8

Municipal Land Restoration Program: The Regreening Process

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Many cities and towns throughout the world suffer from environmental problems that affect the quality of life of their residents. Unfortunately, there are relatively few examples in which the communities have been effective at reducing or eliminating these problems. Sudbury's land reclamation and air pollution reduction program, Los Angeles's (Leuts and Kelly 1993) and Tokyo's (Nishimura 1989) smog reduction programs, the cleaning of the Thames River in London (Andrews 1984), Singapore's multifaceted environmental improvement program (Jee 1988), and land reclamation in the lower Swansea Valley of Wales (Box 8.1) are some examples where measurable success has been achieved.

Community Challenge

The destructive influence of past mining activities not only left Sudbury with a severe environmental problem, but its 160,000 inhabitants also inherited conditions that greatly restricted their socio-economic prospects. In the early 1970s, approximately 17,400 ha of land lacked vegetation, much of the soil had been acidified and metal-contaminated, and severe erosion had occurred on steep slopes and hilltops (Amiro and Courtin 1981; Freedman 1989). An additional 72,100 ha of land was semibarren, consisting mainly of stunted birch (*Betula papyrifera*) and red maple (*Acer rubrum*). Most highway and railway view corridors and many areas around neighborhoods and towns were severely affected. This blackened landscape, described in the media as "moonscape" and "dead zone" (Young 1992), limited the ability of the municipality to attract people and corporations to the area.

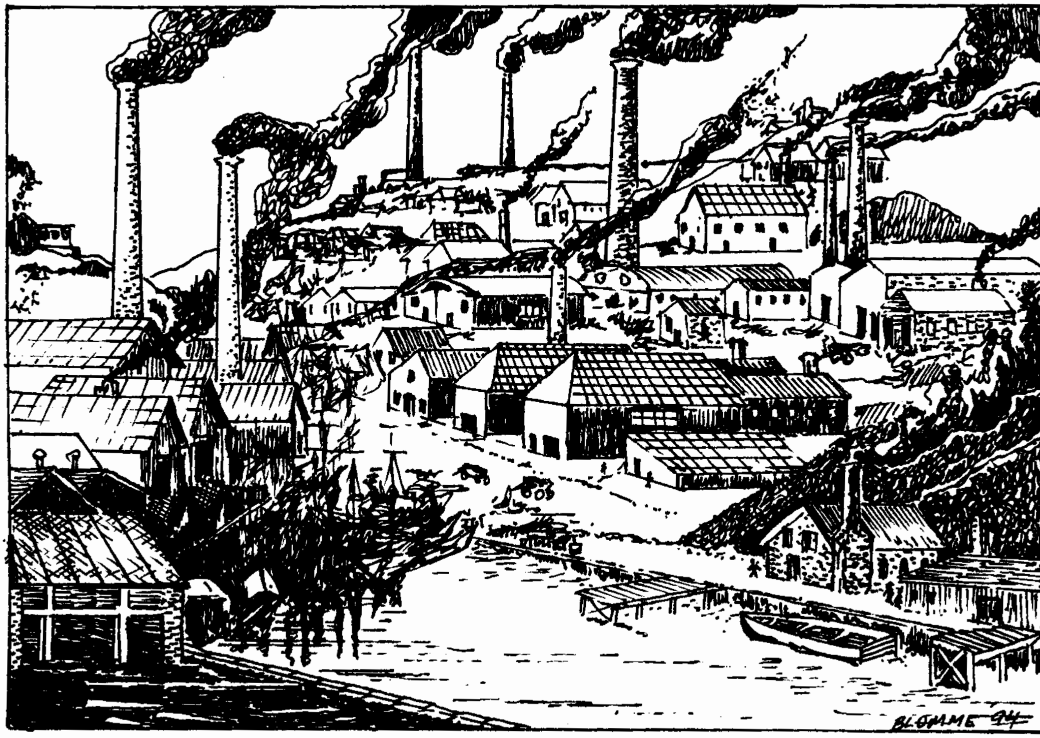
Despite the air pollution controls initiated in 1972, there was little positive response in vegetation growth (see Chapter 7). The damages to the vegetation and soil that had occurred over the past century were not going to recovery quickly without direct human actions. A large-scale remedial program was needed.

