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APPLICATION OF SOIL MOISTURE REGIME TO BLACK SPRUCE MANAGEMENT IN NORTHWESTERN ONTARIO

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WHAT IS SOIL MOISTURE REGIME?

Soil Moisture Regime is an important site factor influencing forest type and productivity in the boreal forest, and is an integral part of forest ecosystem classification (FEC) systems. It is correlated to tree growth, stand composition, degree of competition, nutrient availability, and overall site quality. For forest soils, Soil Moisture Regime provides an estimated ranking of the overall soil moisture supply throughout a complete growing season. Moisture Regime is based upon a relative scale that ranks sites along a soil moisture continuum: the 11 classes are often grouped into Dry (Ø, 0), Fresh (1–3), Moist (4–6), or Wet (7–9) categories. Moisture Regime classes are based upon the duration of saturation, or the duration and intensity of a moisture deficit; they do not provide a meaningful measure of annual seasonal moisture variations nor do they specifically indicate moisture levels during critical periods (e.g., while seeding or planting).

Moisture Regimes are defined according to several soil features that can be consistently measured in the field: soil texture class and pore pattern, depth to bedrock, occurrence of a thick organic horizon, percentage slope, and depth at which evidence of repeated cycles of oxidation or reduction create certain color patterns and changes in the soil (as indicated by the presence of soil mottles or gray, saturated gley horizons). Soil texture and pore pattern are indicators of the number and size of spaces between soil particles, which in turn characterize the drainage and moisture retention properties of the soil.

DETERMINING MOISTURE REGIME IN THE FIELD

Moisture Regime is determined using a soil sample obtained from the unweathered parent material or C horizon. This is usually encountered within 60 to 100 cm of the mineral soil surface in northwestern Ontario. It is important that the soil be sampled at a representative location, one that suitably reflects the general topographic, vegetational, and soil/site conditions of the area that is to be described. Sims et al. (1989) lists five steps for determining the Soil Moisture Regime from a chart:

Step 1. Dig or auger a representative soil pit to a depth of 1 m or to bedrock.
Step 2. Measure the depth to: bedrock, texture change, mottles, gley, compaction.
Step 3. Sample the C horizon.
Step 4. Manually determine the soil texture.

For mineral soils, the texture class of a C horizon sample is typically determined by "hand texturing" in the field. For example, after completing Steps 1–4 and having determined a loamy, medium sand with mottles within 20 cm of the surface, proceed to Step 5.

Step 5. Locate this texture on the appropriate Soil Moisture Regime chart (*see* Sims et al. 1989). Read across the row and select the cell that matches the soil pit properties. Then read the Soil Moisture Regime at the top of the column of the cell selected. The chart indicates a Soil Moisture Regime of 5.

Based upon their degree of decomposition, *organic soils* (soils with organic surface horizons >40 cm thick) may be divided into fibric, mesic, and humic layers. To estimate Moisture Regime, the relative thicknesses of these horizons are measured in the field. *Shallow soils*, which have bedrock within 100 cm of the mineral soil surface, are generally drier than deeper soils of the same texture. *Stratified soils*, in which strata arise from deposition of distinctly different parent materials, often provide a wetter Moisture Regime by increasing the time that soil water is retained. Separate charts are used to estimate Moisture Regime for both shallow and stratified soils (Sims et al. 1989).

DISTRIBUTION OF BLACK SPRUCE ACROSS A GRADIENT OF MOISTURE REGIMES

Based on measurements of Moisture Regime in more than 2,150 FEC plots, the occurrence (%) of tree species across a gradient of Moisture Regimes was compared (Fig. 1). Balsam fir (*Abies balsamea* [L.] Mill.), white spruce (*Picea glauca* [Moench] Voss), trembling aspen (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marsh.) exhibited similar distributions and were most abundant in the transition between Fresh and Moist Moisture Regimes. Jack pine (*Pinus banksiana* Lamb.) and red pine (*P. resinosa* Ait.) are most abundant under Very Fresh Moisture Regimes, with a strong presence under Dry to Fresh Moisture Regimes. White cedar (*Thuja occidentalis* L.) distribution is bimodal, occurring under both Fresh and Wet Moisture Regimes. Black ash (*Fraxinus nigra* Marsh.) and tamarack (*Larix laricina* [Du Roi] K. Koch) are common only under Wet Moisture Regimes. As evidenced by its more level distribution when compared with other species, black spruce (*P. mariana* [Mill.] B.S.P.) occurs across the broadest range of Moisture Regimes. However, its distribution is elevated under Fresh Moisture Regimes.

