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Seedling Growth on Disturbed Soils in Alternative Silvicultural Systems of Coastal British Columbia's Montane Forests

John P. Senyk

Strategic Importance

The mid to high elevation forests of coastal British Columbia have become an increasingly important source of fibre for industry and employment for coastal communities. However, the montane Coastal Western Hemlock (CWH) and the subalpine Mountain Hemlock (MH) biogeoclimatic zones-ecosystems within these elevations-have relatively harsh climates, and their soils are sensitive to disturbance. Maintaining the productivity of montane forest by protecting the inherent quality of the soil is crucial to the future well-being of the forest and to ecosystem integrity.

Ground based harvesting in mid to high elevation, coastal forests creates soil disturbances which affect forest productivity.

Three major forest management problems with these high-elevation ecosystems have been:

- Poor regeneration and growth following clearcut harvesting;
- Loss of soil productivity; and,
- Land slides and mass wasting on steep terrain.

Public concerns over the long-term sustainability of forested ecosystems have placed growing pressure on forest managers to reduce the size and number of clearcuts, and to employ alternative "partial cut" harvesting techniques. However, alternative silvicultural systems and intensive forestry practices that use partial harvesting regimes increase the number of entries into a stand, thereby increasing the potential for soil disturbance and loss of soil productivity. One measure of soil productivity is the growth response of seedlings.

The Montane Alternative Silviculture Systems (MASS) study was established in part to research the biological consequences of alternative silvicultural systems, such as the impacts on seedling growth and productivity caused by harvesting disturbances.

MASS has elevations ranging from 740 to 850 m on slightly to moderately hummocky terrain (slopes generally less than 20%) with a northerly aspect. To study the impacts of different silvicultural systems, 170 ha. of old-growth forest was divided into five treatments: clearcut; patch cut, green tree retention, shelterwood, and retained old growth as the control. A "hoe-chucking" technique with an excavator was used for all extraction except in the shelterwood treatment and some parts of the green tree retention treatment where a grapple skidder was used.

The soils at the MASS site are characterized as follows:

- The main soil groups are Ferro-Humic Podzols, Folisols and minor organic soils;
- The parent material is calcareous;
- Surficial deposits are generally deeper than 1 m;
- Soils are relatively fine in texture and moist to wet for most of the year;
- Inherent total mineral soil bulk density for soils ranged from 0.8 g/cm^3 at the surface to 1.2 g/cm^3 at a depth of 35 cm; and,
- Repeated travel on the relatively fine textured soils destroyed much of the soil structure in the upper 20 cm.

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In the MASS soils, bulk densities would have to be 1.4 g/cm^3 and greater in the seedling rooting zone before there would be a noticeable effect on seedling growth.

Soil Disturbance

Ground-based harvesting has the greatest potential for soil disturbance. It can either negatively or positively affect the long-term yield and quality of second-growth forests. Soil disturbance, such as compaction and displacement, affects soil density, nutrients, hydrology and microclimate, and therefore affects soil productivity. The following observations were made at the MASS study:

- The total soil disturbance resulting from all causes (equipment travel, log gouging, stump removal, etc.) on all treatments averaged 22%.
- Soil disturbance levels in all treatments did not vary by more than 2%.
- Increases in total soil bulk density of the forest floor (LFH) ranged up to 90% in the skidtrail tracks.
- In the mineral soil, increases in total soil bulk density ranged from 15% to about 50% in the upper 20 to 30 cm.

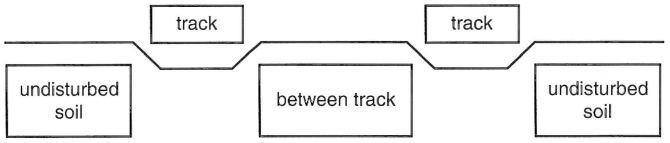

Figure 1

Soil conservation guidelines based mostly on experiences with clear cutting have been developed for harvesting, site restoration, and mechanical site preparation. Although the types of soil disturbance may be similar with alternative silvicultural systems, the extent and severity of the soil disturbance will likely differ. Disturbed soil rehabilitation techniques may have to vary with treatment types.

The degree of soil disturbance varies with the type of equipment used, the number of passes, and the soil type. The type and severity of soil disturbance also varies in different parts of a skidtrail, so the effect of soil disturbance was examined on undisturbed soil on either side of the skidtrail, on the tracks, and in the area between tracks (Figure 1). Soil rehabilitation also alters the soil characteristics - this varies with the type of disturbance.