Program Beginnings

In early 1974, the Regional Municipality of Sudbury, a political entity that brought together the City of Sudbury and six adjoining towns (an area of 2800 km^2) began its restoration effort with the creation of a technical advisory committee composed of representatives of university, industry, government, and the general public. This group was given the challenge of providing the elected members of the regional council with advice on how to restore area vegetation.

One of the first tasks was to identify and map the areas needing treatment. At the same

Box 8.1. Lower Swansea Valley Project



From 1717 to the end of the First World War, Swansea, in southern Wales, was the world center of non-ferrous metal smelting (Weston et al. 1965). At different times, copper, lead, zinc, silver, and arsenic were smelted in 22 works along the tidal area of the River Tawe. Later, 10 steel and tin plants were established, making this one of the highest concentrations of metal works in Britain. Ore came from various parts of Britain as well as Chile, Mexico, Norway, Spain, Portugal, and Australia. A small amount of ore was also shipped to Swansea from Sudbury in 1900 by the Vivian Company that operated the Murray Mine. After the collapse of the metallurgical industries, the city of Swansea was left with the legacy of 325 ha of completely derelict land, consisting of huge piles of slag, ash, and coal shale. The dust, fumes, and physical appearance of the area were a depressing mixture. In 1961, a community-based program was begun to reclaim this derelict land in the lower Swansea Valley. The program succeeded, over the next 30 years, after a great deal of hard work, money, and technical assistance to revegetate the land while revitalizing the community (Bridges 1991).

time, experimental vegetation plots were installed at several locations to test various soil additives and grass mixtures. These small-scale test plots successfully demonstrated that future large-scale program implementation should be possible (Fig. 8.1). Also, relict patches of vegetation could form a nucleus for spread into treated areas.

Unlike restoration efforts on mine site wastes in North America (Daniels and Zipper 1988; Hossner 1988) and Europe (Bradshaw 1983), Sudbury's damaged landscape still possessed

