Soil Disturbance Recovery After Timber Harvests on the Malheur National Forest, Oregon

Leslee Crawford

Soil Scientist Intern (Pathways)

Malheur National Forest

Overview

- Project Overview
- Malheur National Forest Background
- Methods
- Study Results and Discussion
- Management Implications
- Conclusion

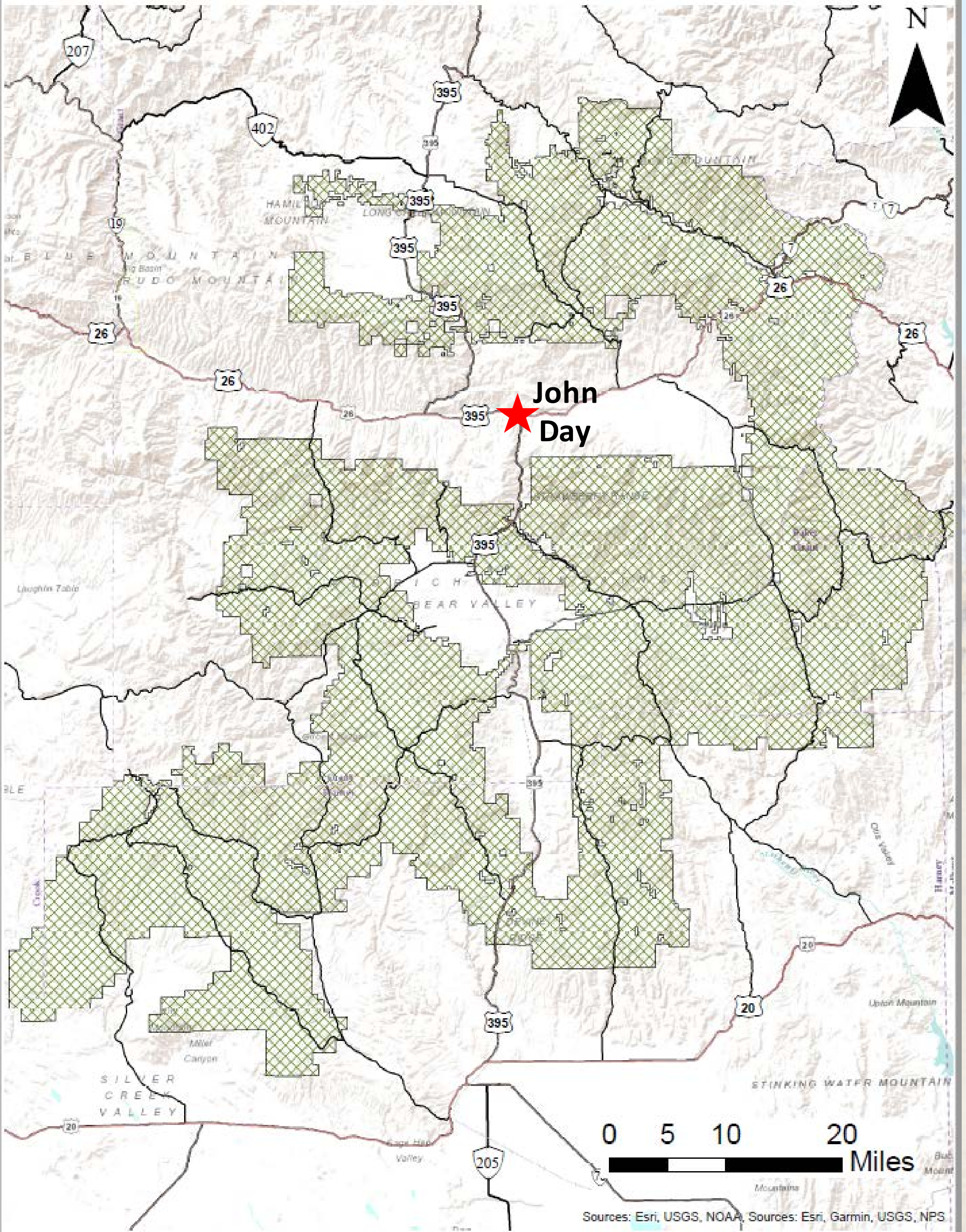
Project Overview

- This work was conducted to fulfill the thesis requirement of a M.S. Degree at the University of Idaho.
  - Graduate May 2020
- Research benefits the Malheur National Forest.
- Project area was selected by the Malheur's Natural Resources and Planning Staff Officer
  - Upcoming watershed restoration project area

Malheur National Forest's Supervisor's Office in John Day, Oregon

Malheur National Forest Background

- Nestled in the Blue Mountains of Oregon
- Malheur National Forest encompasses 688,000 hectares (1.7 million acres)
- Strawberry Mountain range splits the forest into two geologic provinces (Malheur National Forest 1990)



