Minimal Amelioration as Appropriate Technology in the Green Flin Flon/Creighton Project[1]

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Abstract

Vegetation on the acidic, metal-contaminated soils near the Flin Flon, Manitoba copper-zinc smelter comprises a few stunted woody species and a metal-tolerant ecotype of colonial bentgrass (*Agrostis capillaris*). Experiments initiated in 1995 showed that the manual application of ground limestone to the soil surface detoxified the soil sufficiently for spontaneous colonization by seedlings of birch, poplar and willow, and these seedlings continue to thrive. A similar procedure has been in use in Sudbury, Ontario, since 1978, but with the additional feature of seeding with a grass/legume seed mixture. Experiments have shown that standard grass-legume revegetation mixtures do poorly on limed Flin Flon soils, and do not give the aesthetically pleasing green cover seen in Sudbury. In 1999, a community based greening program was initiated in Flin Flon and neighbouring Creighton, Saskatchewan. Since the introduction of a grass/legume cover is not a prerequisite to native woody plant establishment, limited funds are available for seed purchase, and work force is small and volunteer-based, minimal surface soil amelioration with ground limestone is clearly the appropriate technology to employ. The approach is less successful at some sites than others, and future research will investigate possible limiting factors at the recalcitrant sites.

Introduction

Sudbury, Ontario (46°30'N 81°00'W) and Flin Flon, Manitoba (55°00'N 102°00'W), with its twin town Creighton, Saskatchewan, share certain aspects of their environmental histories. Both are on the Precambrian Shield, their landscapes featuring an abundance of rock outcrops, with shallow pockets of soil derived from glacial till. In both centres, the smelting of sulphide ores has occurred over many decades. The emissions acidified the soils close to the smelters, and contaminated them with particles of metal oxide: mostly copper + nickel in Sudbury, and copper + zinc in Flin Flon. In Flin Flon, smelting began in 1930, compared to 1888 in the Sudbury, but at both sites, emissions were initially discharged from relatively low smokestacks. The first Flin Flon stack was less than 30 m in height, while two later stacks were 53 and 69 m high, respectively. In both cities, there was a substantial change in atmospheric chemistry in the late 1960s and early 1970s, with the construction of tall smokestacks and improved electrostatic precipitation of metal particulates. In 1974, a 251 m stack was constructed in Flin Flon, paralleling Sudbury's 381 m "superstack" that commenced operation in 1972.

In both the Sudbury and Flin Flon areas, soil pH in the vicinity of the smelters is usually in the 3.5 - 4.5 range. At Flin Flon, Hogan and Wotton (1984) found soils with up to 4,000 ppm Zn and 1,000 ppm Cu near the smelter, and showed that Cu, Pb and Zn were elevated in the organic layer of the boreal forest system up to 35 km from the smelter stack. Pip (1991) found unamended soils 0.3 km from the smelter with 538 ppm Pb, 332 ppm Cu and 13 ppm Cd, while the present author found 515 ppm Zn and 320 ppm Cu in a barren soil near the smelter. More recently, detailed studies were made of metals in humus and till (Henderson & McMartin 1995, Henderson *et al.* 1997). Soils near the Sudbury smelters routinely contain copper levels above the value of 225 ppm established by the Ontario Ministry of the Environment as an adverse effects-based guideline for soils, sometimes reaching as high as 1,000 ppm (Ontario MOE, 2001). Similarly, the nickel content of Sudbury soils frequently exceeds

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the MOE's effects-based guideline of 150 ppm, also reaching 1,000 ppm on occasions. Zinc levels, however, do not even approach the effects-based guideline of 600 ppm. In contrast, Flin Flon copper levels are similar to those at Sudbury, but zinc levels frequently exceed Ontario's effects-based guideline.

Despite improvement in atmospheric quality, both cities retain a legacy in the form of landscapes that are barren or partly barren of vegetation. The high metal content, interacting with the high acidity, makes the soils phytotoxic. At both sites, some individual plants, mostly woody, have survived in a stunted condition, but regeneration by seed is severely limited. Also at both sites, certain grass species capable of genetic selection for metal-tolerance have colonized the otherwise barren soils. In Sudbury, these are the native grasses *Deschampsia caespitosa* (Tufted Hairgrass) and *Agrostis scabra* (Tickle Grass), while in the case of Flin Flon it is non-native *Agrostis capillaris* (Colonial Bent Grass, locally nicknamed Flinty Grass). Reciprocal transplantation trials of these species between Sudbury and Flin Flon have been successful, but the degree of biodiversity and ecosystem enhancement that can be brought about by the use of metal-tolerant plants is limited (Winterhalder 1999).