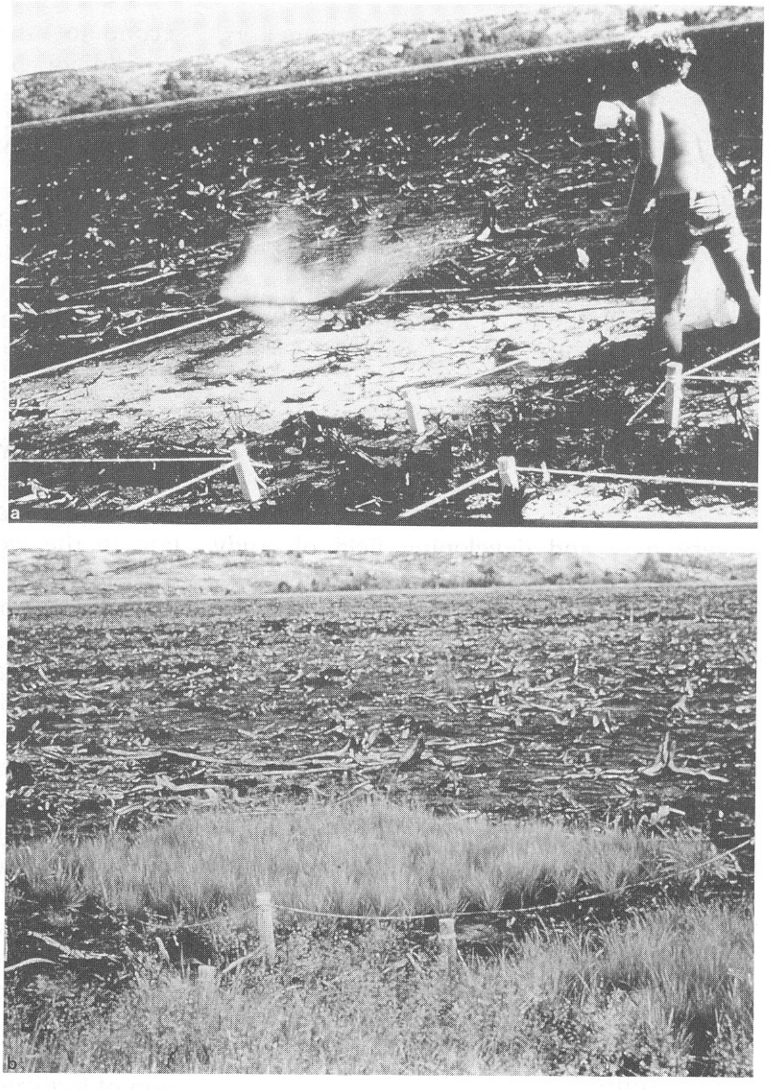


FIGURE 8.1.(*a* and *b*) Example of vegetation plots used to test treatment procedures for land reclamation in Sudbury. (Photo and studies by Winterhalder [1984].)

many of the characteristics of its original form. The topography consisted of rocky Precambrian Shield hillsides with patchy soils and wetlands. Standard mechanical reclamation techniques (Down and Stocks 1977; Peters 1984) were not suitable for treating such landscape. Other methods were required. Use of two local elementary school groups to reclaim trial plots near their school site successfully demonstrated that an alternate manual reclamation method was possible.

In 1978, the municipality began a large-scale reclamation program. In that year, the local mining companies laid off 3500 employees and curtailed all summer student hirings. In response, the municipality explored several programs to create or provide summer employment for students. Land reclamation was chosen as one of the principal programs to address these socio-economic needs. Funds were obtained from various government agencies and local mining companies (Lautenbach 1987).

Scientific Underpinnings

The challenges for an effective reclamation program were many (Winterhalder 1984; Freedman 1989). On barren sites near the smelters, soil pH ranged from about 3.0 to 4.5, whereas copper, nickel, and aluminum frequently reached 1000 μg/g (see Chapter 4). Also, the blackened sites had extreme surface temperatures (>50°C) and were arid in summer and subject to severe frost heaving in winter (see Chapter 18). Laboratory experiments demonstrated that root growth of seedlings in these toxic soils was inhibited, resulting in dehydration and death (Whitby et al. 1976; Winterhalder 1984).

There was little scientific information to guide the design and implementation of an effective reclamation program for this type of landscape. Restoration ecology was and still is a very new and developing field of study (Bradshaw 1983; Cairns 1988). Therefore, testing and monitoring were essential for achieving the objectives of the reclamation program. The objectives were to

- create a self-sustaining ecosystem with minimal maintenance
- use plant species that are tolerant of acidic soils and low nutrient concentrations
- use seed application rates that allow for natural colonization and thus increase species diversity
- give preference to the use of native species
- restore nutrient cycles and pools by the use of species that fix nitrogen (legumes)
- use species that attract and provide cover for wildlife
- undertake initiatives that speed up natural successional changes

Restoration Process

One of the main reclamation goals was to reestablish a forest similar to that which once covered the barren hills. However, initial field trials had demonstrated that liming was needed to detoxify the soils and that a herbaceous grass cover was desirable before shrubs and trees could be successfully established (Winterhalder 1984). Therefore, two major program components evolved: the first to conduct liming and initiate grass-herb cover, and the second to introduce tree and shrub species that did not colonize spontaneously.

Initial Grassing

Soil pH was first measured to determine the amount of crushed limestone required to neutralize soil acidity. An application of approximately 10 tonnes of agricultural-grade calcitic or dolomitic limestone was required per hectare to raise the pH of these soils from 3.0–4.5 to the desired level of 5.5–6.0.

