Prince George Forest Region

Forest Resources & Practices Team

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FOREST RESEARCH NOTE

Understanding Soil Productivity & Site Disturbance

The SBS Long-Term Soil Productivity Study

by Paul Sanborn, Research Soil Scientist

Sustaining the productivity of forest soils is key to the economic future of British Columbia's forest industry. Yet, surprisingly little is known about the effects of human activities on the long-term productivity of forest soils.

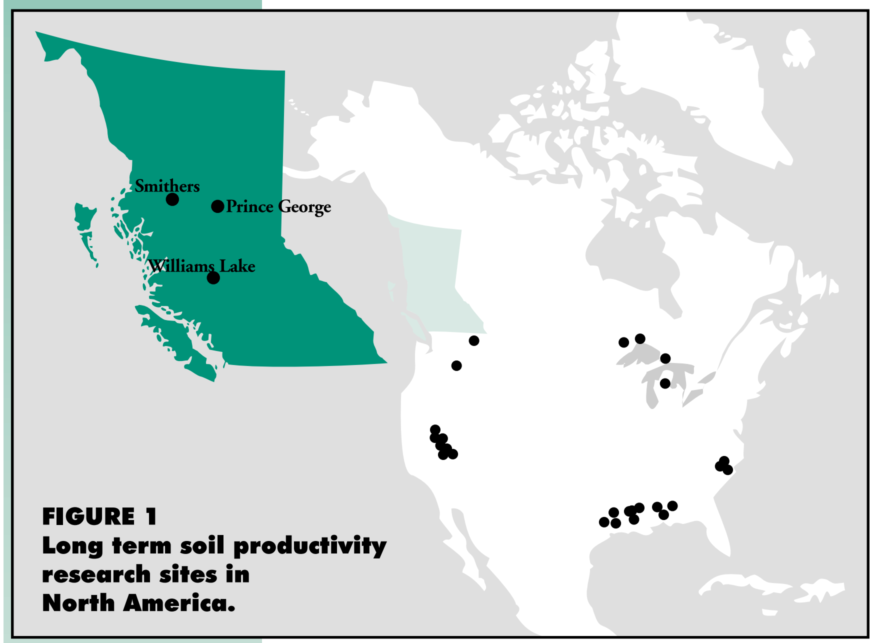


FIGURE 1
Long term soil productivity research sites in North America.

It is clear that harvesting and site preparation activities can adversely affect the chemical, physical and biological properties of soils. Soil compaction and organic matter loss are the two main concerns. All else being equal, tree roots do not grow as well in compacted soils. And, much of the forest nutrient reserve is tied up in the organic matter of the soils and vegetation. Removing or destroying that organic matter depletes the fertility of the soil.

Unfortunately, reliable scientific evidence connecting soil disturbance to long-term productivity declines is rare. Most examples of declining forest soil productivity are anecdotal. Timber rotations are long and historical records seldom survive with enough detail to provide conclusive evidence of soil productivity losses over time (Powers et al., 1990). Real data, derived from long-term monitoring of forest sites, are needed to demonstrate the impacts of management practices on soil productivity.

An international effort

An international collaborative research effort has emerged to meet that need. A large scale research program was proposed by Dr. Bob Powers of the U.S. Forest Service in the late 1980's. Its goal was to create a standardized experimental design involving a core series of treatments on benchmark sites across North America. The sites should represent as many different soil and forest types as possible.

That program now includes a network of researchers working in at least 8 American states and 2 Canadian provinces (Figure 1). The international effort is coordinated by a loosely knit technical committee made up of all the scientists involved in the research. The Prince George research team hosted the annual meeting of that international technical committee in August 1995.

The researchers are trying to quantify the effects of soil disturbance on productivity - not only in a timber management sense, but in a broader ecosystem sense as well. The research must be statistically valid and cover a broad range of site conditions. The experimental designs and manipulations attempt to isolate the effects of important components alone and in combination. The manipulative treatments aim to produce the response of interest, specifically compaction and organic matter removal, not to simulate actual operational practice. (Powers et al., 1990)

The studies centre on manipulation of 2 key soil properties that affect long-term soil productivity.

• Soil porosity: Changes in soil porosity generally result from soil compaction.

