TECHNOLOGY TRANSFER NOTE
Forestry Research Applications Pacific Forestry Centre Number 26, June 2001

Tree Growth on Displaced and Compacted Soils

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Strategic importance

Maintaining or enhancing inherent soil productivity (the capacity of unaltered soil to grow trees) is critical to managing sustainable forests. Since all forestry practices alter soil, it is important to identify those soil properties (physical, chemical and biological) that play a pivotal role in affecting tree growth. In British Columbia, controlled soil studies and plantation trials, established following forestry operations, provide ample evidence of the effects that disturbed soils have on long-term tree growth. Using this approach, research efforts remain current and keep pace with evolving forestry practices.

Nearly all the intensively monitored long-term plantation trials established on disturbed soils in British Columbia are located in clearcuts and only a few are older than ten years. Stable relationships between tree growth and altered soils are often not established until plantations have reached at least 15 to 20 years of age. It is almost impossible to accurately predict soil disturbance impacts on tree growth at rotation age using data from plantations younger than this.

Growth influences

The baseline for measuring soil productivity is the performance of planted seedlings on harvested but otherwise undisturbed soil. Deviations in growth from this baseline (positive or negative) that occur on the various disturbance types can generally be related to soil physical properties. Bulk density is a key soil property affecting both the quality (aeration) and the quantity (penetrability) of root growing space. Evaluating soil chemical properties, site microclimate and foliar nutrient levels may further strengthen tree growth - soil bulk density relationships. However, the roles these factors play are often difficult to interpret.

Forest practices alter soils.
Soil conditions are fundamental to tree growth.

Notwithstanding the differences in biotic and abiotic factors between sites (differences in macro-microclimates, parent material, soil types, severity of disturbance, species planted and vegetation competition), the pattern of seedling survival and growth on disturbance types for all species appears similar among all sites.

Field trials

Trial plantations established on displaced, mixed and compacted topsoils and subsoils associated with skidroads and skidtrails have been evaluated in four clearcut blocks near Golden, British Columbia. Two of the study areas (Block 117 and Marl Creek) were located in the ICHmw1 biogeoclimatic variant, a third area (Small Business Block) was in the ESSFwc2 variant and the fourth area (Dainard) was in the ESSFdk variant. This range of ecosystems (low to high elevation) approximated a climatic gradient from warm and moist to cold and wet to cold and dry.

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Growth of Englemann spruce and lodgepole pine seedlings was measured annually for the first five years after the trial was established, and then again seven and ten years after establishment.

Ideally, the same species and stock types would have been planted in all areas in the year the trial was established so that performance could be monitored over the same number of growing seasons; however, ecosystem differences and operational logistics prevented this. Englemann spruce and lodgepole pine were both planted in most areas in the year of establishment, but spruce was planted at the Small Business Block and lodgepole pine was planted at the Dainard site one year later, so these seedlings are younger than others in this trial by one growing season.

Recognizing that tree growth is a function of a host of other factors besides soil, attempts were made to control and quantify as many biotic and abiotic factors as possible. Seedlings from the same seedlot and stock type used in the operational planting were planted in each block. The seedlings were given ample growing room for at least 10 years, after which time they were spaced. Competing vegetation was controlled and site microclimate was monitored over the life of the study.

In order to examine seedling performance on disturbed soils among cut blocks, the growth of Engelmann spruce and lodgepole pine on similar skidroad-related disturbance types was compared. Engelmann spruce and lodgepole pine were common in three of four cut blocks. Although there were considerable differences in soil types and soil properties among blocks, the disturbance types in relation to skidroads were similar in form and physical condition in all the blocks.

Relationships between tree growth and disturbed soils

The performance of Engelmann spruce planted on the various disturbance types (Figure 1) can be directly related to the climatic gradients between ecosystems (warm, moist; to dry, cool; to cold and wet). The best performance occurred at Block 117 (warm and moist) followed by Small Business Block (cold and wet) followed by Dainard (cold and dry). Lodgepole pine (Figure 2) followed a similar pattern. It had the greatest stem volume after ten years (i.e. after 9 or 10 growing seasons) at Block 117 followed by Marl Creek and Dainard.

In nearly all areas, the average volume of seedlings after nine and ten growing seasons was least on the inner track, an area of exposed and compacted inherently dense subsoils, and greatest on the berm, an area of deposited and mixed topsoil and subsoil that generally was not compacted. The exceptions to this were at Marl Creek and Dainard: lodgepole pine performed slightly better on undisturbed soil at Marl Creek and on the outer track at Dainard.

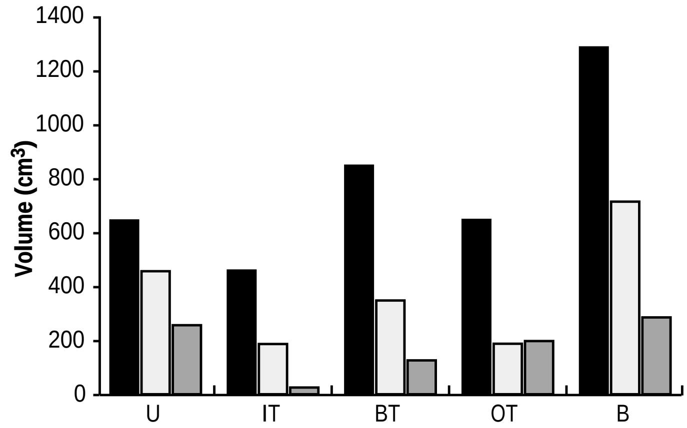

Figure 1. Volume of Engelmann spruce seedlings by disturbance type

- after ten growing seasons at Block 117 (ICHmw1, elevation 1050 m)
- after nine growing seasons at Small Business Block (ESSFwc2, elevation 1700 m)
- after ten growing seasons at Dainard (ESSFdk, elevation 1750)

U = undisturbed; IT = inner track; BT = between track; OT = outer track; B = berm.

