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Effects of Skidroads on Soil Properties and Forest Productivity on Steep Slopes in Interior British Columbia

J.P. Senyk and D. Craigdallie

Strategic Importance

The effects of forestry operations on soil productivity are a serious concern in British Columbia. Maintaining the quality of the soil is crucial to the future well-being of the forest and to sustaining ecosystem integrity. Utzig and Walmsley (1988) estimated that soil degradation from forestry operations reduced annual wood yield by 400 000 m^3 over a 10-year period (1976–1986) and that this was increasing by about 50 000 m^3 each year. Planting trials can be used to assess the effects of those forestry practices by using the seedling's performance as a bioassay of site conditions.

Although the use of aerial or cable systems has been increasing steadily over the past few years wherever terrain characteristics are suitable, forest harvesting throughout most of interior British Columbia is ground-based and highly mechanized. Displacement and compaction are the most common forms of soil degradation caused by ground-based skidding and harvesting.

Harvesting and skidroad construction on steep slopes

Most of the potentially detrimental soil disturbance associated with ground-based systems takes place on steep slopes in mountainous terrain ranging in slope from 30 to 50%. Soil disturbance is related to skidroad construction, cross-contour skidding, and improper rehabilitation or drainage control measures. These disturbances can result in mass wasting and erosion.

Techniques involving a variety of large machines for extracting timber and for the construction of skidroads have evolved. On slopes greater than 30–35%, low ground pressure (LGP) track skidders or crawler tractors are used and skidding patterns are controlled by the operator. Rubber-tired skidders requiring skidroads are also commonly employed on mountainous terrain. The number of stems per hectare and tree size tend to dictate the size of equipment required, as well as the width and spacing of skidroads.

Seedling survival, vigor and growth are strongly related to the disturbance type on skidroads.

Soil disturbances related to skidroads

The degree and severity of soil disturbances from ground-based operations on steep slopes are influenced by the following factors:

- topography;
- season of operation and snowpack;
- size of equipment;
- skidroad and skidtrail layout;
- forest stand characteristics;
- soil type;
- number of equipment passes;
- soil moisture;

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- depth of forest floor; and,
- amount of surface woody debris.

The soil properties affected by skidroads are:

1. **Soil bulk density:** On skidroads with cut-and-fill construction, particularly in morainal material, soil bulk density is higher on the inside track (upslope side, most deeply cut) than between the tracks and on the outside track, the latter generally being an area of fill. Skidder traffic can compact the skidroad running surface resulting in total soil bulk density values that are well above the threshold level considered to impede root development (1.4 Mg/m^3).
2. **Soil porosity:** Compaction decreases soil porosity. Total soil porosity below about 30% is reported to inhibit Douglas-fir seedling growth.
3. **Soil chemistry:** The removal or redistribution of soil nutrients in the forest floor and upper mineral soils can lead to changes in soil chemical and biological properties and subsequent changes in soil productivity.

Physical, chemical, and biological modifications of soil can reduce soil productivity and long-term forest growth. The relationships between soil modifications and productivity is heavily influenced by the biogeoclimatic zone, soil type, site characteristics, severity of disturbance and the tree species used for regeneration.

The Study

In response to concerns that ground-based harvesting operations on steep slopes were causing excessive levels of detrimental soil disturbance, three different clearcut blocks (Figure 1) in the Golden Forest District were studied. One cutblock was located within the Interior Cedar–Hemlock (ICH) biogeoclimatic zone and two were within the Engelmann Spruce–Subalpine Fir (ESSF) biogeoclimatic zones.

The main purpose of these studies was to:

A. determine the impact of specific forestry practices on ecosystem characteristics such as micro-climate and soils, and on seedling performance; and,

B. quantify the relationships between forestry practices, disturbed soil and seedling growth within each ecosystem type.

Conventional harvesting systems were employed, including manual felling and a combination of rubber-tired and tracked-line skidders. The areas on and immediately adjacent to the contour skidroads (Figure 2) were categorized into:

1. Inner track (portion of road on the upslope side, most deeply cut);
2. Between tracks;
3. Outer track (downslope side, generally an area of deposit or fill);
4. Berm (fill material at edge of running surface) and sidecast (fill material on down slope side of skidroad); and,
5. Undisturbed (outside of the skidroad-related disturbances).

Western larch, lodgepole pine and Engelmann spruce seedlings were planted in four disturbance types on the skidroad running surface and in the undisturbed soil adjacent to the skidroads. Tree height growth and micro-climate were monitored for three growing seasons after planting. Three-year measurements are early indicators of productivity but should not be taken as forecasts of long-term trends.

