

TITLE/LOCATION: Soil Compaction Effects on Site Productivity and Organic Matter Storage in Aspen Stands of the Great Lakes States

PROJECT DURATION: August 1, 2003 – July 31, 20 **FUNDING SOURCE:** Base

REQUESTED FUNDING PERIOD: August 1, 2005 – July 31, 2006 (year 3 of 3)

PROJECT LEADERS:

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PROJECT OBJECTIVES:

Higher than average levels of soil compaction have been reported on detection monitoring (DM) plots in the upper Great Lakes states (1998-2000). This study will evaluate the relationship between soil properties, compaction potential, and stand productivity in this region through a series of integrated GIS, field, and laboratory investigations.

Specific objectives include:

- (1) Identify functional relationships between soil properties (e.g., texture, aggregate stability, organic matter, penetrability, bulk density, soil permeability, soil water holding characteristics) and levels of compaction reported on DM plots using digital soil survey data.
- (2) Develop spatial models of potential sensitivity to soil compaction based on soil physical characteristics, slope, landscape position and local hydrology. Use digital models to stratify the region into soils that are at high and low risk for compaction. Apply model to FIA Phase 2 data to determine whether sensitivity to compaction is correlated with other indicators of forest health, including growth, mortality, and damage.
- (3) Test models by establishing experimental field plots on recently harvested and control plots within soils at high and low risk for compaction. Assess how direct measures of compaction (e.g., cone penetrometer, pocket penetrometer, bulk density, soil permeability) correspond to changes in soil properties and site productivity.

JUSTIFICATION:

Soil compaction is measured on detection monitoring plots to address Criteria 4, Indicator 22 of the Montreal Process Criteria and Indicators (Area and percent of forest land with significant compaction or change in soil physical properties resulting from human activities). Data collected on DM plots from 1998-2000 indicate higher than average levels of soil compaction in the upper Great Lakes states (Fig. 1; O'Neill, in review). Equipment limitation ratings derived from published soil surveys (NRCS STATSGO) suggest that the soils of this region may be more sensitive to physical disruption during harvest operations (Fig 2; O'Neill, in review), however, these ratings are qualitative and are not specific to soil compaction. Direct links between soil physical properties, compactability, and observed levels of surface compaction on detection monitoring plots have not yet been established for this region.

Additional research is needed to interpret the ecological significance of the high levels of compaction reported on detection monitoring plots. Key questions to address include: Which soil

types are at greatest risk for compaction from harvest equipment? Is sensitivity to compaction correlated with reported levels of compaction on DM plots? Do growth rates and other indicators of forest health differ measurably on soils that are sensitive to compaction? Are current DM protocols adequate to assess compaction on DM plots?

DESCRIPTION:

a. Background:

For optimal plant growth, approximately half of the total soil volume should consist of pore space that is equally filled with air and water. Reduction in pore space following compaction by forestry equipment can constrain the size, reach, and extent of root systems and impair plant uptake of water, nutrients, and oxygen. At the landscape scale, destruction of soil structure can limit water infiltration sufficiently to increase rates of runoff and soil loss from erosion.

As currently implemented, measurement of compaction on DM plots is based on a visual assessment of observable surface compaction. Limitations of this approach include: (1) compaction more than a few years old may not be readily apparent to field crews, and (2) there is no quantitative measure of the degree of compaction. Although soil compaction typically has a negative impact on site productivity, results from experimental studies conducted as part of the LTSP indicate that on excessively-drained soils in the upper Lake States, high levels of soil compaction improved soil moisture holding capacity and increased site productivity (Stone et al., 1998; Stone and Elioff, 1998). Quantitative relationships between soil physical properties (e.g., texture, aggregate stability, moisture holding capacity), sensitivity to compaction, and other indicators of forest health/productivity are needed to provide analysts and land managers with the context necessary to interpret the ecological significance of compaction levels reported for the Great lakes region.

b. Methods:

Spatial Models of Compaction Potential

Compaction data from DM plots in the upper Great Lake states (1998-2001) will be overlain with digital soil survey data from the NRCS STATSGO (State Soil Geographic) and SSURGO (Soil Survey Geographic) databases to determine relationships between reported compaction levels and soil physical properties. Field results and published literature will be used to develop spatial models of potential sensitivity to soil compaction based on soil physical properties.

