BRINGING BACK THE BOREAL FOREST: HOW TREES RESPOND TO COVER SOILS

Findings from the COSIA Aurora Capping Study (2012-2018)

Soil reconstruction is the single most influential step in mineable oil sands reclamation. It has the potential to determine the trajectory of a mature forest decades into the future. Since trees cannot access nutrients and water beyond their immediate surroundings, it is the responsibility of reclamation personnel to carefully consider which cover soil applications best support tree growth.

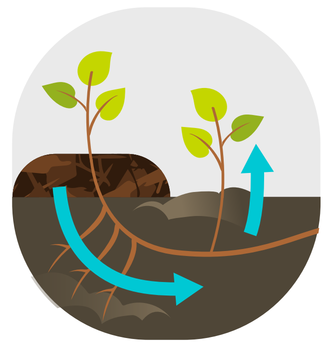
Salvaged peat and forest floor material (FFM) are often used as cover soils in reclamation following oil sands mining, and differ greatly in physical properties and soil biological activity. **The Aurora Soil Capping Study (2012-2018)** explored how tree seedlings respond to the different properties associated with these two soil cover treatments. Below, these findings are explored in greater detail, drawing from a series of independent studies affiliated with the Aurora Soil Capping Study. These conclusions can be used to inform best practices for restoring upland boreal forest ecosystems.

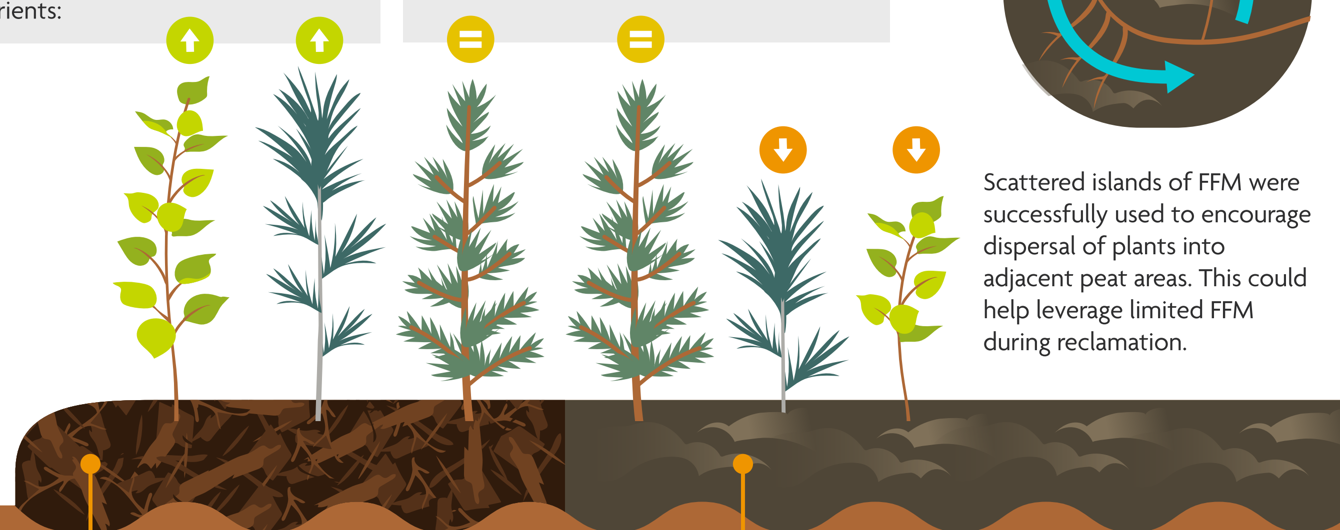
Research activities were conducted at the Syncrude Aurora mine, resulting in insights that are tailored to oil sands reclamation in Northern Alberta.

HOW TREE SEEDLINGS RESPONDED TO **COVER SOIL TYPE**

Grew better on FFM due to availability of key nutrients:	**Trembling aspen**	**Jack pine**

White spruce	Stress-tolerant species, less responsive to soil differences





Scattered islands of FFM were successfully used to encourage dispersal of plants into adjacent peat areas. This could help leverage limited FFM during reclamation.