Soil Disturbance Impacts of Equipment

Excavator, Single-pass Tracks

In treatments where the excavator operated alone, as in the clearcut, patch cut and the green tree retention areas, total soil bulk densities in the tracks (after a single pass) were approximately 15 to 20% greater (to a depth of 30 cm) than in the undisturbed soil. This increase was due largely to the collapse of voids and natural aggregates. Excavator travel on steeper slopes resulted in forest floor displacement, and exposure and minor displacement of mineral soil. In wet depressions, the excavator caused severe rutting and displacement.

Excavator and Grapple Skidder

In treatments where both the excavator and the flexible track grapple skidder traveled on the same trails, as they did in the shelterwood corridors, the soil was more severely impacted. Bulk density increased 25 to 30% over inherent values in the upper 30 cm. In the fine-textured soils, natural aggregation and much of the associated macroporosity collapsed, creating puddled soils. These compacted soils generally have increased soil strength, lower aeration porosity, and modified temperature and moisture regimes.

Excavator, Disturbances Between Tracks

Total soil bulk density in the between track portion of the skidtrails was 15 to 20% greater than in undisturbed soil in the upper 15 cm. It became slightly less than the density of the track with increasing depth. Fine soil bulk densities were 0.3 g/cm^3 less at all depth increments.

Soil Disturbance Impacts on Western Hemlock and Amabilis Fir Seedling Growth

Seedling growth or soil productivity can be limited by modifying any of the soil's interdependent factors including soil strength, aeration porosity and nutrients. Generally, the greater the number of equipment passes, the more severe the soil damage and the greater the reduction in soil productivity. Slash, particularly large pieces, left on the surface following limbing and bucking at the stump buffered the underlying mineral soil from immediate compaction. Once the slash was broken down by successive equipment passes, the mineral soil became rutted and compacted. This compaction limited seedling growth.

Where yarding was done by an excavator alone on well to moderately well drained soils, seedlings grew better on all disturbance types in the clearcut and the patch cut treatments than in the shelterwood and the green tree retention treatments (figures 2 and 3). Where yarding was carried out by both excavator and skidder in the shelterwood area and some parts of the green tree retention treatment area, seedlings were generally taller on the undisturbed soil than on the rehabilitated trails and skidtrail tracks.

For most disturbance types (Figures 2 and 3), height growth of western hemlock and amabilis fir after three growing seasons was greatest in treatments with the least retained overstory, i.e., height growth was greatest in clearcuts and patchcuts, less in the green tree retention treatment, and still less in the shelterwood treatment on disturbed soil.

The survival of amabilis fir after three growing seasons was better than that of western hemlock in all treatments and all disturbance types in the cross-section of skidtrails. Amabilis fir growth was much better than western hemlock on the most severely disturbed soils, such as the skidtrail track and the rehabilitated soil.

Increases in total soil bulk density of the forest floor (LFH) ranged up to 90% in the skidtrail tracks.

In the clearcut, the height of western hemlock seedlings on undisturbed soil was not significantly different from those on rehabilitated soils. In all other treatments, the height growth of western hemlock and amabilis fir seedlings on undisturbed soil was significantly greater than on rehabilitated skidtrail soil.

Although the three year height measurements of the MASS study are early indicators of productivity, they should not be taken as forecasts of long-term trends.

Rehabilitated Skidtrail Soils

The main objective of soil rehabilitation at the MASS site was to decrease soil bulk density, thereby increasing soil productivity. The success of skidtrail rehabilitation was affected by:

- levels of compaction and displacement;
- depth to which the excavator penetrated;
- soil moisture regime;
- soil type;
- horizons intersected;
- how the soil was redeposited on the surface during tilling; and,
- the level to which soil structure and porosity had been affected (puddled).

Rehabilitated skidtrail soils had a soil bulk density at the surface equal to the inherent soil density. This decreased sharply to the 15-20 cm depth. Indications are that the average depth of penetration of the excavator shovel in rehabilitating single pass skidtrails was 40 cm and that the greatest loosening of the soil took place in the upper 30 cm.

Rehabilitation of skidtrails was effective in loosening soil to a depth of 35 cm. On rehabilitated single-pass skidtrails, total soil bulk density averaged as much as 50% less than on the non-rehabilitated skidtrail track. However, total bulk density of rehabilitated soils (upper 20 to 30 cm) on heavily traveled skidtrails (excavator and skidder) was only slightly less than that found in the tracks of the skidtrails themselves.

