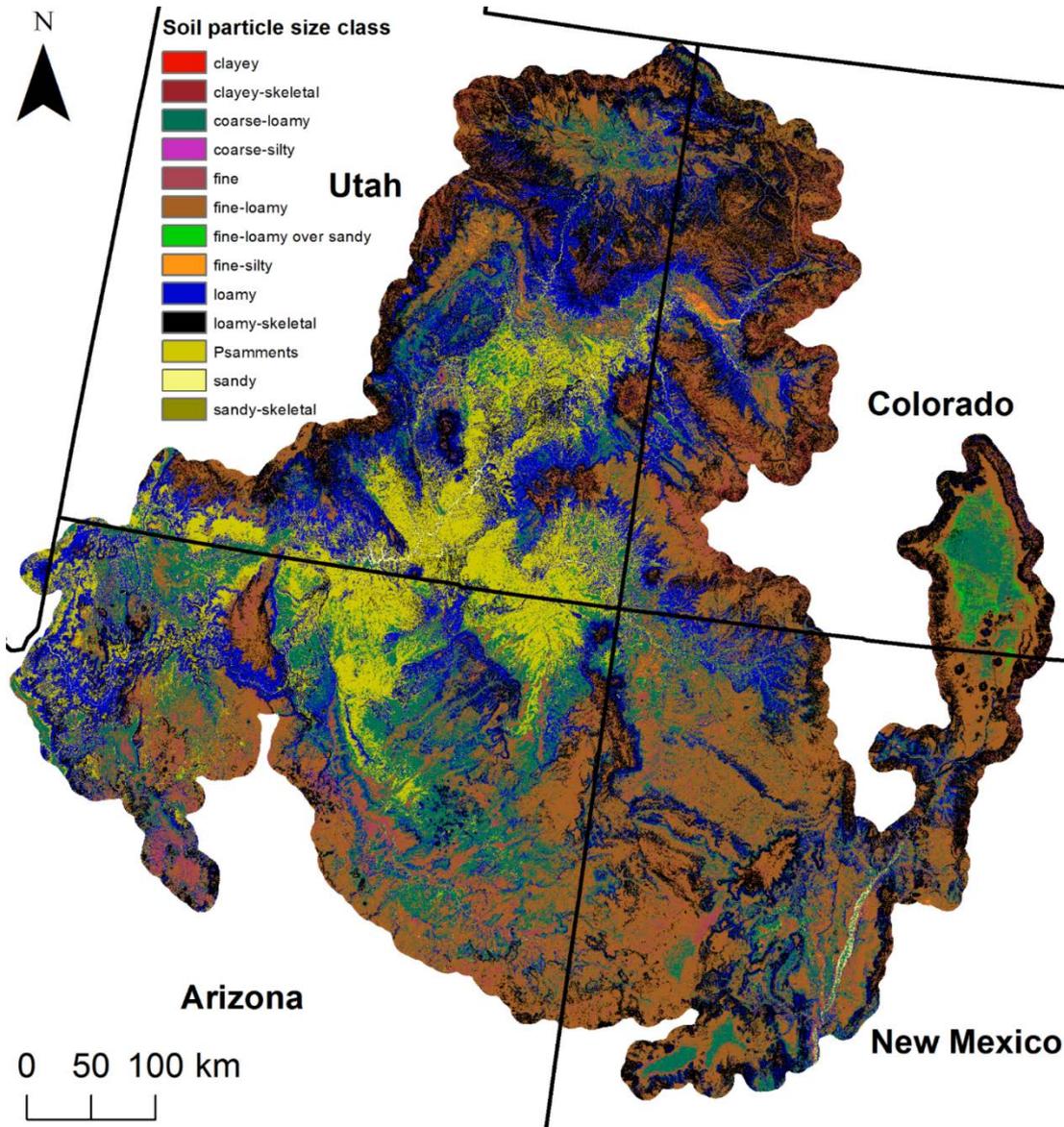
- Our solution: Digital Soil Mapping (McBratney et al., 2003)



Modified from:

Chaney, N.W., Wood, E.F., McBratney, A.B., Hempel, J.W., Nauman, T.W., Brungard, C.W., & Odgers, N.P. (2016). POLARIS: A 30-meter probabilistic soil series map of the contiguous United States. *Geoderma*, 274, 54-67