Cover soil

Disturbed soil

FOREST FLOOR MATERIAL (FFM)

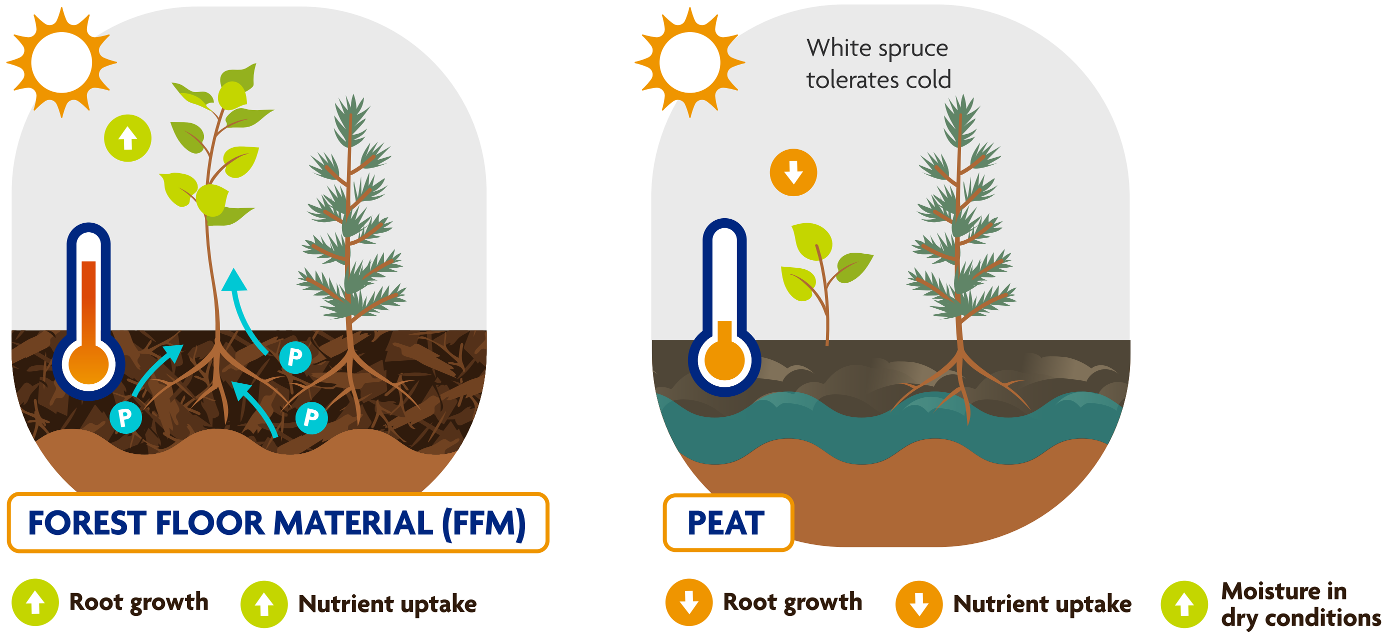
- + **Plant richness**
- + **Plant cover**
- ↑ **Phosphorus (P)**
- ↑ **Potassium (K)**
- ↑ **Ammonium (NH_4^+)**

PEAT

- − **Plant richness**
- − **Plant cover**
- ↑ **Nitrate (NO_3^-)**
- ↑ **Sulfur (S)** Impairs metabolism and growth
- ↑ **Cations (Ca, Mg)** Forms precipitates that limit Phosphorus (P) uptake