In the early 1970s, research on the Sudbury barrens showed that the manual application of ground limestone would detoxify the surface soil sufficiently to trigger spontaneous colonization by a variety of native plant species with wind-dispersed seeds. Ground dolomitic limestone is applied to the soil surface by hand at an average rate of 27.6 cu yds/ha (approximately 70 tonnes/hectare), followed by broadcast seeding of a grass-legume mixture between mid-August and late September. A light application of a low nitrogen fertilizer (e.g. 6:24:24) is also given, although this is not essential when some residual organic matter is present. The seeds germinate within a few weeks, the seedlings overwinter, and growth recommences the next spring. The grassed landscape is soon colonized by seedlings of birch, poplar and willow, and native pine species are usually planted in small random groups within the first few years following liming. Since 1978, the City of Greater Sudbury has revegetated more than 3000 hectares of barren land in this way.

In 1993, the present author was contacted by the Creighton-Denare Beach environmental coordinator, enquiring about the feasibility of greening the Flin Flon-Creighton landscape using the Sudbury technique. Examination of photographs and soil samples confirmed that a similar situation existed at both locations, and the author visited Flin Flon/Creighton in late July, 1994.

Experimental Field Trials at Flin Flon

A few small experimental plots, varying in area from 1 – 3 m^2, were set up in 1994 on a barren hillside in Creighton, 2 km south of the Flin Flon smelter. Ground horticultural dolomitic limestone was manually applied to the barren soil surface, and in some cases the plots were seeded with the same grass/legume seed mixture used in Sudbury. Expectations of success were not high, in view of the more northern latitude with its longer, colder winters and shorter growing season, as well as the presence of elevated levels of zinc.

The experimental plots were revisited in 1995, and it was observed that establishment and survival of the grass/legume mixture varied from sparse to non-existent. This suggested that it would not be possible, at least within a year, to obtain the instant greensward that made the Sudbury revegetation program so aesthetically pleasing. Nevertheless, the second phenomenon characteristic of vegetation dynamics following liming in the Sudbury area, spontaneous colonization by native woody plants from wind-blown seeds (Winterhalder 1995) was in evidence. The success of this seedling establishment in the 1994 plots has been monitored over successive years, and the results continue to be encouraging (Figure 1). Figure 2 shows how the five tallest seedlings in each of twelve of these plots continued to show an annual height increment up to eight years following treatment.

In 1997, the author met with Ms. Heather Acres and Mr. Clarence Petterson of the Flin Flon School District and geologist Dr. David Price, and together they explored the feasibility of using

limestone currently transported from 25 km west of Creighton, Saskatchewan by McKeen's Trucking for industrial purposes, rather than the more expensive horticultural product. Field trials showed that the dolomitic limestone quarried 25 km west of Creighton, Saskatchewan was almost as effective as commercial limestone in soil detoxification.

The Initiation of the Green Flin Flon Program

In 1999, Ms. Acres and her committee formulated the idea of involving Flin Flon/Creighton students, mentors, junior hockey team players and citizens in a "Green Flin Flon" program. In October 1999, the Hudson Bay Mining and Smelting Company and the Flin Flon Economic Development Commission sponsored the author to visit Flin Flon and speak about the project to a number of groups, including schools, service clubs, citizens and HBM&S staff. During the summer of 2000, 4.5 hectares of land were limed by volunteers, mostly elementary and high school students. Dolomitic limestone with a base content of 29% Ca and 22% Mg, ground so that 10% passed 100 mesh, 15% passed 40 mesh and 58% passed 10 mesh, was applied by hand at an average rate of 27.6 cu yds/ha (approximately 70 tonnes/ha). In most cases, small pails were used to carry and spread the limestone, and coverage was very uneven. In 2001, 4.8 ha were limed in a similar fashion, followed a similar area in 2002. Liming has been carried out at sixteen different sites throughout the Flin Flon - Creighton area, varying in area from 0.25 to 2.25 ha.

Because of the relative lack of success of seeded grass establishment in the experimental plots, little emphasis was placed on seeding, although 0.75 ha were seeded with a grass-legume mixture (Table 1) in 2000 and 0.5 ha in 2001 In no case was any form of fertilizer utilized.