Effects of Soil Compaction on Stand Productivity

Dominant Great Lakes soil types have been stratified into regions of high and low potential for soil compaction based on soil texture. The stratification was used to identify potential research sites on high and low risk soils within or adjacent to the Chippewa, Chequamegon-Nicolet, Huron-Manistee, Superior, and Ottawa National Forests. Within the high and low risk soils for each of the five locations, a total of three experimental plots have been established in compacted areas of aspen stands that have been harvested within the last 5 years. Likewise, three randomly selected plots are established in unharvested controls for both high and low risk soils for a total of 12 plots per location (3 compacted, low risk, 3 compacted, high risk, 3 non-compacted, low risk, 3 non-compacted, high risk).

On each study site, soil physical and chemical properties, and post-harvest biomass are measured within a 50-ft X 50-ft grid (15.2-m x 15.2-m) consisting of sampling points located at 10-ft intervals; the size of the sampling plots corresponds to the diameter of a DM subplot. Aerial coverage of surface compaction across the entire plot is assessed following the current DM protocols. Soil strength was assessed at each grid point using both a cone penetrometer and a pocket penetrometer (Amacher and O'Neill, 2004). Forest floor thickness (litter and O) and volumetric samples of the forest floor (litter and O) and upper 20-cm of mineral soil have been

collected at each grid point. Litter and O-horizon samples were collected within a 12-in (30.5-cm) diameter sampling frame. Mineral soil samples from the 0-10 cm and 10-20 cm layers were collected using an impact driven corer. In adjacent locations, soil permeability was measured in the upper 20 cm, using an amoozemeter. Sampling protocols are based on existing methodology for DM plots (<http://fia.fs.fed.us/library.htm>). All samples will be air-dried and analyzed for bulk density, soil moisture holding characteristics, total carbon, and total nitrogen (Carlo Erba CHN dry combustion). Mineral soils collected for each depth increment were composited (six composite samples per plot) and analyzed for soil texture. A set of 10 additional soil cores were collected from the 0-10 and 10-20 cm depth increments at each site for determination of soil moisture holding capacity.

Relationships between soil compaction indicators and site productivity will be assessed by determining relationships between modeled sensitivity to compaction and measures of site productivity and health measured on Phase 2 plots (e.g., growth, damage, mortality).

c. Products:

This research will result in improved techniques for monitoring, analyzing, and interpreting compaction data from detection monitoring plots within the North Central region. Results will contribute to current knowledge on the effects of soil compaction on organic matter storage and site productivity for reporting on Montreal Process C&I.

Results will be presented at scientific and professional meetings such as the Ecological Society of America, the Soil Science Society of America, and the Society of American Foresters. In addition to publication in peer-reviewed journals, compaction sensitivity models and experimental results will be made available on FHM websites.

d. Schedule of Activities:

Year 1: Analysis of soil survey data to determine of physical properties of soils for detection monitoring plots reporting high levels of compaction. Development of spatial models for compaction risk. Identification and establishment of field plots. Begin collection of field data and soil samples.

Year 2: Continue collection of field data and soil samples. Lab analysis of soil samples for chemical and physical properties.

Year 3: Development of integrated spatial models. Refinement of initial compaction sensitivity map based on experimental data. Develop report and publications on results. In addition, we will add a second assessment of soil compaction based on our limited knowledge of the effect of landscape position and harvest timing on soil sensitivity to compaction (Block et al. 2002; McNabb et al. 2001).

“The objective of the FIA Phase 3 (P3) Soils Indicator is to assess forest ecosystem health in terms of the physical and chemical properties of the soils” (Phase 3 Field Guide, 2004). Yet, FIA Phase 3 collection crews do not account for landscape position or harvest timing when collecting samples and recording field measurements. We will select recently harvested aspen clear-cuts in the Chippewa and Chequamegon-Nicollet National Forests. Determination of sensitivity will be accomplished by stratification of aspen clear-cuts into high-risk and low-risk groups based on soil texture, with the low-risk soils containing sands, and sandy loams and high-risk soils encompassing finer-textured soils. Each risk level will contain two plots harvested in the winter, two plots harvested in the summer, and two plots in natural stands. Within each plot, GPS measurements will be recorded on a randomly chosen transect covering a range of landscape positions with samples taken at each landscape position (summit, backslope, footslope, etc), five in each plot. Soil measurements will be identical to those taken during our initial assessment. Data collected will be used to create a digital elevation models showing soil compaction parameters with respect to landscape position.

