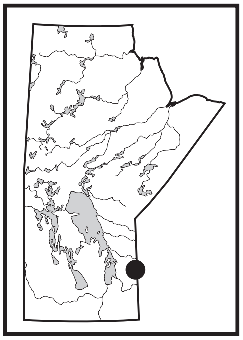
GS-12 Natural revegetation of Gunnar minesite, Manitoba (NTS 52L14)

by J. Markham[1], S. Renault[1], I. Young[1], S. Halwas[1] and S. Kunkel[1]



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Summary

The Gunnar gold mine tailings pond has remained largely nonvegetated since the mine was closed 66 years ago. For this study, the natural spruce/larch forest that has developed on the southwest corner of the site was examined. The trees are moving onto the site at the rate of 1.2 to 1.8 m/a and would take at least another 70 years to completely cover the tailings pond. Both black spruce and larch show a similar pattern of growth, showing positive correlations with spring precipitation. This suggests that increasing water availability on the nonvegetated areas is key to any revegetation efforts. The establishment of the forest is accompanied by a decrease in pH and conductivity of the tailings and a buildup of organic matter. Both the vegetation and the soil organic matter represent a large pool of stored carbon.

Introduction

The Gunnar gold mine, situated within the Archean Rice Lake greenstone belt in southeast Manitoba, was in operation from 1936 to 1942 (Slivitzky, 1996). The minesite (lat. 50°51.37′N, long. 95°15.31′W) contains approximately 11 ha of tailings located in a depression. Since the time that the mine closed, natural revegetation has been limited. On the east side of the tailings pond, a wetland has developed where the tailings grade down towards Beresford Lake. On the southwest side of the pond, vegetation has developed following a regular pattern of colonization (Figure GS-12-1): first by horsetail *(Equisetum)* followed by willow *(Salix* spp.*)* and birch (*Betula pimula*) shrubs and finally black spruce (*Picea mariana*) and larch (*Larix laricina*).

The total vegetation zone varies from 60 to 80 m in width. The remaining non-vegetated area of tailings is approximately 360 by 120 m. A survey conducted this summer showed that the elevation varies by approximately 1.8 m, being greatest at the west end of the pond and grading to the east and to a lesser extent to the south. Previous work (Renault et al., 2006, 2007) has shown that the chemical and physical properties of the tailings may have prevented or limited plant growth on the tailings. These properties could include low levels of nutrients (nitrogen) and low organic matter content (Slivitzky, 1996). The level of heavy metals (arsenic and copper) and cyanide could have also limited plant growth and establishment as they were found to exceed the Canadian Interim Remediation Criteria for Soil (CIRCS) Agricultural and/or Residential/Parkland guidelines in some areas of the tailings (Slivitzky, 1996). However, acid drainage is not likely to be a main concern as the pH of the tailings ranged from 6.4 to 8.5 (Slivitzky, 1996; Londry and Sherriff, 2005; Renault et al., 2007). Both field and lab studies on the nearby Central Manitoba mine tailings site have shown that organic amendments can improve plant growth and survival (Markham, 2005; Szczerski, 2007; Green and Renault, 2008). Consequently, future remediation plans for this site include the application of organic amendments to revegetate the open area of the tailings.

Figure GS-12-1: *Gunnar mine tailings site; south side (on the left) covered with vegetation and north side (on the right) with very limited vegetation.*

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[1] Department of Biological Sciences, University of Manitoba, Winnipeg, Manitoba R3T 2N2

Objectives of the study

The purpose of this study is to examine changes associated with the natural revegetation that has occurred on the Gunnar mine tailings site and to examine which environmental parameters are important predictors of tree growth. This will provide insight into the changes that need to be made in order to fully revegetate this and potentially similar other mine tailings sites and what further changes can be expected in soil development as planned remediated areas become naturalized.

Analytical methods

On June 24, 2008, four transects were sampled along the southwest side of the tailings pond running into the natural vegetation. Transects were set up by selecting points approximately every 30 m along the edge of the vegetation (the *Equisetum* zone) and along perpendicular lines directed towards the pond edge. In every 10 m segment of the transect line, a spruce and a larch tree were selected at random, if present. The depth of the organic matter layer was measured within the crown of the selected trees. Following removal of the organic matter layer, tailings cores were collected to a depth of 20 ±5 cm and air dried. The conductivity of the air-dried tailings was recorded with a Traceable™ Portable conductivity meter (Fisher Scientific) after adding one volume of tailings to one volume of water (Schofield and Taylor, 1955). To determine the pH of the tailings, two volumes of 0.01 M $CaCl_2$ was added to one volume of tailings. The pH of the filtered suspensions was measured with an Accumet pH meter (Fisher Scientific). Tree height was measured with a clinometer. Tree cores were taken from trees with a diameter >6 cm at breast height for growth analysis. The growth increments were measured on the dried and sanded cores. For each core, the increment width was standardized to standard deviation units and a mean of zero. These standardized values were used to calculate the mean deviation in growth for each species in each year. To compare growth increments for each species, years where less than six trees of each species were present were excluded from the analysis. On September 2, shoot tips (20 cm long) of each selected tree were collected and freeze dried. Tailings, organic matter and plant tissues (stems and needles) will be analyzed for metal and nutrient content in the fall of 2008.