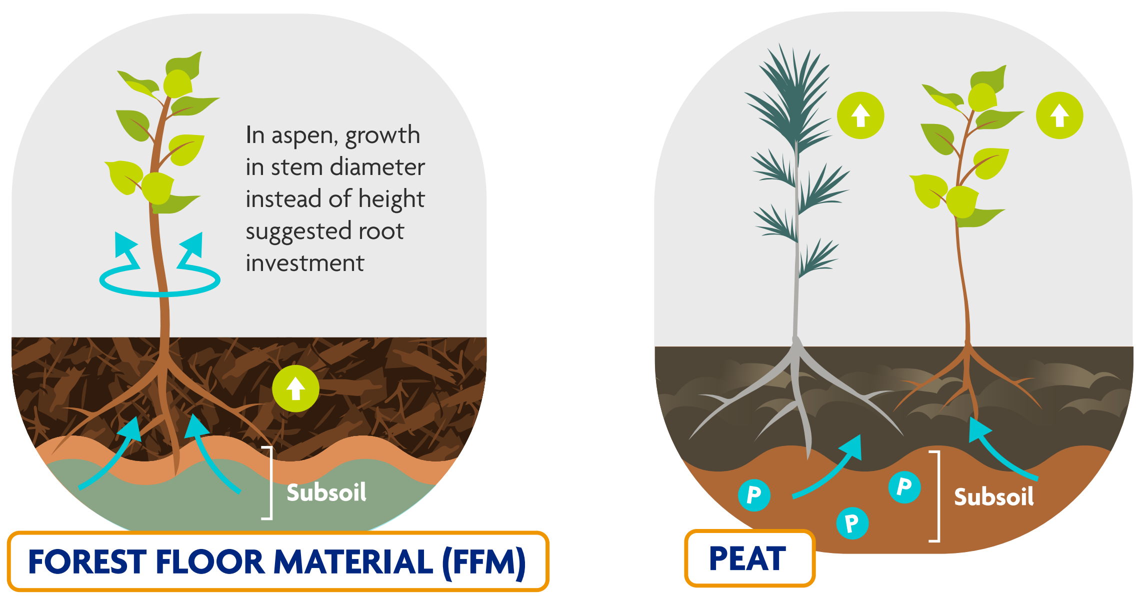
HOW TREE SEEDLINGS RESPONDED TO **SEASONAL SOIL TEMPERATURE**

Using peat as cover soil resulted in colder, wetter spring rooting conditions, which negatively impacted nutrient uptake by broadleaf tree species. The boreal forest experiences prolonged freezing temperatures, and tree growth is limited to a very short period after soil warms in the spring. Most boreal tree species experience limited root growth at temperatures below 5°C, though some, like white spruce, show greater tolerance.



HOW TREE SEEDLINGS RESPONDED TO **UNDERLYING SUBSOIL MATERIALS**

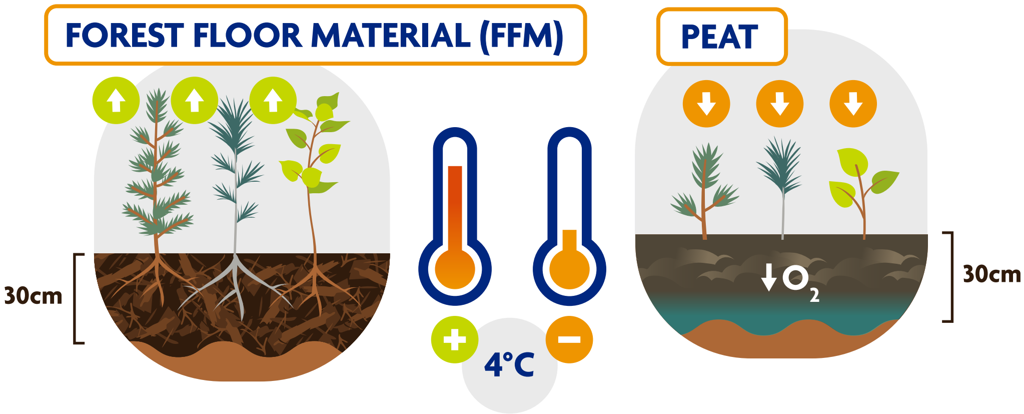
Vegetation responses to subsoil varied depending on the cover soil used. Plant growth is impacted by both the cover soil at the surface and the subsoil layer beneath. Access to the subsoil happens later in the process of establishment, and is dependent on the size of plant's root system. Subsoil can be salvaged from different **soil horizons** (depths), including B, Bm and C soils.