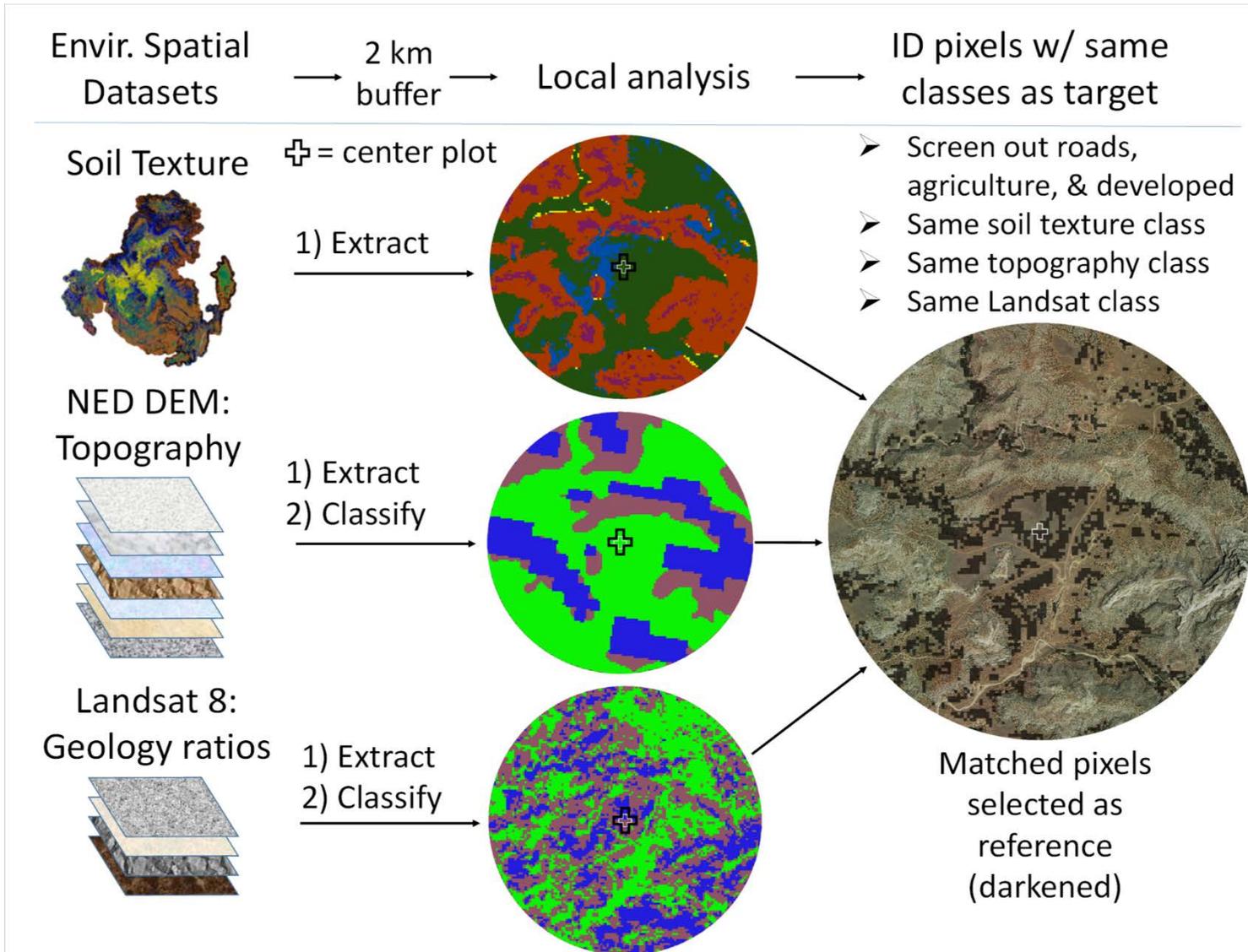
# The soil dilemma



Random forest metrics  
 Out of bag accuracy = 62%  
 Kappa = 0.54,  $p < 0.0001$

Independent validation for  
 Canyonlands area:  
 Overall accuracy = 93.2%  
 Kappa = 0.9,  $p < 0.0001$

# The Automated Reference Toolset (ART)



Nauman, T., & Duniway, M.C. (2016). The Automated Reference Toolset (ART): A soil-geomorphic ecological potential matching algorithm. *Soil Science Society of America Journal*. 10.2136/sssaj2016.05.0151

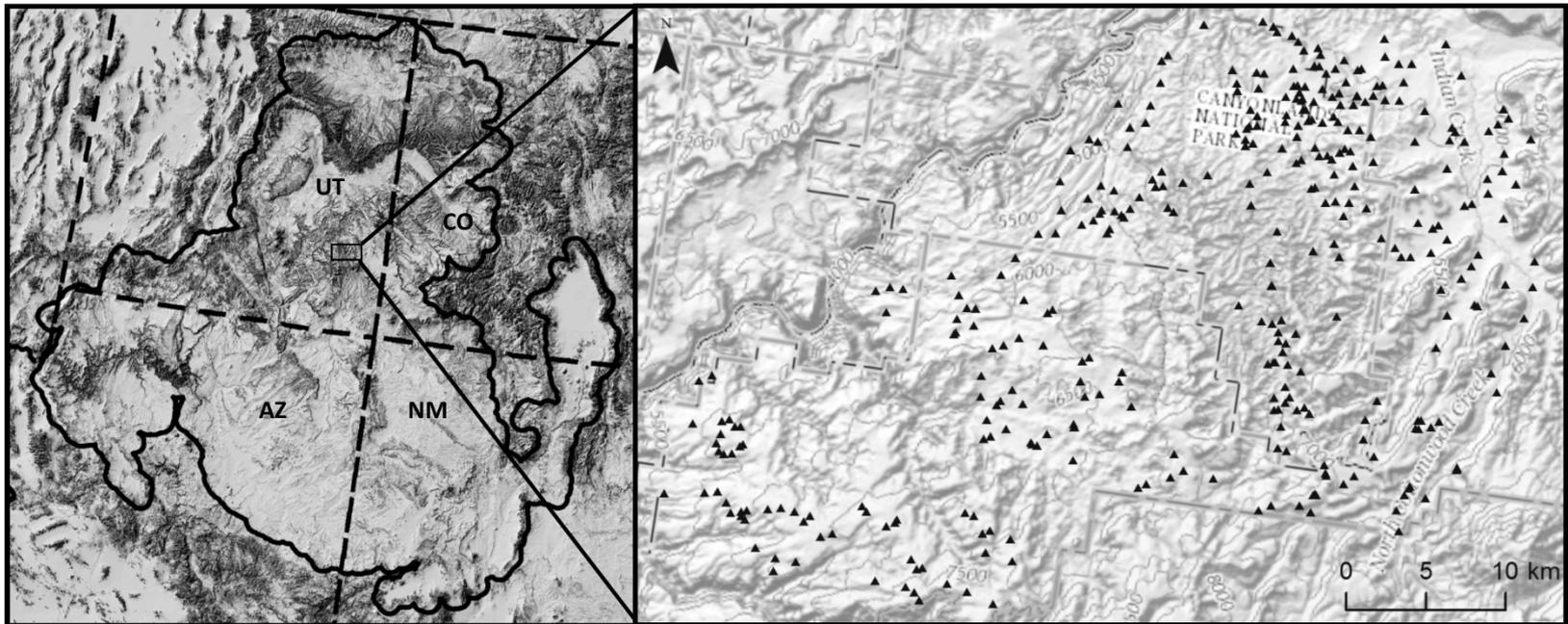
# The Automated Reference Toolset (ART)