Limestone was bulk-shipped to reclamation staging areas, where it was bagged for subsequent transport to barren hillsides. The most practical and economical means of transportation to the work site was used. Equipment used included pickup and flatbed trucks, rail flatbeds, helicopters, and all-terrain vehicles. After the bagged limestone was moved to the work site, it was carried by employees up the hills for spreading. Lime bags were placed at 1-m intervals to ensure adequate area coverage, then spread (Fig. 8.2). Approximately 80% of the workforce's time in grassing was required to bag, move, and spread lime. Most of this work took place early in the spring and summer months.

Later in the summer, after the crushed limestone had reacted with the soil for several weeks, workers returned to limed sites and spread a high-phosphorus fertilizer (6N-24P-24K) at a rate of 400 kg/ha. After the application of fertilizer, a seed mixture of grasses and nitrogen-fixing legumes (Table 8.1) was sown (Fig. 8.3) at a rate of 45 kg/ha. Seeding was done in mid-August to coincide with fall rains. No attempt was made to create an even coverage of grasses and legumes (Winterhalder 1983). In fact, a patchy cover of approximately 24–40% of grasses and legumes was preferred because it allowed subsequent invasion and colonization by native herbs, shrubs, and trees, thus encouraging species and genetic diversity.

Between 1978 and 1993, 3070 ha of barren land was limed, fertilized, and seeded. This represented most of the barren lands immediately adjacent to major road corridors and nearly all the areas within urban neigh-

FIGURE 8.2. Spreading of crushed limestone.

TABLE 8.1. Summary of land reclamation treatment used on barren land affected by industrial emission in Sudbury

1. Limestone (usually dolomitic limestone)
   Applied at a rate of 10 tonnes/ha to raise pH to more than 5
   Applied several weeks before fertilizer and seed
2. Fertilizer—usually 6N-24P-24K
   Applied at 390–400 kg/ha
3. Seed mixture
   Several grasses and two legumes; applied at 30–50 kg/ha
   Mixture (by weight)

Redtop	*Agrostis gigantea*	20%
Creeping red fescue	*Festuca rubra*	10%
Timothy	*Phleum pratense*	20%
Canada bluegrass	*Poa compressa*	15%
Kentucky bluegrass	*Poa pratensis*	15%
Birdsfoot trefoil	*Lotus corniculatus*	10%
Alsike clover	*Trifolium hybridum*	10%

Grass-legume mixture is sown in mid–late August after start of cooler nights and autumn rains

4. Trees and shrubs—plant 1–2 years later
   Commonly used species include jack pine (*Pinus banksiana*), red pine (*P. resinosa*), white pine (*P. strobus*), white spruce (*Picea glauca*), tamarack (*Larix laricina*), red oak (*Quercus borealis*), and black locust (*Robinia pseudocacia*)

borhoods. In total, it represented approximately 20% of the barren land in the region. Also, both mining companies have operated their own restoration projects to cover tailings with vegetation and to rehabilitate land around their operations (see Chapters 9–11).

Tree Planting

Although grass-legume establishment was rapidly followed by spontaneous colonization of birch, poplar, and willows (see Chapter 13), no coniferous species appeared in the first few years

FIGURE 8.3. Cyclone seeding of grass and legumes after an area has been treated with limestone.

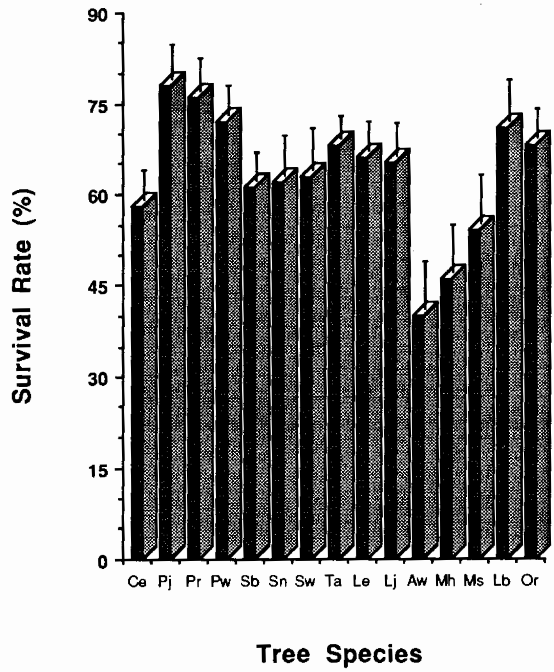
after treatment. Early attempts to plant conifers directly into untreated barren areas were also largely unsuccessful. However, with liming and the establishment of an herbaceous cover with its associated nutrients, soil moisture, and shade, successful tree planting of conifers and other trees became possible. Test plots in 1978–1982 demonstrated good growth and survival of trees planted on reclaimed sites (Lautenbach 1985).