When FFM was used as cover soil, plant growth was driven by the subsoil's water availability. Subsoil from the C horizon maintained higher moisture than Bm or BC (transitional soil between B and C horizons).

When peat was used as a cover soil, plant growth was driven by the subsoil's nutrient availability. Aspen and pine grew taller with a selectively salvaged subsoil from the Bm horizon, likely driven by greater availability of phosphorus.

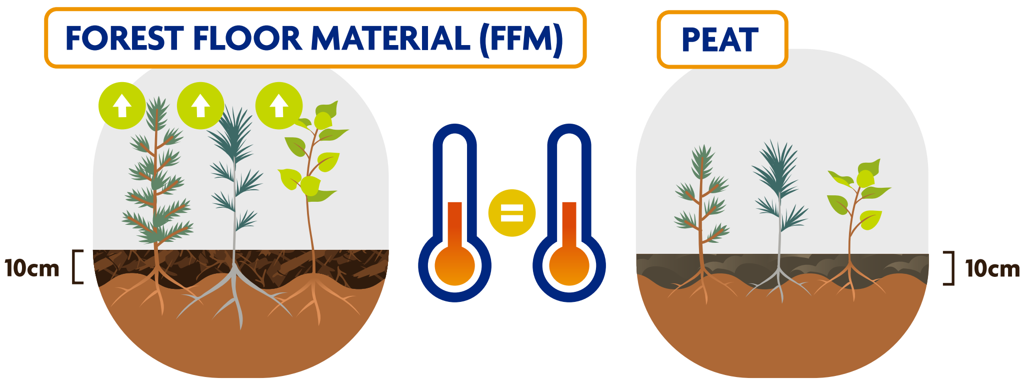
HOW TREE SEEDLINGS RESPONDED TO **CAPPING MATERIAL DEPTH**



Thick peat soil caps led to low-oxygen conditions that impaired root development.

The subsoil layer altered the moisture and chemical conditions of the peat, with thicker cover soil caps (30cm) showing greater water variability linked to seasonal water table fluctuations.