Results and discussions

Tree age ranges from 13 to 37 years for spruce and from 9 to 27 years for larch (Figure GS-12-2). There is a strong relationship between the distance along the

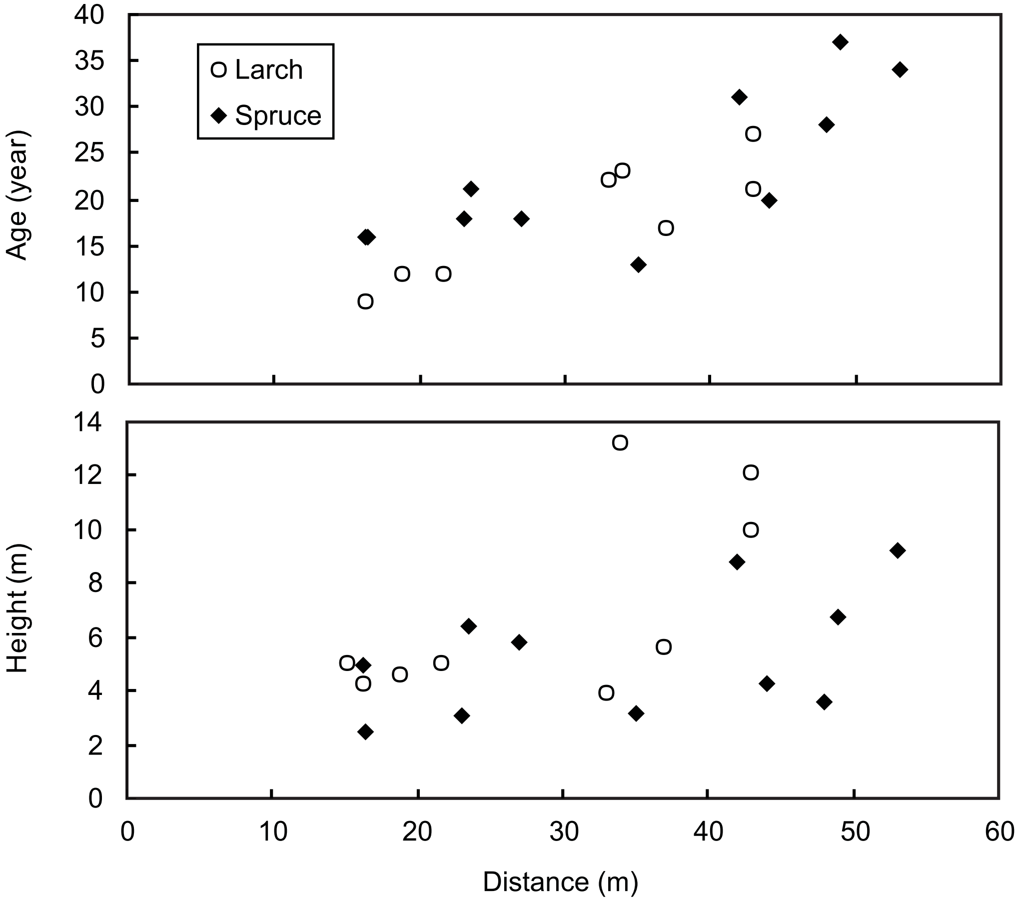

Figure GS-12-2: *Changes in black spruce and larch age and height along the vegetation zone of the Gunnar mine tailings pond.*