• Organic matter content: A number of chemical, physical and biological properties of the soil are directly affected by organic matter removal.

Measurements begin before harvest to establish the baseline characteristics of the site, then continue over many years through the creation and development of new stands. The work encompasses stand productivity measurements along with studies of more fundamental stand and site processes.

Objective

The main objective is to understand and demonstrate how the fundamental processes controlling forest productivity are affected, over the long-term, by soil compaction and organic matter removal.

The British Columbia contribution

Four such experiments are underway in British Columbia - three in the Sub-Boreal Spruce (SBS) biogeoclimatic zone of central BC near Prince George, Williams Lake and Smithers and one in the Boreal White and Black Spruce (BWBS) zone near Dawson Creek.

This research note deals with the three SBS sites. A companion note has been published outlining the preliminary results of the work on an aspen site in the BWBS zone near Dawson Creek. (See Forest Research Note PG 06: Boreal Long Term Soil Productivity Study)

The SBS is the most extensive biogeoclimatic zone in the central interior plateau of British Columbia. It is characterized by continental climates with long cold winters and short summer growing seasons. Mean annual temperature ranges from 1.7° to 5° C with temperatures below 0° C for 4 to 5 months per year and above 10° C for 2 to 5 months. Mean annual precipitation can range from 415 to 1650 mm, with snow accounting for approximately 25 to 50% of the annual precipitation.

Historically, wildfire was a dominant force in shaping the ecological and landscape characteristics of this zone. More recently, the SBS zone has undergone intensive commercial forestry activity.

TABLE 1 - Initial site characteristics

Attribute	Log Lake near Prince George	Skulow Lake near Williams Lake	Topley near Smithers
Biogeoclimatic zone / subzone	SBSwk1 (wet cool)	SBSdw2 (dry warm)	SBSmc2 (moist cold)
Elevation (m)	780	1050	1100
Slope	0-3%	level	2-12%
Aspect	South	N\A	West
Dominant pre-harvest species	*Abies lasiocarpa, Pseudotsuga menziesii, Picea glauca x engelmannii*	*Pinus contorta*	*Pinus contorta, Abies lasiocarpa, Picea glauca x engelmannii*
Site Index (m/at 50 years)	Douglas-fir: 18.4 White Spruce: 18.9	Lodgepole Pine:17.9	White Spruce: 15.5 Lodgepole Pine:15.7

Climax tree species in the SBS are hybrid white spruce (*Picea engelmannii* x *glauca*) and subalpine fir (*Abies lasiocarpa*). Lodgepole pine (*Pinus contorta*) is a seral conifer but common in maturing climax forests in the drier and more southern portions of the zone. Other seral tree species include Douglas-fir (*Pseudotsuga menziesii)*, aspen (*Populus tremuloides)* and paper birch (*Betula papyrifera*).

Study methods

Three maturing seral to maturing climax stands were selected in three different subzones of the SBS (Table 1). These research areas are representative of zonal sites in the moist to wet subzones of the SBS. They have deep medium textured soils, an absence of seepage and Mor humus forms. (Mor humus has an abrupt boundary with the underlying mineral soil.) The surface soils on all three sites are formed on medium textured glacial till. Surface textures range from loam to silt loam with 20 to 40% gravel. Sites are relatively uniform in understorey vegetation, stand structure, soil parent material and soil properties important to growth.

Nine 37.5 metre x 72.5 metre core treatment plots were established between 1991 and 1993 on the three SBS sites. Each of the three replicates (Log Lake, Skulow Lake and Topley) is treated as a block in a randomized block design. (Figure 2) The total cluster of nine plots covers approximately 3 hectares, including the 10 metre access trails around each plot. Pretreatment soil and vegetation sampling were carried out, followed by winter harvesting on a minimum 50 centimetre snowpack. The trees were hand-felled and skidder traffic was restricted to the buffer strips to keep soil disturbance to an absolute minimum during harvesting. A minimum of 1 hectare of mature forest, similar to the original stand, was preserved at each site for comparative purposes.

Treatments, representing a factorial combination of 3 organic matter removal and 3 compaction treatments, were applied the year after harvest. The organic matter treatments were:

- OM1 - stems only were removed.
- OM2 - stems, plus all unharvested branches and understorey trees were removed (whole tree harvesting).
- OM3 - all logging slash and the whole forest floor were removed.

