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When Texture Matters: Compaction in Boreal Forest Soils

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Highlights

- Fine- to medium- textured soils are generally more susceptible to compaction from harvesting and site preparation than coarse textured soils under moist conditions.
- Harvesting and site preparation on dry soils, regardless of texture, is recommended as this substantially reduces the risk of compaction and long-term negative effects on site productivity are unlikely.
- Winter harvesting is preferable on fine to medium textured soils since frozen soils are considerably less prone to compaction and the impact on site productivity will be minimal compared to summer harvest.

After three weeks of rain, the soil beneath a stand of aspen mixedwood that is slated to be cut in the coming weeks, is wet. The soil is a coarse, loamy sand, suggesting little concern over soil compaction by machinery…right? A similar forest, one hundred kilometers to the west, is underlain by a fine-textured soil – a clay loam. Would there be cause to worry here? The short answer to these questions is that while soil texture matters, it's not that simple. Coarse-textured soils (e.g. sandy loams) do not necessarily imply an absence of compaction with harvesting. Nor are clay-rich soils inevitably an immediate cause for concern. There is no doubt that texture influences soil compaction potential—but how? Is it always predictable? This note looks at the current research on compaction, discusses how compaction affects different soil types and offers a glance at how forestry management practices can help minimize the negative impacts of compaction.

Soil texture and origin matter

Fine-textured soils are considered more prone to compaction than their coarse-textured counterparts, as are soils with inherently higher bulk densities. Is this generalization accurate? It depends. Fine-textured soils derived from glaciolacustrine deposits and coarse-textured soils derived from wind deposits are much more susceptible to compaction then coarse-textured, cobbly soils and medium-textured soils derived from till.[7] Luvisolic soils (soils high in clay) are also thought to be more susceptible than brunisolic or regosolic ones.[6] Some studies have shown that in both fine- and coarse-textured soils, compaction remains noticeable in the upper mineral soil layers for 3-5 years after logging.[16] Can (or should) we make any generalizations?

Fine-textured soils

Research evidence suggests that fine- to medium-textured soils are more susceptible to compaction than coarse-textured soils. At the same time, the degree of compaction and recovery time can be influenced by the environmental conditions at the time of harvest and site preparation.

One overriding factor in the potential compactibility of fine- to medium- textured soils is soil moisture. How wet is the soil at the time of harvest? In west-central Alberta, compaction is only thought to be a hazard when the soil is wet.[6] According to another study, wide tracked/tired grapple skidders and forwarders do not seriously compact fine-textured boreal soils when harvesting occurs under dry conditions.[14] Thus, there is some evidence suggesting that clay soils, at least those that are well-aggregated, may actually be able to resist compaction relatively well – in dry conditions.

The degree of traffic is also important. One year after harvesting with three skidding cycles by skidders with wide rubber tires, Albertan fine- to medium- textured luvisols showed significant recovery in terms of water infiltration. On the other hand, intensely (i.e. more than 3 passes) skidded trails did not recover three years after harvest when soil moisture was high.[15]

Effects on nutrients and productivity

There are few studies on the effects of compaction on nutrients and fewer that look specifically at nutrients in relation to soil texture. In the studies that have been done, impacts on nutrient cycling are not equivocal. For example, soil leachates from compacted clay soils (under dry conditions) in northern BC's Long-Term Site Productivity plots, showed dramatic declines in calcium (Ca) and potassium (K).[8] On the other hand, no effect of compaction was found on the nutrient contents of relatively dry, fine-textured soil after harvest in Alberta.[1]

Case in point

Boreal aspen mixedwoods are often found on fine-textured soils that, as discussed above, present some specific problems. Following is one study that provides insight on the management of these sites.