transect and the age of both larch and black spruce, suggesting a gradual spread of trees onto this site. By examining the maximum age of trees along transects, it appears that the trees are spreading onto the tailings ponds at a rate of approximately 1.75 m/a. This is somewhat faster than the average of the approximately 80 m of vegetation that have developed in the 66 years since the site has been abandoned (i.e., the equivalent of 1.2 m/a). By using these two estimates of vegetation spread, it can be derived that it would take between 70 and 110 years more for this site to become completely revegetated naturally. This assumes that conditions in the nonvegetated region of the tailings pond are the same as those in the vegetated region (an analysis that is ongoing) and that environmental conditions will remain favourable for plant growth. The height of the black spruce and larch varies between 2.4 and 6.4 m in the first 30 m of the transects whereas the height of some larch and spruce reached 13.2 m and 9 m, respectively, in the following 30 m (Figure GS-12-2). Both spruce and larch show significant variation in growth (Figure GS-12-3). There appears to be a significant correlation in growth increments between black spruce and larch ($r^2 = 0.667$) when restricted to the period from 1986 to 2007 (i.e., when both species had at least six trees present in the dataset). This suggests that the same environmental conditions are required for both species. There was a significant drop in growth in the mid 1990s and a significant increase in growth from then on. For the period of 1986 to 2007, there were significant positive correlations between the standardized growth increments of both species and the growing season (April–September) mean daily temperature and the total precipitation from the beginning of April until the end of June (Figure GS-12-4). Linear regressions, however, showed that growing season mean daily temperature accounted for less variation in growth of both larch ($r^2 = 0.34$) and spruce ($r^2 = 0.27$) than did the spring precipitation ($r^2 = 0.43$ for larch and $r^2 = 0.40$ for spruce). This suggests that the growth of both tree species on this site is strongly dependent on spring precipitation.

The data from this study suggest that the Gunnar mine tailings site is becoming more fertile as the tree cover develops. The pH of the tailings is relatively homogeneous and slightly lower (7.3–7.7) than the values recorded previously for the tailings (8.15–8.3) in the nonvegetated areas (Renault et al., 2007). The conductivity of the tailings along the transects is higher in the first 35 m (Figure GS-12-5) while lower values were recorded away from the tailings (36–54 m). The overall values of conductivities are also lower than the ones recorded for the tailings of the nonvegetated zone (287–360 mS/m^{-2}; Renault et al., 2007). The organic matter depth along the transects is less than 60 mm in the first 30 m and increases to 225 mm between 30 and 60 m with an average of 91 mm (Figure GS-12-5). This represents a large pool of carbon stored on the site.

Future research

Chemical analysis of the tailings, organic matter and plant tissue samples are presently being conducted. These results will determine how soil fertility on this site is changing and if plants growing on this site have accumulated heavy metal. Given the deep organic layer that has developed on this site, the total amount of stored carbon

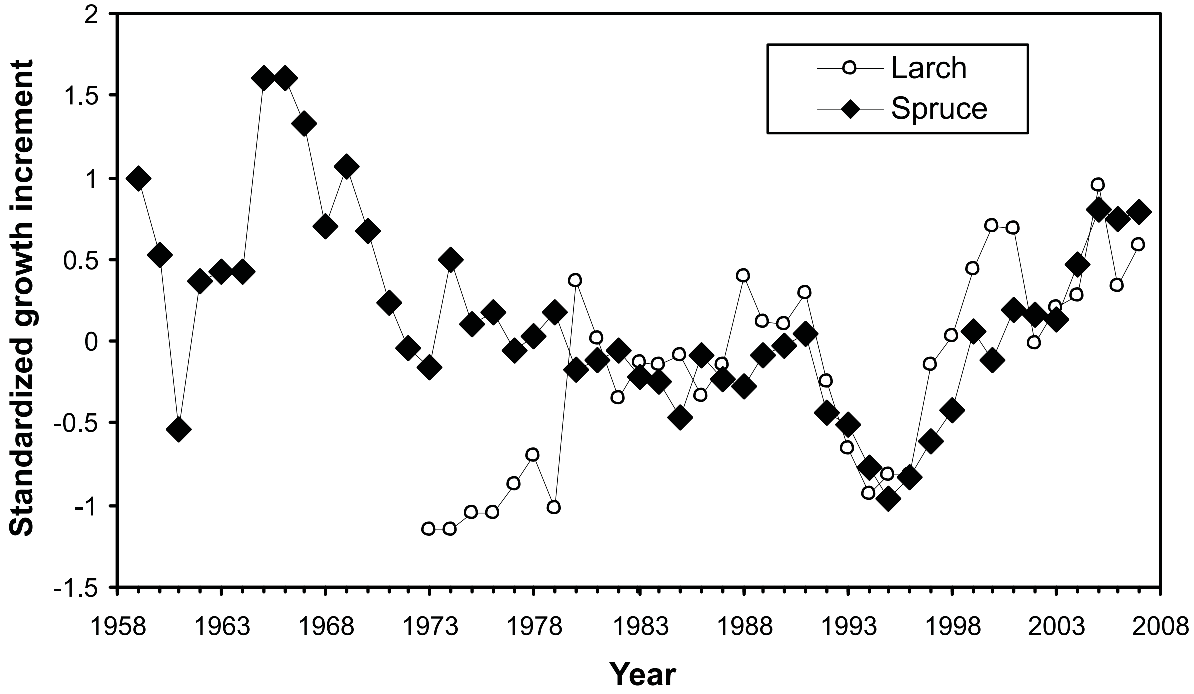

Figure GS-12-3: *Variation in black spruce and larch standardized growth increments from trees along the vegetation zone of the Gunnar mine tailings pond (1958–2008).*

