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Calcareous Soils

B. Kishchuk[1], D. Maynard[1] and M. Curran[2]

[1]Canadian Forest Service, [2]British Columbia Ministry of Forests

Strategic Importance

Calcareous soils are derived from sedimentary rock of marine origin, either limestone-rich parent materials or from calcium-rich sedimentary rock. These soils cover large areas in the Rocky Mountains, the Rocky Mountain Trench and tributary valleys. They are also found in parts of the prairie provinces and Ontario. They have chemical and physical properties that are potentially limiting to seedling establishment and the productivity of established stands, particularly following soil disturbance.

In British Columbia (B.C.), the presence of free lime in the soil is not directly recognized in estimating forest productivity or long-term yield. However, the depth to carbonates is one of the criteria within the Forest Floor Displacement Hazard Rating of the B.C. Forest Practices Code within the hazard assessment keys for evaluating soil disturbances. In Alberta, the implications of limestone derived soils on forest productivity have been recognized for lodgepole pine (including reference to "lime toxicity") in the soil survey interpretations for the Hinton-Edson (Rocky Mt Foothills) area.

Although there is little data available on the impacts of calcareous soils on forest productivity, forest managers should recognize these soils and consider the potential impacts from forest management activities.

Characteristics of Calcareous Soils

Both limestone and calcium-rich sedimentary rock produce soils that are rich in calcium. Calcareous soils are characterized by the presence of free calcium and magnesium carbonates, and pH values over 7.2 (the pH at which free lime occurs).

Disturbing calcareous soils may result in reduced productivity and seedling performance.

In the field, the presence or absence of carbonate is determined by placing a few drops of diluted hydrochloric acid (10% HCl) on a small sample of the soil. Effervescence (or "fizz") indicates the presence of free calcium carbonates.

On calcareous soils, pH and carbonate content increase with soil depth. As soils develop on calcareous parent materials, carbonate minerals are dissolved and leached downward. This weathering and leaching of the carbonate minerals results in gradual acidification (decrease in pH) of the soil from the surface downward (Table 1). Consequently, soils developed in calcareous parent material will have a different nutritional environment for vegetation in comparison to non-calcareous soils.

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Table 1. Chemical properties of soil on the Nine Mile Creek harvesting and stumping trial area.

Sample	pH	$CaCO_3$	Org. C	N	P	Ca	K	B	Zn	Fe
	(in H_2O)	(equiv. % total C)	Total (%)		mg kg^{-1}	(available mg kg^{-1})				
Forest Floor	5.9	N/A	35.9	1.13	1000	9300	1700	1.4	25	75
Mineral Soil										
15-30 cm	7.2	5.5	2.95	0.18	4.1	4500	165	0.2	0.5	9
0-15 cm	7.7	8.9	1.85	0.06	1.8	3200	45	0.1	0.2	1

Precipitation and the carbonate content directly influence the weathering process and soil development. Areas with little rainfall can be expected to leach (or "develop") at a slower rate. It is not uncommon to find the calcareous material still at or near the surface. On these sites, calcareous material may be present from the surface of the mineral soil through the rooting zone to subsoil horizons.

Calcareous Soil Disturbances

Calcareous soils tend to be fine-textured. Finer-textured soils frequently are more susceptible to compaction in clayey soils and to erosion in silty soils. The physical limitations of calcareous soils include cementation of soil aggregates, compaction and cementation of soil horizons, and surface crusting.

Soil disturbance may intensify adverse conditions by exposing unweathered subsoils or by mixing the calcareous subsoil with more acidic surface horizons. Disturbances alter the fragile, shallow topsoil layer from its undisturbed state thereby affecting the soil's ability to sustain forest productivity.

Examples of major disturbances include road construction, site preparation, and stumping for root-rot control. Stumping in calcareous soils resulted in calcareous deposits covering 25-35% of cutblock areas compared to less than 5% in unstumped areas. These activities may bring the free lime of calcareous soils closer to the surface. The free lime may reduce nutrient availability from the shallow forest floor and topsoil horizons. Surface soil pH can also be increased with disturbances. The Whitetail Brook pushover logging trial in the Invermere Enhanced Forest Management Pilot Project area is an example of the impact (Table 2).

A laboratory experiment simulating 5 years of leaching of calcareous surface deposits showed that the forest floor pH increased from 6.8 to over 7.5 under an 8-cm-deep deposit. This is a very large increase in alkalinity (pH is a logarithmic scale). In a greenhouse experiment, carbonate in the irrigation water (as sodium carbonate) reduced the emergence, survival and growth of white spruce seedlings.

Forest Productivity

In west-central Alberta, soil pH was considered an important factor in determining forest productivity classes for lodgepole pine (Table 3). Growth on calcareous soils may be 40 to 50% less than on moderately acid soils derived from other parent materials. Productivity was 36% lower on calcareous portions of the Marlboro soil association (Hinton-Edson, Alberta soil survey area) than on non-calcareous components of the association.

Table 2. First-year results for chemical effects of calcareous deposits in the Whitetail Brook pushover logging trial.

