2018 Project Abstract
For the Period Ending June 30, 2022

PROJECT TITLE: Develop Strategies for Timber Harvest to Minimize Soil Impacts to Maintain Healthy and Diverse Forests

PROJECT MANAGER: Charlie Blinn
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WEBSITE: https://forestry.umn.edu
FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 08f

APPROPRIATION AMOUNT: $200,000
AMOUNT SPENT: $192,459
AMOUNT REMAINING: $7,541

Sound bite of Project Outcomes and Results
Reduced snowfall predicted with climate change is likely to increase the amount of soil frost during winter, increasing the times when forest harvesting can safely occur. We developed tools that will allow managers to predict when and where optimal soil conditions occur to minimize impacts of forest harvesting.

Overall Project Outcome and Results

Soils and forest health can be impacted during forest harvesting depending on how much frost is present during winter and how wet the soils are in summer. Climate change is expected to change these conditions, creating challenges for managers to determine when the optimal harvest time will occur. Our objectives were to determine how 1) snow cover influences the rate of frost development; 2) soil moisture influences soil strength; and 3) each of those relationships vary across areas that span a range of soil drainage (relative wetness). We conducted snow removal and rainfall reduction treatments in three aspen forests and monitored soil temperature and moisture, frost development, and soil strength for a period of three years. Treatments were conducted across a range of drainage classes that were expected to influence the treatment response and which could be readily identified by managers in the field (to improve application of any findings). We determined that snow removal causes significant increases in frost development and that the relationship is dependent on relative soil wetness of the forest: wetter, more poorly drained soils had lower frost development compared to drier, well-drained soils. Rainfall reduction had limited and inconsistent effects on soil moisture, possibly because of the small plot size. The relationships between soil moisture and soil strength were also inconsistent, hindering identification of the optimal soil moisture content where soil strength is optimal to reduce harvest impacts under non-frozen conditions. Based on our findings and previously developed metrics, we developed a map of harvest suitability for all forested areas in Minnesota under two scenarios, which can be used by managers and landowners to identify the season when forest harvesting is likely to have the smallest impact on soil and forest health. The results provide managers with tools that support sustainable forest management and the benefits it provides.

Project Results Use and Dissemination
We summarized the primary project findings into peer-reviewed journal articles that highlight key relationships and considerations that managers can use when determining the optimal time to conduct forest harvests. The information was also shared with resource managers at the annual Research Review conducted annually by UMN's Sustainable Forestry Education Cooperative. The journal articles are still in publication, but a graduate

student thesis is available here that outlines the primary findings. In addition, we created a map of harvest suitability by season for the forested region of Minnesota that can be accessed here. These two references are missing their hyperlink info.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2018 ENRTF Work Plan (Main Document) Final Report

Today's Date: 08/12/2022

Date of Next Status Update Report: Final Report

Date of Work Plan Approval: 06/05/2018

Project Completion Date: June 30, 2022

PROJECT TITLE: Develop Strategies for Timber Harvest to Minimize Soil Impacts to Maintain Healthy and Diverse Forests

Project Manager: Charlie Blinn

Organization: University of Minnesota

College/Department/Division: Department of Forest Resources

Mailing Address: 115 Green Hall, 1530 Cleveland Avenue N.

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Location: All counties in the NE Region of Minnesota in addition to Crow Wing Co., Cass Co., Wadena Co., Mille Lacs Co. Hubbard Co. Clearwater Co., Beltrami Co., Lake of the Woods Co., and Roseau Co.

Total Project Budget: $200,000

Amount Spent: $192,332

Balance: $7,668

Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 08f

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Appropriation Language: $200,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop strategies and practical tools to minimize soil compaction and other impacts across a range of conditions during timber harvest to maintain timber availability, improve regeneration of diverse forests, and benefit wildlife habitat. This appropriation is available until June 30, 2022, by which time the project must be completed and final products delivered.