Stems were removed from all treatments with a line skidder. Branches and understorey trees were removed by hand from the OM2 plots. An excavator carefully removed the forest floor from the OM3 treatments by gently scraping it back into small piles. At no time did the machines travel on exposed mineral soil.

The three compaction treatments were applied by a compaction plate mounted on the arm of an excavator. Figure 3b) The treatments were:

- C0 - no compaction.
- C1- intermediate compaction (a 2 to 3 centimetre impression was made into the mineral soil).
- C2 - heavy compaction (a 5 centimetre impression was made into the mineral soil). This treatment produced conditions roughly comparable to areas subjected to heavy traffic by logging equipment.

Each treated plot was divided in two. Half of each plot was replanted to hybrid white spruce and half to lodgepole pine.

The researchers did not attempt to duplicate actual operational practices at any of the sites. Instead, they attempted to isolate specific effects of soil compaction and organic matter removal during harvesting and site preparation, regardless of how they occur.

Natural processes will be allowed to repair the damage caused by compaction and organic matter loss over time. The long-term effects of these treatments and their recovery rates will be assessed by repeated measurements of tree growth and key physical and chemical properties including soil bulk density, porosity, organic matter and nutrient content. Baseline measurements were taken before the harvest and will be repeated at five-year intervals over at least one whole rotation period.

A number of ancillary studies are planned, including monitoring soil fauna, soil gas composition and water infiltration rates.

Discussion

It is too early to assess conifer response to the treatments applied during 1992 to 1994. However, some interesting preliminary observations of other ecological responses have emerged.

Vegetation response: The vegetation responses are most dramatic at the Prince George site which was established in 1992. There was a considerable decrease in herb and shrub diversity on the OM3 plots where the entire forest floor was removed. The compacted plots, with or without forest floor removal, had greatly reduced aspen sprouting compared to the uncompacted plots. This same effect was observed in the BWBS site at Dawson Creek.

Sedge (*Carex aenea*) rapidly became the dominant herbaceous species on the heavily compacted, bare mineral soil. In fact, this plot quickly took on the appearance of a grassy meadow. (Figure 3c) This vegetative community may be a useful indicator of compacted mineral soils.

Soil gases: The composition of gases in the soil can differ dramatically from the gases present in the atmosphere. Carbon dioxide concentrations are usually higher, reflecting the respiration by plant roots and soil microbes. Early results of soil gas monitoring by Dr. Tim Conlin of the Ministry of Forests Research Branch, suggest that the compaction treatments applied in this study may be affecting soil CO_2 concentrations. At the Prince George site in 1994, CO_2 concentrations in the surface mineral soil of uncompacted treatments were about 3,000 parts per million – almost 10 times

FIGURE 2 - 3x3 treatment design

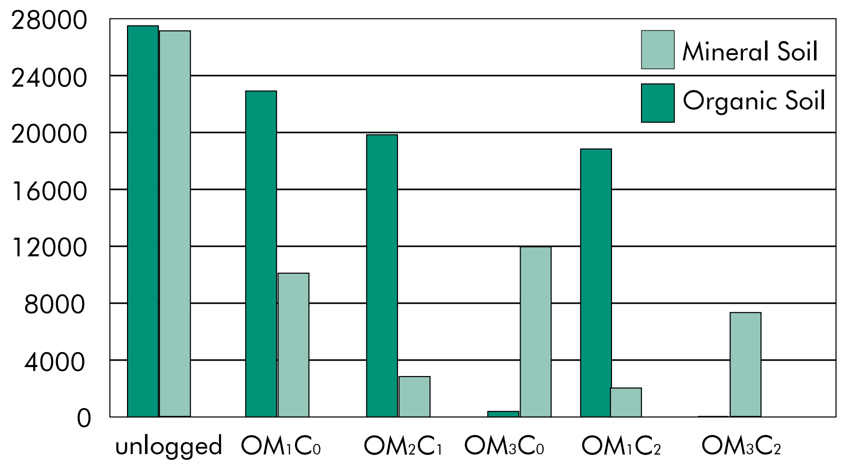
OM_1C_0	OM_1C_1	OM_1C_2
OM_2C_0	OM_2C_1	OM_2C_2
OM_3C_0	OM_3C_1	OM_3C_2

Figure 3a.
Research plot following complete organic matter removal, OM_3 treatment, June 1993.