Table 1. Composition of seed mixture.
10% Perennial Ryegrass *Lolium perenne*
10% Meadow Foxtail *Alopecurus pratensis*
15% Kentucky Bluegrass *Poa pratensis*
10% Redtop *Agrostis gigantea*
15% Timothy *Phleum pratense*
15% Red Fescue *Festuca rubra*
10% Tall Fescue *Festuca arundinacea*
10% Alsike Clover *Trifolium hybridum*
5% Birdsfoot Trefoil *Lotus corniculatus*

Vegetation Establishment Monitoring

Since the primary goal of the liming procedure is to stimulate colonization by native woody species, this was the more intensively monitored variable. However, in view of the fact that an increase in grass cover, whether or not the site was seeded, contributes to the visual "greening" effect, this variable was also measured in a less intensive fashion.

Methods – Woody Plant Establishment

One or two 25 m belt transects, each 2 m wide, were set up at each liming site. The identity of each colonizing seedling, its position along the transect, its distance from a line representing the centre of the belt and its height were recorded. The number of seedlings of each species and their aggregate and mean height in each 50 m^2 rectangle was determined. The purpose of determining the precise position of each seedling in the transect is to create a baseline database that can be used in tracing the survival and growth of individual seedlings over subsequent years.

Results – Woody Plant Establishment

An interesting aspect of the results of liming has been the great variability between sites. At some sites there has been conspicuous colonization by native woody species, in others there has been a significant increase in cover by the tolerant grass *Agrostis capillaris,* while at a few sites the liming appears to have had little or no impact on vegetation.

Figure 3 shows the density of woody colonists at the Hapnot Lake and Knight St. sites in stems/50 square metres. The species that colonized most rapidly, appearing in the first year, was Manitoba maple, which is not native to the area but is commonly planted as a street or yard tree. At Hapnot, seedlings showed little growth beyond the first pair of foliage leaves, and rarely survived the first winter, but performed better at Knight St. In the second year, the density of the native species is in the order birch>willow>aspen at both

sites. At Hapnot, there is a slight decrease in the density of all species in the third year, whereas at Knight St. birch, aspen and willow continue to colonize The increase in aspen seedlings is especially striking, and it indicates the concurrence of the short summer period of seed rain combined with an appropriate wind direction and soil moisture level, since aspen seeds are of short viability. When the mean height of each species is calculated (Figure 4), it becomes evident that the surviving seedlings are growing consistently.

Figure 5 shows how dense seedling establishment can be at the Knight Street site in certain sheltered microenvironments.

One very encouraging feature is the occasional establishment of a spruce seedling. Spruce forest is the expected climax ecosystem for this area, and the spontaneous appearance of coniferous seedlings so early in the revegetation process is a phenomenon that not even Sudbury can boast.

Methods – Changes in Herbaceous Cover

Along each line transect, five 1m x 1m quadrats were constructed on each side for a total of ten, 4-5, 9-10, 14-15, 19-20 and 24-25 m, respectively, from the "base" end. Percent cover by herbaceous vegetation, which was almost entirely flinty grass, was determined in each quadrat, as well as rock and moss cover if present at a significant level.

Results – Changes in Herbaceous Cover

In six of the nine transects in which measurements were made over three years, there was a steady upward trend in herbaceous cover (Figure 6).

At the two sites with two years of data, herbaceous colonization was slow at Pizza Hill, presumably because the base cover was 0%. In the case of the Balsam site, transects were set up both on the limed area and the unlimed area. The data clearly show an increase in cover on the limed area and none on the control area.

Soil pH Adjustment

The soil pH value on the Flin Flon/Creighton barrens varies from approximately 3.0 to approximately 5.0, with the greater number of the soils sampled being between pH 3.50 and 4.0. Figure 7 shows of the degree of pH change that occurs in various sites from one to three years following liming. It is clear that soils differ in their buffering capacity, since some show a much greater change in pH than others following liming.

Discussion

It is clear that the Sudbury technique for establishing native woody species on acidic, metal-contaminated soils is applicable in certain parts of the Flin Flon pollution zone, but not in others. However, the establishment of a grass-legume sward, which is the typical first phase in Sudbury, appears not to be an option in Flin Flon. This is not considered to be a problem. Since the goal of the project is to return the landscape to native forest, the lack of non-native grasses and legumes could be considered an ecological asset, while savings are made by not having to purchase seed. The major drawback is that the "greening" process is a gradual one, and participants are not rewarded with a carpet of green the first spring following liming. The lack of nitrogen-fixing legumes could slow the process of nitrogen accretion, although there are native nitrogen fixers, such as green alder and soap buffaloberry, that might fill this niche.

The presence of recalcitrant sites that do not respond to liming in the short term is a greater concern. Data on soil pH show that the more successful sites have the lowest pH values prior to liming, but that all soils are adjusted to what appears to be a reasonable pH level. Clearly this paradox requires further research.

