Soil Disturbance Monitoring
On the Green Mountain National Forest





Prepared by
the LAND Stewardship Program
July 2010

The Land Stewardship Program

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About the LANDS College Sustainability Corps

The field of conservation is rapidly evolving to meet our growing understanding of ecological health and sustainability. New ideas and strategies are changing how we protect and steward land. The Land Stewardship Program (LANDS) is a new approach to today's stewardship challenges. During the Great Depression, the conservation corps model was pioneered as a means to promote nationwide stewardship and provide jobs for the unemployed. That idea has since been reinvented over 116 times by local and state corps across the United States. However, the general theme is the same – young people learning *and* growing through service. LANDS is an innovative College Sustainability Corps designed to train tomorrow's conservationist practitioners and leaders, and is a pilot partnership between the University of Vermont and the Student Conservation Association in its fourth year of service.

Thanks to college level education and prior experience in environmental science fields, LANDS interns are able to take on projects that are more technical than the work traditionally done by conservation corps crews. LANDS interns draft management plans, map areas of interest using GPS and GIS, inventory resources, survey for non-native invasive species, calculate carbon stocks, survey soils for forestry impact, and even find time to build trails and perform public education and outreach. Municipalities, land trusts, state agencies, university researchers, National Forests and Parks, and volunteer-managed conservation organizations all benefit from LANDS's high quality, affordable services. LANDS interns are advanced undergraduates and recent graduates with natural resource experience from all over the world, who bring a range of skills and interests to the program. LANDS is a unique service-learning model that addresses an ever expanding list of conservation needs while training students as future sustainability leaders.

For more information, visit: http://www.uvm.edu/~conserve/lands_website/

LANDS 2010
Back Row: Sam Schaefer-Joel, Ben Bisbach, Kyle Hodgeson, Dan Hale, Reed Carr, Jessie Fefer, Lucy deWahl, Jon Bergman, Lydia Menendez
Front Row: Zac Ispa-Landa, Deanna Saltmarsh, Toral Patel

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Project Overview

The purpose of the LANDS work was to support the Green Mountain National Forest (GMNF) in monitoring soil disturbances in timber harvest units. Although there are many reasons why monitoring soil disturbances is important, the GMNF intends to use this information to generate the best management practices for maintaining site productivity and forest sustainability. LANDS interns surveyed pre-disturbance harvest units as well as previously harvested units in order to analyze soil disturbance for the GMNF. The LANDS crew also benefited from the opportunity to practice their field skills and to expand their knowledge about soils and harvesting practices.

Introduction

Managed by the U.S. Forest Service (USFS), the Green Mountain National Forest stretches across over 400,000 acres throughout southern and central Vermont. GMNF management goals include wildlife, recreation, ecosystem health and harvesting. Accordingly, ensuring soil productivity despite the impacts of logging machinery is an important responsibility. Productivity may be compromised by compaction, erosion, rutting, and loss of forest floor. Excessive disturbance – particularly rutting in skid roads, haul roads, and landing areas – may impact the recovery and regeneration of the harvest areas. Understanding the impacts of timber harvest informs sustainable management of GMNF lands.

Methods

In order to gather accurate and statistically significant data, soil plots evenly spaced intervals along random transects throughout harvest units.

Pre-Disturbance Monitoring

For pre-disturbance monitoring, samples were taken at ten points along predetermined transects to identify the soil disturbance class prior to harvesting. In order to gather this information, different pre-disturbance indicators were considered at each point. Disturbance indicators include wheel tracks or depressions, penetration and resistance, soil physical condition, forest floor presence, mineral soil status and erosion. For each disturbance indicator, there are four different disturbance classes ranging from 0-3, with 0 signifying undisturbed and 3 signifying most disturbed (Appendix C). The data collected serves as a baseline for comparison to post-harvest results.

Post-Harvest Monitoring

For post-harvest monitoring, thirty points were sampled along a predetermined transect to identify harvesting impacts on the soils. For each of these points, the presence or absence of the following indicators were recorded: floor depth, forest floor impaction, topsoil displacement, mixed topsoil and subsoil, erosion, rutting, compaction, platy/massive structure, live plant, woody material, bare soil, rocks and non-native invasive species. Based on these indicators, the soil disturbance class was gauged. If the findings within a unit were variable, more points were sampled in order to keep the data statistically significant with a confidence level of 85%.

Skid Road Inventory

Global Positioning System (GPS) was used to measure the area of landings, haul roads, and skid roads with a soil disturbance class of 2 or 3, determining how much of the harvest unit was impacted by these disturbances. Because most of the heavily impacted areas are skid roads, haul roads or landings due to the heavy machinery used, this data helps determine area of overall impacts.

Skid roads exhibit the highest levels of forest floor impaction.

Results

Pre-Disturbance Monitoring

The Dorset-Peru area and parts of the Snow Valley area were monitored in their pre-harvested state. This was done in order to provide a baseline data-set and to ensure that past logging operations, dating back 15 to 30 years ago, do not have residual detrimental effects to soils. Seven types of disturbances served as criteria – including compaction, rutting, erosion – with a range of four severity classes, from zero to three. Ten data points were taken at even intervals along random transects in each unit. Each unit's history was classified as having no previous entry, faint signs of entry, or obvious signs of entry.

