Modeling volcanic ash presence across the Palouse Range of north Idaho

Robert Brown[1], Paul Gessler[2], and Paul McDaniel[1]

[1]Soil & Land Resources Division, [2]Dept. of Forest Resources, Univ. of Idaho, Moscow

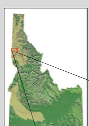
INTRODUCTION

- Volcanic ash mantles add water-holding capacity to many forested soils of the Pacific Northwest and are closely linked to forest productivity in the region.
- Little is understood about how environmental factors control the distribution of these andic soils across the landscape.
- In this study we present results on modeling presence/absence of ash mantles and their degree of mixing in the Palouse Range of northern Idaho.

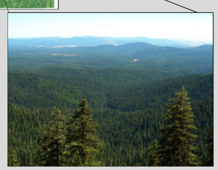
OBJECTIVES

- Examine the relationships between terrain attributes and the presence of volcanic ash mantles.
- Evaluate the degree to which post-depositional processes have mixed the ash mantles.
- Develop detailed volcanic ash soil-landscape models using classification and regression trees .

STUDY AREA



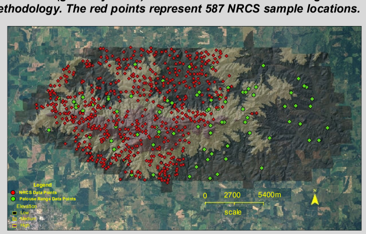
- The study area comprises 250 km² that is centered around the Palouse Range in northern Idaho.
- Soil parent materials include volcanic ash, loess, and colluvium/residuum derived from granite.



- Soil moisture regimes range from xeric to udic; soil temperatures range from mesic to cryic.
- Forest types range from drier ponderosa pine series to moister western redcedar series.

METHODS

- Solar insolation and elevation were combined to generate 9 stratified sample categories; 84 randomly selected points from these categories were visited (green symbols) and soils were described using standard methodology. The red points represent 587 NRCS sample locations.



METHODS (cont'd)

- Ash purity was examined in the field for texture, color, structure, plasticity, and stickiness. The samples were then compared with NaF pH and Al_{ox} + ½ Fe_{ox} determined by ammonium oxalate dissolution (AOD) to ensure quality of the field assessment (Perrott et al. 1966).
- Each of the 84 samples were assessed using the Ash Mixing Index (Gardner, 2007) to identify the level of ash purity (Below) .

Ash Mixing Index

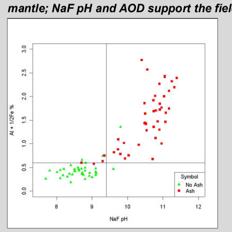
Moist Hue: 7.5 YR = 1 Other = 0	Structure Grade: Weak = 1 Other = 0	Dry Consistence: S O = 2 Other = 0
Stickiness: S O = 2 Other = 0	Plasticity: P O = 2 Other = 0	Texture: SiL = 2 Other = 0

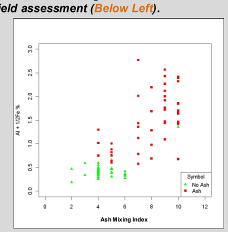
For: Consistence S O = soft; Stickiness S O = non-sticky; Plasticity P O = non-plastic

- Digital Elevation Models (DEMs) were generated from LIDAR (Light Detection and Ranging) points data with 1-m resolution. Then, DEMs were resampled to 10-30-m resolution.
- Primary and secondary terrain attributes, % slope, aspect , elevation, profile curvature, plan curvature, compound topographic index (CTI), and specific catchment area (SCA), were extracted using TauDEM (Tarboton, 2004) and GIS software. These attributes were evaluated as explanatory variables to explore presence/absence of volcanic ash.
- Box plots were constructed to identify terrain attributes that showed strong relationships to ash presence/absence.
- Decision trees were implemented using GIS map algebra and conditional statements to generate probability maps. (Brieman et al., 1993).
- 587 NRCS data points were used for accuracy assessment; NRCS field descriptions were used to determine presence/absence of volcanic ash mantles; data indicating an ash depth were given a presence value of 1 and others that did not were given an absence value of 0.
- Decision tree statistics were used to identify landscape attributes most associated with mixing of 46 of the 84 samples that had ash present.