In the late 90's, research was conducted on the effects of compaction in a Saskatchewan aspen mixedwood on a clay loam luvisol.[8] Grapple skidders with wide tires were used (John Deere model 648D) in the fall when soil moisture was low. Although there was a more or less linear relationship between the number of passes and compaction, the researchers found that while there was an increase in bulk density with up to six machine passes, no further increases were found with up to 16 passes. Instead of negative effects on aspen suckering, they found growth stimulation with compaction. This was attributed to greater heat retention in compacted soils. They also found that compaction had no effect on soil chemical properties in the organic or mineral soil horizons. Their results suggested that:

- **Logging on similar aspen mixedwood plots with the same equipment may only have a short-term negative effects on soil properties (i.e. bulk density) when the soil is relatively dry.**
- **The same logging practice, however, would be expected to reduce soil pore space, increase root damage and lead to reduced aspen sucker densities in wet soil conditions.**

Largely negative impacts of compaction on tree growth have been documented on fine-textured soils. With moderate compaction, significantly fewer aspen suckers were found on moist fine-textured soils in northern BC.[2] Similarly, on the fine-textured gray luvisols of the Abitibi region, black spruce and balsam fir regeneration were reduced by up to 95% on heavily trafficked skid trails.[10] More evidence comes from Idaho; the compaction of low bulk density, silt loam soils there resulted in the significant, short-term reduction of Douglas-fir productivity. The researchers attributed this to a dramatic decrease in pore space (i.e. limitations on root growth) and in the reduced number of ectomycorrhizal root tips (i.e. reduced nutrient uptake).[12]

Coarse textured soils

While it is true - to a large extent - that coarse-textured soils are considerably less susceptible to soil compaction, this doesn't mean they are not prone to compaction. Heavily trafficked areas are still subject to compaction (lasting several years post-harvest) even on sandy soils, possibly leading to a decline in site productivity. In boreal Saskatchewan, mineral soil bulk densities of coarse-textured soils increased with summer harvesting in moist soil conditions compared to winter harvesting on frozen ground.[3]

Effects on nutrients and productivity

How do compacted coarse-textured soils fare in terms of productivity? After patch clear-cutting an aspen stand on a coarse-textured luvisol in Saskatchewan, researchers found no change in nutrient concentration in the mineral soil or the LFH horizons. In fact, they noted that the annual variation in nutrients was by far greater than any impact of compaction (which was not significant) on their site.[11]

In the boreal mixedwoods of northern Ontario, researchers found enhanced growth of conifer seedlings in compacted sandy soils.[17] In Long-Term Site Productivity plots the greatest stem volume of ponderosa pine was found under compacted sandy loam sites compared to undisturbed plots.[9] Nitrogen (N) uptake by plant roots was also enhanced. In some cases, compaction may actually enhance growing conditions in these coarse-textured soils by promoting root-soil contact (i.e. greater nutrient uptake and water retention). Whether or not this effect is long or short term is unknown.

Full tree harvesting on frozen loamy sands appears to have little effect on soil physical properties—nor aspen suckering—over the long term. However, in early stand development there can be temporary lowering of stocking status and site productivity.[16] In compacted sites in Maine on coarse loamy soil, spruce and balsam fir regeneration was dramatically reduced with a noticeable decline in growth and vigour, at least for the short term.[5]

Frozen soils

Winter harvesting is recommended whenever feasible since compaction is limited on frozen soils.[11,16] For example, winter harvest is recommended for forests in northern B.C. on fine- to medium- textured soils to avoid compaction and reductions in soil productivity.[2] In the boreal mixedwoods of the Northwest Territories, mechanical harvesting and site preparation on frozen, fine-textured soils results in minimal physical disturbance and does not significantly alter the nutrient status of the soil either.[4] Winter harvesting of black spruce in northern Quebec resulted in a 23% gain in stocking compared to summer harvesting.[13]

Summary

In general, fine- to medium- textured soils are more prone to compaction than their coarse-textured counterparts. This doesn't always hold true, however. In wet conditions, even coarse-textured soils can be compacted. Conversely, in dry, summer or fall conditions, well-aggregated soils can withstand compaction. Similarly, frozen soils – regardless of texture – have a reduced risk of compaction as a result of mechanized harvesting and site preparation.

Implementation

- **Mechanical harvesting and site preparation should be avoided in all soil types under wet conditions, as soil properties are impacted which, in turn, affect tree growth.**
- **Under dry soil conditions, compaction of most soil types is unlikely to have a long-term negative effect on nutrient cycling, tree growth and site productivity.**
- **Frozen soils are less susceptible to compaction; thus, winter logging—particularly on fine-textured soils—is recommended (providing that the soils are indeed frozen).**

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