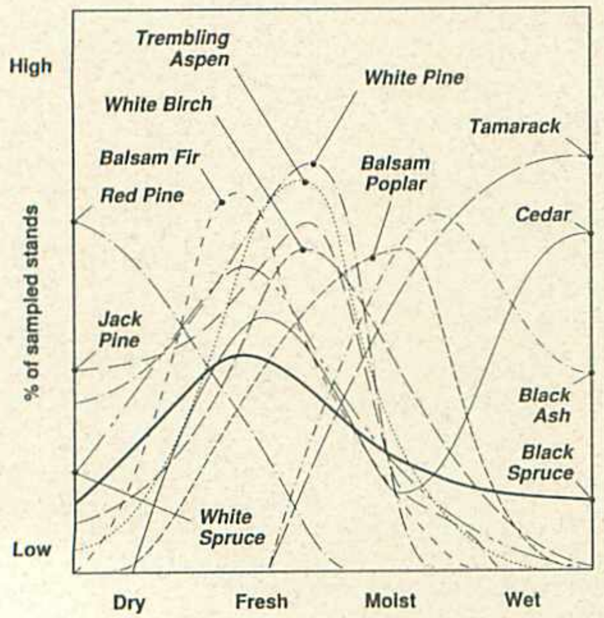

Figure 1. Percent relative occurrence of black spruce and other common tree species across a Moisture Regime gradient in northwestern Ontario.

Moderately dry to fresh sites support mixed forest stands with a low to moderate black spruce component. More than 50% of the stands with Moderately Dry Moisture Regimes lacked a black spruce component, but under Moist Moisture Regimes the number of stands exhibiting a higher percentage of black spruce cover increases.

MOISTURE REGIME AND BLACK SPRUCE VEGETATION TYPES

The distribution of FEC vegetation types (V-types) across environmental gradients can be interpreted from plotted diagrams derived from computer-assisted "ordination" analyses of vegetation data (*cf.* Sims et al. 1989). The ordination diagram in Figure 2 summarizes abundance information for all species recorded in more than 2,150 FEC field plots. Neither of the axes are calibrated to an absolute scale, but the vertical axis is an inferred Soil Moisture gradient and the horizontal axis is a soil nutrient gradient.

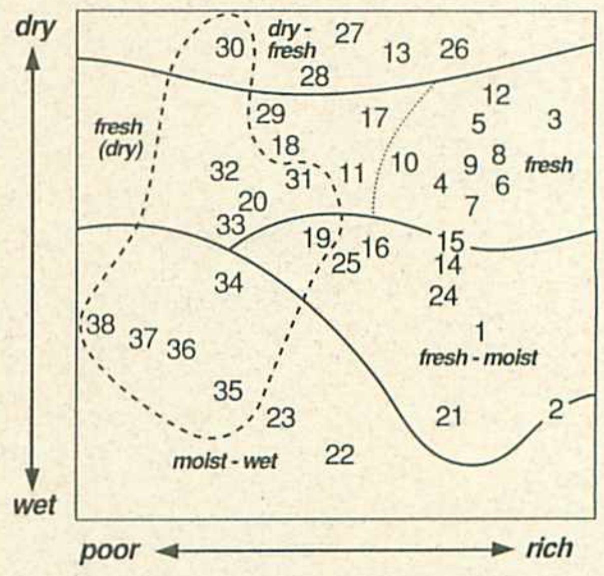

Figure 2. The FEC V-type ordination overlayed with groupings of Soil Moisture Regime classes. Black spruce dominated V-types are indicated by a hatched line.

