Predicting Biological Soil Crust and Ecological Site Classes Using Soil Survey, Topographic, and Spectral Data

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Background

- Existing soil surveys did not meet National Park Service (NPS) needs:
  - NPS paid for update
  - NPS concerned with:
    - Biological soil crust
    - Improved ecological site concepts
    - Improved ecological site-soil correlations

Research Rationale

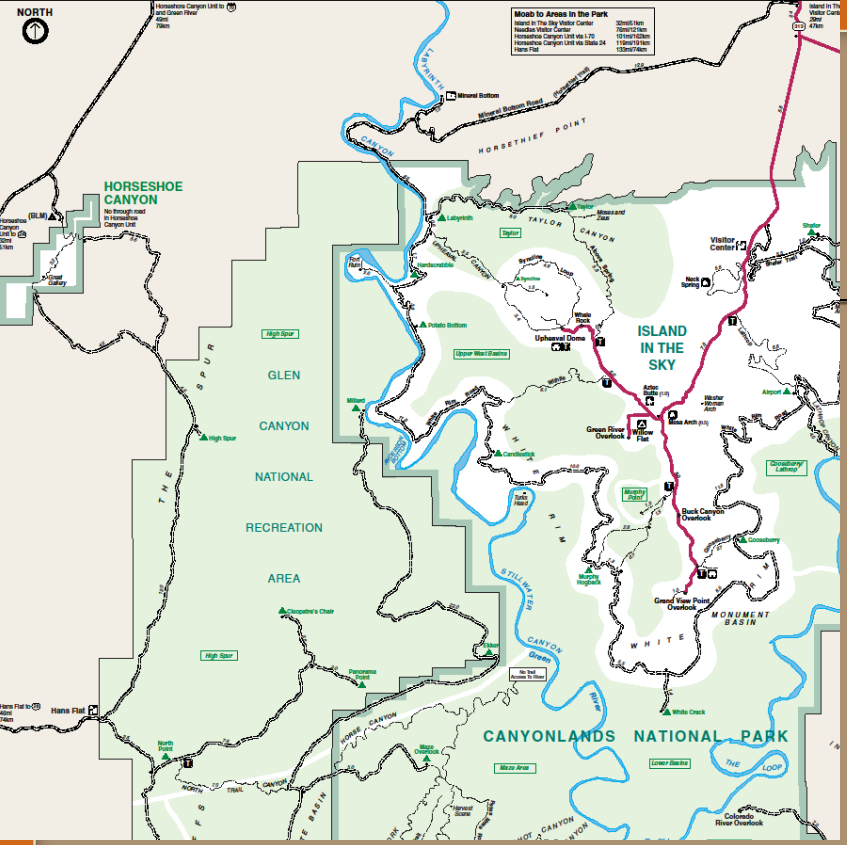
- Canyonlands National Park soil survey update
  - Provide digital "value added" interpretations
    - Biological Soil Crust
    - Ecological Site
  - Useful for management

  - Digital Soil Mapping
    - Field and laboratory observations
    - Digital environmental covariates
    - Quantitative statistical models

Project Location

Colorado Plateau

http://rst.gsfc.nasa.gov/Sect6/cp_map.jpg



Project Location

Canyonlands National Park

http://www.nps.gov/cany/planyourvisit/upload/tripmap.pdf

20
40
60

Biological Soil Crust

- Community of cyanobacteria, green algae, microfungi, mosses, liverworts and lichens at the surface of desert soils. (www.soilcrust.org)

- Soil stability
- Primary producers
  - Organic carbon
  - Nitrogen fixation
- Rangeland health

- Six classes

Crust Classes

Ecological Sites

- 50 Ecological Sites
- <u>Examples</u>
  - Alkali Bottom (Greasewood)
  - Desert Sandy Loam (Shadscale)
  - Desert Very Steep Gravelly Loam (Blackbrush)
  - Semidesert Sand (Dune)
  - Semidesert Shallow Sandy Loam (Utah Juniper/Pinyon)

Field Data

- Pedons
  - NRCS soil survey crew 2007 – 2009.
  - NASIS export
  - ~ 1100 point pedon observations
    - ~2/3 for model
    - ~1/3 for validation

Digital Environmental Covariates
(biophysical)