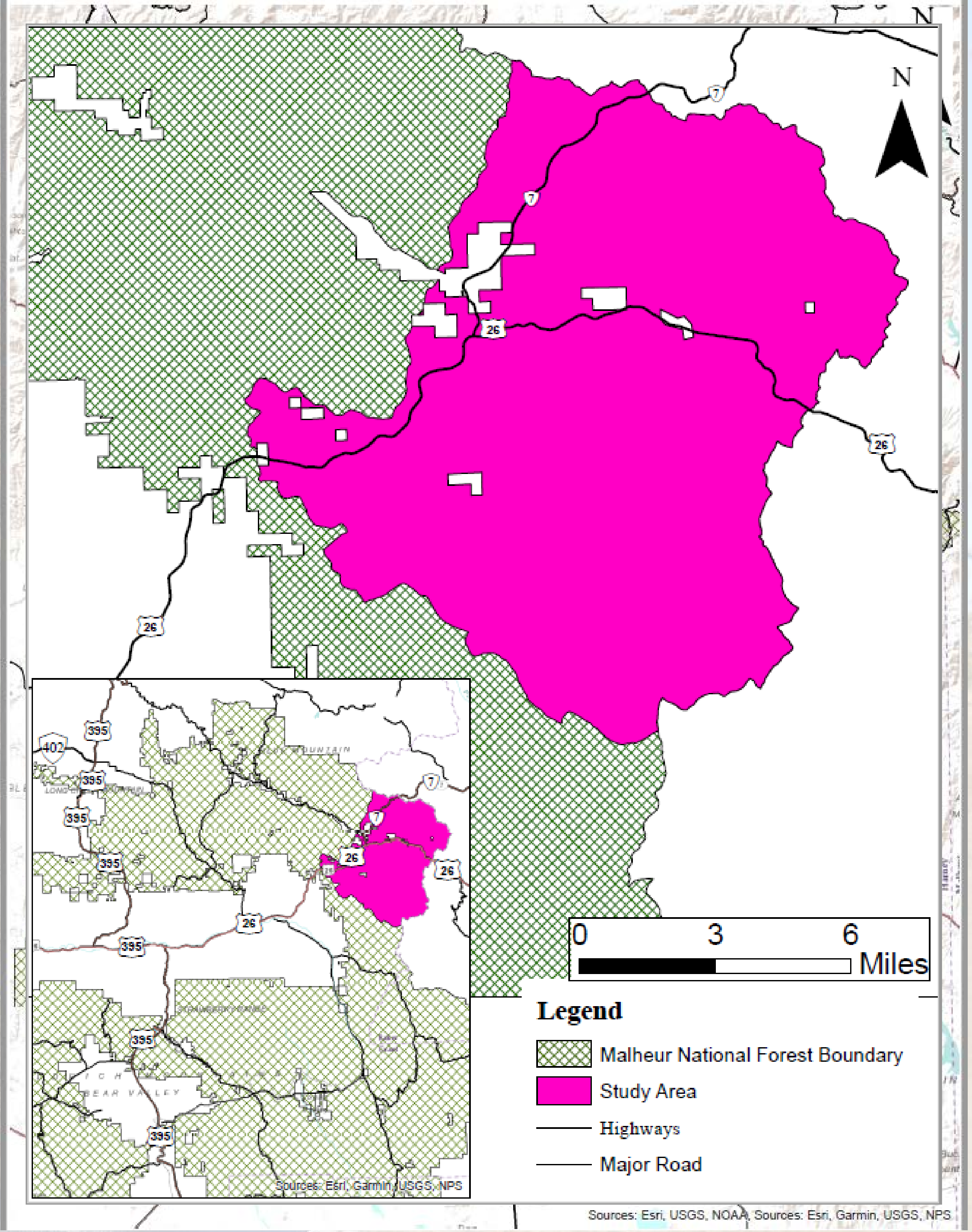
Forest Management

- National Forest Multiple-Use Principle:
  - “For the greatest good of the greatest number in the long run”
- 10-year Accelerated Restoration Stewardship
  - Currently in year 7 out of 10.
  - Collaboration with groups
    - “Diverse interests working together – is key to the success of these efforts” (Malheur National Forest 2020)
- Goals for Forest Health:
  - Promoting ecological restoration
  - Reducing wildfire risk

Canyon Creek Complex 2015. Photo from MyCentralOregon.com
https://www.mycentraloregon.com/2015/08/18/canyon-creek-complex-0-percent-contained-nations-top-priority/

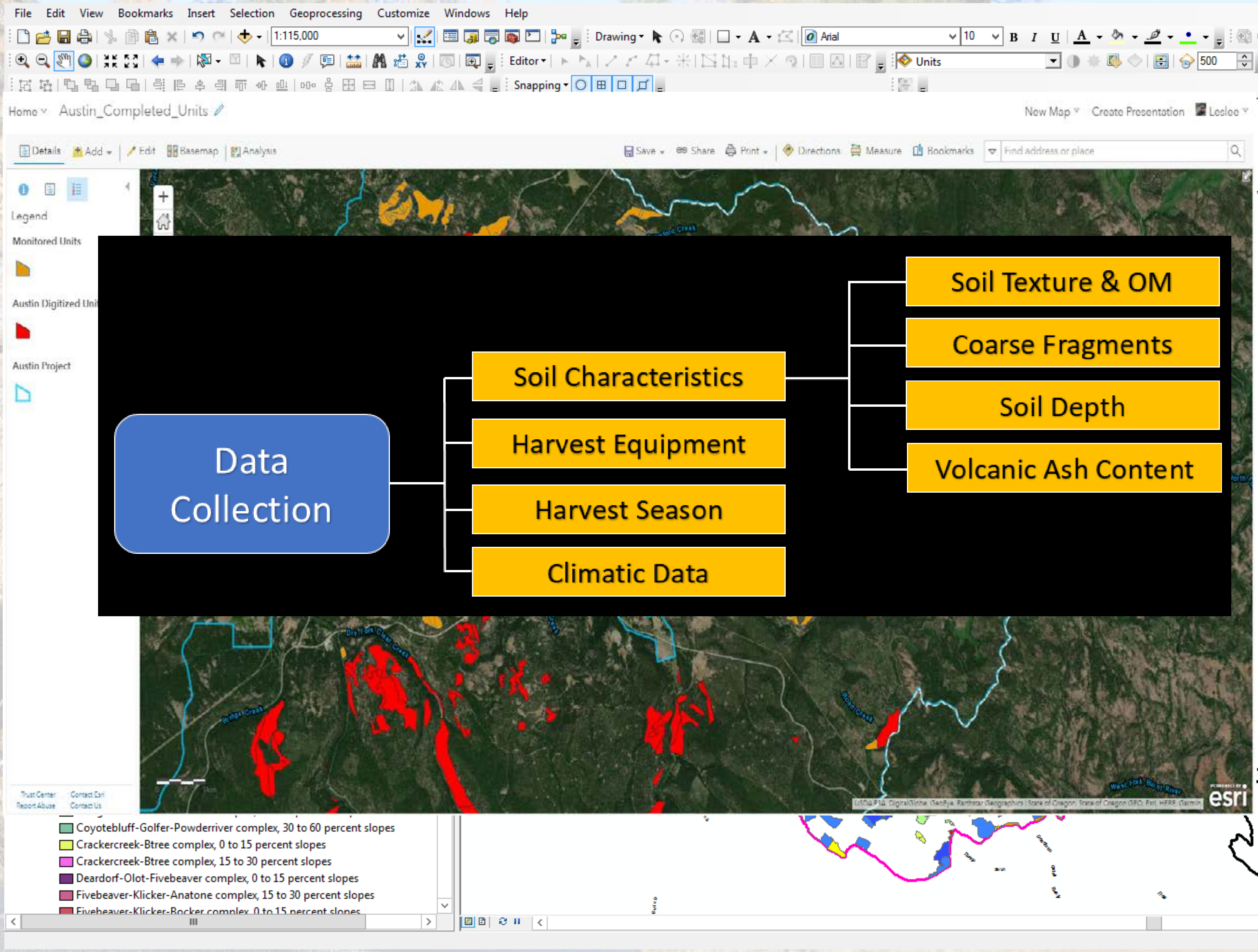
Methods

- Study Location:
  - Harvest unit approximately 31,000 hectares (76,000 acres) in size
  - Elevation ranges: 1331 m (4367 ft.) to 1585 m (5200 ft.)
  - Frost-free season: 55 to 70 days
- Potential Natural Vegetation Communities
  - Tree Species



Methods Continued

- Stand Selection:
  - Soil complexes were mapped over study area from the Forest Service Terrestrial Ecological Unit Inventory (TEUI)
  - Complexes were overlain with the Malheur's historic logging layer
  - Stands of varying post-harvest ages were stratified and digitized within ESRI ArcGIS
- Data Collection:
  - Further data collection for each digitized stand was gathered:
    - TEUI
    - Malheur's Historical Logging Layer
    - SoilWeb and Web Soil Survey
    - ClimateNA Website



Climatic Data and Soil Properties

- Climatic data was collected through ClimateNA website.
- Data included annual, seasonal and monthly variables from historical data fro 30-year normal.
  - Over 225 climatic variables were compiled for each stand monitored.
- Soil Properties:

USFS TEUI	Soil Parent Material
	Wind Erodibility Index
SoilWeb	Dominant Soil Series
Soil Series Descriptions	Coarse Fragment Content
	Volcanic Ash
Web Soil Survey	Percentages of Sand, Silt, Clay, and Organic Matter
	Textural Class
	Bulk Density
	Depth to Restrictive Layer (Lithic Bedrock)

Soil Disturbance Monitoring

- Monitoring data collected utilizing the Forest Soil Disturbance Monitoring Protocol (FSDMP).
- Transects were randomly oriented in each stand .
- Using a 95% confidence level and a 10% (+/- 5%) confidence interval, 30 points were measured in each stand.
- Amount of disturbance was assessed at each sample point.
- Classified into 1 of 4 severity classes:
  - Range from 0 (undisturbed) to 3 (highly impacted)
- Visual attribute data was collected.