In Figure 2, general classes of moisture are overlayed on the FEC ordination to show how the Wet to Dry (vertical axis) gradient is related to the 38 V-types. The 11 black spruce dominated V-types occur across the entire range of soil moisture conditions present in northwestern Ontario, i.e., from Wet (V-type 38) to Dry (V-type 30). Within individual V-types, stands may exhibit a range of Moisture Regimes.

MOISTURE REGIME AND BLACK SPRUCE GROWTH

Studies in eastern Canada's boreal forests indicate that site quality of natural black spruce stands is related primarily to soil moisture and nutrients (Jeglum 1974). Although initial survival is not strongly correlated with depth to the water table, black spruce seedling height, diameter growth, and biomass production usually increase as the depth to water table increases (Sims et al. 1990). The black spruce site index is highest on freely drained, mesic mineral soils with modest humus accumulations (Lowry 1975) and lowest on deep, poorly aerated organic soils with Wet Moisture Regimes. Growth is intermediate on dry sites.

Racey et al. (1989) summarized black spruce productivity in relation to Moisture Regime using information collected during the development of the FEC. The results showed best growth on Fresh to Very Fresh soils (Moisture Regimes 2 and 3) on middle and lower slopes. For such areas, the Site Index is >14 m at 50 years. Moderate black spruce growth occurs on Moderately Fresh (Moisture Regime 1) or Moderately Moist to Moderately Wet (Moisture Regimes 4 to 7) soils on upper slope, toe slope, and level positions. For such sites, the Site Index ranges from 10 to 14 m at 50 years. The poorest growth is found on dry to moderately dry (Moisture Regimes Ø to 0) and wet to very wet (Moisture Regimes 8 to 9) soils, with a Site Index that is often well below 10 m at 50 years.

MANAGEMENT IMPLICATIONS FOR BLACK SPRUCE

Soil Moisture Regime influences many aspects of forest management and planning because it can be directly linked to a site's susceptibility to rutting, puddling, and windthrow. It also helps to forecast the likelihood of natural regeneration, susceptibility to insects and diseases, and degree of competition after harvest (Table 1).

Black spruce advance growth is more abundant on sites with Moist to Wet moisture regimes (Wickware et al. 1990). Post-harvest competition potential is generally correlated with Moisture Regime. Competition is greater under Fresh to Moist, and less under Dry Moisture Regimes. Therefore, silvicultural prescriptions for the more moist sites must include competition control. On fresh or moist soils regeneration is typically accomplished through planting or seeding, whereas sites with dry soils are usually managed for jack pine by cone scattering or aerial seeding. The fungi *Armillaria* spp. and *Inonotus tomentosus* may become management problems on dry sites with coarse-textured soils. Moist sites are more prone to compaction or rutting problems; on such sites winter harvesting is usually recommended (Racey et al. 1989).

Table 1. Sample forest management interpretations for black spruce dominated V-types in northwestern Ontario, organized according to groupings of Soil Moisture Regime and soil depth (shallow <100 cm, deep >100 cm) classes.

	Soil moisture and soil depth					
	Dry, shallow	Dry, deep	Fresh, deep	Fresh to moist, deep	Moist to wet, deep	Very wet, deep
Competition	L	L–M	M–H	H	M	L
Regeneration	N	N,P	N,P	P,S	N,S	N
Equipment selection	S	F,S	F,S	C,R	R,C	R,C
Prescribed burning	L	H	M	M	L	L
Susceptibility to spruce budworm	M–H	–	M	M	H	L–M

LEGEND:

Harvest Season
W- mainly winter (frozen ground)
S - mainly summer dry season (unfrozen ground)
A - no limitations for harvesting

Regeneration
N - natural regeneration
P - planting
S - seeding

Competition, Budworm Susceptibility, Potential for Prescribed Burning
L - low
M - moderate
H - high

Site Limitations for Equipment Selection
F - few limitations
C - compaction
R - rutting
S - stoniness

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