Environmental Covariate	Source
Slope	DEM
Elevation	DEM
Diffuse Solar Radiation	DEM
Direct Solar Radiation	DEM
Global Solar Radiation	DEM
Duration of Solar Radiation	DEM
Biological Soil Crust Index	Landsat
Normalized Difference Vegetation Index (NDVI)	Landsat
Band Ratio 5/7	Landsat
Band Ratio 5/2	Landsat

Random Forests

(Breiman, 2001)

- Multiple classification trees (Forest)
- Each tree is doubly random (Random)

Random Forests

- For each tree
  - Random sample with replacement (bootstrap)
  - ~1/3 of samples not selected
    - "Out of bag" (OOB)
    - OOB samples used to validate tree
- At each node
  - Random selection of covariates
- Final class
  - Majority "vote" of forest

Random Forests Output

- OOB error rate
  - For model
  - For each class
- Predictions
- Probabilities
  - Proportion of forest votes
- Covariate importance

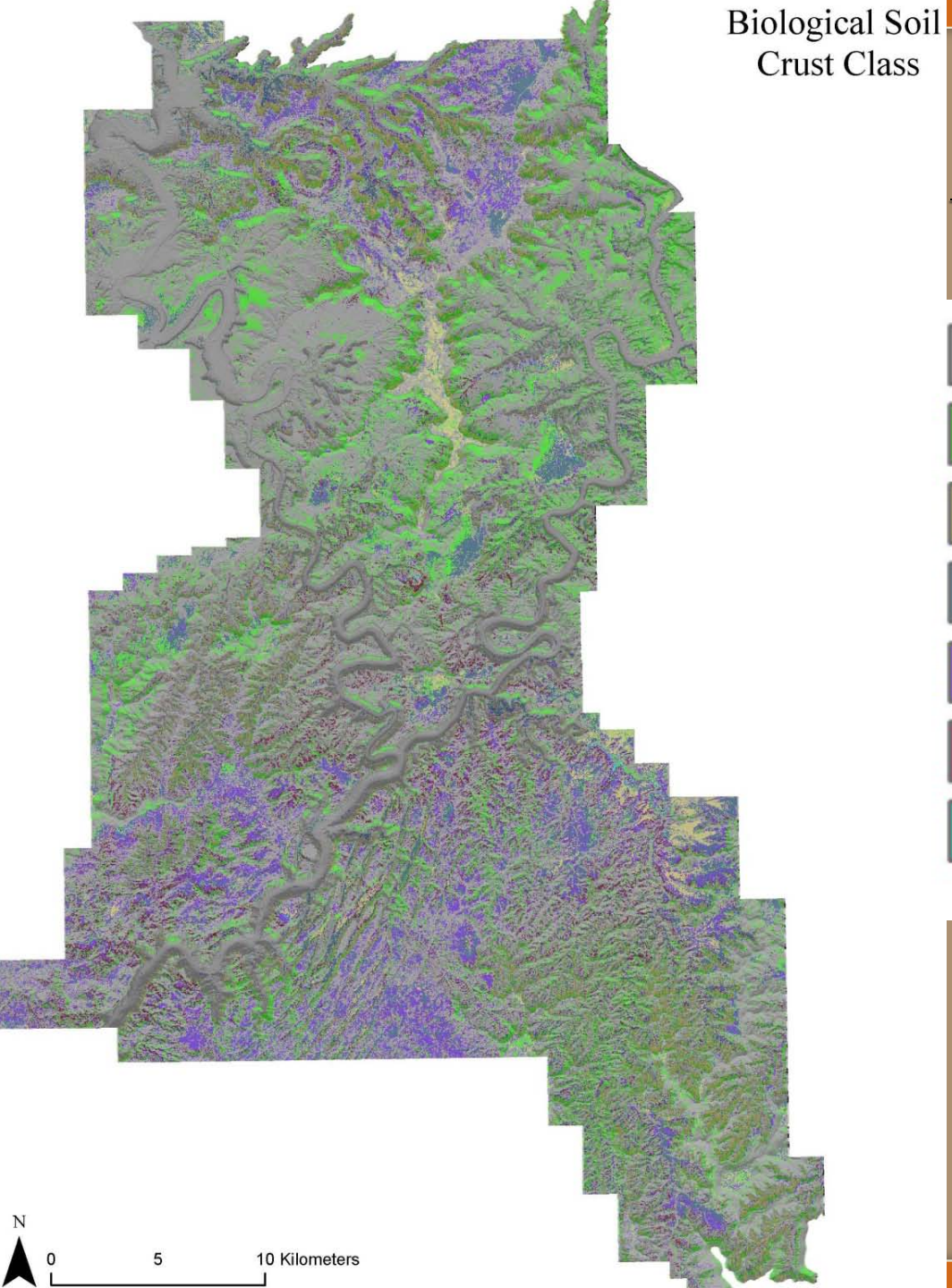
OOB Error

- Overall OOB error
  - Biological Soil Crust - 0.76
  - Ecological Site – 0.84
- Validation data set
  - Suggests much higher accuracy