Figure 3b.
Severe compaction treatment was applied in late June, 1993.

Figure 3c.
About 2 months later, midsummer 1993, sedge rapidly took over following the severe compaction (C2) treatment.

FIGURE 4. Number of soil animals per m² collected from each plot at the Prince George LTSP installation in 1994.



higher than the ambient atmosphere. However, under the compaction treatments, CO_2 concentrations were substantially higher (10,000 to 50,000 ppm). Such high soil CO_2 levels can affect plant growth, either positively or negatively.

Soil fauna: Soil animals, ranging in size from microscopic mites to earthworms, play important roles in the ecological functioning of forest soils. In particular, these organisms assist with plant litter decomposition by chewing and fragmenting larger particles, making them more accessible to microbes. The treatments applied in this research provide a valuable opportunity to examine the effects of soil disturbances on populations of these important organisms.

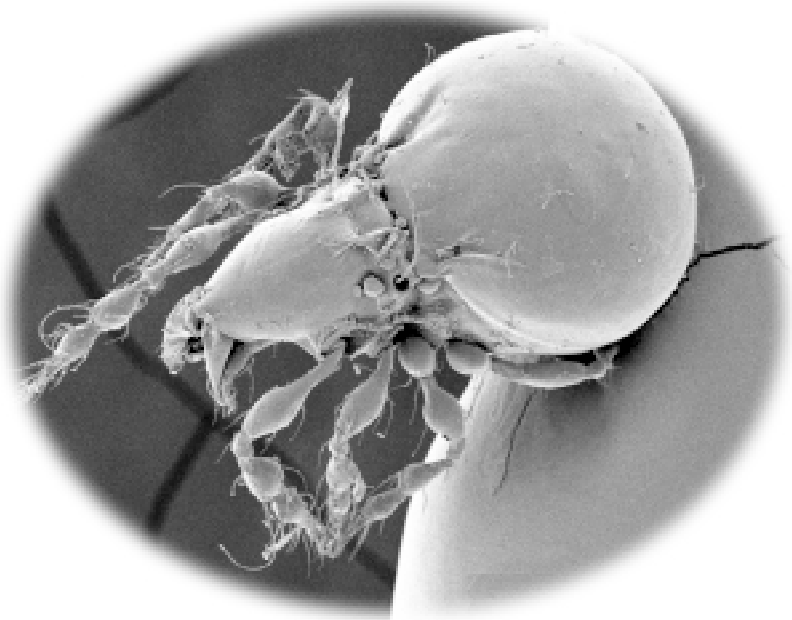


Figure 5. Scanning electron microscope image of an oribatid mite Oppiella nova, a species that is negatively affected by organic matter removal.

For further information
Paul Sanborn, Research Soil Scientist
BC Ministry of Forests, Prince George Region
1011-4th Avenue, Prince George, B.C., V2L 3H9
Phone (604) 565-6100, Fax (604) 565-4349
e-mail psanborn@mforØ1.for.gov.bc.ca

Jeff Battigelli, Ph.D. student at the University of Alberta, has sampled and counted soil fauna populations at the three SBS research sites. Some noteworthy trends are apparent from these early observations (Figure 4):

- There were marked declines in faunal populations on the more severe treatments in 1994, one year after the compaction treatments and two years after organic matter removal treatments were applied on the Prince George site.
- Organic matter removal, especially the forest floor removal treatments (OM3), appear to have a greater effect than compaction on the soil fauna. Populations were lower in all the treated plots, compared to the adjacent undisturbed forest.
- Not all taxonomic groups were affected to same extent — Collembola (springtails), Oribatid mites (Figure 5) and Mesostigmatid mites were particularly affected by forest floor removal.

Conclusions

Definitive conclusions on the effects of these compaction and organic matter removal treatments on conifer growth will not be available for several years.

New information will be collected at regular intervals and this should shed new light on various processes occurring in the establishment and growth phases of plantations. Along the way, it is hoped that this work will offer new insights into the recovery of damaged forest soils.

References

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