Disturbance Type	Severity Class			
	0	1	2	3
Equipment Impact				
Past operation	None.	Dispersed.	Faint.	Obvious.
Wheel Tracks or depression	None.	Faint wheel tracks evident (< 5 cm deep).	Wheel tracks or are > 5 cm deep.	Wheel tracks highly evident, > 10 cm deep
Penetration and resistance	Natural Condition.	Increased resistance is in surface (10 cm).	Increased resistance in the top 30 cm of soil.	Increased resistance is deep into the soil profile (> 30 cm).
Soil physical condition	Natural Condition	Change in soil structure from granular structure to massive or platy structure in the surface (10 cm).	Change in soil structure in the surface (30 cm). Platy (or massive) structure is generally continuous.	Change in soil structure extends beyond the top 30 cm. Platy (or massive) structure is continuous.

Examples of soil visual indicators and management activities by disturbance severity class, as described in the FSDMP Volume 1 (Page-Dumroese et al. 2009a)

Compaction

Displacement

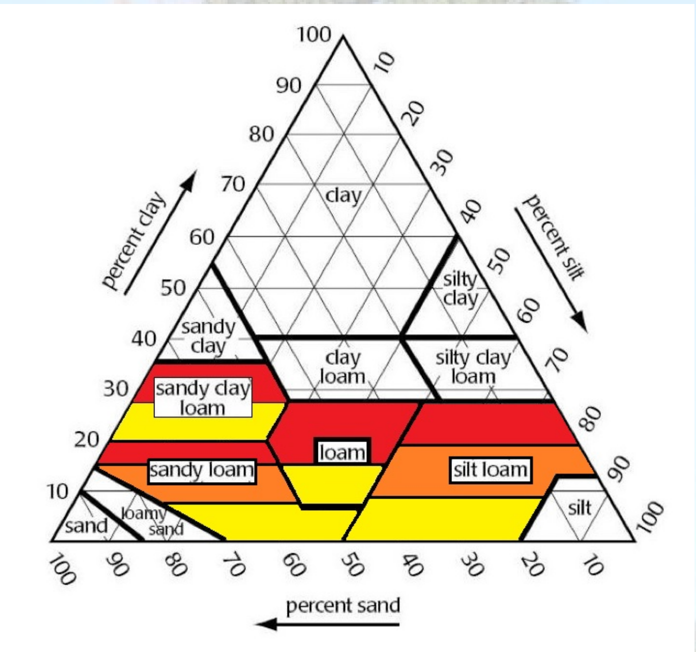
Pierzchala, M. et al. 2014

Burned Soils

Rutting

Soil Pit Descriptions

- A small pit was dug and soil profile was described at each stand.
- Each mineral horizon texture was determined then compiled into a spreadsheet in the office.
- Additionally, clay percentage ranges were established for each texture to develop bins for clay content (low, moderate, high) based on soil textural triangle .



Soil textural triangle illustrating different clay percentages.

Texture	Bin	Clay Percentage
Sandy Loam	Low	0 – 8%
Sandy Loam	Moderate	9 – 15%
Sandy Loam	High	16 – 20%
Silt Loam	Low	0 – 9%
Silt Loam	Moderate	10 – 19%
Silt Loam	High	20 – 28%
Loam	Low	6 – 15%
Loam	High	16 – 28%
Sandy Clay Loam	Low	20 – 27%
Sandy Clay Loam	High	28 – 36%

Description of each textural class & range of clay percentages

Data Analysis

- Analysis was completed in SAS software
- Climatic variables were reduced through the use of PROC VARCLUS in SAS down to four variables used in analysis. These variables include:
  - Mean annual solar radiation
  - Winter degree days below 0°C
  - Spring Hargreaves climatic moisture deficit
  - Autumn mean maximum temperature (°C)
- Response variable analyzed was the overall disturbance, the sum of Class 1, 2, and 3 percentages of soil disturbance
  - Allows us to describe the total amount of disturbance that was found at each point within a stand.
- Data then analyzed through PROC GLM in SAS
- Inherent variability in soil factors motivated the use of a higher alpha, α = 0.10, therefore a higher p-value. This was done to assess soil or site characteristics in this study

Results

- Results will be presented in the following sections:
  - Harvest Season and Time
  - Climate
  - Soil

Harvest Season and Time Results

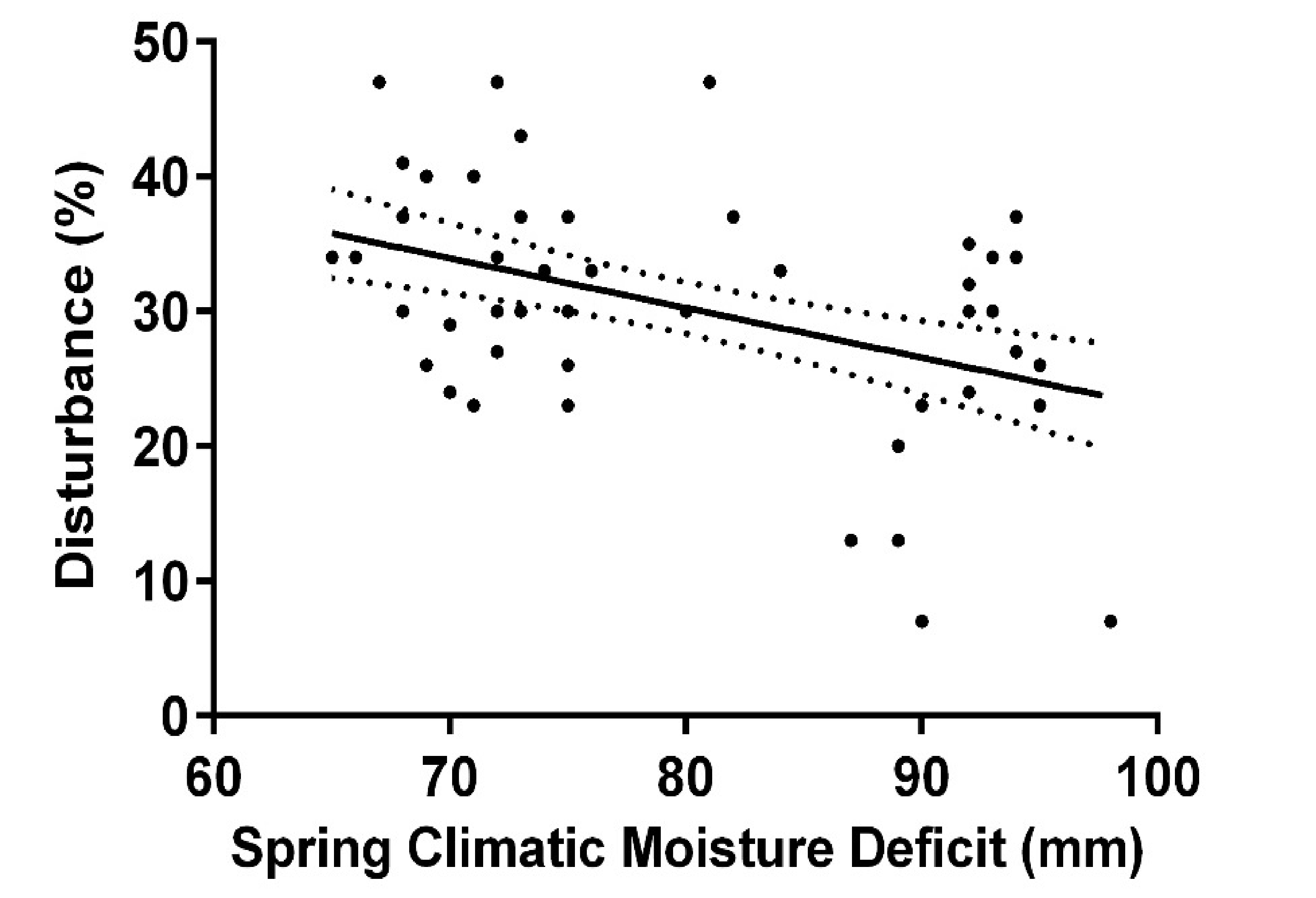
- Prior to inclusion of soil characteristics in the stepwise regression model:
  - Harvest operations conducted during spring, summer, or fall resulted in higher disturbance than winter harvest harvests
- Once soil characteristics were included in the statistical model:
  - Weak relationship of harvest season was no longer significant (p-value > 0.1)
- Trend towards recovery after 10 years post-harvest