In the Dorset Peru area, three of the five surveyed units showed faint signs of entry, roughly estimated to have taken place 20 or more years ago. Only 1.4% of data-points showed slight compaction of surface soils. No occurrences of severity class two or three were observed, and 97% of survey responses fell under severity class zero.

In the Snow Valley area, only one of the three surveyed units showed faint signs of previous logging, 20 or more years ago. Of all 250 data-points in the three units, only three points was found to have wheel tracks or depressions greater than two inches deep.

In both areas, soil productivity was unaffected. Disturbances were both rare and minimal when present. Figure 1 summarizes the pre-disturbance data collected, illustrating how both areas were significantly undisturbed.

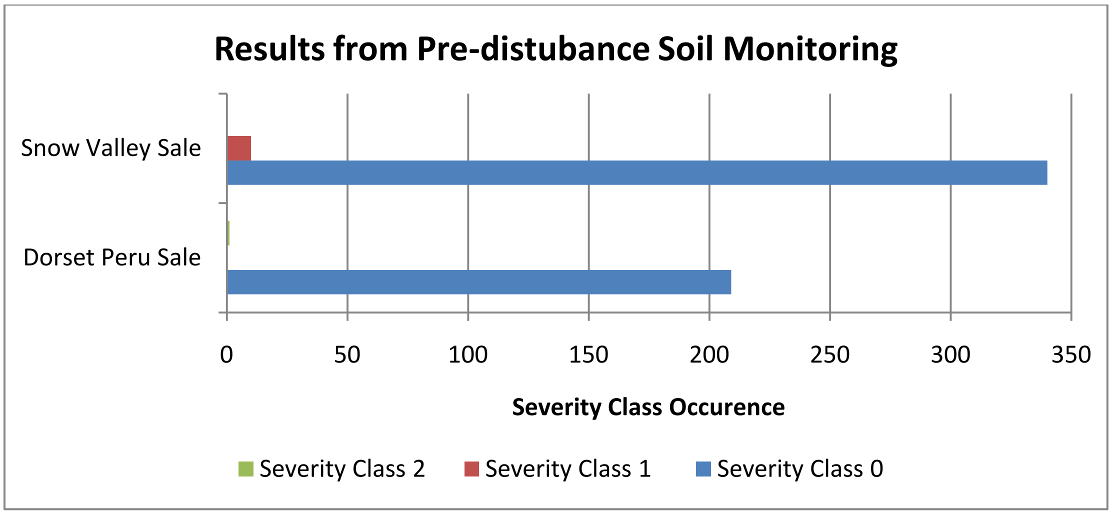

Figure 1: Summary of Dorset-Peru and Snow Vally pre-disturbance soil monitoring severity class 0, 1, and 2 occurances.

Discussion

Soil Disturbance

The Green Mountain National Forest aims to sustain forest ecosystem health for multiple uses. Soil productivity must therefore be maintained, alongside timber harvest and recreation, to the highest extent possible. Timber harvests cause soil disturbance, and monitoring helps determine whether the impacts are acceptable or detrimental to forest regeneration.

Human activity, and logging in particular, has the potential to disrupt both soil structure and horizons (Appendix B). This occurs through processes of compaction, erosion, and rutting. Compaction of forest soils occurs when heavy logging machinery compresses soil, eliminating the pore spaces between the soil particles. The result is a hardened layer through which water, roots, and air cannot penetrate. Light compaction often reverses after a few years; however, more severe compaction can persist for decades, inhibiting regeneration and leading to erosion. Erosion is the removal of soil from an area by physical forces such as water, wind, ice, or gravity. Though some erosion is natural, it is accelerated when compaction prevents precipitation from infiltrating the surface and when the water-absorbing organic layer has been destroyed. Rutting of the forest floor is caused when heavy machinery travels over an area repeatedly, such as on skid roads, and contributes to both compaction and erosion. In a rut, the upper soil layers are often mixed, resulting in bare soil, which may be underlain by a heavily compacted layer. The combination results in rapid erosion and slow forest regeneration.

When soil structure is compromised, soil productivity can suffer. Bare soil, puddling, erosion, compaction, and/or rutting are the main factors in determining whether or not soil conditions are detrimental to forest regeneration. The combination of these factors determines the soil disturbance class (SDC). SDC ranges from zero, for mostly undisturbed soil, to three, for highly disturbed soil. (See Appendix D for classification criteria.)

Slash piles often inhibit forest regeneration.

All points at which the SDC was zero are not detrimental to soil productivity. Points with an SDC of two or three are always detrimental, and points with and SDC of one are considered detrimental if plant growth or establishment is obviously slowed or impaired. Additionally, points with large slash piles and thick woodchip cover are considered to be detrimental, since such soils do not have exposure to light, air, and water.