I. PROJECT STATEMENT:

Managed forests are essential to maintain clean water, promote wildlife habitat, and regenerate tree species which require disturbance, but only if forest management activities minimize impacts to soils and the critical functions they control. In Minnesota, soil compaction during forest harvesting is a common concern because it can degrade soil and reduce future site productivity. Because of this, logging during winter when soil is frozen is one of the most common approaches to protect soil when harvesting timber. However, compaction can still

occur during winter if insufficient frost is present, and there is limited information on what a sufficient level of frost is and under what conditions it will form. In addition, focus on winter harvesting constrains the supply of timber during summer months and may inhibit establishment of certain desirable cover types. Past work and field experience indicates that harvesting can be safely conducted during summer on certain soil types and soil conditions. However, our current ability to predict the soil types and conditions where impacts are minimized during summer harvesting is surprisingly limited.

This project will quantify the factors that control soil operability in summer and winter across a range of soil types, soil conditions, and regional weather patterns. Understanding how these factors control soil operability will allow us to identify soil types and threshold conditions when harvesting can be conducted without degrading the soil and forecast when these situations will exist. We will use the project findings to develop practices and tools that minimize soil impacts and maximize benefits of forest resources including wildlife habitat and the supply of high-quality timber. Specific products that will be developed include a GIS-based soil operability metric and a tool that can be used in the field to directly assess soil operability. The potential impact of this work is large because the products can be easily used by land managers (e.g., the DNR, County land departments, forest industry, and federal agencies) and loggers to identify suitable site operating conditions and reduce uncertainty related to soil impacts. The findings and products will be widely used by the forestry community to increase site access for management and promote a wide range of benefits associated with working forest lands and the communities they support.

II. OVERALL PROJECT STATUS UPDATES:

First January 31, 2019

We have made excellent progress under Activity 1 and are on track with the overall project timeline. Research plots were installed in the fall of 2018 and we continue to monitor soil temperature and moisture at each of them.

Second Update June 30, 2019

Progress continues to be made on Activity 1 and everything is proceeding with the planned project timeline. Rainout shelters were installed at the experimental plots, and soil temperature and moisture continue to be monitored.

Third Update January 31, 2020

Excellent progress continues to be made on Activity 1 with one year of winter and summer measurements completed. Tasks associated with Activity 1 are all on time and we will begin analyzing the first years data later this month**.**

Fourth Update June 30, 2020,

We continue to make good progress on Activity 1, with only minor adjustments associated with the coronavirus outbreak and associated work closures. The first year of data has been fully analyzed and experimental treatments are being maintained. We have also initiated work on Activity 2.

Amendment request June 10, 2020

We are requesting that Robert Slesak be removed as project manager and that Charlie Blinn be named as his replacement. This change is being requested because Slesak has taken a new position which prohibits him from being a PI on UMN affiliated projects. Blinn, who is a UMN faculty member, is on the project team and has been

involved in all aspects of work to date. Slesak will continue to be involved in the project going forward, but at a reduced capacity.

Amendment Approved by LCCMR 6/25/2020

Fifth Update January 31, 2021

Work on Activity 1 continues and all data collection is proceeding as planned. We now have two years of data that has been processed and analyzed. Datasets associated with Activity 2 have been acquired and we are currently conducting preliminary analysis. Progress to date is on time.

Amendment request January 31, 2021

We are requesting that funds be shifted from personnel to the travel budget line.

- Personnel budget would be reduced by $3,000 to a revised budget of $158,000
- Travel budget would increase by $3,000 to a revised budget of $18,000

This change is being requested because we underestimated travel costs associated with the project and have identified some savings in personnel costs. The 3 project sites are located north of Duluth, near McGregor, and north of Grand Rapids. We visit the sites at least weekly during the winter and biweekly during the summer, requiring extensive fleet costs. Remaining travel funds are insufficient to cover travel costs associated with Activity 1 throughout the project period.

Sixth Update June 30, 2021

Work proceeds on schedule for both Activity 1 and 2. We do not anticipate any difficulties with completing the project on time.

Seventh Update January 31, 2022

Work proceeds on schedule for Activity 1 and 2. We have identified one issue with Activity 2 which will influence the deliverables outlined in the workplan.

Amendment request January 31, 2022

We are requesting that funds be shifted from personnel to the travel budget line.

- Personnel budget would be reduced by $4,000 to a revised budget of $154,000
- Travel budget would increase by $4,000 to a revised budget of $22,000

This change is being requested because travel costs continue to exceed what we have budgeted given several unplanned field visits which were necessary to maintain the soil monitoring equipment and repair rainout shelters. We have included a cushion in this request to account for more snow removal days associated with Activity 1 that may be necessary this winter. Remaining travel funds are insufficient to cover travel costs associated with Activity 1 throughout the project period.