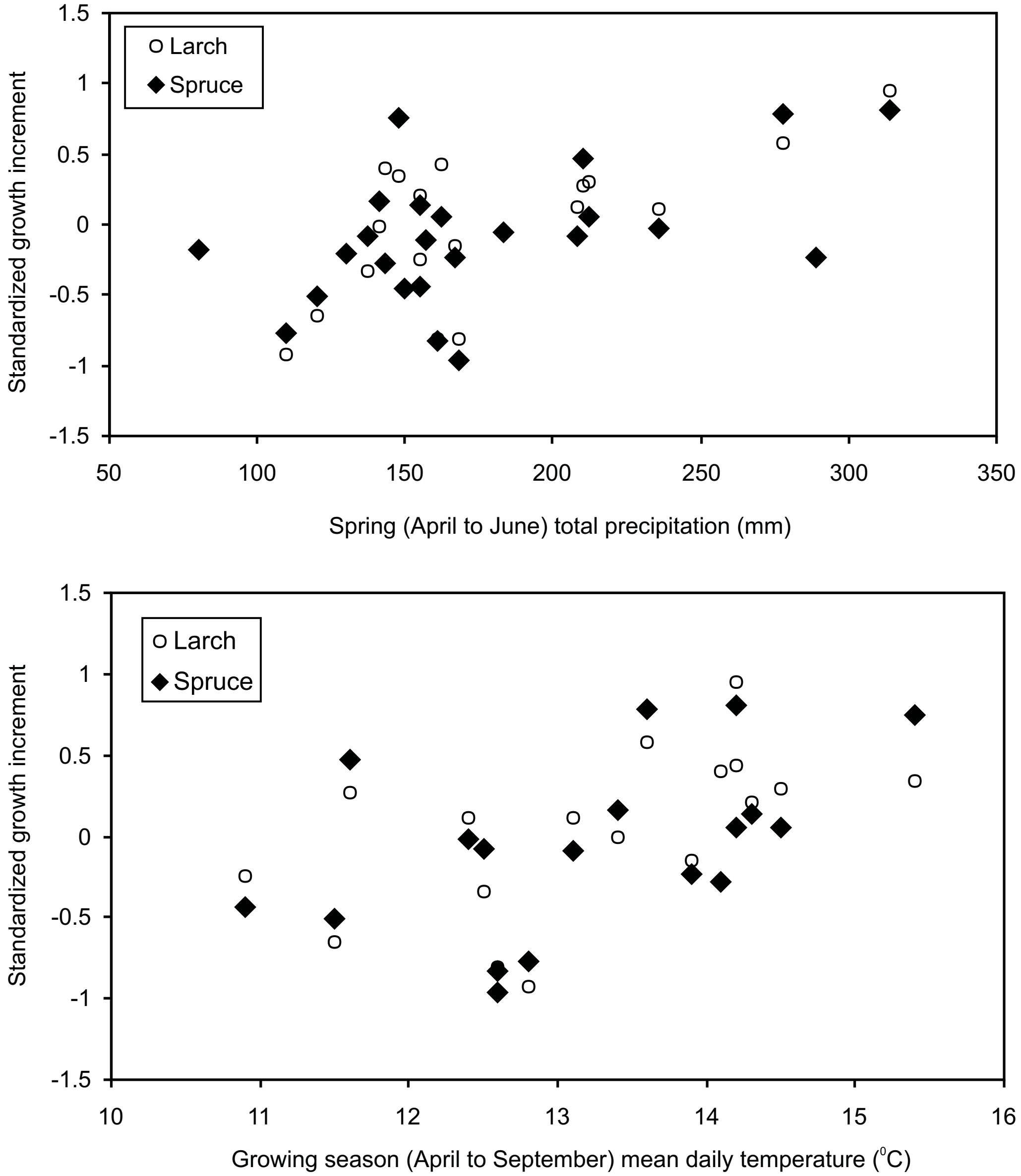

Figure GS-12-4: *Relationships between standardized growth increments and spring (April–June) total precipitation and growing season (April–September) mean daily temperature (1986–2008), vegetation zone of the Gunnar mine tailings pond.*

needs to be assessed. This will provide a benchmark for future site remediation studies planned for 2009.

