Soil compaction and soil organic matter loss: criteria for long-term soil productivity

Berch, S.M.[1], B. Chapman[2], M. Curran[2], S. Dube[3], G. Hope[2], R. Kabzems[3], M. Kranabetter[3]

1. British Columbia Ministry of Forests, Research Branch, Victoria, BC, Canada.
2. British Columbia Ministry of Forests, Southern Interior Forest Region, Williams Lake, Nelson, Kamloops, BC, Canada.
3. British Columbia Ministry of Forests, Northern Interior Forest Region, Prince George, Dawson Creek, Smithers BC, Canada.

Main collaborators: BCMoF Forest Districts & Protection Program, Can. For. Service, USFS, Selkirk College, Univ.of BC, MichiganTech.Univ., UofA, Tembec Industries, Kalesnikoff Lumber

Background

• The Long-Term Soil Productivity (LTSP) study addresses two key soil factors that limit tree growth and site productivity in the timber-harvesting land base and that can be affected by forestry operations, soil compaction and organic matter loss.
• Throughout North America, there are 62 LTSP installations (Bob Powers, USDA Forest Service and co-investigators) (Figure 1).

Figure 1. Network of core and related Long-Term Soil Productivity Study installations in North America.

Objectives

• Determine the effects of different levels of organic matter (above-ground biomass and forest floor) retention and soil compaction on long-term (full timber rotation) forest soil productivity across a range of species, sites and ecological conditions.
• Provide sites that illustrate the effects of soil disturbance on forest productivity for extension and demonstration purposes.
• Provide data on long-term soil productivity to validate policies for sustainable forest management.

Table 1. 3 x 3 factorial design of organic matter removal and soil compaction for LTSP study.

OM0C0 Boles removed No compaction	OM0C1 Boles removed Moderate compaction	OM0C2 Boles removed Heavy compaction
OM1C0 Boles and crowns removed No compaction	OM1C1 Boles and crowns removed Moderate compaction	OM1C2 Boles and crowns removed Heavy compaction
OM2C0 Boles, crowns, forest floor removed No compaction	OM2C1 Boles, crowns, forest floor removed Moderate compaction	OM2C2 Boles, crowns, forest floor removed Heavy compaction

Study Design for British Columbia LTSP sites

• Within each replicate a minimum of nine core treatment plots have been established, representing a factorial combination of three organic matter removal treatments (Table 1).
• Four fully replicated installations now exist in the province (Table 2) and 2 replicates in the ICH are being installed to match the single replicate in Idaho.
• Sites are representative of the zonal ecosystem (medium moisture and nutrient conditions) and replicates have similar soil and site features.
• Each installation is treated as a block in a randomized block, split-plot (2 tree species) design.

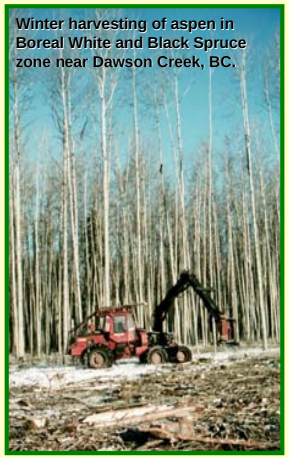
Table 2. LTSP installations in British Columbia.

Site number	Biogeoclimatic zone	Location
BWBS-1,2,3	Boreal White and Black Spruce	40 km N of Dawson Creek
SBS-1 PG	Sub-Boreal Spruce	65 km N of Prince George
SBS-2 SM	Sub-Boreal Spruce	12 km N of Topley
SBS-3 WL	Sub-Boreal Spruce	30 km E of Williams Lake
IDF-1 DC	Interior Douglas-fir	30 km NW of Kamloops
IDF-2 BP	Interior Douglas-fir	50 km N of Kamloops
IDF-3 OL	Interior Douglas-fir	40 km N of Kamloops
IDF Nel-1	Interior Douglas-fir, calcareous subsoil	70 km N of Cranbrook
IDF Nel-2	Interior Douglas-fir, calcareous subsoil	80 km N of Cranbrook
IDF Nel-3	Interior Douglas-fir, calcareous subsoil	75 km N of Cranbrook
ICH-1	Interior Cedar Hemlock	15 km W of Nelson
ICH-2 Selkirk	Interior Cedar Hemlock	5 km E of Castlegar

