The influence of soil reconstruction materials and targeted fertilization on the regeneration dynamics in boreal upland forest reclamation

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Abstract

Soil is an essential component supporting the growth and maintenance of terrestrial ecosystems such as forests, providing anchorage, water, and nutrients. In Canada's boreal forest landscape, surface soils can differ widely in their chemical and physical conditions, ranging from coarse to fine textured mineral soils in the uplands to organic soils in the lowlands. Industrial disturbances in the boreal region require the salvage of surface- and sub-soils from low- and upland areas during open pit mine operations that are used in the reconstruction of soil profiles for forest reclamation. These materials are selectively salvaged and can be arranged in variable layers and thicknesses, which could have profound effects on early forest establishment. For the first project of my thesis, I compared the growth of trembling aspen (*Populus tremuloides* Michx.), jack pine (*Pinus banksiana* Lamb.), and white spruce (*Picea glauca* Moench.) on different reconstructed soil profiles using varying surface soil materials (salvaged lowland peat and upland forest floor material (FFM)), placement depths (10 or 30cm for peat, 10 or 20cm for FFM), and subsoil material types determined by salvage depth (Bm, BC, and C). Early seedling establishment and growth as well as soil and climatic parameters were monitored over a five-year period. Seedling growth was greatest on FFM and appeared to be related to phosphorous availability, while peat as a surface soil reduced growth, likely due to delayed soil warming in the spring and overall cooler soil conditions that potentially limited resource availability. However, the greater water

holding capacity of the organic matter in peat provided a benefit for seedling growth that was apparent during water limiting climatic conditions. The underlying subsoil material influenced growth later in establishment when roots occupied the deeper subsoils. Aspen growth was greatest when the subsoil was shallow salvaged and represented a weathered subsoil (Bm) compared to the more deeply salvaged, less weathered subsoils BC and C. Aspen and pine seedlings, with their larger roots systems, may have benefited from small increases in the silt fraction of the subsoils that increased the water holding capacity of these otherwise coarse textured sandy soils. Spruce regeneration responded marginally to soil treatments because of its overall slow growth-strategy and tolerance to resource limitations.

Based on the initial 5-year study, seedlings may have been limited by low phosphorus (P) and potassium (K) availability in the peat and the homogenized subsoil materials, while nitrogen (N) was readily available in the peat coversoil. Broadcast fertilization is a common method used to treat nutrient limitations on reclamation sites, supplying a wide range of nutrients to fulfill the varying requirements that are unique to each tree species; however, operational applications of NPK on organic soils often induce strong responses from unwanted colonizing vegetation, which reduces the nutritional benefits intended for the seedlings and could render the fertilizer application ineffective. A follow-up study was developed to test the use of a broadcast fertilizer application that targets specific nutrient deficiencies in the soil and in each tree species, while simultaneously reducing the response of competing vegetation. Liquid fertilizer was applied to six-year-old seedlings using five treatments in the field: Control (no fertilizer), NPK, PK, P, and K. Seedling growth, foliar nutrients, and vegetation cover as well as environmental parameters were measured over two growing seasons. Aspen responded the strongest to fertilization, particularly in the P treatment, while pine and spruce marginally responded to the NPK

treatment; however, growth responses depended on the type of subsoil treatment. All three species had foliar P concentrations below their optimal levels in the Controls, while foliar N concentrations were low for both conifers. The competing vegetation increased in NPK and did not respond to the P, K and the Control treatments, indicating targeted fertilization reduced responses from colonizing competitors. Additional analyses of the soil conditions (e.g. pH, cation sorption, water availability, temperature) suggest that other factors were more limiting to the trees during the study, which reduced their responses to the fertilizer additions. Results from this thesis demonstrate how different strategies used for soil reconstruction and targeted fertilization can affect the performance of forest regeneration in post-mine areas, and boreal forest species responses may vary according to their ecological adaptations and the site conditions.