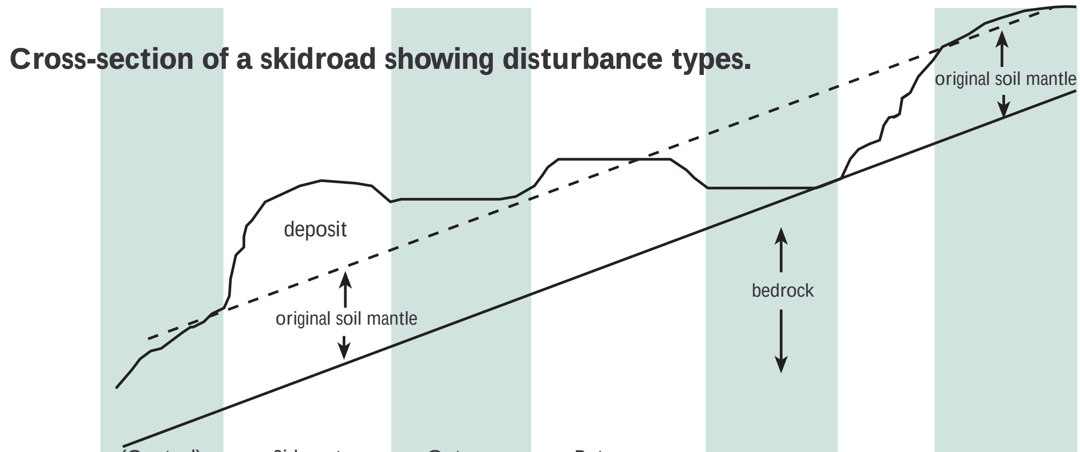
Results by Block

117 Block (ICHmw1):

In the 117 block, the berm had slightly higher organic C and N concentrations than the other disturbance types and the undisturbed soil. The undisturbed soil and the berm (low bulk density and high soil porosity) were more favorable for seedling growth than all disturbance types. At all soil depths up to 50 cm, soil bulk densities of the inner track and between tracks exceeded the suggested threshold level for tree growth of 1.4 Mg/m^3. The soil porosity of the inner and between track disturbance types was often below the acceptable lower limit (30%) thought to affect root growth. On the outer track, the porosity was above 30% only in the upper 20 cm of soil.

	117 Block	Dainard Block	Small Business Block
BGC zone/variant	ICHmw1	ESSFdk	ESSFwc2
Area (ha)	120	8.1	26.3
Mean elevation (m)	1050	1750	1725
Mean slope	40%	42%	43%
Aspect	S/SW	SW	E
Soil type	Orthic Eutric, Dystric, Brunisol silt loam – sandy loam	Orthic Eutric Brunisol silt loam	Orthic and Gleyed Humo-Ferric Podzol loam – sandy loam
Coarse fragments	30–40%	30–40%	50%+
Tree species planted	Western larch Lodgepole pine Engelmann spruce	Lodgeple pine Engelmann spruce	Engelmann spruce

Figure 1. The three cutblocks used to assess the effects of disturbance.



Key Factors of Productivity	(Control) Undistrurbed	Sidecast Berm	Outer Track	Between Track	Inner Track	Cutbank	Undisturbed
Soil Porosity (%) depth:							
0–30cm	>30	>>30	>30	>30	low (<30%)		
30–50cm	%>30	>>30	>30	usually >30	N/A		
Soil bulk density 0–30cm	<1.4	<<1.4	usually <1.4	usually <1.4	always >1.4		
(Mg/m^3) 30–50cm	often >1.4	N/A	>1.4	>1.4	>>1.4		
Water Erosion			more active	some erosion	more active	soil ravelling	
Tree Height Performance							
Engelmann spruce	good	fair	fair	fair	poor		good
Lodgepole pine	fair	good	fair	fair	poor		fair
Western larch	fair	good	good	good	poor		fair

Figure 2. Effects of skidroad disturbances on soil properties and seedling growth.

All three tree species (Engelmann spruce, western larch, and lodgepole pine) performed significantly better on the berm than on the other disturbance types or the undisturbed soil. This is believed to be the result of a combination of higher organic C and N concentrations, favorable soil moisture conditions, low soil bulk density and high soil porosity of the berm. Tree growth was consistently poorer in the inner track. Lodgepole pine performed relatively poorly on undisturbed sites.

Dainard Block (ESSFdk):

The berm in this block contained slightly higher levels of organic C than the other disturbance types and the undisturbed soil. Although the level of calcium and the pH of the upper 10 cm of soil were significantly higher in all disturbance types than in undisturbed soil, nutrient availability was not severely affected. The bulk density of the inner track disturbance types in the upper 20 cm was only slightly above threshold level, while soil porosity was considered acceptable in all disturbance types. Undisturbed soil generally had lower bulk density and higher porosity than disturbed soil.