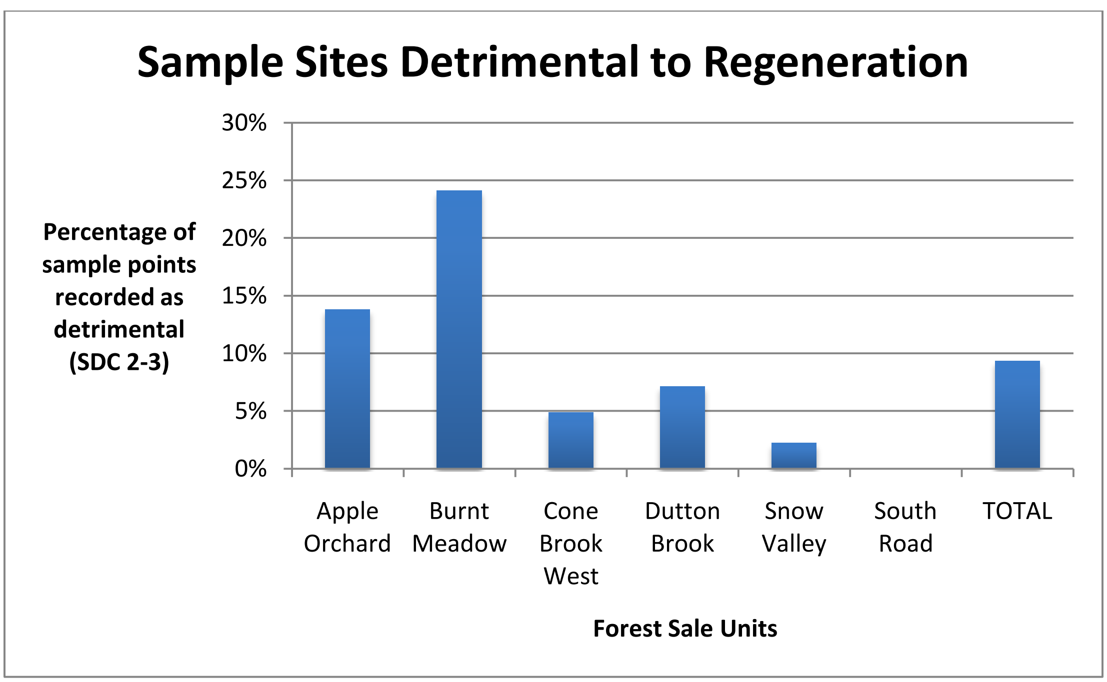

Figure 2: Overview of logging machinery impact on GMNF sales surveyed showing the percent of sample sites identified as detrimental to regeneration.

There is a notable difference in soil condition from one sale to another (Figure 2). South Road, for example, had no instances of disturbance that could be considered detrimental to regeneration, but 24% of sample points in Burnt Meadow sale were classified as detrimental. At Burnt Meadow, rutting was the primary soil disturbance. Much of the area was covered in roads with bare soil, ruts, erosion, and puddling. In the area between skid roads it was common to find the soil covered in thick piles of branches and wood chips. Apple Orchard sale, a clear cut area, also had a significant amount of slash on the soil surface. Other sales showed much less soil disturbance, with fewer skid roads and fewer ruts.

All units were harvested during winter '09-'10 except for Dutton Brook Units 7 and 9, which were harvested during winter '08-'09 and summer '09, respectively. Differences in soil disturbance could be due in part to weather conditions at the time of harvest. Snow cover may protect the underlying soil in areas harvested in the winter, while a thaw can leave soil bare and more vulnerable to rutting and mixing.

Soil Hydrology

Soil has a close and codependent relationship with forest ecosystems through its hydrologic functions. Forest soils provide great benefits by slowing surface water, reducing runoff and erosion, promoting infiltration and nutrient capture, and reducing evaporation (due to the lower temperatures offered by the forest canopy). The presence of woody material and other organic matter on the forest floor acts as a buffer, protecting the soil from displacement and compaction associated with harvest machinery activity. Disturbance of natural soil conditions can have considerable effects on the hydrologic functions and the health of the forest ecosystem.

Logging Impacts

Compaction disrupts water movement by reducing the permeability of the soil surface, reducing both water and nutrient capture as well as increasing moving surface water and erosion. Compaction of deeper soil horizons reduces percolation, or movement of water through the soil. The creation of an impermeable underground layer, or hardpan, results in water-logging and puddling, disrupting the structure, stability, and productivity of the soil and slowing the recharge of aquifers in the area.

Puddling as a result of rutting can be an indicator of compaction.

Disturbance or removal of the forest floor can lead to bare soil and may slow the capture of water. The forest floor acts as a sponge, slowing and absorbing rain and surface water; it also acts as a barrier against evaporation, keeping moisture in the soil. Bare soil is more susceptible to compaction, water loss, and mixing of soil horizons, all of which reduce the natural functions of soil structure, particularly infiltration and percolation.

The erosive forces of wind, gravity, ice or water have an increased impact on bare soil. Prolonged erosion can lead to the redirection of water flow, affecting soil structure and function, local watershed attributes, and even aquifer recharge. Rutting has a similar effect on soil hydrology. In addition to the detrimental effects of compaction described above, ruts can redirect or slow water flow both above and below the soil surface. The presence of woody debris either fine or coarse (defined as < 7cm and > 7cm, respectively) has a profound effect on the erodibility of the forest floor, bare soil or not. The layer of woody debris slows surface water and protects the ground from falling water, aids in water retention, and helps to more evenly distribute the weight of harvest machinery.

The incidence of woody debris, though observed in nearly all harvest sites, is not included in the data below because the data did not differentiate between natural woody debris and that resulting from logging. Its presence did not correlate to the level of impact in the sale.