Overall Project Outcomes and Results

Soils and forest health can be impacted during forest harvesting depending on how much frost is present during winter and how wet the soils are in summer. Climate change is expected to change these conditions, creating challenges for managers to determine when the optimal harvest time will occur. Our objectives were to determine how 1) snow cover influences the rate of frost development, 2) soil moisture influences soil strength,

and 3) each of those relationships vary across areas that span a range of soil drainage (relative wetness). We conducted snow removal and rainfall reduction treatments in three aspen forests and monitored soil temperature and moisture, frost development, and soil strength for a period of three years. Treatments were conducted across a range of drainage classes that were expected to influence the treatment response and which could be readily identified by managers in the field (to improve application of any findings). We determined that snow removal causes significant increases in frost development and that the relationship is dependent on relative soil wetness of the forest: wetter, more poorly drained soils had lower frost development compared to drier, well-drained soils. Rainfall reduction had limited and inconsistent effects on soil moisture, possibly because of the small plot size. The relationships between soil moisture and soil strength were also inconsistent, hindering identification of the optimal soil moisture content where soil strength is optimal to reduce harvest impacts under non-frozen conditions. Based on our findings and previously developed metrics, we developed a map of harvest suitability for all forested areas in Minnesota, which can be used by managers and landowners to identify the season when forest harvesting is likely to have the smallest impact on soil and forest health. The results provide managers with tools that support sustainable forest management and the benefits it provides.

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Assess the influence of different soils and weather on operability across a range of site conditions
Description: We will develop a network of seven research sites along a temperature gradient and across a range of soil textures in northern Minnesota. Soil texture is a key property that influences soil operability because it controls soil moisture and frost dynamics – the primary factors influencing soil strength and susceptibility to compaction during summer and winter, respectively. For this project we will focus on fine to medium textured soils because these typically are most susceptible to degradation and have the most constraints influencing soil operability. Experimental treatments that manipulate soil moisture during the summer and snow depth during the winter will be replicated at each site. Treatments will be applied throughout the project period to assess the influence of inter-annual variability in weather on soil operability. We will measure and analyze the effect of these treatments on soil temperature and moisture, frost occurrence and depth (during winter), soil strength, and variation in response over a three year time period. Results will be used to identify thresholds of soil strength associated with soil moisture levels and frost depth for a range of soil textural classes.

ENRTF BUDGET: $ 175,500

Outcome	Completion Date
1. Initial site evaluation completed and site selection finalized (7 total)	Sept. 2018
2. Pretreatment field measurements and soil sensors installed	Oct. 2018
3. Assessment of soil conditions (soil strength, water content, frost, etc.) for 3 years	Oct. 2021
4. Data synthesis complete and final report completed	June 2022

First January 31, 2019

Primary work conducted this far includes the hiring of the Research Associate who is leading all efforts related to the field experiment, and the identification of sites and installation of experimental plots and soil sensors. We worked with MN DNR and county land departments to identify sites for inclusion in the study. We were able to install a total of 12 plots (5 more than outlined in the work plan) at three regions that encompass a range of soil texture and drainage classes. Soil moisture sensors and dataloggers were purchased and installed at each of the plots, and data has been collected since early November. We also collected soil samples from each of the sites at time of installation for characterization of soil physical properties. Snow removal treatments are being

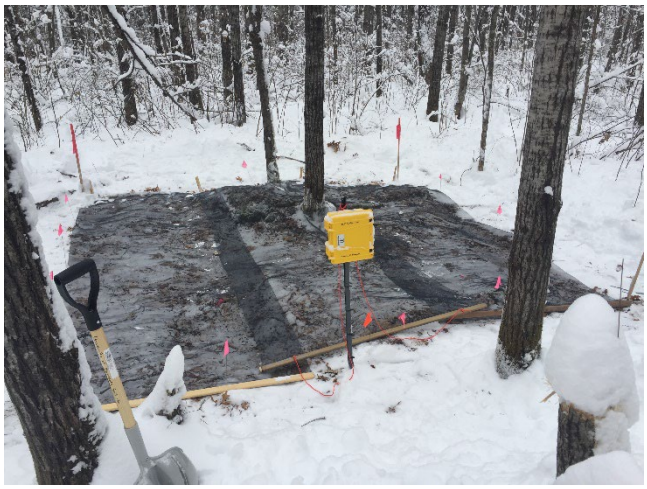
conducted at each site as needed, and we have completed the first data download across the network. Preliminary design of rainfall exclusion shelters has commenced, and soil samples are currently being processed.