BSC Class	Error	N
0	0.36	223
1	0.82	124
2	0.72	127
3	0.72	140
4	0.81	129
5	0.89	75
6	1.00	19
		837

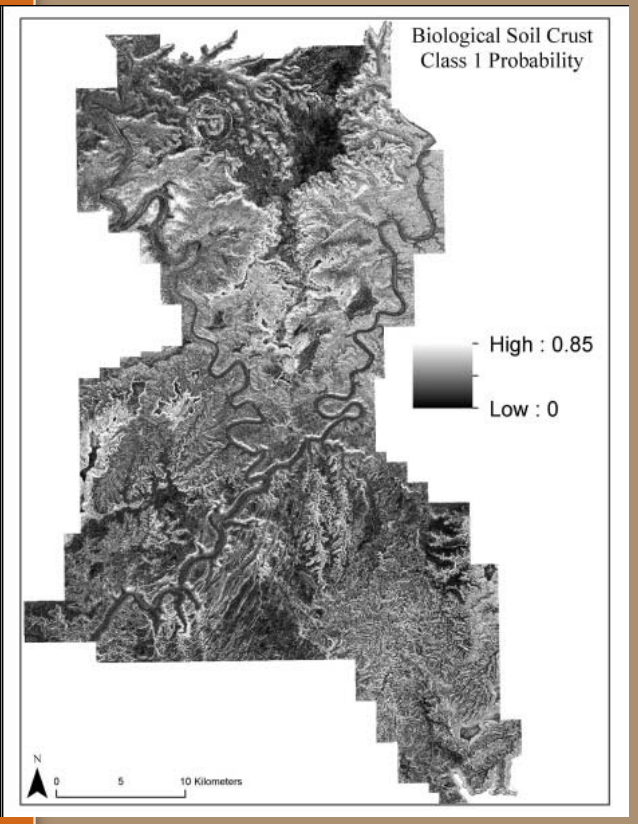
Results