RESULTS

- Field assessment indicates 44 of 84 soils have a distinguishable volcanic ash mantle; NaF pH and AOD support the field assessment (Below Left).





- The values on the ash index range from 0–10 and were compared with AOD values. Pure ash samples score high on the ash index and have high AOD values, while samples that have been subject to post depositional reworking score low (Above Right).

REFERENCES

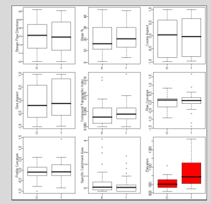
Brieman, L.; Friedman, J.; Olshenm, R.; Stone, C. 1993. Classification and Regression Trees, Chapman & Hall, New York, NY.

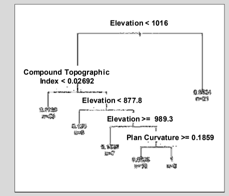
Gardner, B. 2007. Field Identification of Andic Soil Properties for soils of North-central Idaho, Page-Dumroese et al., USDA-Forest Service RMRS-P-44.

Perrott, K; Fieldes, M. 1966. Nature of Allophane in Soils. Part 3- Rapid Field And Laboratory test for Allophane, N Z J. Sci., 9 : 599-607.

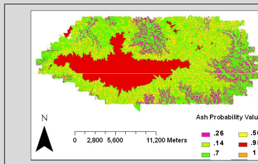
Tarboton, D. 2004 Terrain Analysis Using Digital Elevation Models (TauDEM), Utah State Univ.

RESULTS (CONT'D)





- Exploratory boxplots (Above Left) suggest that elevation is the most useful explanatory variable for differentiating volcanic ash mantle presence (1) and absence (0). Other topographic attributes provide little additional explanation of presence/absence patterns.
- The best decision tree (Above Right) shows that ash is almost always present above the elevation of 1016 meters. Below this elevation a more complex pattern exists suggesting multiple interacting factors perhaps related to disturbance and redistribution.



Grid cell size	Points correctly predicted	Total # of points	Overall accuracy
30m	455	587	77.5%

Producer's Accuracy (Omission error)	User's Accuracy (Commission error)
Ash = 126/220 = 57.27%	Ash = 126/164 = 76.83%
No Ash = 329/367 = 89.65%	No Ash = 329/423 = 77.78%

- The 30m spacing probability map (Above Left) was implemented using the decision tree rules and explanatory terrain attributes with GIS map algebra and conditional statements.
- An accuracy assessment (Above Right) using the NRCS 587 sample points provided a 78% overall accuracy.

- Decision tree modeling suggests that CTI and elevation are the most influential topographic attributes that explain the intensity of ash mixing across a range of DEM grid scales. This suggests that elevation and hillslope redistribution processes are important for understanding ash distribution in the region.

10m	15m	20m	30m
CTI Elevation	CTI ----	Elevation ----	Elevation CTI

CONCLUSIONS

- The Ash Mixing Index and decision tree statistics indicate that elevation and CTI are important terrain attributes that influence andic soil distribution.
- Unmixed ash is found in areas of high CTI values, which suggests that original ash fall has been subject to erosion and re-deposition in larger drainages.
- Elevation is important suggesting that moister and cooler climatic conditions, usually associated with more dense forest cover, may stabilize the ash and minimize redistribution via erosion.
- Plan curvature plays a role in ash distribution concave slopes concentrate water run-off and enable greater erosion.
- Decision tree modeling provided a volcanic ash mantle presence map with 78% accuracy as well as a set of useful process-based thresholds that provide a good preliminary understanding of the factors influencing ash distribution across the Palouse Range of northern Idaho.