The first main planting, consisting of 228,000 trees, occurred in 1983. Since then, work crews have planted more than 1.5 million trees on previously grassed sites (Fig. 8.4).

The basic goal of the municipal tree planting program is to create a self-sustaining ecosystem by matching tree species to the unique habitat features (soil moisture, exposure, slope, etc.) of the site being reclaimed. In an effort to create informal natural-appearing landscapes, plantation-style plantings have been avoided, and trees are planted in groups at fairly low densities to allow for natural infilling. Often, several different types of conifer

FIGURE 8.4. Tree planting.

FIGURE 8.5. Survival rates (+1 SD) after 3 years (1984–1987) of a sample of 300 trees for species used in reclamation work in the Sudbury area. The species included *Ce,* white cedar; *Pj,* jack pine; *Pr,* red pine; *Pw,* white pine; *Sb,* black spruce; *Sn,* Norway spruce; *Sw,* white spruce; *Ta,* tamarack; *Le,* European larch; *Lj,* Japanese larch; *Aw,* white ash; *Mh,* sugar maple; *Ms,* silver maple; *Lb,* black locust; *Or,* red oak. (Data from Beckett and Negusanti [1990].)



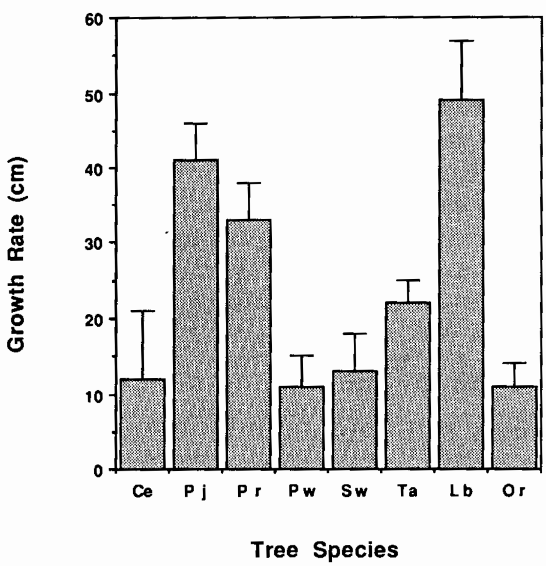


FIGURE 8.6. Mean annual growth in height of major tree species used in reclamation work in the Sudbury area. Measurements made in 1987, 3 years after planting. Means + SE are indicated for a sample of 300 trees for each species. Species included in *Ce,* white cedar; *Pj,* jack pine; *Pr,* red pine; *Pw,* white pine; *Sw,* white spruce; *Ta,* tamarack; *Lb,* black locust; *Or,* red oak. (Data from Beckett and Negusanti [1990].)

and deciduous trees are planted in each location. Species that have shown good survival (Fig. 8.5) and growth (Fig. 8.6) and are readily available from nurseries are selected. Planting stock mainly consists of 2- or 3-year-old bareroot seedlings and 6-month- to 1-year-old containerized or paper pot seedlings. More than three-quarters of the planted material has been conifers, with an emphasis on pines (red pine [*Pinus resinosa*], white pine [*P. strobus*], and jack pine [*P. banksiana*]) that have high survival and growth rates. The general aim is to plant species typical of mature northern Ontario forests to accelerate the slow pro-