Data Analysis

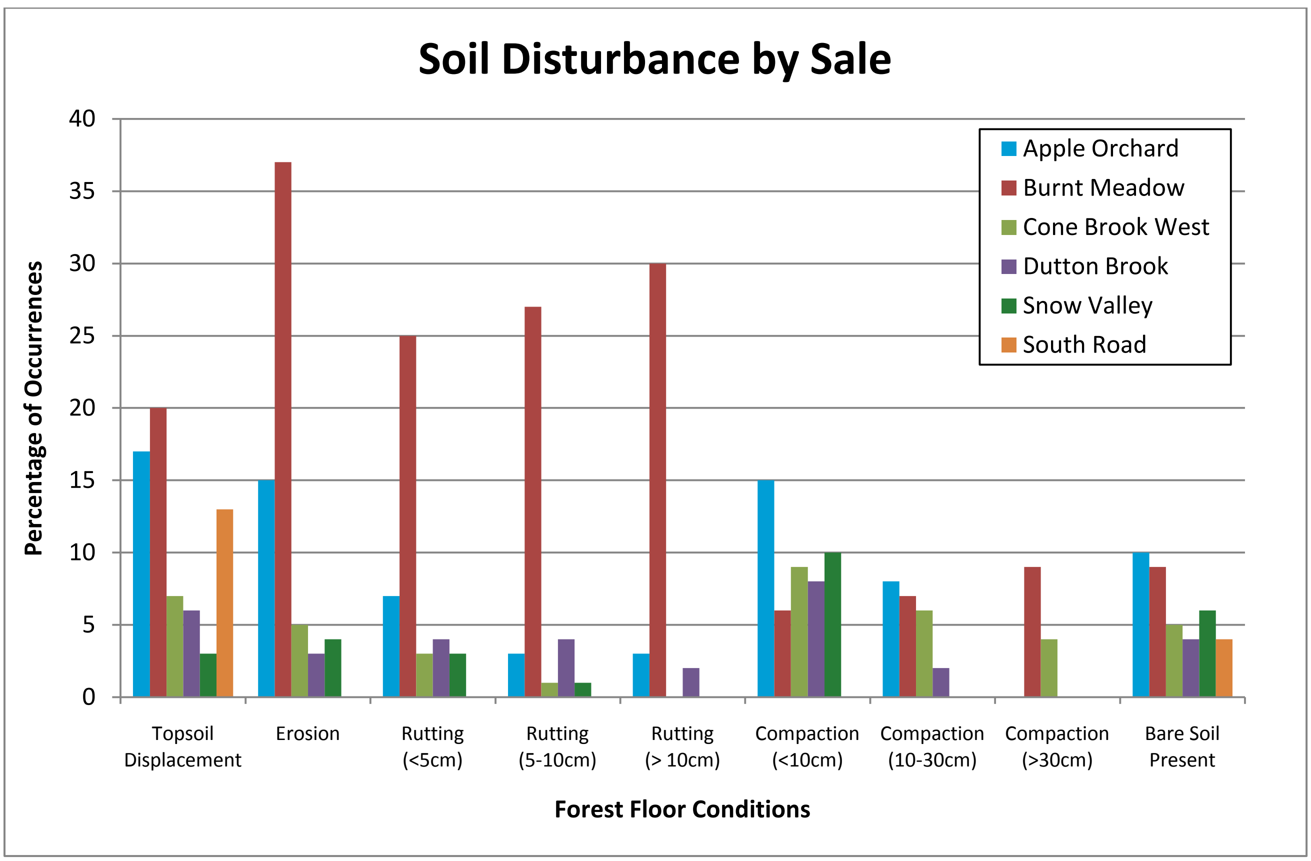

Figure 3: Overview of logging machinery impact on GMNF sales surveyed showing the percent of sample sites identified as detrimental to regeneration.

The Burnt Meadow sale was the most impacted harvest area followed by the Apple Orchard sale (Figure 3). Though Burnt Meadow did not exhibit greater than average compaction, the level of erosion and topsoil displacement were considerably greater than in other sales, as was rutting. Visible puddling was strong evidence of logging impact, and there was concern that the puddling may have skewed the compaction data collected in some areas (Appendix E: C, 4).

The Snow Valley, Cone Brook West, and Dutton Brook Sales did not stand out in the data as being particularly disturbed, however, compaction may be cause for concern in the Snow Valley and Cone Brook West sales. Topsoil displacement in the South Road Sale was unusually high considering the low occurrence of other disturbance criteria.

Skid Road Inventory

The skid road and landing inventory was implemented in two sales totaling five units. In total, 0.4 acres of landings and 4.34 acres of skid roads were inventoried. No concrete assessment of disturbance levels could be made based on the skid road and landing inventory data. Instead, data collected during soil disturbance monitoring was used to determine the presence and assess the conditions of skid roads, haul roads, and landings; where there was disturbance, it was assumed that the point fell on a skid road.

Disturbed soil was defined as any location in disturbance class 1, 2, or 3 (Appendix D). Forest soil disturbance monitoring transect data indicated that 24% of points in all sale areas combined were disturbed (Figure 4). Locations with soils in disturbance classes 2 and 3 are of greatest concern in regards to long term soil and forest recovery. The Apple Orchard and Burnt Meadow sales had the most disturbance class 2 or 3 occurrences (17% combined), while the Cone Brook West, Dutton Brook, Snow Valley, and South Road sales combined had only 2% occurrence of disturbance class 2 or 3. Percentages of points showing disturbance versus no disturbance appear in Appendix A in the Master Summary Report Table. The data indicates that only 7% of points sampled in all sale areas combined were in soil disturbance class 2 or 3.