Second Update June 30, 2019

Snow removal treatments were continued throughout the winter period until the end of April. Rainfall exclusion shelters were constructed during May, and installation was completed at each of the plots in mid June (see picture at right). Soil temperature and moisture continues to be measured at high frequency within each of the plots, and data has been downloaded and initially processed up until the April time period. Pretreatment soil samples have been analyzed for total C and N. The protocol for soil strength measures has been finalized, and measurements will commence in the first week of July.

Third Update January 31, 2020

Soil moisture and temperature readings were successfully collected throughout the summer and are currently being analyzed for treatment effects. We also collected soil strength measurements on a biweekly schedule using two different measurement techniques. The rainout shelters were removed in late October and the plots converted in preparation for the winter snow removal which is currently underway fpr the season (see picture at right). Soil frost tubes were purchased and installed this past fall to allow for measurement of soil frost in each of the treatment plots. Lastly, pretreatment soil samples were further analyzed for additional chemical properties (extractable cations and phosphorus) and for soil texture.

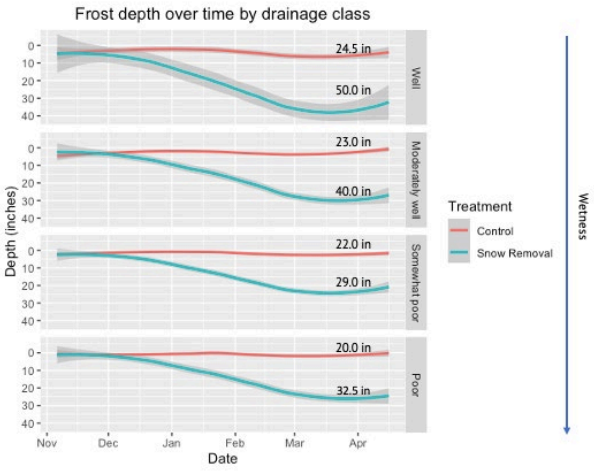


Fourth Update June 30, 2020,

Snow removal treatments were maintained throughout the winter field season, and we were able to acquire permission to visit the sites in April to download data and install the rainout shelters. Several faulty sensors were replaced at this time. Soil moisture and temperature data has been processed and analyzed from experiment initiation until November 2019. Early results are promising, with clear effects of snow removal on soil temperature and effects of rainfall exclusion on soil moisture, confirming that treatments are creating the intended soil conditions. In addition, we have analyzed relationships between soil strength and soil moisture measurements by soil drainage class across sites. We will be analyzing frost depth measurements in the coming months and updating the analysis on soil temperature and moisture with new data downloaded in April. Lastly, a new graduate student has been recruited to work on the project starting in June, 2020.

Fifth Update January 31, 2021

Data collection proceeded smoothly throughout the summer despite coronavirus restrictions on travel and personnel activities. We were able to collect soil strength measures on a biweekly schedule across all the sites, and also initiated new measurements on soil chemical properties. Rainout shelters were removed and stored in the fall, and plots were configured for snow removal which began in December. Soil moisture and temperature data has been processed and analyzed to determine effects of soil drainage class and treatment on these variables. We have also completed summation and analysis of soil frost data from winter 2019/20 (see figure to right), and updated regression relationships between soil strength and soil water content for each of the drainage classes.



Sixth Update June 30, 2021

Rainfall exclusion shelters were redeployed in April 2021. One unit was repaired following bear damage to the structure. Data from April 2021 and prior has now all been processed and analyzed for effects of soil drainage and treatment (snow removal and precipitation exclusion) on soil temperature, moisture, and frost depth. We continue to collect soil moisture, temperature, and soil strength data, and have initiated new measurements to quantify the effectiveness of the rainfall exclusion shelters and evaluate biological response to the treatments.