## Overall Agreements

Confusion Metrics	n
False match: ART match, wrong ES	130
Correct match: ART pixel overlaps correct ES point	268
Correct Exclusion: Correctly unmatched ES points	1256
Omission Error: Same ES not matched by ART pixel	510
User Accuracy: $(\text{Correct match}) / (\text{Correct match} + \text{False match})$	67.3%

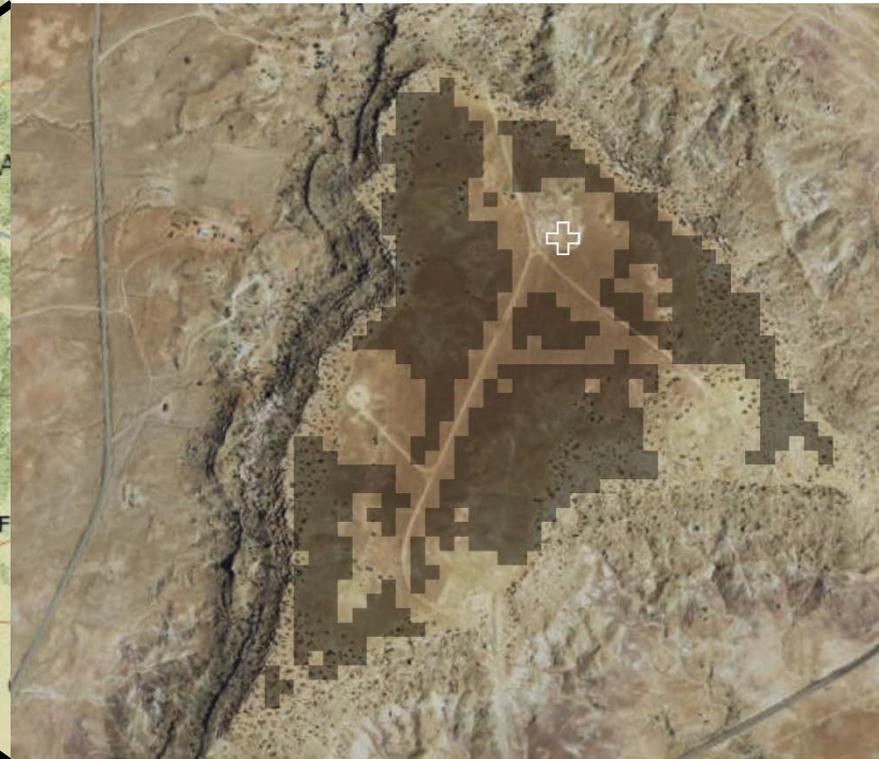
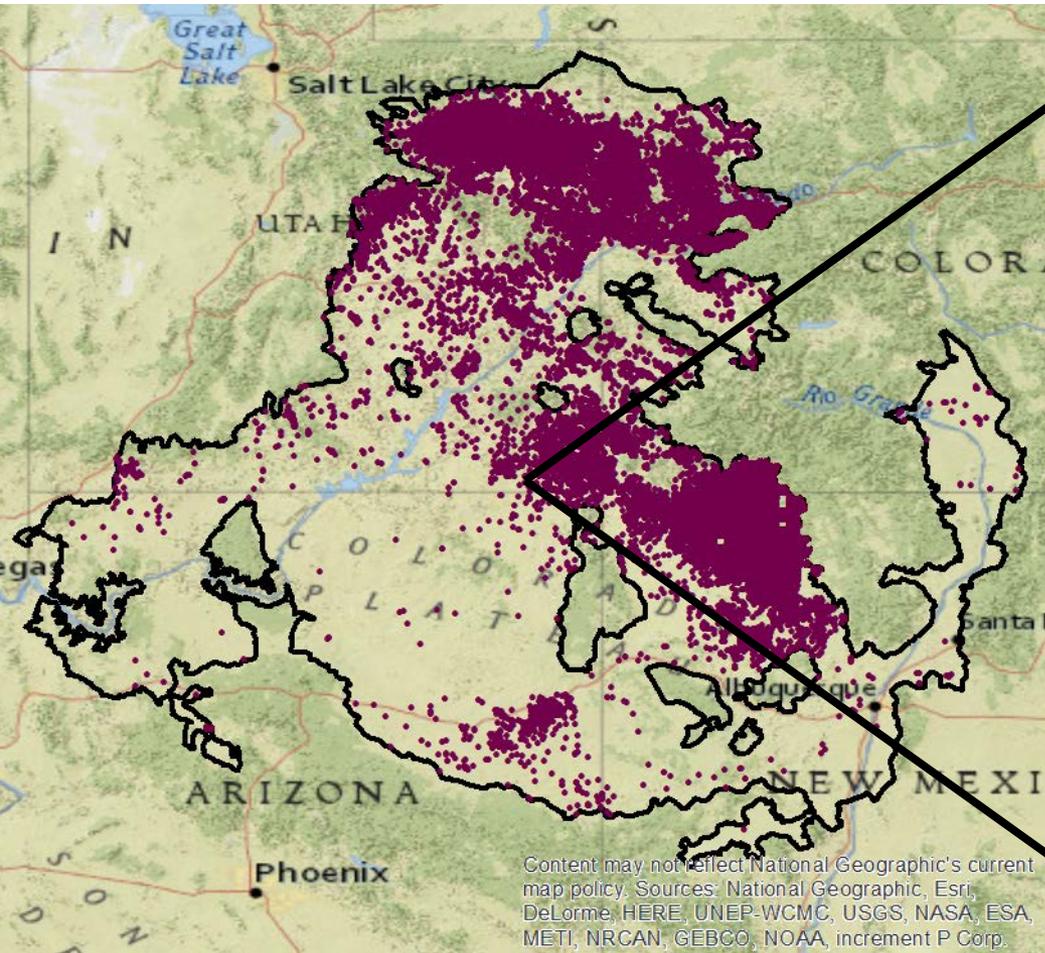
## Validation!

