CENTRE FOR BOREAL RESEARCH
TECHNICAL NOTE #39
FOREST RECLAMATION AND BOREAL REFORESTATION - SYNTHESIS OF TECHNIQUE - DECEMBER 2020

Soil Site Preparation Options for Enhancing Woody Seedling Establishment Part 2: Soil Amendments

CONTEXT

Anthropogenic activities can lead to environmental degradation through the alteration of physical, chemical, and biological properties of soil. Industrial activities such as mining, oil and gas exploration, and quarrying often require the removal of surface soil horizons, which shrinks the soil organic matter (SOM) pool[1] due to the breakdown of SOM within the stockpiled soil over many decades. With a lack of SOM, the microbial activity in the soil is negatively affected, and due to increased runoff capacity caused by compaction, the water-holding capacity is also reduced.[1] Since SOM plays a vital role in productivity by improving the physical, chemical, and biological properties of soil, replacing a surface horizon with salvaged topsoil may lead to sustainable reclamation success. However, there are situations where insufficient topsoil is available, for example where the stockpiled topsoil is of lower quality as a consequence of historical stripping practices, as well as the age of the stockpiled material. In these situations, secondary amendments provide an opportunity to supplement poor quality topsoil or potentially to combine with other soil profiles in the absence of suitable topsoil.

Within the Peace River region, a locally available organic amendment (biosolids) is presently being used by farmers on their agricultural fields as a SOM supplement and fertilizer amendment (DMI 2014). This program is freely available (within 25 km of Mercer's plant site) and the biosolids are applied in August of each year to interested parties. These particular biosolids are a by-product of kraft pulp mill production and contain a carbon: nitrogen ratio of 10.1:1, in addition to other nutrients such as sulfates, phosphorous, and potassium. When biosolids are used in agriculture, they are generally applied at rates sufficient to meet the nitrogen (fertility) requirements of the crop and only reapplied every 3-5 years. The organic matter that is supplied along with nitrogen can improve the physical properties of the soil. However, the improvement in soil physical properties occurs only after repeated biosolid applications due to the relatively small fertility application rates, or due to the method of incorporation and soil type.[2,3]

When biosolids are used for reclamation, application rates are generally higher than those used for agriculture as no supplemental applications are intended to follow. While these biosolids have shown positive results in agricultural trials, they have yet to be tested in a land reclamation application. The purpose of this technical note is to illustrate the effect of using a locally available organic amendment source on soil properties and forest vegetation development on a recently reclaimed industrial site.

STUDY DESIGN

This study was conducted on a decommissioned airstrip located approximately 30 km northeast of Peace River, Alberta (lat 56° 23.792´N, long 116 52.887´W). In August 2014, following site recontouring and topsoil placement, Mercer biosolids were applied at two different rates: 15.5 (high) and 6.2 (low) dt ha-1 each applied to a single 25 x 175 m plot. As these biosolids were applied as a wet slurry (95% water) with tanker trucks, this constrained the dimensions of these experimental plots. Adjacent to these plots, a single plot of the same dimensions was demarcated as a control with no amendment added. Following application of this amendment, the surface soil was disced to incorporate the biosolids.

The entire study area was seeded in April 2015 with two native grass species: fringed brome (*Bromus ciliatus*) and awned wheatgrass (*Agropyron trachycaulum var. unilaterale*) at the rate of 4.1 kg ha^{-1} and 3.0 kg ha^{-1} respectively, following biosolids application. Dormant container stock of aspen (*Populus tremuloides*, 1200 stem ha^{-1}), jack pine (*Pinus banksiana*, 500 stems ha^{-1}), dogwood (*Cornus sericea*, 250 stems ha^{-1}), green alder (*Alnus viridis*, 200 stems ha^{-1}), Bebb's willow (*Salix bebbiana*, 500 stems ha^{-1}), buffaloberry (*Shepherdia canadensis*, 50 stems ha^{-1}) and unrooted balsam poplar cuttings (*P. balsamifera*, 500 stems ha^{-1}) were planted in the third week of May 2015. In addition, hot-lifted greenhouse stock of two native forbs, fireweed (*Chamerion angustifolium*) and goldenrod (*Solidago canadensis*) were planted in mid-June 2015 at 500 stems ha^{-1} each, while white spruce (*Picea glauca*, 1000 stems ha^{-1}) was planted in early August 2015. Vegetation and soil surveys were conducted over the following five-year period (2015-2019).

KEY FINDINGS

Figure 1 (below). Site images from the fourth year of study (2018) showing view looking south (from north end of treatment plots).

Control (no biosolids)

Low biosolids

High biosolids

Table 1 (below). Key soil property changes with addition of biosolids. Arrows indicate an upward or downward change. NC is no change relative to control. NM is not measured.

YEAR	RATE	NITRATE	TOTAL ORGANIC CARBON	EXTRACTABLE SULFUR	ELECTRICAL CONDUCTIVITY
1	Low	⬆	NC	NM	NC
	High	⬆	NC	NM	NC
5	Low	NC	⬆	NC	NC
	Hogh	NC	⬆	⬇	⬇

Figure 2 (right). Woody plant densities by soil treatment after five years. Blue dotted arrow indicates initial target density established in year 1 with nursery stock or stem cuttings. Black line indicates mean estimate from field trial and rectangle outer boundaries are 95% confidence intervals on the mean estimate (n=15).