Seventh Update January 31, 2022

There were several issues with faulty dataloggers at the Aitken and Itasca sites in the later summer 2021, which required several field trips to rectify. All loggers and sensors have been repaired and are currently operating as intended. Rainout shelters were removed in October and plots were configured for snow removal treatments. Field measurements and snow removal are being conducted as planned and we do not anticipate any additional issues prior to the end of the project period. We have made substantial progress on data analysis, including summarization treatment effects on soil moisture, temperature, and frost development. We have also evaluated relationships between soil strength and soil moisture, and have concluded that the soil penetrometers were inadequate to quantify soil strength at out sites. Anna Stockstad has measured and quantified treatment effects on soil C and N cycling, and expanded the study to include a lab incubation which was conducted in December 2021. The incubation was conducted to determine how the treatments and drainage class influence production of carbon dioxide, nitrous oxide, and methane under controlled environmental conditions.

Final Report Summary

We were able to increase the number of plots and sites where the experiment was conducted, greatly increasing the inference of findings to northern Minnesota. In particular, this allowed us to stratify the plots across a soil drainage class gradient, which we expected to modify the response to snow removal and rainfall reduction (the treatments we assessed). Plot establishment and treatment implementation went relatively smoothly given the inherent difficulties in reducing rainfall and removing snow in forest locations far from our work locations. Soil moisture, temperature, frost, soil strength, and ancillary variables likely to influence these variables (e.g., snow depth, soil texture, etc) were measured as planned over a three-year period. Key findings from these measurements include:

- Snow removal caused large increases in the rate and total amount of soil frost development as the loss of the insulating effect of snow allowed soils to obtain colder temperatures. The effect was dependent

on drainage class (soil wetness), where wetter drainage classes had slower and lower frost development compared to drier drainage classes.

- There was a significant relationship between air freezing index (sum of mean daily temperatures below freezing) and frost development that differed among drainage classes and if snow was present or absent.
- Rainfall exclusion treatments were successful at reducing precipitation by half, but there was no consistent pattern of soil moisture response to this reduction across drainage classes and soil depths.
- Soil strength was measured with two types of soil penetrometers during the growing season of each project year. There was no effect of treatment on soil strength, likely because the rainfall reduction treatment did not consistently affect soil moisture content.
- Relationships between soil moisture and soil strength were variable with no clear patterns; relationships were positive, negative, or most often not significant. Our expectation was that soil strength would increase as soil moisture content decreased, allowing for determination of soil moisture contents where soil strength is greatest. This was not supported by the data.

Our findings have important implications for operational management practices and considerations for similar experiments:

- Increased frost is likely to occur if predicted decreases in snowfall occur in the future. This has important implications for forest management, as it could conceivably increase the times when winter harvesting could occur without impact to soils. A key uncertainty with this conclusion is that we are not accounting for concurrent increases in winter temperature that are expected to also occur. However, future winter temperatures are still predicted to be below freezing, and we observed the deepest frost in our study in winter 2020-21, which had the lowest snow cover and highest air temperatures of the three study years. Because of this, we think it is more likely that future conditions will support more frost development and a longer winter harvest season.
- The models relating air freezing index (AFI) to frost depth may be particularly useful to foresters and loggers, as it will allow them to have some predictive capacity to know when sufficient frost is present at a given site and harvest operations may proceed.
- The incorporation of drainage class into our assessment was very beneficial as it strongly influenced the soil response. This is important because it allowed us to improve the AFI-frost models. On a practical level, inclusion of drainage class will be very useful because it is commonly mapped in spatial datasets and readily identified in the field with minimal training. This should facilitate application of the findings in the field.
- The lack of a consistent effect of rainfall reduction on soil moisture was surprising and may be due to the (relatively) small plot size we used in the study. All field experiments must strike a balance between the ideal and what is achievable; we recommend that future experiments evaluating rainfall reduction utilize plots larger than ours (4 m^2) but within constraints of what is feasible given field conditions and available resources.
- The lack of consistent relationships between soil moisture and soil strength was disappointing, as information to evaluate summer soil operability is desperately needed by the forestry community. The lack of a rainfall reduction effect on soil moisture did not influence this, as we assessed soil strength throughout the growing season and across drainage classes (i.e., across a wide range of soil moisture). Almost assuredly, the lack of relationship was due to the tools we had available to measure soil strength, which are not readily suitable for forest soil applications.