On the single-pass skidtrails, tilling the running surface

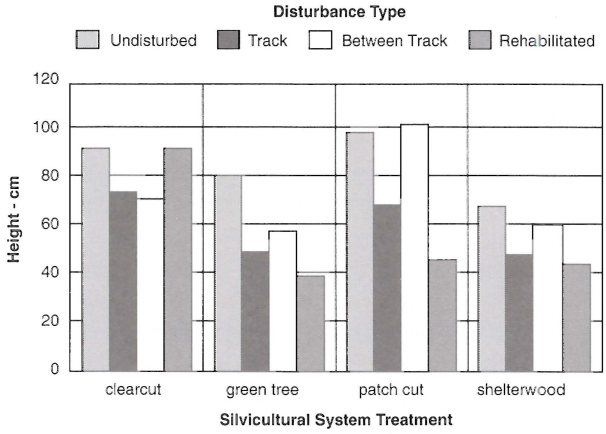

Figure 2. Height of western hemlock by disturbance type

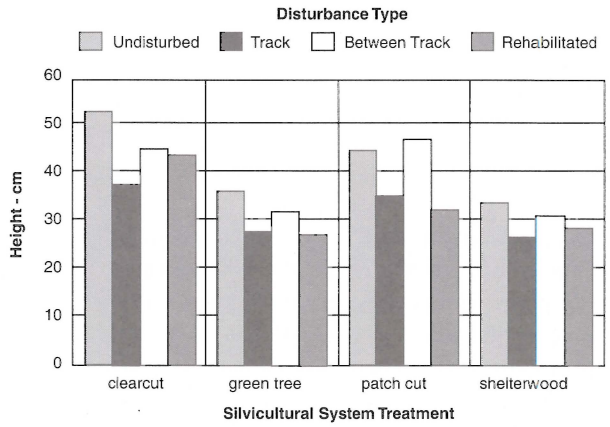

Figure 3. Height of Amabilis fir by disturbance type

decompacted the soil and restored much of the original structure and porosity, at least in the short term. However, it may not be possible to restore porosity and structure in severely impacted (puddled) soils with permanently moist to wet organic and mineral characteristics.

On rehabilitated skidtrails in the shelterwood treatments, there was very little difference in the bulk density of the tilled and untilled track soil. Natural soil amelioration processes are improving conditions on untilled tracks in the shelterwood treatments.

Restoring Productivity

Findings to date indicate that restoring site productivity requires:

- careful assessment of the properties of disturbed soils and site conditions,
- an evaluation plan to enhance soil physical (structure, porosity) and chemical (nutrients and organic matter) properties,
- precise matching of equipment and operational techniques to ecosystem type, and,
- evaluation of the suitability and effectiveness of the treatments across a range of ecosystems using the long-term performance of planted seedlings.

Seedling height, a reflection of productivity, is affected by the moisture and soil characteristics in the rooting zone. Within the clearcut (where the excavator alone operated) rehabilitation was effective because soils were not as severely damaged as in the shelterwood treatments where both the excavator and skidder traveled. Growth was poorer in the partial cuts and the green tree rehabilitation sites due to wet soil conditions.

Soil drainage characteristics on skidtrails and rehabilitated trails are different from those on undisturbed soil. Many of the yarding corridors followed natural drainage channels where the relatively hummocky topography was subdued because this allowed easier equipment travel. Soils in these channels were subjected to overland water flow during a large part of the growing season. Consequently, there was 90% seedling mortality on rehabilitated soils in parts of the green tree retention and patch cut treatments.

Decompaction of skidtrails, using an excavator to till the soil, effectively loosened the skidtrail running surface in all treatments. However, on the heavily impacted skidtrails in the shelterwood treatments, bulk density in the upper 20 to 30 cm of rehabilitated soil was the same as or only slightly less than the density of the untilled track immediately after treatment.

Natural amelioration processes appear to be reconsolidating some rehabilitated mineral soils on the trail segments, particularly in wet areas. On skidtrails, some natural decompaction is taking place in the upper 5 cm of the more severely compacted trail sections. This is likely due to frost-heave during spring and fall freeze-thaw cycles. In compacted and puddled trails in the shelterwood treatments, decomposition of finer woody material appears to be improving soil conditions near the surface.

Management Implications

Planting in skidtrail tracks, particularly in heavily traveled shelterwood corridors, should be avoided.

Mechanical restoration of desirable properties (physical, chemical and biological) to disturbed soils can help restore soil productivity. On the single-pass skidtrails, tilling the skidtrail running surface was effective in decompacting the soil.

However, tilling may fail to restore porosity and structure of severely puddled, mineral soils even in the short term.

Soil rehabilitation can be effective if the nature of the disturbance and impact on species growth are clearly understood and if appropriate techniques that recognize the interdependent nature of site and soil processes are used.

Laying slash on skidtrails where mineral soil may become seriously disturbed will buffer detrimental soil impacts.

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Contact:

John Senyk, Canadian Forest Service, Pacific Forestry Centre, 506 West Burnside Rd. Victoria, B.C. V8Z 1M5
250-363-0688, email: jsenyk@pfc.forestry.ca

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