Achieving treatment levels

• Compaction goals were depression of the mineral soil surface by 2 and 4 cm for moderate and heavy compaction respectively.
• Boles were removed by hand on plots that were to be compacted and then replaced.
• Forest floor was removed using an excavator bucket and by hand from around stumps.

Figure 2. Boles only removed (left) and boles and crowns removed with forest floor scalped (right) at the Sub-Boreal Spruce LTSP installation near Topley, BC.


Winter harvesting of aspen in Boreal White and Black Spruce zone near Dawson Creek, BC.

LTSP Installation in the Boreal White and Black Spruce Biogeoclimatic Zone

Richard Kabzems, Northern Interior Forest Region

•Scalping increased the density of aspen stems in years 1 and 2 (Figure3)

• Compaction did not significantly affect density of aspen stems (Figure 4)

• Scalping decreased aspen stem height in years 1 and 2 (Figure 5)

• Compaction insignificantly decreased aspen stem height in year 2 (Figure 6)


Luvisol at Boreal White and Black Spruce zone LTSP site near Dawson Creek, BC

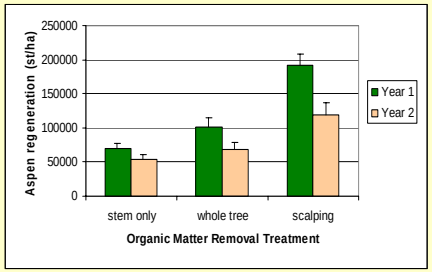


Figure 3. Aspen regeneration in response to organic matter removal.

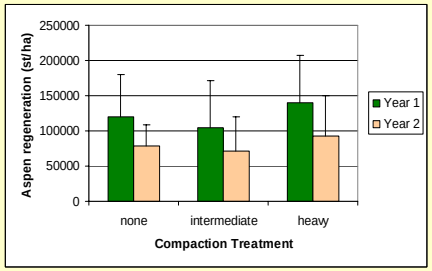


Figure 4. Aspen regeneration in response to soil compaction.

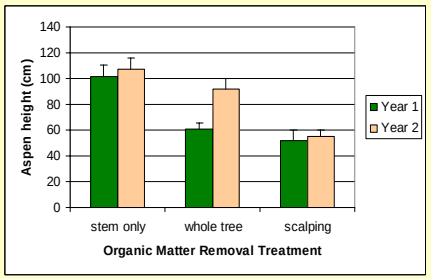


Figure 5. Aspen height in response to organic matter removal.

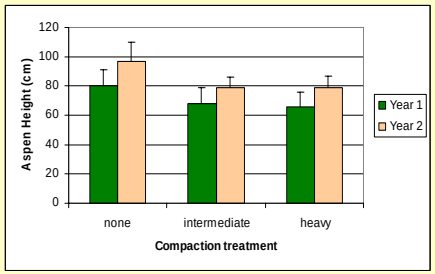


Figure 6. Aspen height in response to soil compaction.

• Whole tree harvesting + scalping significantly decreased spruce height increment in years 1, 2, 3 (Figure 7)

• Scalping significantly decreased spruce height increment over whole tree harvesting in year 3 (Figure 7)

• Intermediate and heavy compaction significantly decreased spruce height increment in year 3 (Figure 8)

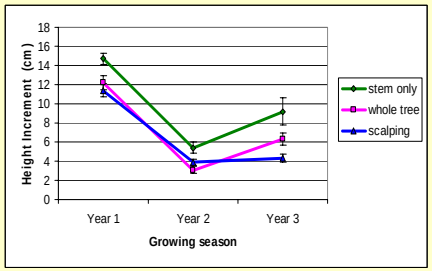


Figure 7. White spruce height increment in response to organic matter removal.