Activity 2: Develop GIS-based soil operability metric and a field measurement tool

Description: Results from Activity 1 will be used to identify key factors and conditions influencing soil operability, and develop guidelines on when operations may occur for a given set of weather scenarios. Specifically, we will develop a GIS-based metric that assigns a given soil type into an operability class (low, medium, high) based on estimated soil conditions (i.e., soil moisture or frost depth). The metric will utilize the soil strength-soil condition relationships identified in Activity 1 in combination with publically-available spatial soil and weather datasets. A field tool, based on relationships between mass and soil strength, will also be developed for direct assessment of real-time conditions by loggers and managers. We will also develop strategies and recommendations to enhance operability under subpar conditions including post-storm rain events and early season snowfall.

ENRTF BUDGET: $ 24,500

Outcome	Completion Date
1. Field tool prototype completed	Apr. 2021
2. Initial development of GIS-based metric completed	Oct. 2021
3. Beta testing of GIS metric completed and updates incorporated into final product	June 2022
4. Specifications for field tool completed	June 2022
5. Strategies and recommendations to improve operability incorporated into final report	June 2022

First January 31, 2019

Work will commence on this task in early 2020

Second Update June 30, 2019

Work will commence on this task in 2020

Third Update January 31, 2020

Work will commence on this task in the coming months.

Fourth Update June 30, 2020,

We have acquired and processed spatial datasets on soil properties and topography for the GIS-based operability metric. Initial work is being conducted to evaluate the suitability of SSURGO database for this effort.

Fifth Update January 31, 2021

Evaluation of the SSURGO database has been completed. There are three counties in MN that do not have updated soil maps available and we are exploring alternative datasets for use in those counties. We have conducted some preliminary analysis to map a metric of soil operability based on drainage class and soil texture.

Sixth Update June 30, 2021

Work has continued processing the spatial datasets and we have preliminary drafts of maps showing estimated soil operability by drainage class for each of the counties in MN that have soil datasets available. We will begin validating and refining the maps over the next project period.

Seventh Update January 31, 2022

The soil operability map has been finalized, and we are now working to incorporate other factors into a GIS that influence operability including season of harvest, equipment type, and time since last precipitation event.

We have attempted to develop a rating curve between soil strength and penetration depth of a rudimentary strength probe, but are unable to identify any relationships between the two variables. This is likely a result of using the portable soil penetrometers to measure soil strength, which are known to be unreliable in forest soil (because of roots, rocks, etc). Because of this, we will not be able to develop the rating curve for the field tool as originally planned.

Final Report Summary

We were able to develop a harvest suitability map using publicly available soils information combined with our findings from Activity 1 and a metric of soil operability previously developed by MN DNR that incorporates information on soil texture, drainage class, depth to restrictive layers, and landscape position (see Supplementary Materials). For the map, we elected to base the suitability on season of harvest since that is the primary aspect considered by foresters when planning a timber sale. In addition, we created two levels of suitability that 1) incorporated the full list of soil properties and their associated constraints in the base metric, and 2) removed the depth to semi-permeable layer constraint and relaxed the classification of a given soil into less restrictive operating seasons based on findings from Activity 1. The map was created by downloading all county-level SSURGO data, developing database queries to extract and define properties used in the metric, and assignment of an operability rating to individual soil map units. When more than one soil component existed in a map unit (e.g., soil associations), the dominant soil type (by area of unit) was used to classify the map unit into an operability class. We then used a statewide landcover map to identify those map units that occur within forested areas of the state. This map can be used by managers and landowners to identify the preferred operating season at a given site, allowing them to plan accordingly to limit impacts to soil (see Supplementary Materials). Note that the metric was originally developed for field application; our conversion for the spatial display of the metric will greatly increase its utility and use, but field application may be more accurate because of inherent constraints of the SSURGO database in estimating soil unit extent and related properties.