e. Progress/Accomplishments:

We received \$30,818 from FHM in Year 1 and \$37,600 in year 2 to begin the project. Funding was used to develop a cooperative agreement between the North Central Research Station and the University of Minnesota. Drs. Brooks and Kolka selected a M.S. candidate, Aaron Steber, who is beginning his second year of his degree. Funding requested in this proposal is for the final year of the project. Mr. Steber will be finishing his degree within the third year of funding after which we plan to hire him as a research associate for 6 months to complete the second compaction assessment related to landscape position and harvest timing discussed above. Newly hired, Dr. Hobie Perry, Research Soil Scientist & Eastern Soils Indicator Advisor for the FIA program in the North Central Research Station is included in all aspects of the project and, in particular, will oversee the continued development of the spatial models for risk assessment.

BUDGET:

		Requested FHM Funding	Match
Salary	Research Assistant/ Fellow	\$21,000	
Fringe	0.34 Salary	\$7,140	
GPS Unit (Garmin)		\$500	
Computer for GIS analysis		\$1,895	
Travel	MN,WI	\$9,360	
Indirect Costs (U of MN contribution)	0.485		\$19,349
Totals	Research Assistant/ Fellow	\$39,895	\$19,349

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- Stone, D.M., Gates, J.A., and Elioff, J.D. 1998. Are we maintaining aspen productivity on sand soils? Proceedings of Improving forest productivity for timber: A key to sustainability. December 1-3, 1998, Duluth, MN.
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Figure 1. Soil compaction on detection monitoring plots (1998-2000). The size of the symbols indicates mean compaction reported on each plot. Shaded areas represent mean value aggregated by ecoregion section. Note the high levels of compaction reported for DM plots in the upper Great Lakes states.

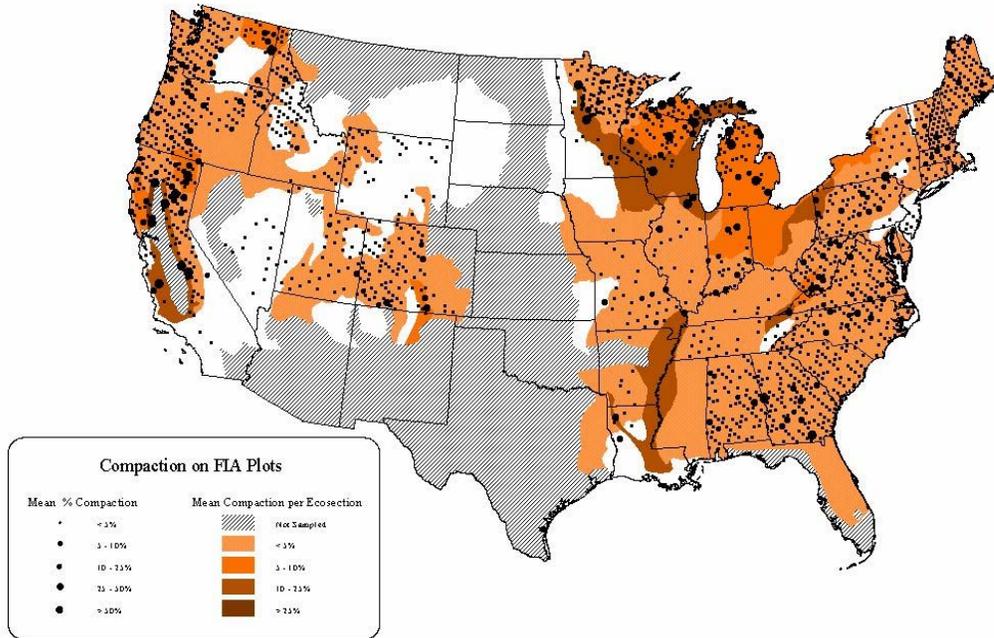


Figure 2. Equipment limitation ratings derived from STATSGO soils data. Ratings indicate that soils of the upper Great Lakes states may be more sensitive to physical disturbance during harvesting operations. However, equipment limitation ratings are based on qualitative assessments and are not specific to compaction. Additional research is needed to develop relationships between soil compactibility and quantitative physical properties.