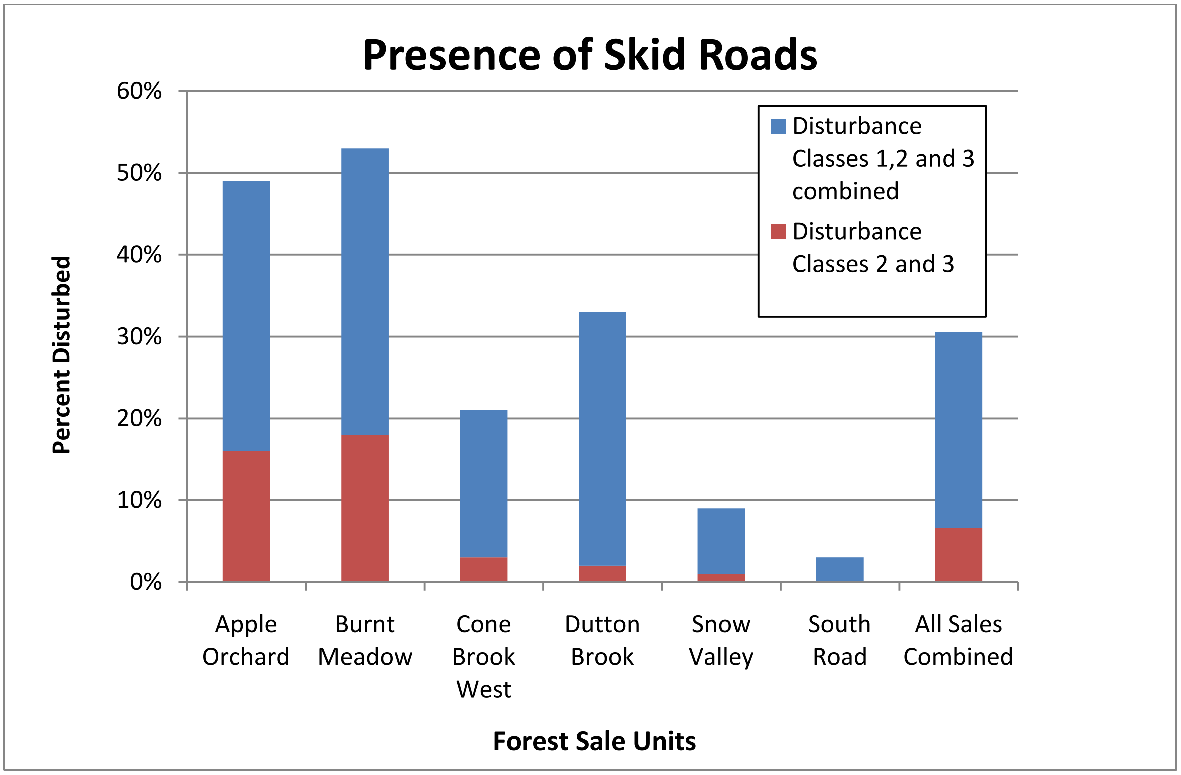

Figure 4: Presence of skid roads in sales and all sale areas combined as determined by the occurance of sample sites in disturbance classes 1-3. Disturbance class 2-3 occurances are of greatest concern.

Conclusions

The pre-disturbance monitoring data set provides a baseline that will act as a reference for post-harvest monitoring. After completing the survey, it was confirmed that ten data points is an adequate sample size to assess an undisturbed site, as opposed to the 30 points taken in logged sites. There was not enough variability in the pre-disturbance monitoring data to require more points.

Additionally, there are two factors that likely affect soil conditions that were not included in this study: logging method(s) and weather conditions at the time of logging. While more disruptive logging methods have more of an immediate impact, the harvesting method did not necessarily correlate with the observed soil disturbance levels in this study. More detailed information about logging methods would enhance future research.

All sites except for one were logged in the winter because frozen ground and snow cover allow access for heavy logging equipment with limited damage to the soil. Variable freezing and thawing cycles, especially in the winter of 2009/2010, could have made the difference between dramatic rutting and minimal impacts. Understanding the correlation between weather conditions at the time of logging, especially temperature and snow/ice depth, is imperative for making proper management decisions.

Burnt Meadow was by far the most impacted timber sale, with 35% of the data points that were impacted by logging and 24% of the data points that were considered detrimental to soil productivity and forest regeneration. While the Apple Orchard site was a clear-cut site, and 40% of the data points were impacted, only 14% were found to be detrimental. There were fewer skid roads at Apple Orchard than at Burnt Meadow as well. The South Road site was the least impacted, with absolutely no detrimental data points recorded.

The original skid road walking protocol was found to return unclear data and was ultimately ineffective. Instead, the percentage of disturbance class 2 or 3 occurrences was used to estimate skid road prevalence in a given sale. Overall, 7% of data points fell on skid roads. Future monitoring of forest recovery in the six sales surveyed is likely to help provide a greater context for these results.