Ecological Sites (ES) are an ecological potential-based land classification system linked to Soil Survey.



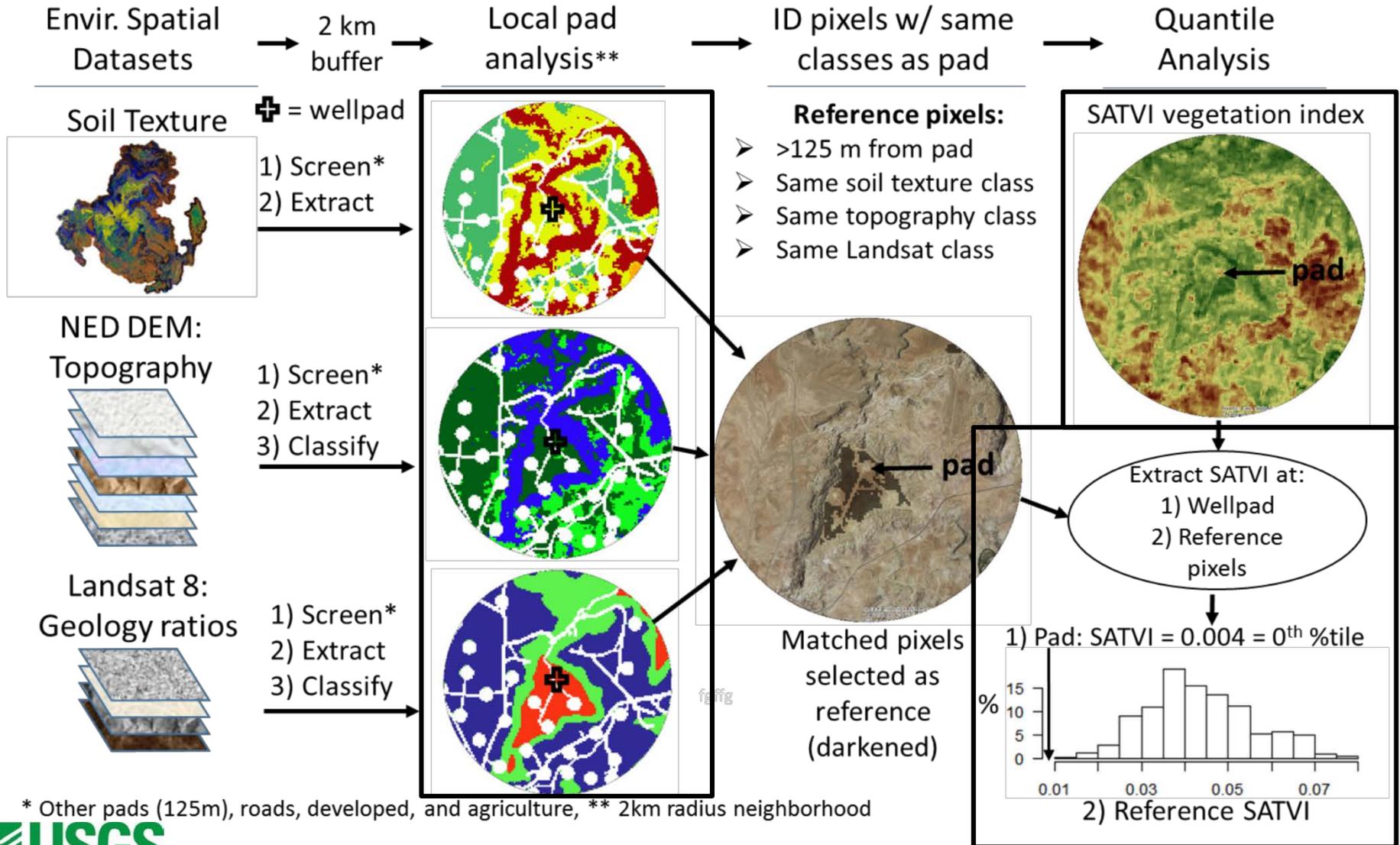
Miller et al. 2011. *Ecosphere* **2**:art55.