Engelmann spruce seedlings performed significantly better in the undisturbed soil than on disturbed soils in this block. Lodgepole pine performed slightly less favorably on inner and between track disturbances than elsewhere.

Small Business Block (ESSFwc2):

Total soil bulk density of the inner and outer tracks in this block were often well in excess of 1.4 Mg/m^3 at all soil depths. The mean bulk density of all disturbance types (except the berm), as well that of the undisturbed soil, exceeded 1.4 Mg/m^3 at depths greater than 20 cm. Only in the inner track did the average soil porosity fall below the 30% lower threshold level.

Engelmann spruce in this block performed best on undisturbed sites; growth was poorest on the inner track.

General Results

Due to differences between trial sites – soil properties, biogeoclimatic zones and variants, and other uncontrolled variables – results should be compared with caution. However, the following results were consistent in all three study locations.

1. The study confirms that seedling vigor and growth is strongly related to the disturbance type on skidroads.
2. Engelmann spruce height growth after three years was more sensitive than that of lodgepole pine or western larch to soil disturbances.
3. Growth and vigor of all three species was generally poorest on the inner track.

4. Skidtrail tracks generally had low soil porosity, high bulk density, and a high susceptibility to water erosion. These factors contributed to reduced productivity.
5. Soil ravelling on skidroad cutbanks was common. Soil erosion and deposition resulted in both exposed roots and buried seedling stems, particularly on the inner and outer tracks.

Management Implications

1. In areas where skidroads have not been rehabilitated, the inner track and cutbank should not be planted.
2. On deeply cut skidroads, the area between the tracks and the outer track should be avoided as well.
3. Plant suitable, seral species such as lodgepole pine and western larch on disturbed soils.

Particular attention should be paid to minimizing the frequency, width and length of skidroads, thereby reducing soil disturbance. Planning skidroad locations on cutblocks prior to harvesting may also help reduce soil disturbance compared to the conventional or operator-choice method of skidroad location.

Additional Reading

Ballard, T.M.; Carter, R.E. 1986. Evaluating forest stand nutrient status. B.C. Min. For. Land Manage. Rep. 20. 60 p.

B.C. Ministry of Forests and B.C. Ministry of Environment. 1995(a). Hazard assessment keys for evaluating site sensitivity to soil degrading processes guidebook. Victoria, B.C. For. Prac. Code Guidebook. 24 p.

B.C. Ministry of Forests and B.C. Ministry of Environment. 1995(b). Soil conservation guidebook. Victoria, B.C. For. Prac. Code Guidebook. 17 p.

Lewis, T. and the Timber Harvesting Subcommittee. 1991. Developing timber harvesting prescriptions to minimize site degradation. B.C. Min. For. Victoria, B.C. Land Manage. Handb. No. 62.

Senyk, J. P.; Craigdallie, D. 1997. Effects of harvesting methods on soil properties and forest productivity in interior British Columbia. Canadian Forest Service, Effects of Forestry Practices Network, Pacific Forestry Centre, Information Report BC-X-365.

Senyk, J. P.; Smith, R. B. 1991. Estimating impacts of forest harvesting and mechanical site preparation practices on productivity in British Columbia. Proc. International Energy Agency/Bioenergy Implementing Agreement T6/A6 Workshop, Fla., Feb. 1990. IEA/BE T6/A6 Rep. No. 5.

Senyk, J.P.; Smith, R.B. 1988. Forestry practices and soil degradation in B.C., Proceedings of the 69th annual meeting of the Woodlands Section, Cdn. Pulp Paper Assoc., W.S.I. No. 3071 (bi.) F-1 ODC 114.5.

Utzig, G.F.; Walmsley, M.E. 1988. Evaluation of soil degradation as a factor affecting forest productivity in British Columbia. A problem analysis. FRDA Report 025. Canadian Forest Service/BC Ministry of Forests. Victoria, BC.

Warila, J.; Boyle, J.R. 1995. The effects of forest practices on soil. Coastal Oregon Productivity Enhancement program. Report Vol. 8, No. 2. Oregon State Univ. Newport, OR. 3p.

Wass, E. F.; Smith, R. B. 1997. Impacts of cross-contour skidroads on properties of a gravel sandy loam soil and on planted seedling performance. Canadian Forest Service, Effects of Forestry Practices Network, Pacific Forestry Centre, Information Report BC-X-369.

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Contacts

John Senyk
Canadian Forest Service
Pacific Forestry Centre
506 West Burnside Rd.
Victoria, B.C. V8Z 1M5
250-363-0600
email: jsenyk@pfc.forestry.ca

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