In conclusion, the LANDS crew surveyed pre- and post-harvest sale areas for soil disturbance and found that overall soil productivity is high. Measuring soil health ensures the long-term stewardship of GMNF ecosystems.

Appendix A: Master Summary Report Table

This report table summarizes the soil characteristics data collected during the project and provides weighted totals for all surveyed areas combined.

Surveyed Soil Characteristics	Apple Orchard	Burnt Meadow	Cone Brook West	Dutton Brook	Snow Valley	South Road	Total Weighted Average
Detrimental	14%	24%	5%	7%	2%	0%	9%
Forest floor Impacted	40%	35%	19%	22%	7%	19%	23%
Topsoil displacement	17%	20%	7%	6%	3%	13%	8%
Erosion	15%	37%	5%	3%	4%	0%	7%
Estimated Soil Disturbance Class							
Proportion 0's	69%	45%	84%	68%	92%	97%	72%
Proportion 1's	17%	17%	15%	29%	7%	3%	17%
Proportion 2's	14%	11%	3%	0%	1%	0%	5%
Proportion 3's	2%	7%	0%	2%	0%	0%	2%
Rutting							
Under 5 cm	7%	25%	3%	4%	3%	0%	3%
Between 5-10 cm	3%	27%	1%	4%	1%	0%	6%
Over 10 cm	3%	30%	0%	2%	0%	0%	4%
No Rutting	87%	17%	96%	90%	96%	100%	87%
Compaction							
Under 10 cm	15%	6%	9%	8%	10%	0%	8%
Between 10-30 cm	8%	7%	6%	2%	0%	0%	3%
Over 30 cm	0%	9%	4%	0%	0%	0%	2%
No Compaction	77%	78%	81%	90%	90%	100%	87%
Platy/Massive/Puddled Structure							
Under 10 cm	8%	5%	1%	4%	1%	6%	2%
Between 10-30 cm	5%	3%	0%	1%	0%	0%	1%
Over 30 cm	0%	2%	0%	1%	0%	0%	0%
No Platy/Massive/ Puddled Structure	87%	90%	99%	94%	99%	94%	97%
Other							
Live Plant	38%	0%	60%	69%	53%	60%	46%
Invasive Plant	0%	58%	0%	0%	0%	0%	13%
Fine Woody <7 cm	83%	96%	82%	70%	84%	88%	62%
Coarse Woody >7cm	15%	22%	9%	15%	12%	16%	31%
Bare Soil	10%	9%	5%	4%	6%	4%	9%
Rock	0%	7%	4%	5%	1%	4%	4%
Forestry Treatment	Clear-cut	CTM, Clear-cut	CTM, Clear-cut	Thinning, Shelter wood	CTM	CTM, Shelterwood	
Acreage	12	62	242	108	93	9	
Number of Sample Points	60	158	164	182	90	67	

Appendix B: Soil Structure

Healthy soil is composed of structural units called peds. Ped formation and characteristics are the result of various factors acting over years, decades, and centuries. These include the parent material from which the soil was formed, vegetation cover, climate, and precipitation. Though there exists a wide natural variation in soil structure across different types of soils, a productive soil contains pores between its peds which allow for aeration, root growth, and water infiltration. In addition, soil is made up of different layers, or horizons, each of which has different characteristics and is formed by different processes.

The horizon at the surface is called the O horizon. This layer is made up of leaves, woody debris, and other organic matter in varying states of decay. It is rich in nutrients and serves as a sponge, absorbing precipitation and limiting runoff and erosion. It also serves as a substrate for fungi and habitat for invertebrates and microorganisms. Its depth ranges from less than 1 cm in areas with high decomposition rates, to several meters in areas where decomposition cannot take place.

Below the O horizon is the A horizon, commonly referred to as topsoil. This horizon includes the sand, silt, and clay of the parent material from which the soil formed, as well as highly decomposed organic matter from the O horizon. It is in this horizon that soil structure appears, and the quality of this horizon is a key factor in the overall productivity of the soil. The A horizon is underlain by the B horizon. This horizon is very low in organic matter and is dominated by the sand, silt, and clay, and bedrock from which the soil formed. It is also referred to as subsoil.

Appendix C: Pre-Disturbance Monitoring Form

Soil Disturbance Severity Class

Project ID			Name of Observer:	
Unit ID				
GPS Location			Date:	
Unit History	No Previous Entry	Faint Signs of Entry	Obvious Signs of Entry	Transect Points (track each pt) 1 2 3 4 5 6 7 8 9 10
		Severity Class		
Disturbance Type	**0**	**1**	**2**	**3**
Wheel tracks or depressions	Natural conditions.	Faint or slight (<2 in deep).	Tracks >2 in.	Obvious tracks > 4 in.
Penetration and resistance	Natural conditions.	Slight resistance of surface soil.	Increased resistance throughout the top 12 in.	Packed (major skid trail or landing).
Soil Physical Condition	Natural conditions.	Change in soil structure from crumb or granular to platy in the surface.	Change in soil structure to greater depth up to 12 in.	Change in soil structure > 30 cm.
Forest floor	Natural conditions.	Present and intact.	Partially missing or patchy.	Bare soil.
Mineral soil	Natural conditions.	Soil surface has no cover.	Mineral topsoil shows some mixing with subsoil (different soil colors present).	Obvious topsoil removal, gouging, piling. Subsurface soil exposed.
Erosion	Natural conditions.	Slight evidence (sheet erosion)of soil movement but some litter present.	Rills present.	Gullies evident.
Burning	Natural conditions.	Lightly charred residues.	Litter consumed but soil is not visibly changed.	All woody material consumed and soil visbly altered - white ash present - soil may appear orange and powdery.
Number of Occurrences				

Directions: Complete form by circling the best answer 0, 1, 2, or 3 at each point along a 10 point transect. Make a mark in each box as you collect the 10 points and then tally the results at the bottom to determine the number of class 0, 1, 2, and 3 for the sample area.