One of our objectives for this activity was to develop base information for the development of a tool that could be used be managers to test soil operability conditions in the field. Note that this objective was focused on initially developing a rating curve relating penetration depth of a given mass to soil strength (See approved Research Addendum). The approach we took was to first identify a relationship between soil strength and moisture content, using two types of soil penetrometers that measure soil strength. We conducted these measures over two field seasons and a wide range of soil moisture for each drainage class. However, as noted in Activity 1, we were unable to detect any consistent or meaningful relationships between soil strength and soil moisture content. The primary reason for this is almost certainly related to our use of penetrometers to measure soil strength. These devices are widely used in construction and geotechnical applications, but are known to have limitations in forest soils because of the large amount of woody material (e.g, roots)) and rock fragments present, which cause inaccurate estimates of soil strength. We were aware of this limitation, and originally proposed for funding and development of a customized tool to accurately measure soil strength or compaction in forest soils. In future assessments of forest soil operability or compaction, we recommend that investment be made in such tools to accurately assess the heterogenous conditions typically found in forest soils.

IV. DISSEMINATION:

The products developed from this project are intended to be used by practitioners in a variety of operational settings. A final report will document relationships among soil conditions and soil operability in both winter and summer. Recommendations on optimal soil operability related to these relationships will be included in the

report. This report will be made available on the webpages of the Department of Forest Resources and the Minnesota Forest Resources Council. Spatial data products will disseminated directly to primary stakeholders (e.g., DNR, Forest Service, County land departments) and will also be uploaded to the Minnesota Geospatial Commons (https://gisdata.mn.gov/) for general access. In addition, several manuscripts will be written based on this research and submitted for publication in peer-reviewed journals. Results and related recommendations will be also be presented directly to public forest management agencies, forest industry and logging trade organizations, and other forestry professionals in cooperation with the Sustainable Forestry Education Cooperative. All reports and publications from this project will be made available via the Department of Forest Resources web site.

Description:

First January 31, 2019

We have given several presentations on the planned work and project objectives to partners at the DNR and the MN Forest Resources Partnership, and have communicated regularly with members of the MN Forest Resources Council on project status.

Second Update June 30, 2019

Periodic updates have been provided to the MN Forest Resources Council on the project status.

Third Update January 31, 2020

No presentations or external communication related to this project occurred since the last update. We will begin actively disseminating findings to user groups later this year once the first year data has been analyzed and initial findings determined.

Fourth Update June 30, 2020

No presentations or external communication related to this project occurred since the last update.

Fifth Update January 31, 2021

Graduate student Anna Stockstad presented findings from the first two years of the study at the annual Forestry and Wildlife Research Review to forest practitioners and managers on January 14, 2021.

Sixth Update June 30, 2021

No presentations or external communication related to this project occurred since the last update.

Seventh Update January 31, 2022

We developed and delivered a summary document of findings to date to project cooperators and stakeholders in August 2021. We received positive feedback from a number of stakeholders on the document, and plan to send another update in the Spring.

Robert Slesak and Anna Stockstad both gave presentations on project findings at the annual meeting of the Soil Science Society of America meeting, held in Salt Lake City during November 7-10, 2021.

Final Update June 30, 2022

Anna Stockstad gave a final presentation of findings at the annual Forestry and Wildlife Research Review on February 15, 2022. Throughout the project we engaged with key stakeholder groups to share project updates and preliminary findings including MN DNR, MN Association of County Land Commissioners, the MN Forest Resources Council, and UMNs Sustainable Forestry Education Cooperative. Final documents and findings will continue to be shared with our stakeholders at periodic meetings, field tours, and workshops. The presentations by Stockstad and Slesak at the SSSA annual meeting allowed for broader dissemination of findings at the national level. Lastly, two manuscripts have been prepared to disseminate the results more broadly; one manuscript has recently been published in the journal *Forests* and the other manuscript is under review at the journal of *Forest Ecology and Management*. Both of these journals are widely read by forestry professionals, and we expect that findings from this project will be widely disseminated into the natural resource management community.

V. PROJECT BUDGET SUMMARY:

The total recommended budget request is $200,000 over a four year period. Salary (1.0 FTE) and fringe (0.335) is budgeted for a Research Associate for approximately 2 years. The research associate will be responsible for field work associated with Result 1 including site identification, treatment application, and data collection. Salary and fringe (0.15 + 19.32/hr tuition; no summer tuition) is budgeted for one year for 1 graduate student, who will conduct field work, analyses, and interpretation of study data associated with Result 1. The student will begin in the second year of the project so that data is immediately available to them. Work associated with Result 2 will be conducted by the graduate student and members of the project team. The $24,000 budgeted for supplies includes funds for soil temperature and moisture sensors, dataloggers, tipping bucket rain gauges, a soil penetrometer, snow tube and scale, and miscellaneous supplies for treatment application including rainout shelters and shovels. The $15,000 budgeted for travel includes costs associated with mileage (75%) and lodging (25%) within Minnesota for researchers, the research associate, and graduate student to the project sites. A large numbers of visits will be required because sites will be located around the state and require periodic visits following snow and rain events.