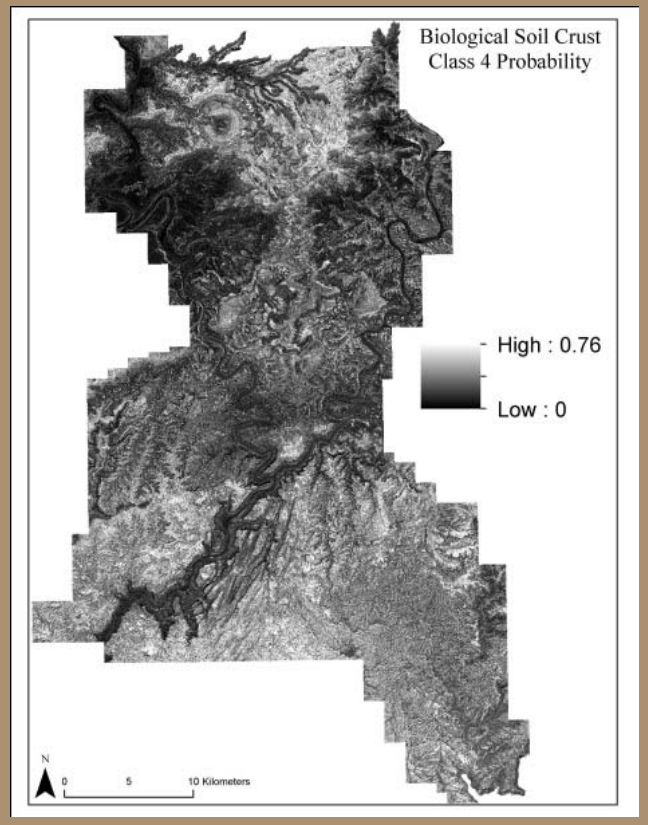
Spatial prediction of BSC

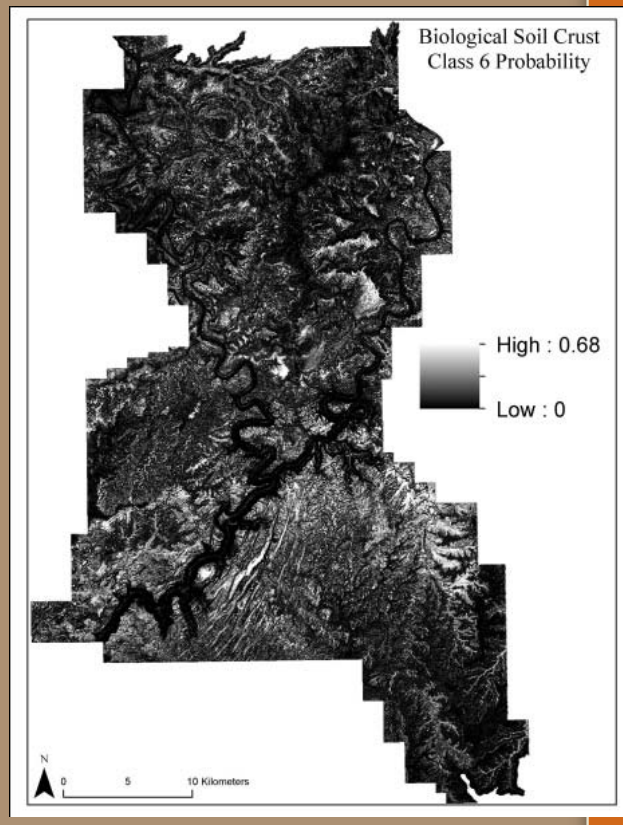


Results

Spatial probabilities of BSC

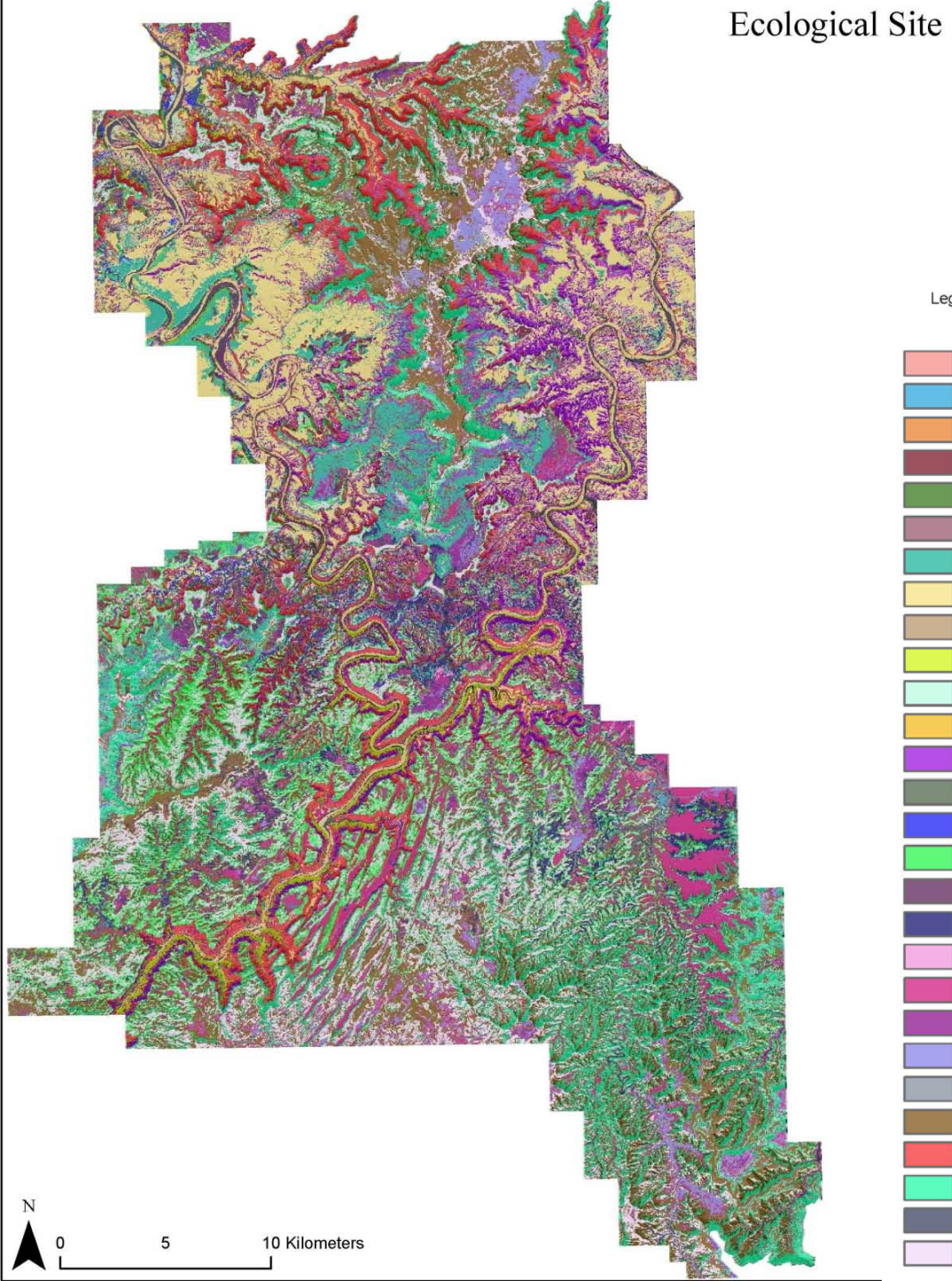