Appendix D: Soil Disturbance Class Table

Soil disturbance classes used in the Forest Service Disturbance Monitoring Protocol. Soil disturbance classes increase in severity of impact from class 0 to class 3.

<table>
<tr><th>Soil disturbance class 0</th><th>Soil disturbance class 1</th></tr>
<tr><td>Soil surface:

• No evidence of compaction; i.e., past equipment operation, ruts, skid trails.
• No depressions or wheel tracks evident.
• Forest floor layers present and intact
• No soil displacement evident
• No management-generated soil erosion
• Litter and duff layers not burned. No soil char. Water repellency may be present.</td><td>Soil surface:

• Faint wheel tracks or slight depressions evident and are <5cm deep.
• Forest floor layers present and intact.
• Surface soil has not been displaced and shows minimal mixing with subsoil.
• Burning light: Depth of char <1cm. Accessory*: Litter charred or consumed. Duff largely intact. Water repellency is similar to preborn conditions.

Soil Compaction:

• Compaction in the surface soil is slightly greater than observed under natural conditions.
• Concentrated from 0 to 10 cm deep.

Observations of soil physical conditions:

• Change in soil structure from crumb or granular structure to massive or platy structure; restricted to the surface 0 to 10 cm.
• Platy structure is noncontinuous.
• Fine, medium, and large roots can penetrate or grow around the platy structure. No “J” rooting observed.
• Erosion is slight.</td></tr>
</table>

Soil disturbance class 2	**Soil disturbance class 3**
Soil surface: • Wheel tracks or depressions are 5 to 10 cm deep. • **Accessory*:** Forest floor layers partially intact or missing • Surface soil partially intact and may be mixed with subsoil. • Burning moderate: Depth of char is 1 to 5 cm. **Accessory*:** Duff deeply charred or consumed. Surface soil water repellency increased compared with the preborn condition. Soil compaction: • Increased compaction is present from 10 to 30 cm deep. Observation of soil physical condition: • Change in soil structure from crumb or granular structure to massive or platy structure; restricted to the surface, 10 to 30 cm. • Platy structure is generally continuous • **Accessory*:** Large roots may penetrate the platy structure, but fine and medium roots may not. • Erosion is moderate.	Soil surface: • Wheel tracks and depressions highly evident with depth >10 cm. • **Accessory*:** Forest floor layers missing. • Evidence of surface soil removal, gouging, and piling. • Most surface soil displaced. Surface soil may be mixed with subsoil. Subsoil partially or totally exposed. • Burning severe: Depth of char is >5cm. **Accessory*:** Duff and litter layer completely consumed. Surface soil is water repellent. Surface is reddish or orange in places. Soil compaction: • Increased compaction is deep in the soil profile (>30cm deep). Observations of soil conditions: • Change in soil structure from granular structure to massive or platy structure extends beyond 30 cm deep. • Platy structure is continuous • **Accessory*:** Roots do not penetrate the platy structure. • Erosion is severe and has produced deep gullies or rills.

*Accessory items are those descriptors that may help identify individual severity classes.

Table acquired from the USDA’s Forest Soil Disturbance Monitoring Protocol, Volume 1: Rapid Assessment

Appendix E: Suggestions for Protocol and Training

A. Technology
   1. Upload maps onto GPS for increased efficiency in the field
   2. A soil probe may be a useful supplement to the shovel
   3. Load points on GPS would save time in the field.

B. Training
   1. Provide solid foundation about the project: goals, purpose, future direction
   2. Minimize reliance on PowerPoint presentation during training
   3. Educate interns on soils. In particular, offer background on the history of land use as it pertains to soils and previous USFS efforts in maintaining soil health.
   4. Provide field examples of platy/massive structures
   5. Provide a glossary of terms at the onset of training
   6. Provide a list of logging symbols (blazes, colors, etc) to aid field navigation
   7. Create more criteria to gauge whether soil conditions are 'detrimental' to forest regeneration
      - Presence of woody debris – how deep is detrimental?
      - Slash piles with undisturbed forest floor – how to categorize?
   8. Provide rationale for protocol
      - Why random transects?
      - Why 6-inch holes?, etc.)

C. Protocol
   1. Provide clearly defined guidelines to minimize discrepancies in data caused by subjective decisions in the field.
   2. Change protocol for staying off skid roads to avoid skewing the data (maybe move left THEN right, then left, etc).
   3. Address presence of slash piles that make it difficult to access the soil by adding a "covered in slash" option to the data sheet.
   4. Include a category for water (creek, vernal pools, puddles, etc) in order to differentiate between puddling from ruts and natural pooling.
   5. Electronic data forms ask for more samples when sample size exceeds 30 points. Why?
   6. In the future, ask loggers/foresters create maps, collect pre-data, make notes about conditions to better focus the data collection later. Putting GPS units on harvesting machines to map roads would also be more efficient.
   7. Reduce ambiguity in data form. "Forest Floor Disturbed" is clearer than "Forest Floor Impacted."
   8. Skid road inventory and mapping may better capture the impact of harvest on soils.