# The challenge



~90,000 records on CO Plateau

# The Disturbance Automated Reference Toolset (DART)



\* Other pads (125m), roads, developed, and agriculture, \*\* 2km radius neighborhood

# DART Quantiles

Well-pad plugged in 2010

**quantile = 0.14**



Well-pad reference site



Well-pad plugged in 1976

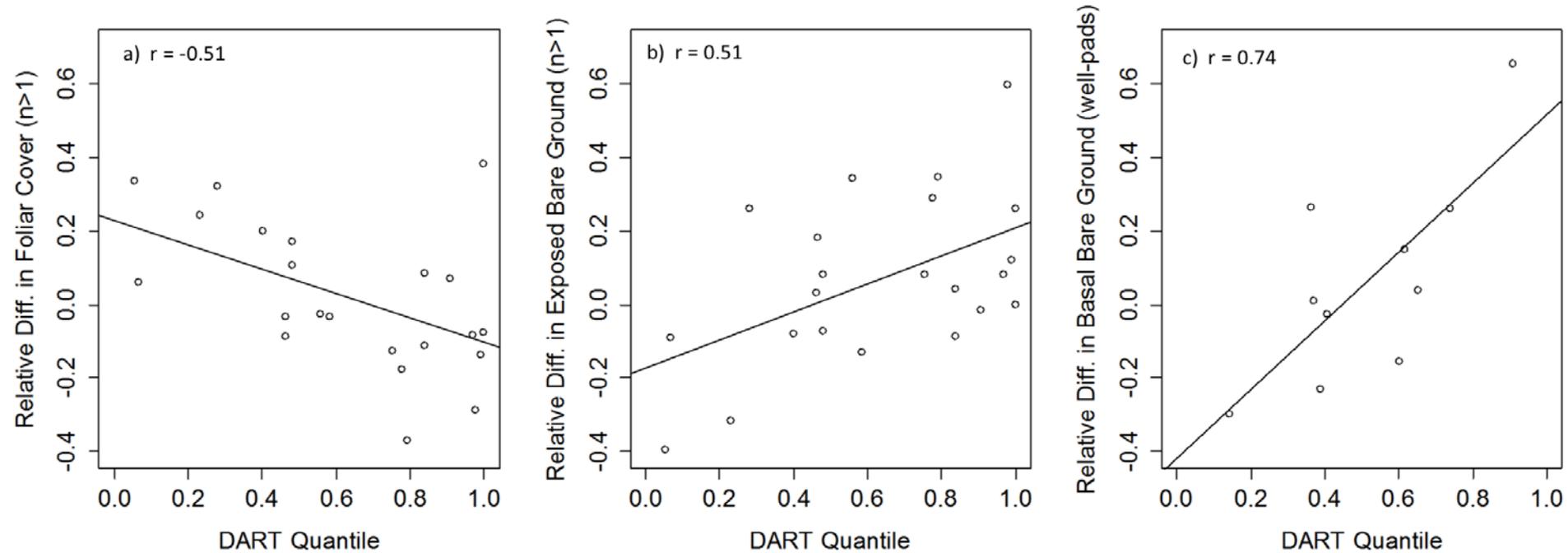
**quantile = 0.39**



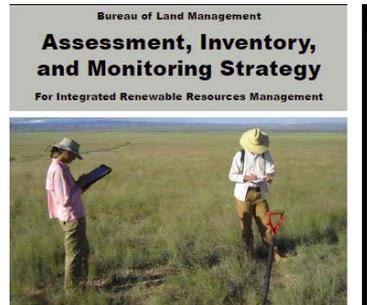
Well-pad reference site



# DART validation



BLM Assessment Inventory and Monitoring plots (n=22)



Oil and gas well-pad evaluations (n=10)

- Plot simulation with DART

$$\text{Relative difference} = \frac{\text{Avg}(\text{reference cover}) - \text{Target cover}}{\text{Avg}(\text{reference cover}) + \text{Target Cover}}$$