One hypothesis to explain the lack of response to liming at certain is a differential soil metal content or availability. As suggested by preliminary analyses. A second possible limiting factor is a physical one. The soils that do not respond have a relatively high organic matter content, and in some cases consist entirely of partially decomposed organic matter and the remains of

senescent flinty grass tussocks at the surface. This residual organic matter forms a poor seedbed, drying out quickly at the surface. Preliminary experiments have been initiated in which the surface of the problem soils are scarified, in the hope that the exposed mineral soil will prove to be a suitable safe site for birch, aspen and willow seeds.

It is clear that further research is required in an attempt to determine the factors liming success in the recalcitrant sites. This should include soil metal and organic matter analysis, as well as a greenhouse trial in which the soil surface of an organic Flin Flon soils is varied to test the drying-out hypothesis, and one in which seeds are sown onto a graded series of limed high metal and low metal soil mixes, to test the metal toxicity theory.

Acknowledgments

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I would also like to acknowledge the role that Rena Gummerson, Cathy Hynes & Donna O'Brien played in drawing my attention to the Flin Flon-Creighton environment in the first place.

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Figure 1. Plot 15, 2 m^2 in area, 8 years after application of dolomitic limestone

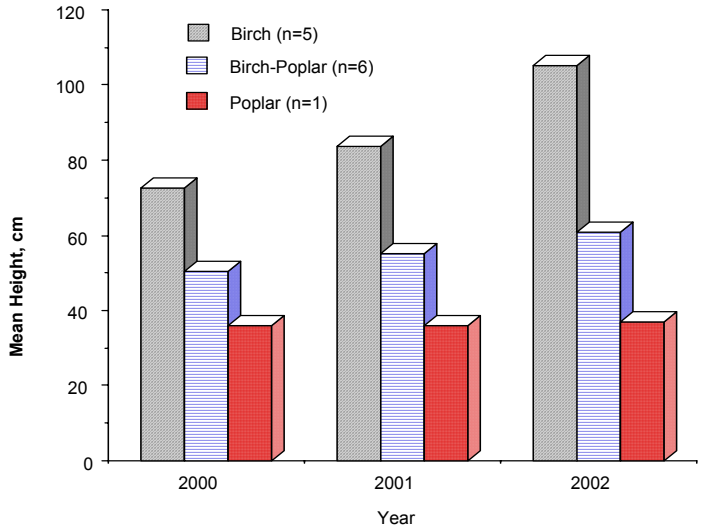

Figure 2. Mean height of the five tallest tree seedlings in twelve experimental plots, six to eight years after limestone application

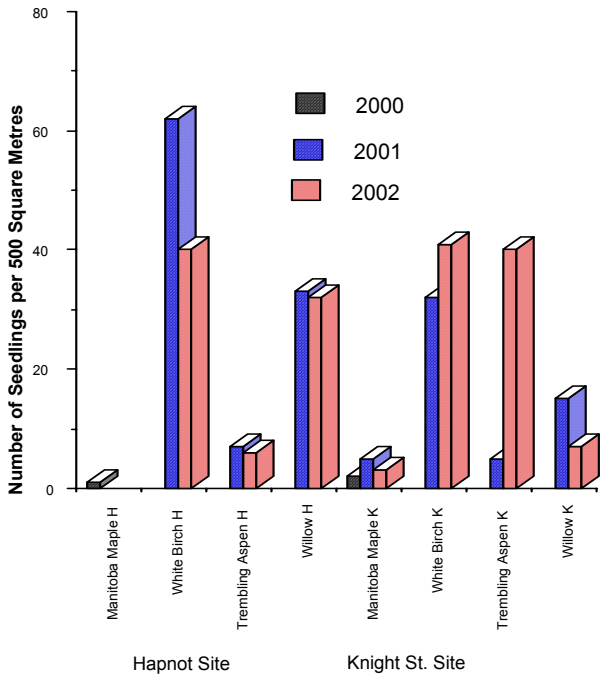

Figure 3. Woody plant colonization and survival, Hapnot Lake (Flin Flon) and Knight St. (Creighton)