Economic considerations

Mining activities result in the loss of timber, biodiversity and ecosystem services. The Gunnar mine tailings site has missed a full timber rotation since it was abandoned. Without remediation, the site will be barren for another rotation. The site has also undergone a loss of carbon-holding capacity. Based on estimates for other coniferous stands (Yemshanov et al., 2005), the forests on the Gunnar mine tailings pond could have stored 57 tonnes of carbon per hectare as wood. The large buildup of organic matter suggests that much more than the 200 tonnes of carbon per hectare generally estimated to be stored in forest floors (van Kooten et al., 1991) can accumulate in the soil on this site. Based on a modest dollar value for carbon storage (e.g., $10/t), the ability of this site to hold in the order of 3000 tonnes of carbon represents a significant economic potential.

Acknowledgments

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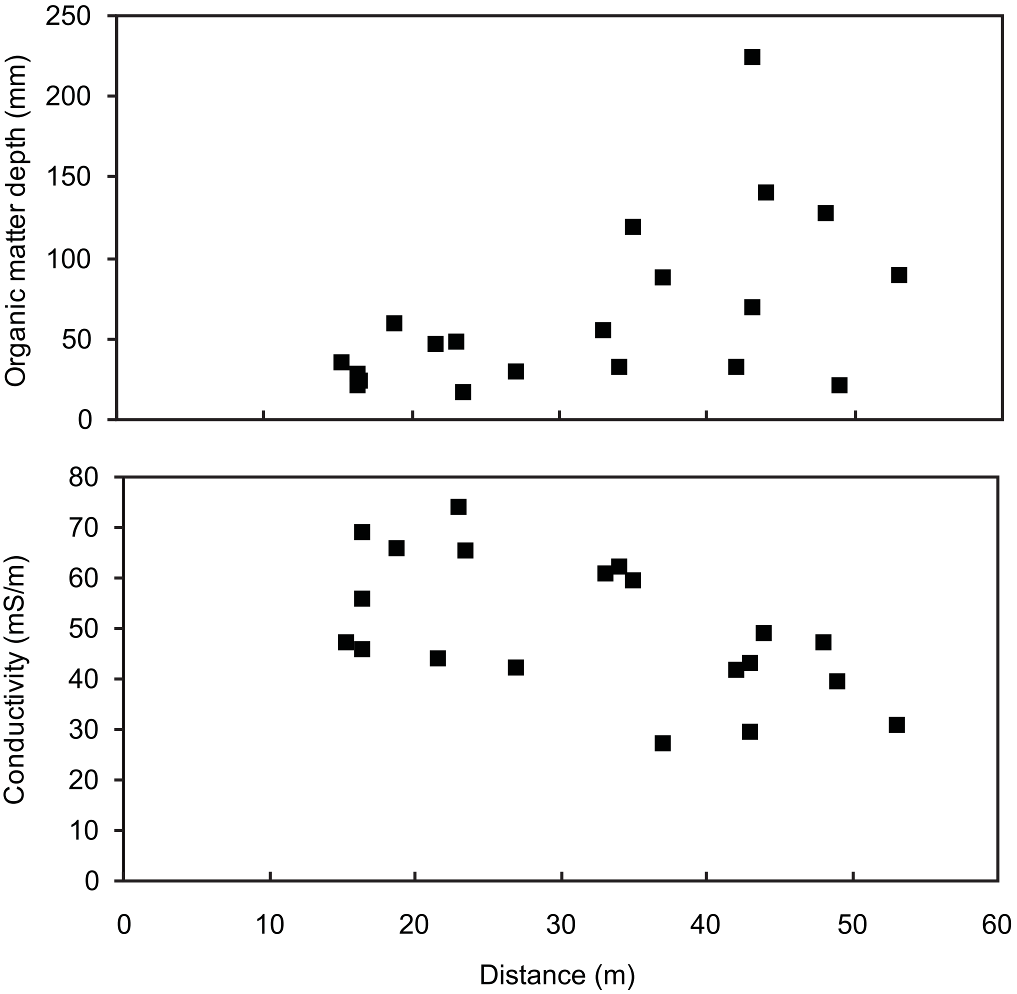

Figure GS-12-5: *Changes in tailings conductivity and organic matter depth (OM) along the vegetation zone of the Gunnar mine tailings pond.*

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