Disturbance type	Layer	pH
Undisturbed	Forest floor and mineral soil	6.1
Stump hole	Mineral soil at bottom	8.1
Deposit	Mineral soil deposit	8.4
Deposit	Underlying the forest floor	7.3

Table 3. Forest productivity interpretations from the Hinton-Edson Soil Survey

pH Class	ph Range	Forest productivity adjustment factor
strongly acid	5.1 to 5.5	decrease by 5%
medium acid	5.6 to 6.0	increase by 20%
slightly acid	6.1 to 6.5	no adjustment
neutral	6.6 to 7.3	decrease by 10%
mildly alkaline	7.4 to 7.8	decrease by 20%
moderately alkaline	7.9 to 8.4	decrease by 30%

From J. Dumanski; T.M. Macyk; C.F. Veauvy; J.D. Lindsay. 1972. Alberta Institute of Pedology.

Work in 60-year-old lodgepole pine stands in the foothills of Alberta also showed that depth to lime was an important factor in growth. Increasing depth to lime was positively correlated with height and basal area of even-aged lodgepole pine.

The Canada Land Inventory recognizes the potential limitations calcareous soils place on production through "Subclass L", which is used to indicate excessive levels of calcium. These areas are mostly limited to the lower elevations and major river valleys throughout the Rocky Mountains and Rocky Mountain Trench. Excessive or high levels of carbonates were one of the most common limitations in Classes 4 and 5 for the growth of commercial forests.

Chemical Limitations and Forest Productivity

Soil morphology and chemistry provide the foundation for plant productivity. While soil morphology such as aggregation, horizon thickness and organic matter are more readily observed than the chemical properties; both need to be considered in any prescriptions.

Chemical limitations associated with calcareous deposits are related to soil nutrient availability. The availability of nitrogen, calcium and magnesium may be increased with increased pH, while the availability of others such as phosphorus, boron, iron, manganese or zinc may be decreased. Nutrient deficiencies, excess nutrients, and nutrient imbalances can result in productivity losses as well as changes to wood quality.

Interior spruce

In a performance trial of interior spruce families in the East Kootenays, height and diameter were about 25% greater on acidic sites compared to calcareous sites, although families originating from calcareous sites were superior on both calcareous and acidic sites. Height and diameter of interior spruce decreased with decreasing depth to carbonates at the East White River (Table 4).

There was no evidence of reduced growth at a second interior spruce site (Lussier River) where median depth to carbonates was 31 cm.

Lodgepole pine

Two provenance trials for lodgepole pine in the Invermere Enhanced Forest Management Pilot Project area are also being evaluated. Height and diameter of lodgepole pine were about 13% lower when carbonates were present in the top 40 cm of the soil (Table 5). At the second lodgepole pine site, depth to carbonates was greater than 40 cm and there was no relationship between depth to carbonates and productivity.

Summary

Increases in soil pH and the presence of carbonates will affect the availability and balance of several essential nutrients. To date, however, there is little information on whether these soils are less productive than acidic soils or whether these soils are more sensitive to disturbance resulting from harvesting operations.

An understanding of the processes affecting forest productivity on calcareous soils is required. Forest managers should ask the following questions related to their forest management activities:

Table 4. Interior spruce - height and diameter compared to depths of carbonates, East White River, B.C.

Depth to carbonates (cm)	Spruce height (cm)	Spruce diameter (mm)
0-15	319 ± 20	44.6 ± 4.9
15-30	318 ± 14	43.2 ± 2.9
30-45+	362 ± 30	56.7 ± 4.1

Table 5. Lodgepole pine - height and diameter compared to depths of carbonates, Lussier River, B.C.

Depth to carbonates	Good provenances		Medium provenances		Poor provenances	
	Height (cm)	Diameter (mm)	Height (cm)	Diameter (mm)	Height (cm)	Diameter (mm)
< 40 cm	650 ± 24	94 ± 4	589 ± 27	79 ± 5	382 ± 27	58 ± 5
> 40 cm	752 ± 48	102 ± 9	649 ± 34	96 ± 6	465 ± 34	68 ± 6

- What is the relationship between carbonate depth and productivity?
- What are the effects of calcareous soils on nutrient availability?
- What are the relationships between tree nutrition and productivity on calcareous soil?
- Are calcareous soils more sensitive than other soils to disturbances as a result of forest practices?
- What is the interaction between calcareous soils and other site attributes (e.g., elevation, slope, and aspect)?
- Are there opportunities for amelioration of nutrient limitations and enhancement of growth on these soils?

Additional Reading

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Contacts

Doug Maynard
Canadian Forest Service
506 West Burnside Rd.
Victoria, BC V8Z 1M5
(250) 363-0722
Email: dmaynard@pfc.forestry.ca

Barbara Kishchuk
Canadian Forest Service
5320-122 Street
Edmonton, Alberta. T6H 3S5
(780) 435-7336
Email: Bkishchuk@NRCan.gc.ca

Mike Curran
British Columbia Ministry of Forests
518 Lake Street
Nelson, BC V1L 4C6
(250) 354-6274
Email: Mike.Curran@gems5.gov.bc.ca

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