Image Source: Malheur National Forest Slide Records from 1979 of Crawford Creek and Crawford Meadows.

Climate Results

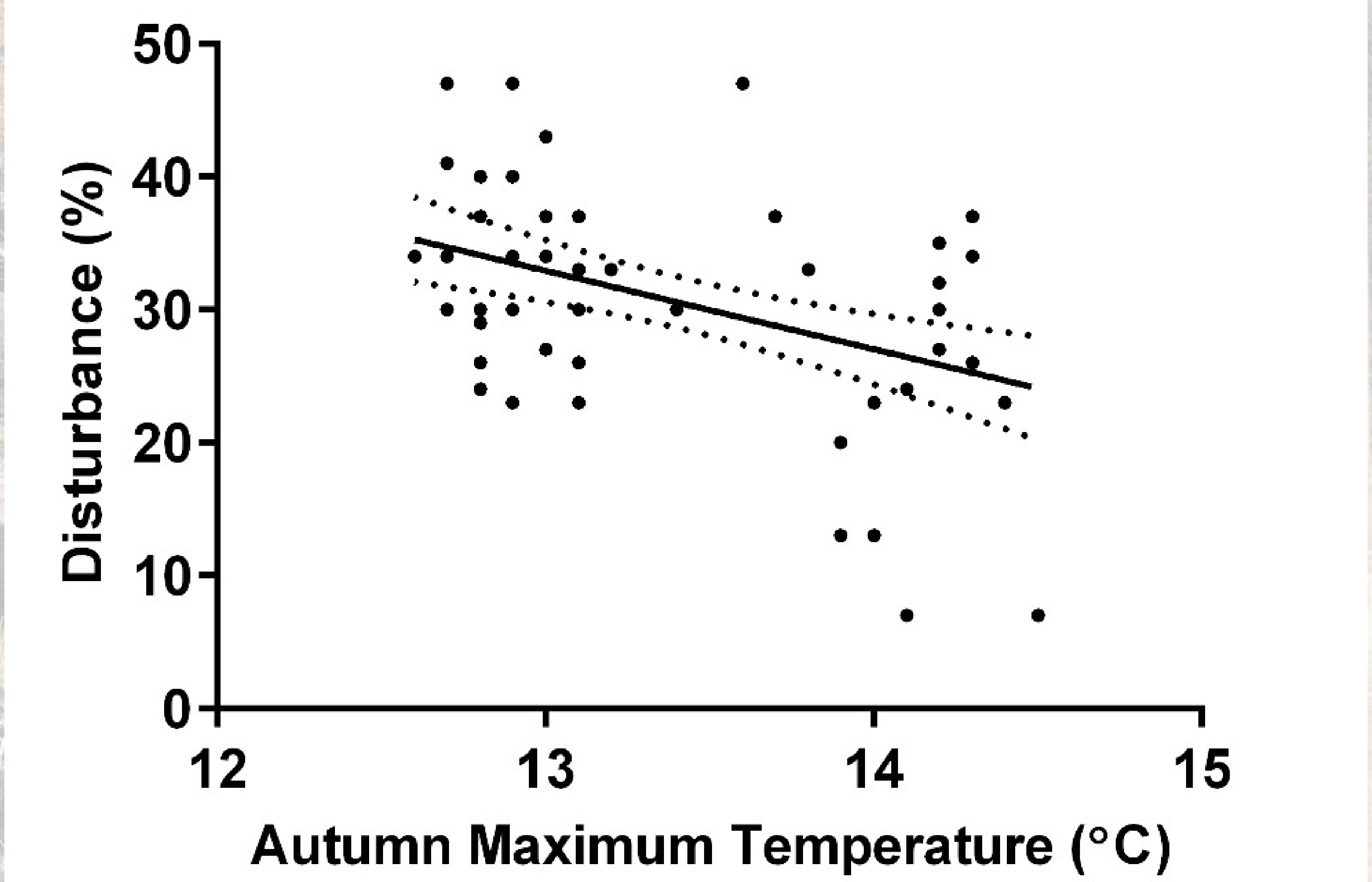
- Prior to inclusion of soil characteristics in the statistical model, two climatic variables were significant:
  - Spring Hargreaves climatic moisture deficit (CMD)
  - Autumn maximum air temperature in °C (Tmax_at)
- These relationships were no longer significant once soil properties were included in the statistical model

Spring Hargreaves Climatic Moisture Deficit



Solid line on graph is simple linear regression fit to the data.
Dotted lines are the 90% confidence intervals.