Results

Spatial Prediction of Ecological Site

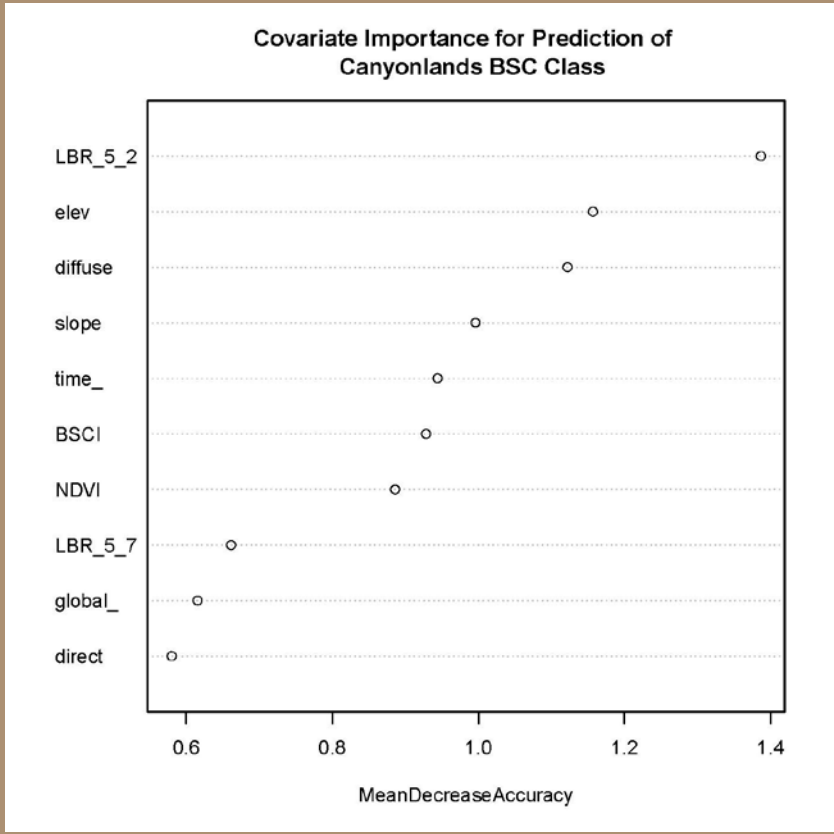


Legend (Only ecological sites with > 1000 cells shown)