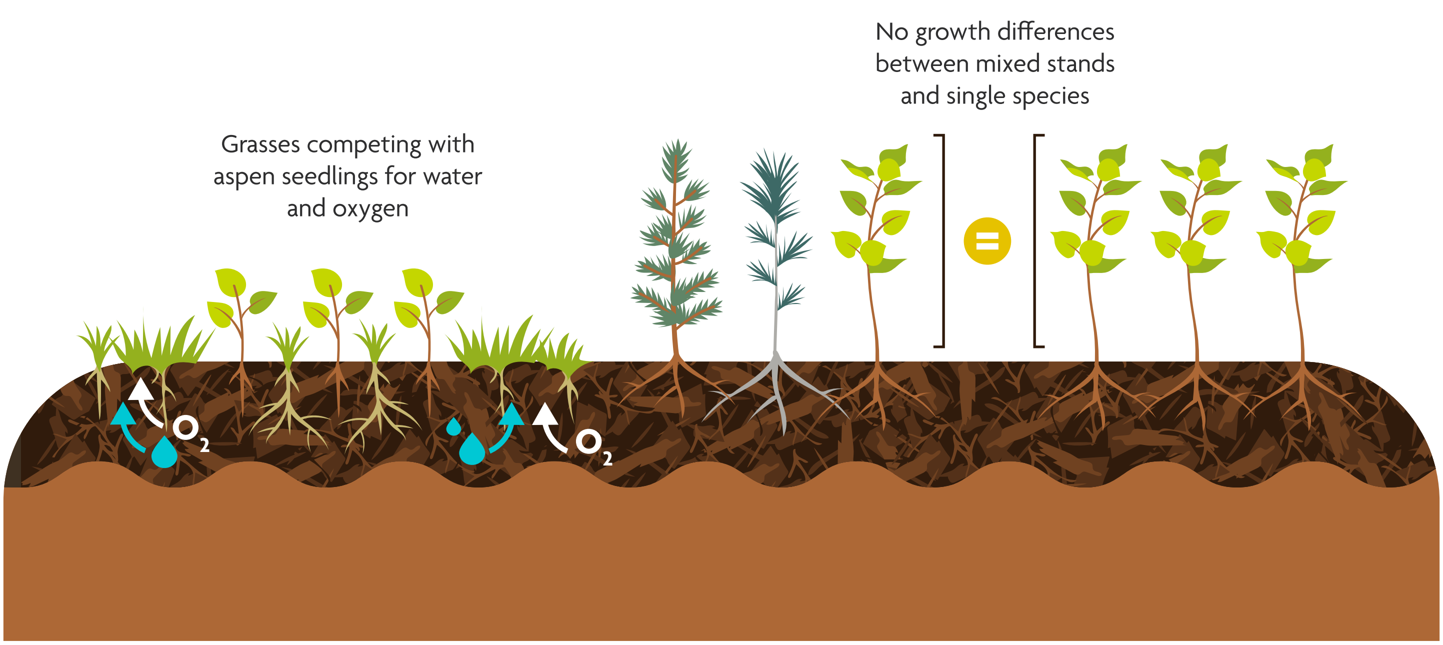
While these fluctuations can enhance nutrient movement, consistently high water content in the thick peat layer may have led to anaerobic conditions that hindered root development.



Thinner caps (10cm) showed no notable difference in temperature between cover soil types, although seedlings performed better on FFM than peat.

HOW TREE SEEDLINGS RESPONDED TO **INTERACTIONS WITH OTHER PLANTS**

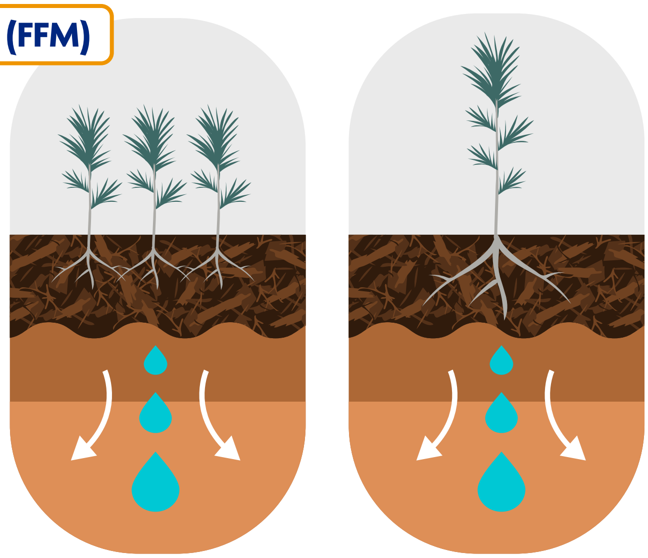
Tree seedlings received belowground competition from grasses, but growing in a stand with mixed tree species had minimal impacts on growth. In fertile reconstructed soils, belowground competition from grasses significantly limited root development in aspen seedlings, more so than soil compaction, by rapidly occupying rooting space and depleting water and oxygen.



FOREST FLOOR MATERIAL (FFM)

Pine grew taller at lower planting densities due to reduced competition for water in sandy FFM soil.

This shows that early density effects may be species-specific and tied to moisture available in the soil.