Autumn Maximum Air Temperature



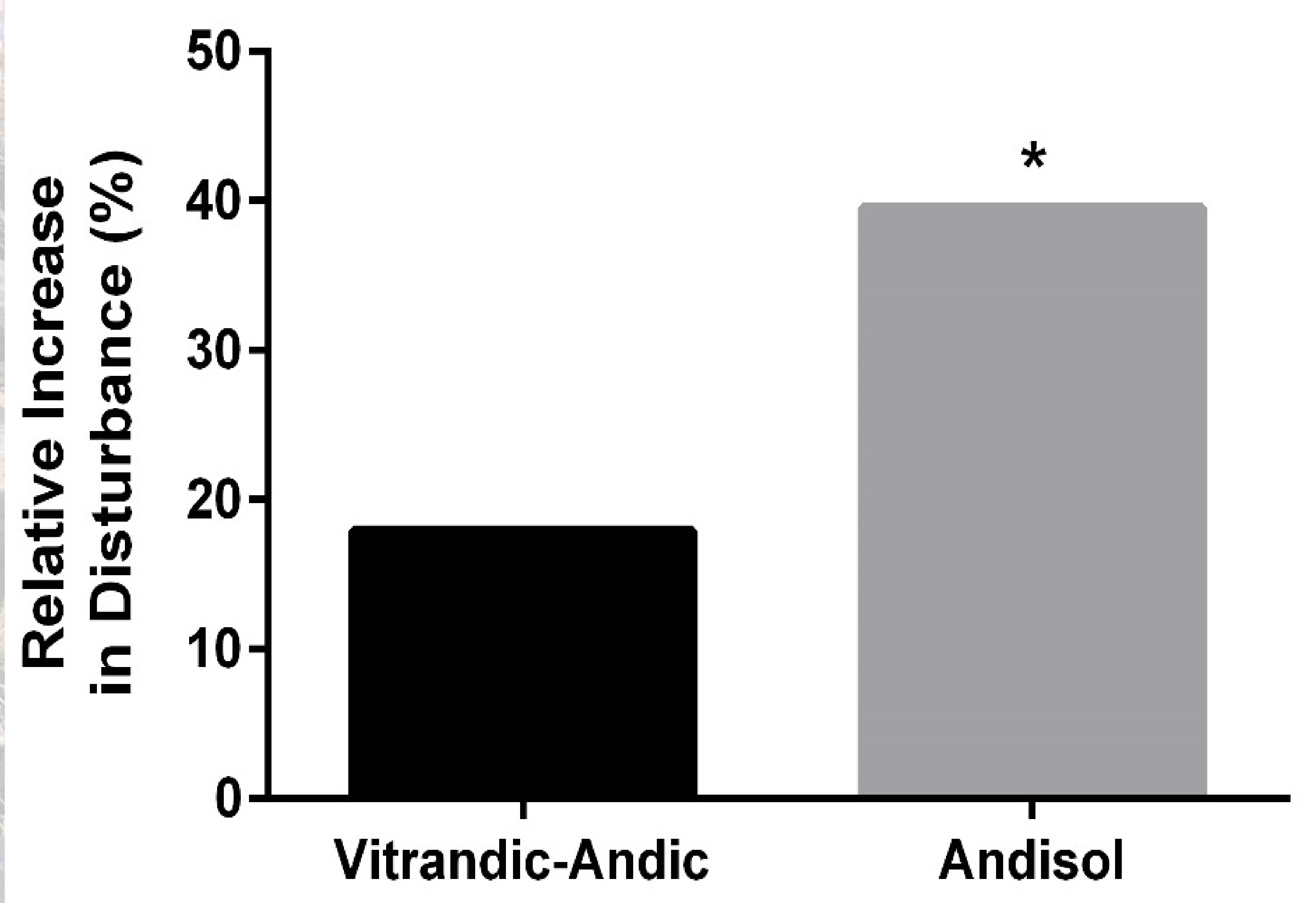
Solid line on graph is simple linear regression fit to the data.
Dotted lines are the 90% confidence intervals.

Soil Results

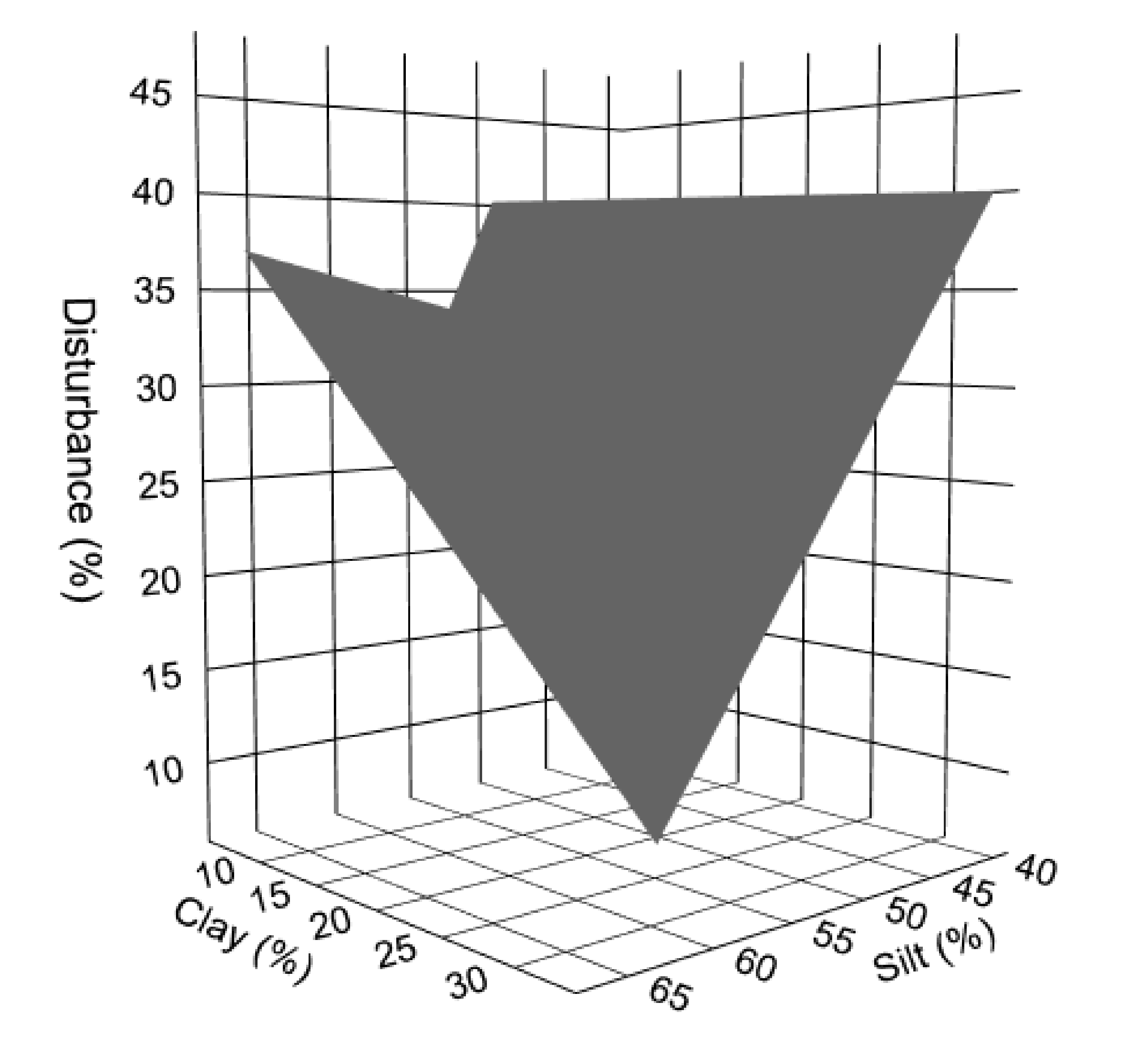
- Main effects and interactions that significantly affected soil disturbance in the model (p-value < 0.10) were:

Variable	p-value
Clay content (%)	0.0309
Silt content (%)	0.0213
Ash classification	0.0542
Clay content (%) *X* Silt content (%)	0.0317
Depth to restrictive layer *X* Coarse Fragments (%)	0.0370
Silt content (%) *X* Depth to restrictive layer	0.0444

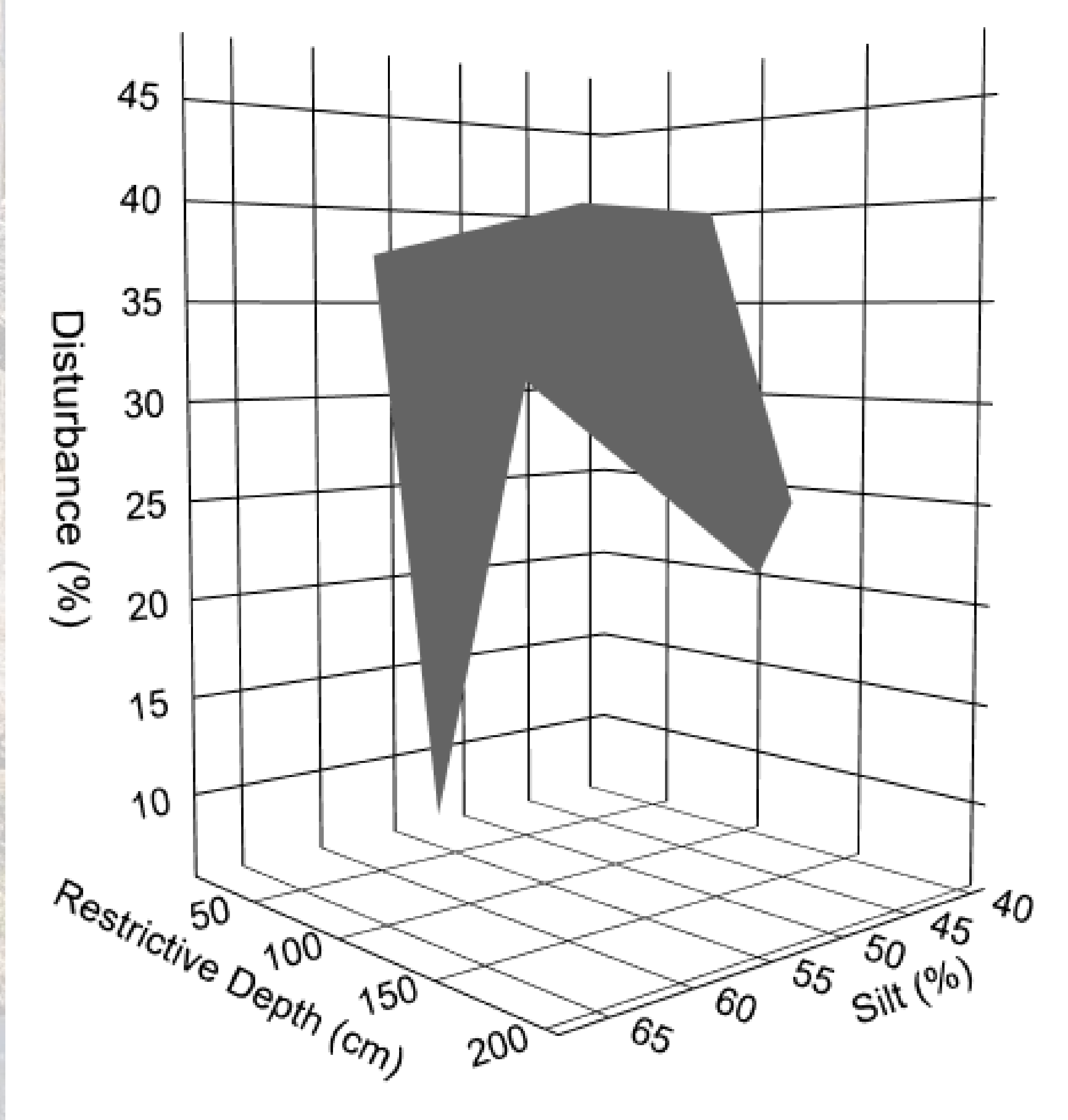
Volcanic Ash



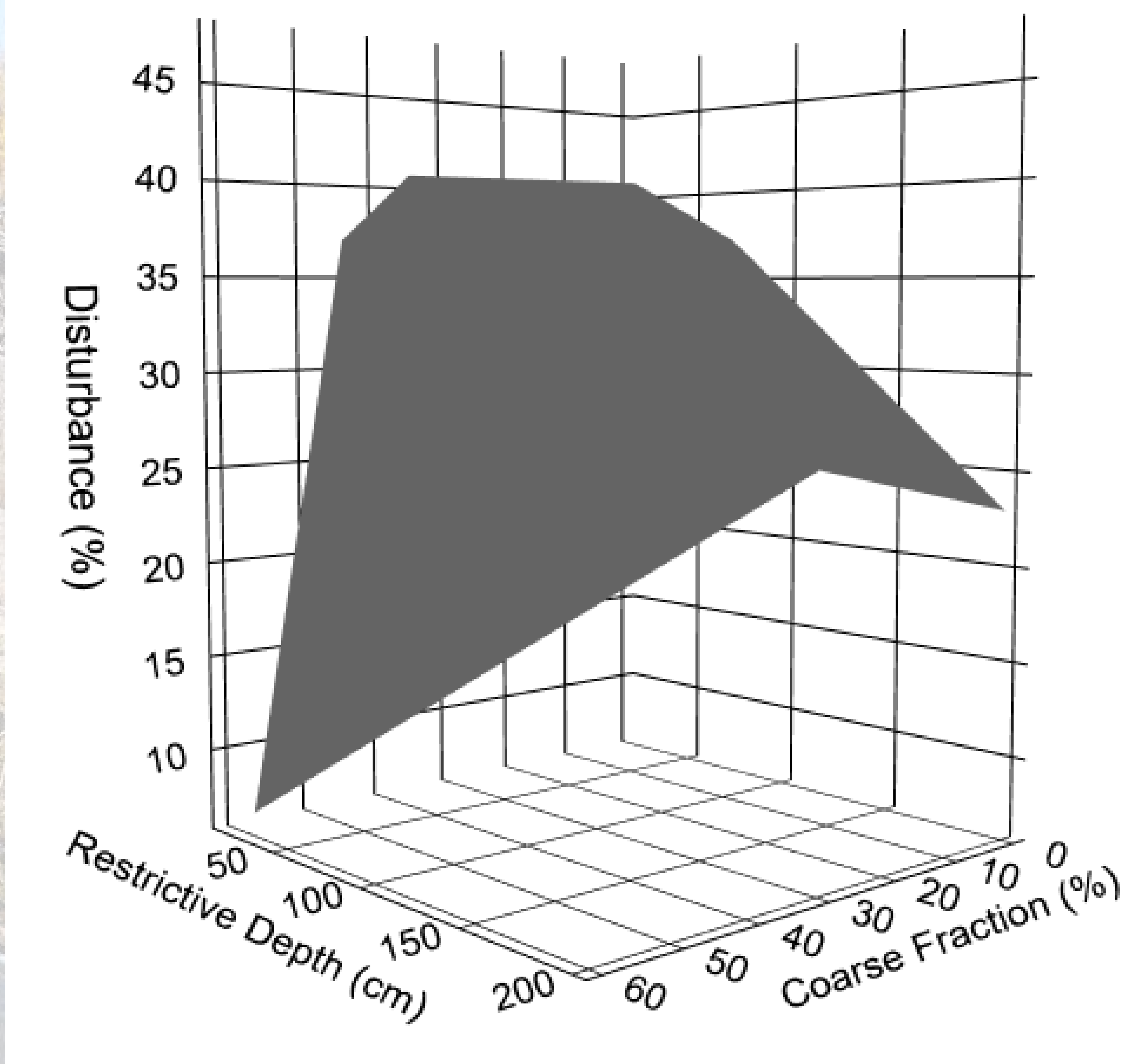
Soil Texture



Silt Content and Depth to Restrictive Layer Interaction



Coarse Fragment Content and Depth to Restrictive Layer Interaction



Discussion

- Soils are essential component for sustaining the function and productivity of forests.
- Forest management activities that:
  - Reduce organic matter levels
  - Compact mineral soil
  - Cause puddling, rutting, or erosion
- Can decrease site productivity and disrupt hydrologic function.
- Benefits of using visual soil disturbance monitoring.

Compaction Impacts on Plant Growth

- Limiting plant growth by inhibiting roots from penetrating the soil
- Large pore spaces are needed for roots to penetrate deeper into the soil profile.
  - Compacted soil - pore spaces can be too small or too rigid to allow roots from growing through these locations (Page-Dumroese et al. 2006).
- Growth-limiting soil bulk density
  - Limitations to root growth
  - Influence of soil texture (Aubertin and Kardos 1965; Daddow and Warring 1983;Wiersum 1957)

Season of Harvest Operations

- Spring Harvests:
  - Can cause substantial soil impacts because soils often have a high soil moisture content
  - Lower disturbance when harvests conducted in a relatively dry spring likely due to warm, dry springs during these harvest seasons
  - As soil moisture deficit increases during the spring then the amount of soil disturbance decreases
- Fall harvests
  - Harvest operations conducted during hot, dry fall there was an increase in soil disturbance
  - Lack of existing vegetation to be used as a mat as a buffer
- Winter Harvests
  - Trended towards lower amount of soil disturbance on both the Malheur (this study) and on the Kootenai National Forest (Reeves et al. 2012)
  - Frozen soils or snowpack

Rock Content

- Important factor governing a soils ability to resist compaction.
- Type and size of rocks (gravel, cobbles, etc.) are important factors.
- On some soil types high levels of coarse rock fragments may contribute to less soil disturbance (Williamson and Neilsen 2000).
- Coarse-textured gravely soils resisted compaction (Corns 1988).
- Soils with high gravel content, >15-20% by volume, acts as supporting frame.
  - Protects fine earth fraction from compaction
  - Increase precompression stress
- Soils with very high gravel content lack enough fine earth fraction in spaces between gravel that can become heavily compacted (Rücknagel et al. 2013).

Picture taken in harvest stand that was commercially thinned previously in 1982 showing the rock content on the surface.

Rock Fragments

- Rock fragments below soil surface support soils existing structure.
- Rock fragments have a negative effect on the soil's susceptibility to compaction (Poesen and Lavee 1994).
- Saini and Grant (1980) found that rock fragments decreased compaction of fine earth fraction in a loamy textured soil.