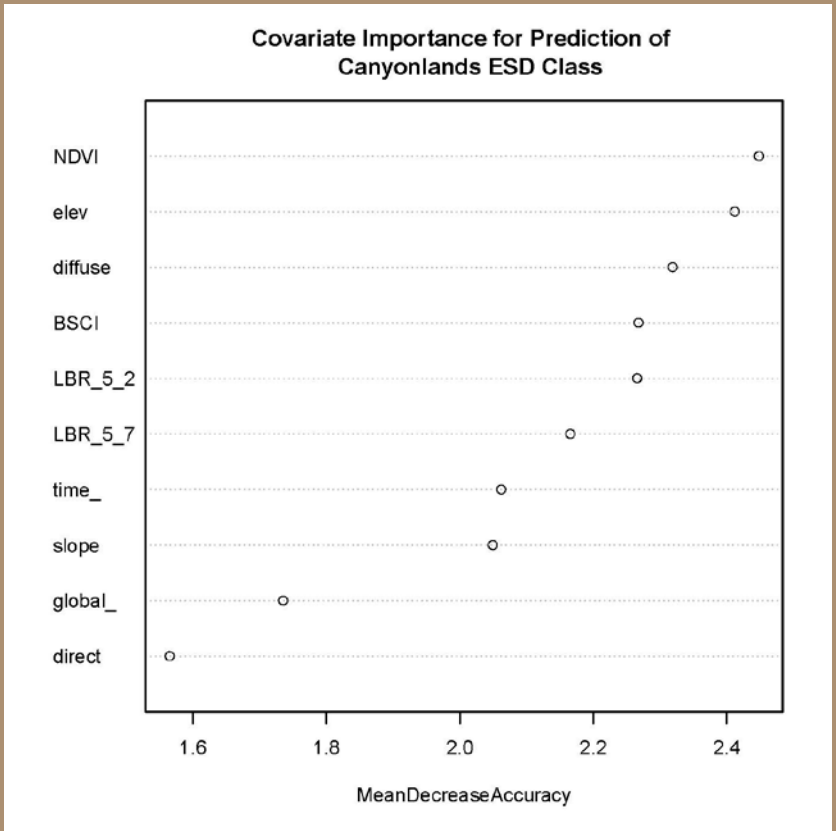
- Alkali Bottom (Greasewood)
- Alkali Flat (Greasewood)
- Desert Sand (Sand Sagebrush)
- Desert Sandy Loam (Blackbrush)
- Desert Sandy Loam (Fourwing Saltbush)
- Desert Shallow Loam (Shadscale)
- Desert Shallow Sandy Loam (Blackbrush)
- Desert Shallow Sandy Loam (Shadscale)
- Desert Steep Shallow Loam (Castlevalley Saltbush)
- Desert Steep Stony Loam (Shadscale)
- Desert Stony Loam (Shadscale-Bud sagebrush)
- Desert Very Steep Gravelly Loam (Blackbrush)
- Desert Very Steep Stony Loam (Shadscale)
- Loamy Bottom (Basin Sagebrush)
- No ESD-Riverwash
- No ESD-Rock Outcrop
- Sandy Bottom (Fourwing Saltbush)
- Semidesert Sand (Blackbrush)
- Semidesert Sand (Dune)
- Semidesert Sand (Fourwing Saltbush)
- Semidesert Sandy Loam (Blackbrush)
- Semidesert Sandy Loam (Fourwing Saltbush)
- Semidesert Shallow Sandy Loam (Blackbrush)
- Semidesert Shallow Sandy Loam (Utah Juniper/Blackbrush)
- Semidesert Very Steep Stony Loam (Salina Wildrye)
- Semidesert Very Steep Stony Loam (Utah Juniper/Pinyon)
- Semiwet Fresh Streambank (Fremont Cottonwood)
- Shallow Sand Rock Pocket (Utah Juniper/Pinyon)

Variable Importance

Biological Soil Crust



Ecological Site



Significance

- Digital Soil Mapping
  - Field data
  - Digital environmental covariates
  - Quantitative statistical models
  - “Inter-polygon” predictions
  - Quantitative – estimate of probability/uncertainty
  - Covariate importance
- Assume Biological Soil Crust/Ecological sites inside park represent “potential”
  - Park created in 1964
  - Cattle grazing stopped in 1975
- Extend predictions outside the park where no mapping/course mapping exists
  - Land management

Acknowledgements

- USDA-NRCS
  - Funding
    - Predictive Soil Mapping – CESU agreement with Utah State University
- Cathy Scott
  - USDA-NRCS National Parks soil survey project leader

Questions?

Conclusions

- OOB errors
  - Actual prediction accuracy
- Spatial prediction
- Covariate importance
  - Biological Soil Crust
    - Parent material
      - Landsat Band Ratio 5/2
  - Ecological Site
    - Vegetation (NDVI)
    - Elevation

Could I use yaImpute, etc. to select the nearest neighbor/class center with six classes of BSC and divide the entire area up into 6 classes. Then use this to select the point nearest the multidimensional k-means class center as a training point to make predictions and use all of the other points as validations? I should investigate this.