Unique aspect of plots with FFM cover soil and pine:

Year-over-year draw down of water each growing season, may impact growth of future trees

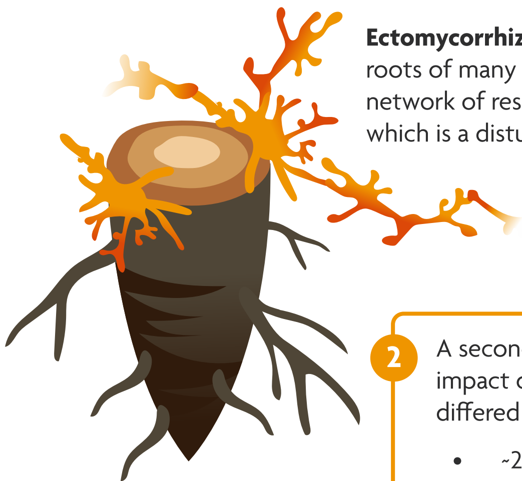
Year 1

Year 2

Year 3

HOW **FUNGAL COMMUNITY COMPOSITION** RESPONDED TO COVER SOILS

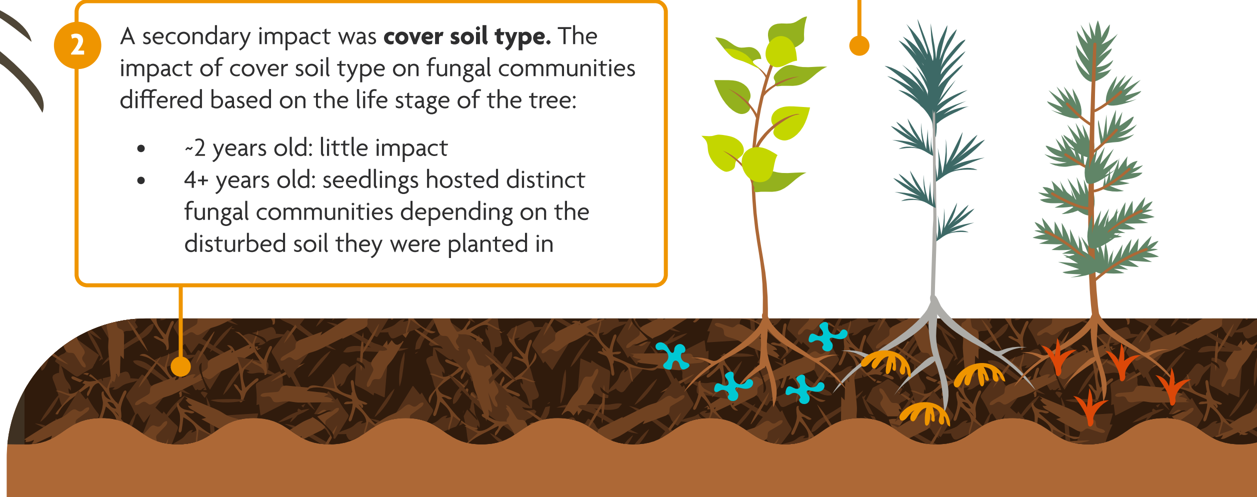
Ectomycorrhizal fungi are a group of symbiotic fungi that form mutualistic relationships with the roots of many tree species. Symbiotic fungi are essential for tree growth because they create a network of resource exchange between trees and the soil. This is especially critical in the boreal forest, which is a disturbance prone ecosystem characterized by harsh winters and low nutrient mobility.



Close-up cross section of a root

1. At study sites, symbiotic fungi communities were primarily driven by **host tree identity.**

2. A secondary impact was **cover soil type.** The impact of cover soil type on fungal communities differed based on the life stage of the tree:
   - ~2 years old: little impact
   - 4+ years old: seedlings hosted distinct fungal communities depending on the disturbed soil they were planted in



Overall, the Aurora Soil Capping Study found that tree seedlings grow better in FFM than peat, provided that the underlaying subsoil layer contains sufficient moisture.

FFM characteristics that contributed to growth:
- Higher availability of key nutrients
- Warmer spring rooting conditions
- Better drainage

Impacts of other vegetation:
- Grasses competed with seedlings for resources
- Mixed stands had little impact on individual tree growth
- Symbiotic fungi were primarily driven by host tree species