- Smallest rock fragments found to be most effective at reducing potential for compaction (Poesen and Lavee 1994; Saini and Grant 1980)

Picture taken in harvest stand that was commercially thinned previously in 2011 showing rock fragments in the soil.

Soil Recovery

- Chronosequence of 40 years since last timber harvests were accomplished
- Did not see significant recovery after 10 years
- Evidence that recovery begins at approximately year 10, post-harvest
- Variability in data and presence of volcanic ash across most soils may be the primary reasons we did not see substantial recovery

Volcanic Ash

- Similarly, John Gier and others (2018) found that volcanic ash-cap soils did not show signs of recovery
- Data from this study is not similar to that from the Kootenai National Forest in Montana where soil recovery occurred in the first 3-5 years (Gier et al. 2018)
- Ash-cap soils often experience a greater degree of compaction as compared to other mineral soils (Froehlich et al. 1985)
- Lack of recovery on volcanic ash soils poses a risk to:
    - Future stand productivity
    - Water movement and storage
    - Understory production
    - Other ecosystem services (Daddow and Warrington 1983; Purser and Cundy 1992; Smeltzer et al. 1986)

Lasting Impacts

- Soil recovery was not constant throughout all stands monitored.
- Trend towards recovery after 10 years post-harvest, but it is not statistically significant.
- Volcanic ash-cap soils may not recover as readily from compaction than non-volcanic ash soils.
- Volcanic ash type soils are very sensitive to disturbance.

Management Implications

- Recovery from soil disturbance is not a constant or consistent trend for all soil types sampled.
- Volcanic ash-cap soils may have a recovery period that may last numerous decades.
  - With the potential to cause decreased stand productivity or altered hydrologic function.
- Harvest Season
  - As noted by other authors (e.g., Flatten 2002; Johnson et al. 2007; Reeves et al. 2011; Williamson and Neilsen 2000) winter logging can limit amount of soil disturbance.
  - Dry spring weather can be utilized for early season harvest operations.
- Deep soils with high silt, low clay, and low coarse fragment content resulted in greater soil disturbance.
  - Limiting this soil type to winter harvest operations may reduce soil disturbance.
  - Take advantage of frozen soil or a snowpack, if available.

Management Implications – Monitoring

- FSDMP is an important tool for rapid assessment of pre- and post-timber harvest soil disturbance.
- Utilizes visual soil attributes and physical soil properties to quantify a level of disturbance.
- Crucial steps:
  - Collecting soil monitoring data
  - Documenting disturbance
  - Utilizing data
- Employing a consistent soil monitoring protocol

Future Work

- Determining cause and effect relationship of growth-limiting soil impacts is difficult (Curran et al. 2007).
  - Variations in climate and site properties.
- Soil disturbance is identifiable with visual categories and is manageable.
- Monitoring pre- and post-harvest and over time helps determine long-term effects to promote adaptive management (Curran et al. 2005).