A. Preliminary ENRTF Budget Overview: See attached budget spreadsheet

Explanation of Capital Expenditures Greater Than $5,000: N/A

Explanation of Use of Classified Staff: N/A

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 2.5

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: N/A

B. Other Funds:

SOURCE OF AND USE OF OTHER FUNDS	Amount Proposed	Amount Spent	Status and Timeframe
Other Non-State $ To Be Applied To Project During Project Period:			
In-kind salary from R. Slesak (0.1 FTE) , R. Kolka (0.05 FTE) and S. Sebestyen (0.05 FTE)	$ 76,900	$	Secured

VI. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Charlie Blinn	Professor	UMN	Project Manager, principle investigator (PI)

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
Robert Slesak	Research Scientist	USDA Forest Service – PNW Research Station	Co-PI
Randy Kolka	Research Scientist	USDA Forest Service – North. Research Station	Co-PI
Stephen Sebestyen	Research Scientist	USDA Forest Service – North. Research Station	Co-PI
Dan Hanson	ECS Program Coordinator	DNR Forestry	Co-PI

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

Initial implementation of the GIS metric should go smoothly since members of the forestry community have consistently requested this information and it will be provided in a GIS format that is widely used and accessible. However, future refinements of the metric will likely be needed in response to user feedback and new field data that can be used to improve calibration equations. We will work closely with forestry stakeholders to demonstrate the utility of the metric, and to provide resources needed for its improvement. Further, we expect that the soil operability metric will change with changing weather patterns and climate, so additional work will be needed in the future to maintain overall utility. Funding requests for these efforts will be targeted at state agencies, federal agencies, and forest industry. For the field tool, we will explore working with UMNs Minnesota Innovation Partnerships to identify opportunities for product development. Once the tool becomes available, we will partner with UMN Extension and the MN logger Education Program to train field foresters and loggers in its use.

VIII. REPORTING REQUIREMENTS:

- **The project is for 4 years, will begin on July 1, 2018, and end on June 30, 2022.**
- **Periodic project status update reports will be submitted June 30th of each year.**
- **A final report and associated products will be submitted between June 30 and August 15, 2022.**

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual component
C. Research Addendum

X. Supplementary Materials

A. **Stockstad condensed thesis**
B. **MN DNR soil operability metric**
C. **Soil operability map – Scenario 1**
D. **Soil operability map – Scenario 2**

Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2018 M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 08f Project Budget - Final

Project Title: Develop Strategies for Timber Harvest to Minimize Soil Impacts to Maintain Healthy and P
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 08f
Project Manager: Charlie Blinn
Organization: University of Minnesota
College/Department/Division: Department of Forest Resources
M.L. 2018 ENRTF Appropriation:
Project Length and Completion Date: 4 years, June 30, 2022
Date of Report: 8.12.2022

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits) - Overall	$149,000	$144,942	$4,058
Research Associate - salary and fringe (0.335) for 2 years who will coordinate treatment application and data collection at the project sites for Activity 1 (Total estimated amount $118,858)			
Graduate student - Salary (0.5 FTE) and fringe (0.15) + 19.32/hr tuitionfor 1 year who will analyze data from Ativity 1 and develop recommendations and tools for Activity 2 (Total estimated amount $42,142)			
Equipment/Tools/Supplies			
Soil temperature and moisture sensors (80 totaling $12,000), dataloggers (16 totaling $8,000), snow tube and scale ($500), shovels, soil penetrometer ($1000), and misc. supplies for treatment application ($2500)	$24,000	$23,512	$488
Travel expenses in Minnesota			
Travel for mileage (75%) and lodging (25%) within Minnesota for researchers, the Research Associate, and Graduate Student to the project sites in Activity 1 and work in Activity 2. A large amount of travel will be requiried because sites will be located across northern Minnesota and require periodic visits following snow events and throughout the growing season	$27,000	$23,878	$3,122
COLUMN TOTAL	$200,000	$192,332	$7,668