# DART Quantiles

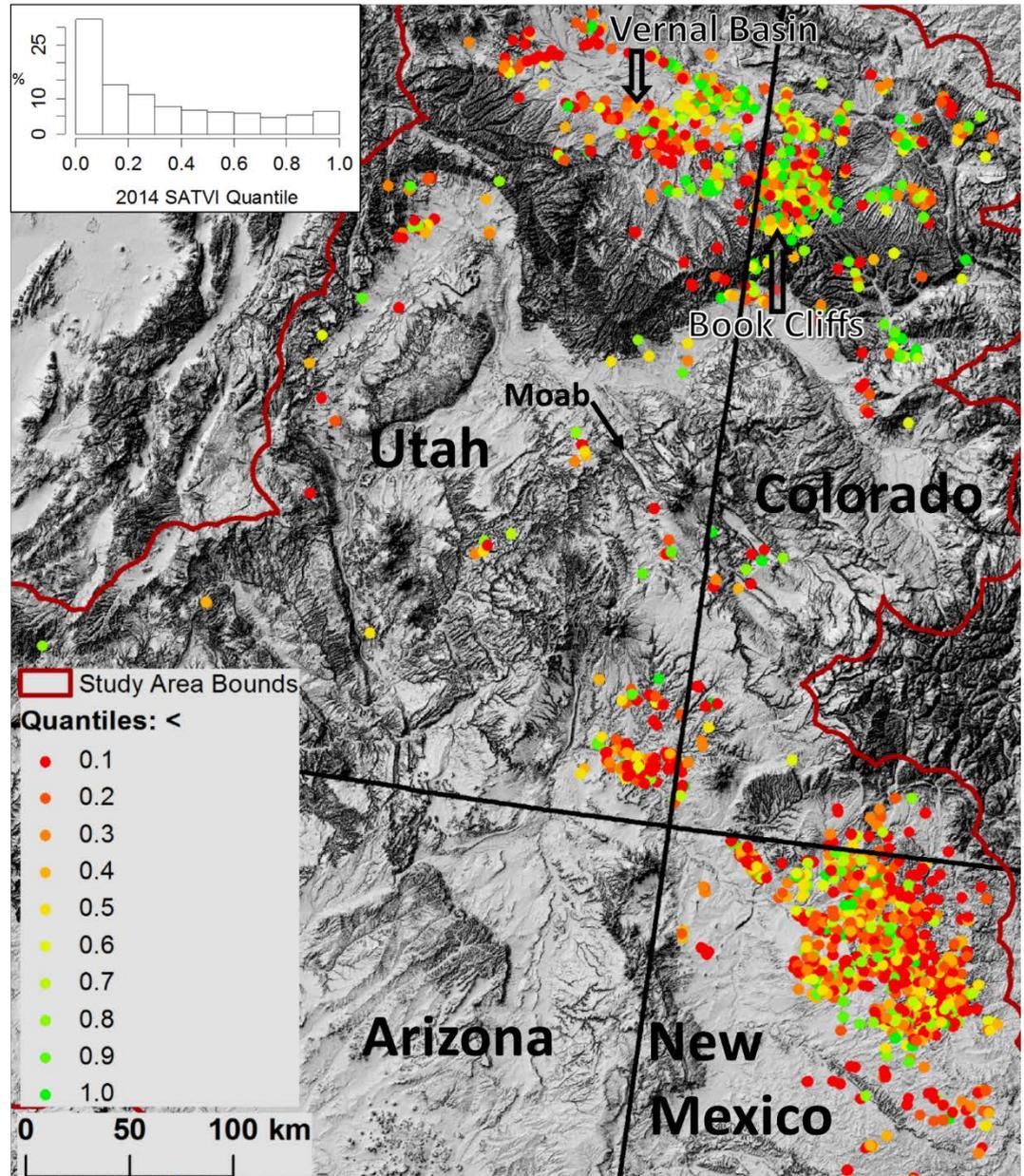
2014 assessment of abandoned oil and gas well-pad recovery status

Red = Poor recovery

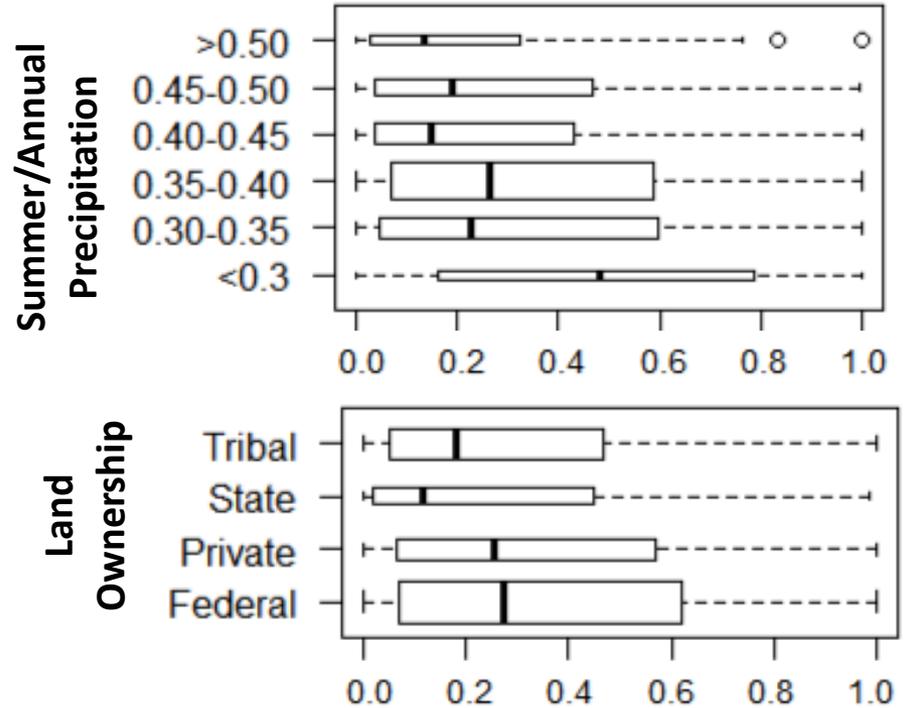
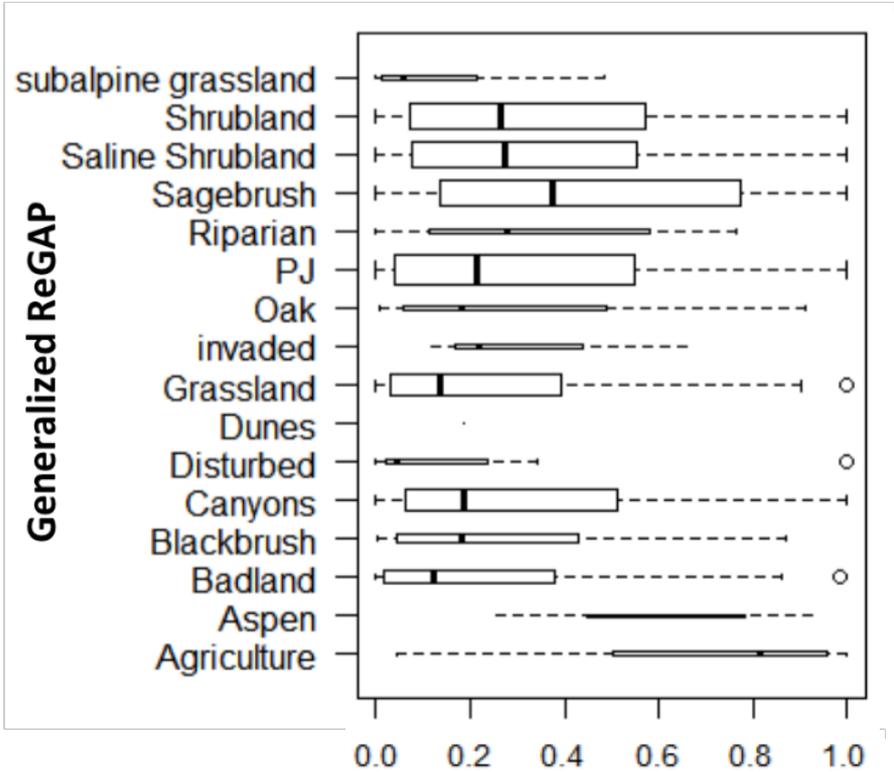
Yellow = Moderate recovery