Conclusion

- Understanding range of soil impacts is first step in determining soil changes.
- Next step will be to use vegetation growth to validate the soil disturbance categories on the Malheur (Page-Dumroese et al. 2012).
- Will help in determining:
  1. Which FSDMP categories appropriate to determine when disturbance may be detrimental to soil processes, stand productivity, and hydrologic function
  2. Best management practices that promote limited disturbance

References

- Aubertin, G.M., and L.T. Kardos. 1965. Root growth through porous media under controlled conditions II. Effect of aeration levels and rigidity. Soil Sci. Soc. of Am. Proc. 29:363-365.
- Aust, W.M., J.A. Burger, E.A. Carter, D.P. Preston, and S.C. Patterson. 1998. Visually determined soil disturbance classes used as indices of forest harvesting disturbance. S. J. of App. For. 22:245-250.
- Beaudette, D.E., and A.T. O'Green. 2009. Soil-Web: An online soil survey for California, Arizona, and Nevada. Comp. & Geosci. 35:2119-2128.
- Cambi, M., G. Certini, F. Neri, and E. Marchi. 2015. The impact of heavy traffic on forest soils: A review. For. Ecol. Manage. 338:124-138.
- Cerise, L., D.S. Page-Dumroese, P. McDaniel, C. Mayn, and R. Heinse. 2013. Productivity and soil properties 45 years after timber harvest and mechanical site preparation in western Montana. West. J. Appl. For. 28(4):158-165.
- Corns, I.G.W. 1988. Compaction by forestry equipment and effects on coniferous seedling growth on four soils in the Alberta foothills. Can. J. For. Res. 18:75-84.
- Curran, M., D. Maynard, R. Heninger, T. Terry, S. Howes, D. Stone, T. Niemann, and R.E. Miller. 2007. Elements and rationale for a common approach to assess and report soil disturbance. The For. Chron. 83:852-866.
- Curran, M.P., R.E. Miller, S.W. Howes, D.G. Maynard, T.A. Terry, R.L. Heninger, T. Niemann, K. van Rees, R.F. Powers, and S.H. Schoenholtz. 2005. Progress towards more uniform assessment and reporting of soil disturbance for operations, research, and sustainability protocols. For. Ecol. and Manage. 220:17-30.
- Daddow, R.L., and G.E. Warrington. 1983. Growth-limiting soil bulk densities as influenced by soil texture. USDA For. Serv. WSDG Rep. WSDG-TN-00005, 17p.
- Flatten, B. 2002. Determining appropriate winter logging conditions for protection of the soil resource. Presented to SALHI-W (Sale area layout & harvesting institute – west) Ground-based systems session; 2002 June; Moscow, ID., 14 p.
- Froehlich, H.A., D.W.R. Miles, and R.W. Robbins. 1985. Soil bulk density recovery on compacted skid trails in Central Idaho. Soil Sci. Soc. Am. J. 49:1015-1017.
- Froehlich, H.A., D.W.R. Miles, and R.W. Robbins. 1986. Growth of young *Pinus ponderosa* and *Pinus contorta* on compacted soils in central Washington. For. Ecol. and Man. 15:285-294.
- Gier, J.M., K.M. Kindel, D.S. Page-Dumroese, and L.J. Kuennen. 2018. Soil disturbance recovery on the Kootenai national forest, Montana. USDA Forest Service Gen. Tech. Rep. RMRS-GTR-380, 31 p.
- Johnson, L.R., D. Page-Dumroese, and H.S. Han. 2007. Effects of machine traffic on the physical properties of ash-cap soils. USDA Forest Service Proc. RMRS-P-44:69-82.
- Malheur National Forest. 1990. Land and Resource Management Plan. United States Department of Agriculture, Forest Service. Pacific Northwest Region, Portland, OR. 353 p.
- Page-Dumroese, D.S. 1993. Susceptibility of volcanic ash-influenced soil in northern Idaho to mechanical compaction. Res. Note INT-409. Ogden, UT; U.S. Department of Agriculture Forest Service, Intermountain Research Station, 5 p.
- Page-Dumroese, D.S., A.M. Abbott, and T.M. Rice. 2009a. Forest soil disturbance monitoring protocol volume I: Rapid assessment. USDA Forest Service, Gen. Tech. Rep. WO-82a, 35 p.
- Page-Dumroese, D.S., A.M. Abbott, and T.M. Rice. 2009b. Forest soil disturbance monitoring protocol volume II: Supplementary methods, statistics, and data collection. USDA Forest Service, Gen. Tech. Rep. WO-82b, 70 p.
- Page-Dumroese, D.S., A.M. Abbott, M.P. Curran, and M.F. Jurgensen. 2012. Validating visual disturbance types and classes used for forest soil monitoring protocols. USDA Forest Service, Gen. Tech Rep. RMRS-GTR-267, 23 p.
- Page-Dumroese, D.S., M.F. Jurgensen, A.E. Tiarks, F. Ponder Jr., F.G. Sanchez, R.L. Fleming, J.M. Kranabetter, R.F. Powers, D.M. Stone, J.D. Elioff, and D.A. Scott. 2006. Soil physical property changes at the North American long-term soil productivity study sites: 1 and 5 years after compaction. Can. J. For. Res. 36:551-564.
- Poesen, J., and H. Lavee. 1994. Rock fragments in top soils: significance and processes. Catena 23:1-28.
- Purser, M.D., and T.W. Cundy. 1992. Changes in soil physical properties due to cable yarding and their hydrologic implications. West. J. of App. For. 7:36-39.
- Reeves, D., D. Page-Dumroese, and M. Coleman. 2011. Detrimental soil disturbance associated with timber harvest systems on national forests in the northern region. U.S. For. Serv. Res. Pap. RMRS-RP-89, 30 p.
- Reeves, D.A., M.C. Reeves, A.M. Abbott, D.S. Page-Dumroese, and M.D. Coleman. 2012. A detrimental soil disturbance prediction model for ground-based timber harvesting. Can. J. For. Res. 42:821-830.
- Robinson, S.B. 2011. Assessing visual disturbance conditions on the Custer national forest. M.S. thesis. Michigan Tech. Univ., Houghton, MI.
- Rücknagel, J., P. Götze, B. Hofmann, O. Christen, and K. Marschall. 2013. The influence of soil gravel content on compaction behaviour and pre-compression stress. Geoderma 209-210:226-232.
- Saini, G.R., and W.J. Grant. 1980. Long-term effects of intensive cultivation on soil quality in the potato-growing areas of New Brunswick (Canada) and Maine (U.S.A.). Can. J. Soil Sci. 60:421-428.
- SAS Institute Inc. 2016. SAS/STAT® 9.4 User's Guide. Cary, NC: SAS Institute Inc.
- SAS Institute Inc. 2018. SAS/STAT® 15.1 User's Guide: The GLM Procedure [Online]. Available at https://support.sas.com/documentation/onlinedoc/stat/132/glm.pdf (verified 6 Dec. 2019).
- Smeltzer, D.L.K., D.R. Bergdahl, and J.R. Donnelly. 1986. Forest ecosystems responses to artificially induced soil compaction. II. Selected soil microorganism populations. Can. J. For. Res. 16:870-872.
- Smith, C.W., M.A. Johnson, and S. Lorentz. 1997. Assessing the compaction susceptibility of South African forestry soils. I. The effect of soil type, water content and applied pressure on uni-axial compaction. Soil Till. Res. 41:53-73.
- The University of British Columbia. 2019. ClimateWNA: An interactive platform for visualization and data access [Online]. Available at http://www.climatewna.com/ClimateWNA.aspx (verified 6 Dec. 2019).
- USDA Forest Service. 2019. Terrestrial ecological unit inventory (TEUI). Geospatial Toolkit. USFS Remote Sensing Applications Center. Salt Lake City, UT.
- Wiersum, L.K. 1957. The relationship of the size and structural rigidity of pores to their penetration by roots. Pl. and Soil 9:75-85
- Williamson, J.R., and W.A. Neilsen. 2000. The influence of forest site on rate and extent of soil compaction and profile disturbance of skid trails during ground-based harvesting. Can. J. For. Res. 30:1196-1205.


Questions?