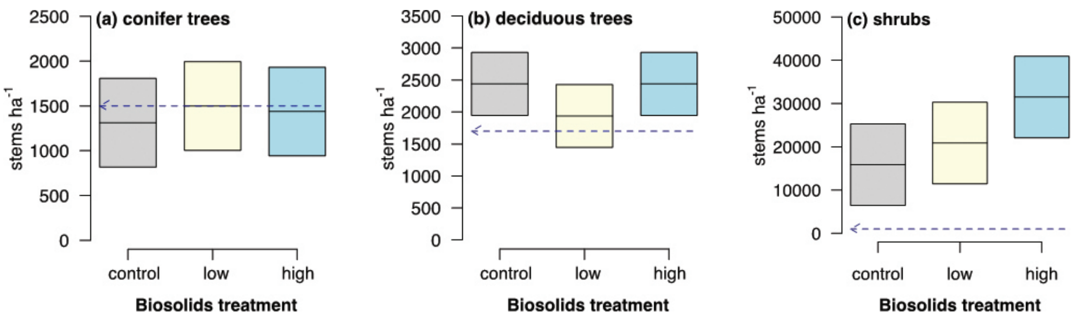


Figure 3 (right). Total tree heights for (a) aspen, (b) white spruce and (d) jack pine after five years of biosolids treatment. The mean value is shown in light green triangles and the lower and upper 95% confidence intervals on the mean shown by dark green triangles (n=15).

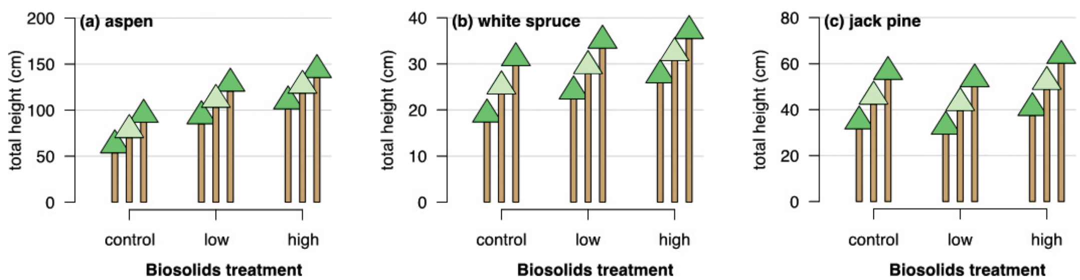
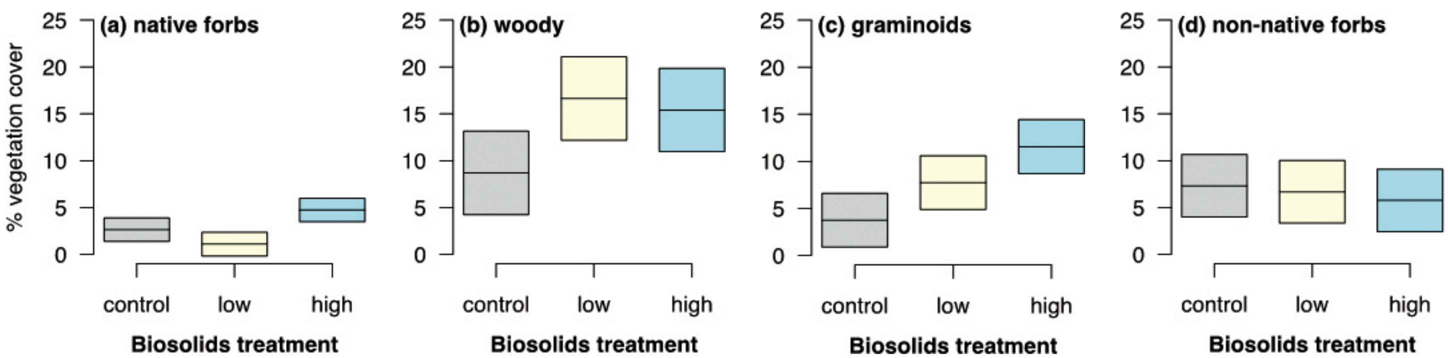


Figure 4 (below). Vegetation cover by soil treatment after five years. Black line indicates mean estimate from field trial and rectangle outer boundaries are 95% confidence intervals on the mean estimate (n=15).



PRACTICAL RECOMMENDATIONS

Use of biosolids, particularly at the higher application rate of 15.5 dt ha-1, resulted in clear increases in vegetation cover (of all classes with the exception of non-native forbs) that were sustained even after five years (Figure 1, 4). While there was no substantial difference in stem densities of tree species, shrub densities were also substantially higher (nearly twice as much) in the high biosolids treatment relative to the control (Figure 2). In addition, tree species were consistently taller, and for some species this was even evident in the low biosolids application rate (Figure 3). The initial increase in soil nitrates likely facilitated the increased vegetation growth, and though nitrate concentrations had stabilized by year 5, there were secondary improvements in soil properties (decreased extractable sulphur and electrical conductivity) that could have further improved conditions for plant growth. The increase in soil organic carbon was likely the consequence of initially high grass development, which would have contributed organic matter through root turnover as well as interacting effects with microbial populations.

Use of these biosolids, however, should be combined with vegetation management treatments during the establishment phase (1-2 years) of the site as the initial grass competition was observed to be counter-productive to seedling growth early on, despite the observed benefits later in the study. As this treatment provides an initial boost to key soil properties (Table 1), it has potential for the greatest utility on sites where limited topsoil is available or the existing soils are of low quality. As the cost of long-term transport is not insignificant, the choice of using this material will have to consider proximity to a regional supply of biosolids.

COST IMPLICATIONS

The biosolids used in this study are freely available, provided the site is located within approximately 25 km of the Mercer Peace River mill site.

Additional costs to consider before using this material include: sufficient accessibility of the site for tanker trucks to apply biosolids (**Figure 5A**), and availability of equipment to surface incorporate the biosolids into the soil as it is applied as a wet slurry (**Figure 5B**). In the present study, a tractor with a disc attachment was used, though other tools may also be applicable.

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