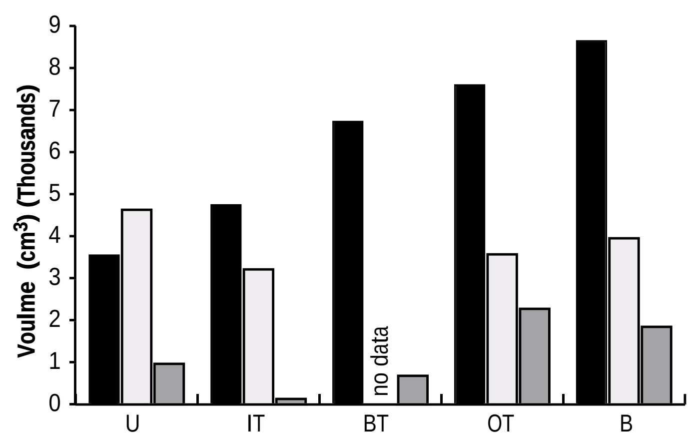

Figure 2. Volume of lodgepole pine seedlings by disturbance type

- after ten growing seasons at Block 117 (ICHmw1, elevation 1050 m)
- after ten growing seasons at Marl Creek (ICHmw1, elevation 1200 m)
- after nine growing seasons at Dainard (ESSFdk, elevation 1750 m)

U = undisturbed; IT = inner track; BT = between track; OT = outer track; B = berm.

Characteristics and properties of disturbance types

Bulk density and porosity of disturbed and undisturbed soils, averaged for all areas, are described in Tables 1 and 2. Bulk density on the inner track was always high, most often well above what is considered to be the growth-limiting threshold (about 1.4 g/cm^3). The total percentage porosity was generally low on the inner track, frequently below the level where severe growth impacts can be expected (30-35%). On the berm, bulk density in the upper 30 cm was generally low, often similar to and occasionally lower than that of undisturbed soil and the percentage porosity often as high or higher than that of undisturbed soil. These properties varied in the other disturbance types on the skidroad running surface.

There were no consistent relationships between total soil nitrogen percentage and disturbance type. Higher concentrations generally occurred in the between track, undisturbed, berm and outer track. There were no clear relationships between soil chemical properties, foliar nutrient concentrations and tree growth. The variability in disturbed soil chemistry and foliar nutrient concentrations are affected by factors other than soil nutrient amounts. Variations in soil moisture, soil porosity, rate of tree growth and species utilization can affect nutrient absorption which in turn can be reflected in foliar concentrations. These factors make interpretation of nutrient deficiency levels difficult.

Available potassium was consistently higher in the inner track and berm and outer track. No trends between phosphorus concentrations and disturbance type could be determined.

Calcium was always highest in the outer track and berm. Although concentration levels were higher on calcareous parent material, the relationships with disturbance type were identical in all areas.

Management Implications

1. Ecosystems studied to date show that total soil bulk density and the percentage porosity of disturbed soils are directly related to seedling performance.
2. Research indicates that trees planted in disturbed soils often grow better than those growing in undisturbed soil over the first 10 to 15 years. The berm disturbance types are an example where seedlings out-performed those growing on most other disturbance types. Typically, soils on the berm were comprised of displaced, mixed and re-deposited topsoil and subsoil. They had initial soil bulk density values that were equal to or lower than, and total percent porosity higher than, that found in undisturbed, surface mineral soil.
3. Forestry practices such as site preparation and soil rehabilitation activities that decrease bulk density and increase porosity are likely to increase tree growth in most soil types and across a broad range of ecosystems and climatic regimes.
4. Soil textures in interior studies to date have ranged from gravelly sandy-loam to clay loam with coarse fragment content ranging from 30 to 50%. Little information is available on coarser textured soils (gravelly, sandy). One study in coastal British Columbia found that an 8 to 10% increase in total bulk density over the undisturbed soil on a gravelly-loamy sand, glaciofluvial deposit (coarse fragments 70%) improved survival and growth of western hemlock seedlings. Moisture measurements indicated a more favourable moisture regime in the compacted track than in undisturbed soil.

Table 1. Total soil bulk density (g/cm^3) by disturbance type and depth class, averaged for all areas.

Depth (cm)	Undisturbed	Berm	Outer Track	Between Track	Inner Track
0-10	0.92	1.06	1.36	1.23	1.60
10-20	1.22	1.07	1.45	1.39	1.75
20-30	1.46	1.23	1.60	1.66	1.81

Table 2. Total soil porosity percentage by disturbance type and depth class, averaged for all areas.

Depth (cm)	Undisturbed	Berm	Outer Track	Between Track	Inner Track
0-10	65.6	61.7	50.4	52.7	40.3
10-20	53.6	58.4	48.1	48.5	33.8
20-30	44.3	52.1	38.9	36.0	30.7

5. It is becoming increasingly clear that plantations must be diligently maintained (particularly important is control of competing vegetation) and growth must be monitored a minimum of 15 to 20 year before accurate growth predictions can be made. In the first five years of growth, trends on all disturbance types are quite similar. Between years five and ten, considerable growth differentiation between disturbance types usually takes place.

Additional Reading

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Acknowledgments

Dean Mills, CFS, contributor.

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Printed on recycled paper
ISSN 1209-6571 Cat. No. Fo29-47/26-2001E
ISBN No. 0-662-30753-4

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