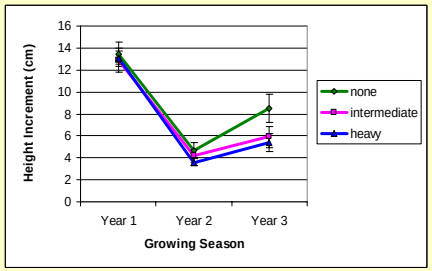


Figure 8. White spruce height increment in response to soil compaction.

LTSP Installation in the Sub-Boreal Spruce Biogeoclimatic Zone

Marty Kranabetter, Bill Chapman, Stephane Dubé, Paul Sanborn (UNBC), Northern Interior Forest Region

• Lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*) growth were not significantly different after 5 years for either compaction or organic matter removal (Table 3).

• Lodgepole pine height showed some trend for increased growth with compaction (p=0.0920), but leader increment at year 5 was similar enough that current differences in growth seem unlikely.

Table 3. 5th year tree height, diameter and height increment for lodgepole pine and white spruce, central British Columbia.

Treatment	Lodgepole pine			White spruce		
	Ht (cm)	Dia (mm)	Inc (cm)	Ht (cm)	Dia (mm)	Inc (cm)
OM0	97.3	23.1	28.0	62.4	14.3	13.3
OM1	95.3	23.2	27.4	64.2	14.7	13.8
OM2	90.6	23.8	28.0	60.1	15.7	8.7
p	*0.7975*	*0.9364*	*0.9500*	*0.7882*	*0.5508*	*0.1484*
C0	92.1	22.0	27.4	64.1	14.9	13.2
C1	93.4	23.3	27.3	60.8	14.5	11.1
C2	97.8	24.9	28.8	61.9	15.2	11.5
p	*0.0920*	*0.1118*	*0.6162*	*0.6357*	*0.7244*	*0.3120*
OM x C *p*	*0.2996*	*0.2136*	*0.2226*	*0.7266*	*0.9409*	*0.8671*

• White spruce increment had decreased by approximately 50% after organic removal and compaction, which might become significant over time.

• Early growth in central British Columbia is slow and after 5 years both tree species were still approaching breast height (1.3 m).


Uncut forest control in sub-boreal spruce zone near Topley, BC


Early vegetation response at Log Lake to bole only removal with no soil compaction

•Two of the SBS sites are in year 10 this year and the third in 2004, so 10 year results will be available soon.


Early vegetation response at Log Lake to scalping and heavy soil compaction

Grass competitor response to LTSP treatments


Calamagrostis rubescens on LTSP site at O'Connor Lake, BC

• Percent cover of vegetation species has been determined in the years following treatment application

• *Calamagrostis rubescens* was reduced by severe organic matter removal but not by compaction (IDF LTSP site, Kamloops, Graeme Hope).

• *Calamagrostis canadensis* was increased by compaction where organic matter was retained (BWBS LTSP site, Richard Kabzems).

LTSP sites in the Interior Cedar Hemlock Biogeoclimatic zone

Mike Curran, Southern Forest Region, and Deborah Page-Dumroese, Rocky Mountain Research Station, USDA Forest Service

• Replicate 1 near Priest Lake, Idaho, is in Year 11


Planting Royer Creek rehab plot in spring 2003

• Replicates 2 and 3 near Castlegar, BC, are in Years 0 and 1

Operational mini-plots

Doug Maynard & Brian Titus, Pacific Forestry Centre, Mike Curran

•Treatments:
- undisturbed no compaction
- undisturbed light compaction
- undisturbed heavy compaction
- deposit no compaction
- shallow gouge no compaction
- shallow gouge light compaction
- deep gouge no compaction
- deep gouge light compaction

• Douglas-fir and lodgepole pine were planted


Deep gouge