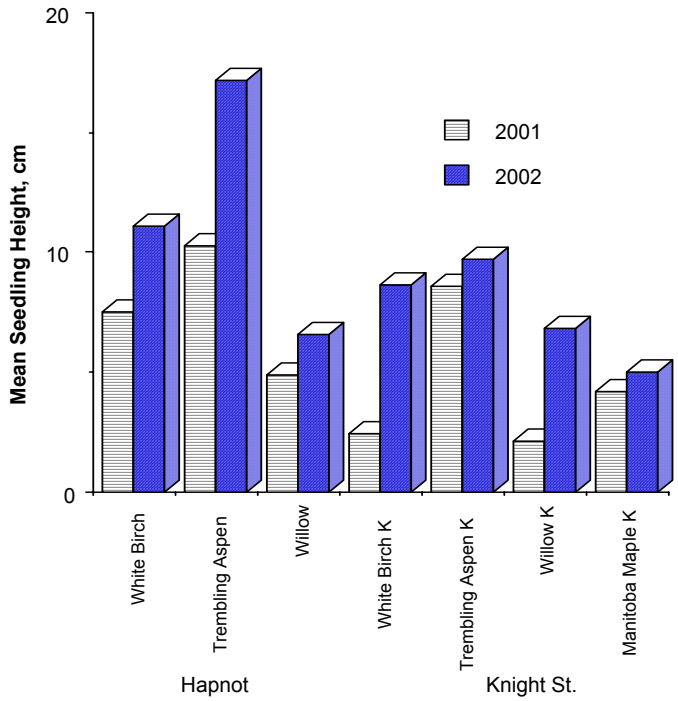

Figure 4. Changes in mean seedling height over time, Hapnot and Knight Street sites

Figure 5. Birch, aspen and willow seedlings at the Knight St. Creighton site, two years following limestone application

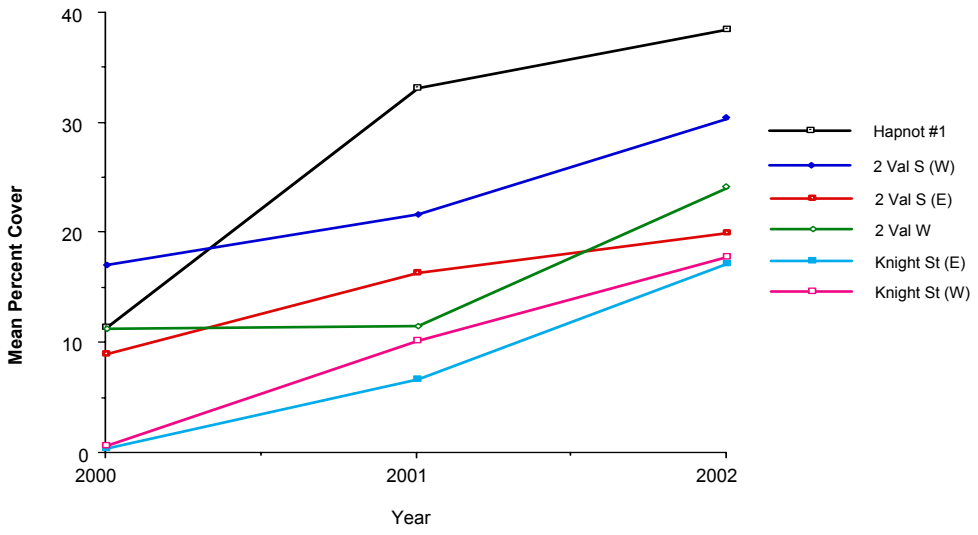

Figure 6. Trends in *Agrostis capillaris* (colonial bentgrass, flinty grass) cover following limestone application in the year 2000.

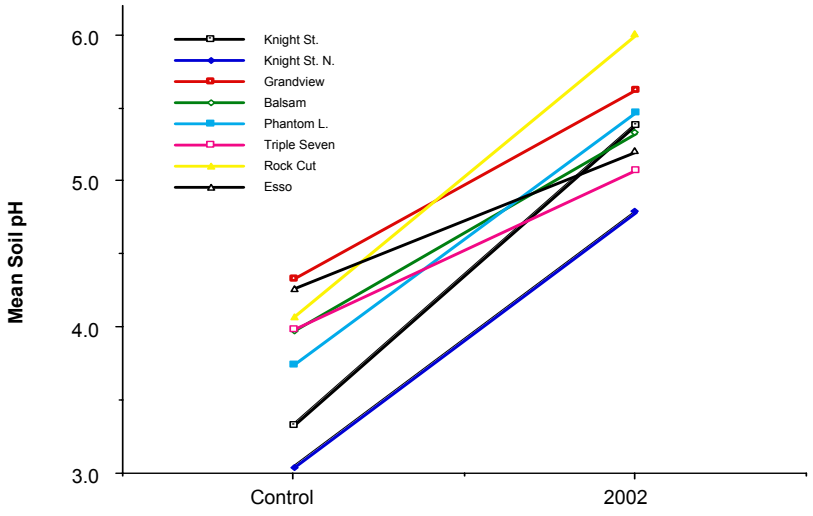

Figure 7. Soil pH adjustment following liming