Green = Good recovery

Wells: plugged 1997-2005, validated for pad via Google Earth Pro, n=1858



# DART: Well-pad recovery patterns



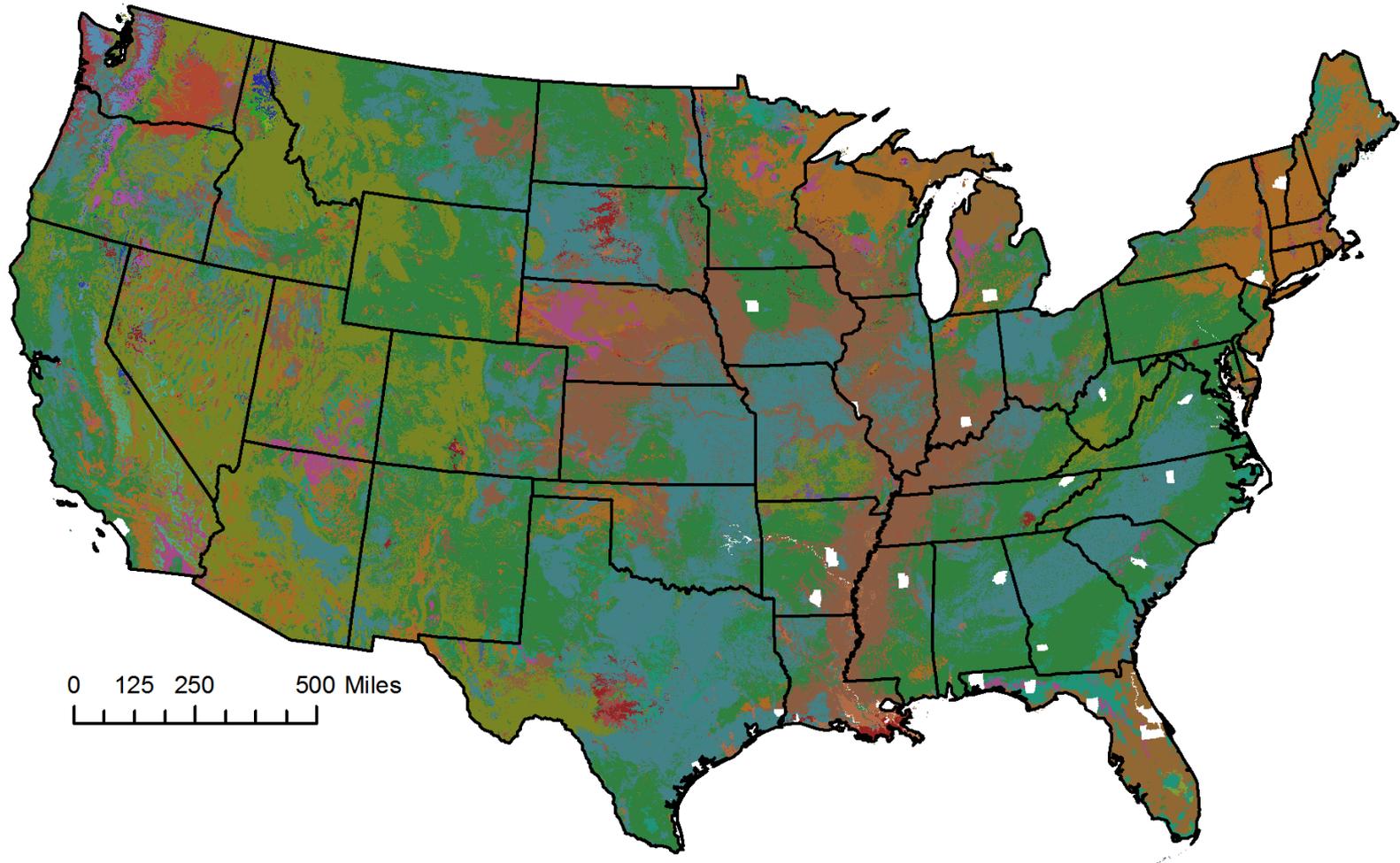
Poorer recovery associated with:

- Higher ratio of summer/annual precip
- State owned lands
- Certain ecotypes: grasslands, badlands, blackbrush, canyon areas
- More exposed convex landforms

# ART and DART recap

- New 30m soil map of CO Plateau: particle size in control section
- Neighborhood analysis: Topography and Geology
- Reference pixel selection
  - Generally picks same ecological site
- Soil Adjusted Total Vegetation Index (SATVI) for recovery index
  - Detects vegetation cover differences
- Detected patterns in recovery that have implications for management

# Expanding (D)ART



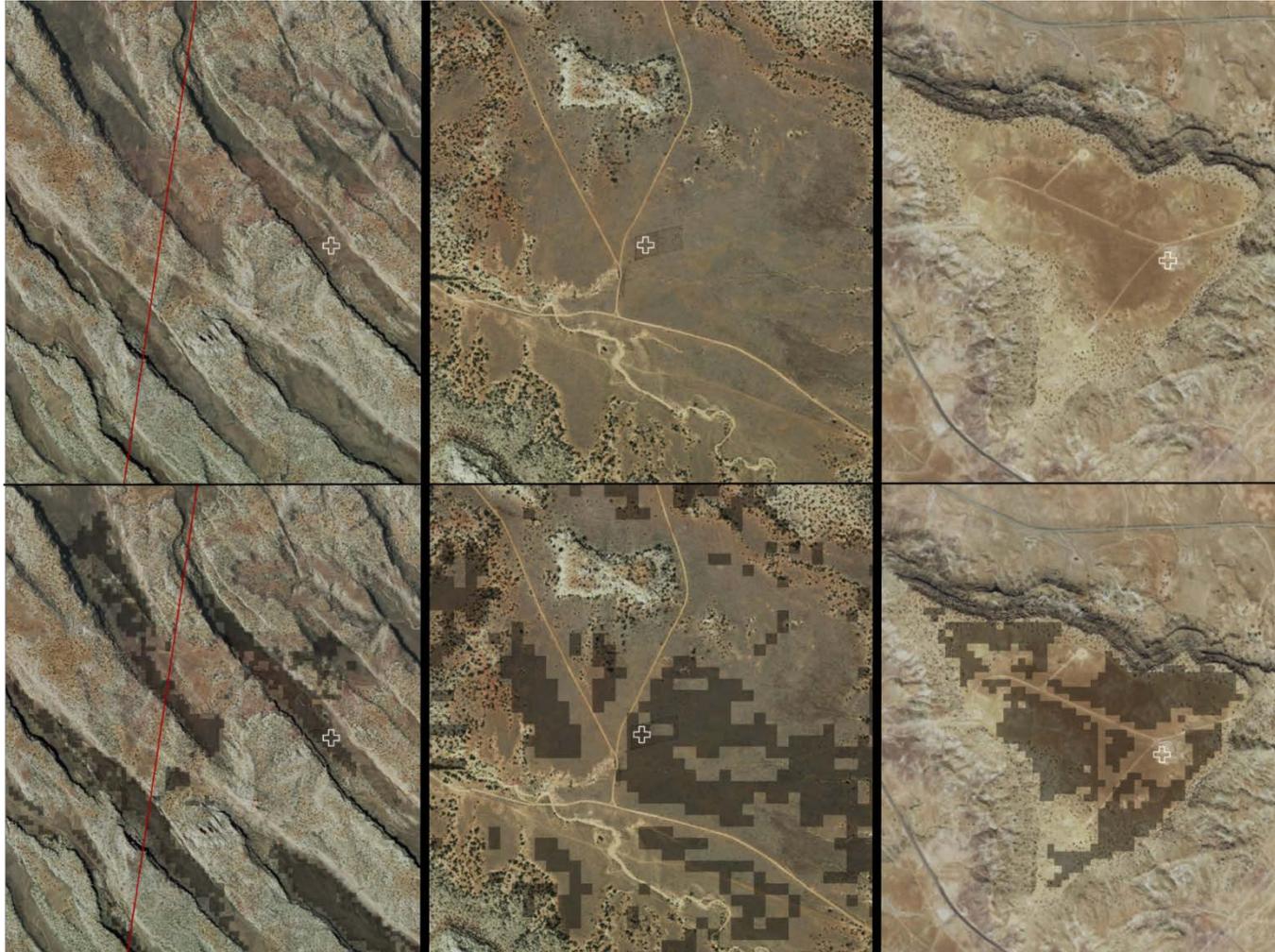
Draft map: Particle Size in Control Section. Conterminous USA. 100m resolution. In collaboration with SoilGrids.org and isric.org

# Future (D)ART Applications

Boundary monitoring

Grazing exclosures

Discrete disturbances



# Thanks! Questions?

## Next steps for our research

- Field investigations to understand barriers to recovery
- Temporal applications (monitoring recovery through time)
- Relating dust to DART

## Other applications of ART

- Post-fire assessment & monitoring
- Wildlife habitat restoration monitoring
- Integration into local-scale monitoring & management

## Exporting ART

- Deriving underlying spatial framework for rest of US
- Web-ART (web interface)

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Mike: [mduniway@usgs.gov](mailto:mduniway@usgs.gov)