D. Good Things

1. Clearly defining expectations for final product
2. Making transects in office before going out into the field
3. Protocol seems to work well, but it could be streamlined.
4. Data entry works well – linked files were great
5. Using paper instead of data loggers was good.

Appendix F: Glossary of Terms

Activity Area: A harvest unit, excluding system road, landings, and temporary roads, outside the harvest unit boundary. An activity area may also be a prescribed burn unit or any area delineated on the ground for a specific treatment.

Aquifer: A layer of permeable rock, sand, or gravel through which ground water flows, containing enough water to supply wells and springs.

Areal Extent: The measured area (length times width or diameter) affected by any activity.

Biological Indicators of Soil Quality: Measures of living organisms or their activity used as indicators of soil quality. Measuring soil organisms can be done in three general ways:
1. Counting soil organisms or measuring microbial biomass.
2. Measuring biologic activity (e.g., soil basal respiration, cotton strip assay, or potentially mineralizable nitrogen).
3. Measuring diversity, such as diversity of functions (e.g., BIOLOG plates) or diversity of chemical structure (e.g., cell components, fatty acids, or DNA).

Chemical Indicators of Soil Quality: Indicators that include tests of organic matter, pH, electrical conductivity, heavy metals, cation exchange capacity, and other parameters.

Coarse Woody Debris: Fallen dead trees and the remains of large branches with a diameter greater than 7 cm on the ground in forests.

Compaction: The consolidation of sediments resulting from the weight of overlying deposits or above ground traffic.

Dynamic Soil Quality: An aspect of soil quality relating to soil properties that changes as a result of soil use and management or over the human time scale.

Erosion: The detachment and movement of soil or rock by water, wind, ice, gravity or human vectors.

Fine Woody Debris: Sticks and small branches with a diameter of less than 7 cm generated during logging operations or through natural forest disturbances.

Forest Floor: All organic soil horizons consisting of dead plant material on the surface of the mineral soil surface.

Forest Floor Impacted: The forest floor being surveyed has been directly affected by a human influence. Not to be confused with detrimental.

Harvest Unit: An area in which a logging operation takes place.

Haul Road: A more substantial, usually packed dirt, road which transport vehicles use to bring logs out of the woods and eventually to a mill.

Inherent Soil Quality: An aspect of soil quality relating to a soil's natural composition and properties as influenced by the factors and processes of soil formation in the absence of human effects.

Landing: A cleared area into which logs are dragged for processing and loading onto transport vehicles.

Massive Structure: No soil structural units are present and soil material is a coherent mass.

Percolation: The ability of water to move or filter though soil.

Physical Indicators of Soil Disturbance: Characteristics that vary with management including bulk density, aggregate stability, infiltration, hydraulic conductivity, and penetration resistance.

Platy Soil Structure: The arrangement of soil particles into aggregates that is flat horizontally. Platy structure can be natural or caused by trafficking.

Puddling: The destruction of soil structure and the associated loss of macro porosity that results from working on a soil that is wet.

Rutting: Impressions or furrows in the soil caused by the passage of heavy equipment.

Sale: An agreement made between the logger and the landowner where payments are received by the landowner based on a percentage of the revenue generated as the timber is cut and sold.

Slash: Limbs removed from trees and left on the forest floor after logging operations.

Skid Road: A trail along which newly cut logs are dragged into the landing area.

Soil Function: Any service, role, or task that soil performs, including the following:
1. Sustaining biological activity, diversity, and productivity.
2. Regulating and partitioning water and solute flow (hydrologic function).
3. Filtering, buffering, degrading, and detoxifying potential pollutants.
4. Storing and cycling nutrients.
5. Providing support for buildings and other structures (trees) and protecting archaeological treasures (cultural features).

Soil Horizon: A relatively uniform soil layer which lies at any depth in the soil profile, which is parallel, or nearly so, with the soil surface, and which is differentiated from adjacent horizons above and below by contrasts in mineral or organic properties. Soil horizons are grouped primarily into O, A, B, and C horizons.

Soil Quality: The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation and ecosystem health. Two aspects of the definition are dynamic soil quality and inherent soil quality.

Soil Quality Indicator: A quantitative or qualitative measure used to estimate soil functional capacity. Indicators should be adequately sensitive to change, accurately reflect the processes or biophysical mechanisms relevant to the function of interest, and be cost effective and relatively easy and practical to measure. Soil quality indicators are often categorized into biological, chemical, and physical indicators.

Soil Quality Monitoring: The act of tracking trends in quantitative indicators or the functional capacity of the soil to determine the success of, or changes associated with, management practices (land uses or disturbances) or the need for additional management changes. Monitoring involves the orderly collection, analysis, and interpretation of data from the same locations over time.

Topsoil: The upper, outermost layer of soil, usually the top 2 to 8 inches (5 to 20cm), also known as the A soil horizon. It has the highest concentration of organic matter and microorganisms and is where most of the Earth's biological soil activity occurs.