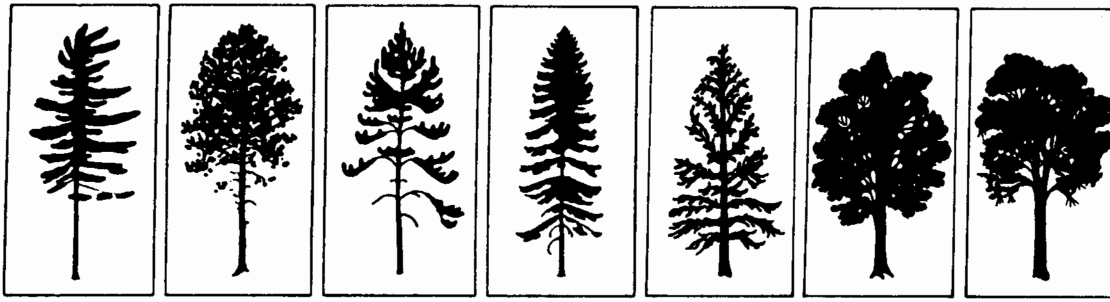


FIGURE 8.7. Principal tree species used in revegetation. The trees are not drawn to scale.

gression through successional birch and poplar woodland stages (Fig. 8.7). Planting of conifers also provides winter greenery and achieves part of the aesthetic goals of the program.

The black locust (*Robinia pseudoacacia*) is used for its nitrogen-fixing ability and tolerance in very dry and exposed sites. Although a non-native species, black locust has been useful in other reclamation efforts (Ashby et al. 1980) because of its rapid growth and good survival characteristics (Figs. 8.5 and 8.6). In addition to improving the nitrogen content of the soil, it also appears to be a useful "nurse" tree, providing shelter for more-sensitive species planted beneath it.

At present, all tree planting activity is limited to the spring season of the year. Trees are shipped from nurseries as soon as the ground thaws and are stored in refrigerated vans for planting. Planting generally occurs during the months of May and June.

In the past few years, many school classes, clubs, and environmental groups have volunteered their time and labor to assist in grassing and tree planting activities. Many of these organizations are now volunteering each year and are being encouraged to adopt areas for longer-term reclamation activity.

Monitoring

Field crews working under the supervision of faculty at Laurentian University monitor results of the reclamation program. Monitoring involves assessment of grass, shrub, and tree planting survival and the measurement of various chemical and physical site characteristics. Key findings include (1) pH values have remained elevated after liming; (2) metal uptake by plants declines after liming; (3) insects, birds, and small mammal populations have increased in reclaimed areas; (4) spontaneous colonization of herbaceous and woody species has occurred on treated sites; and (5) the percentage of grass cover has tended to decrease relative to the percentage cover of legumes and woody species. Greater details of these studies are provided in Chapter 13.

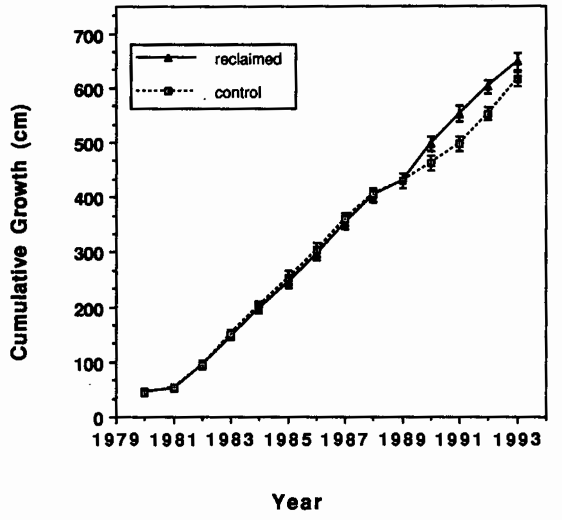
Findings for tree planting activities have been equally encouraging. Survival rates after 3 years have averaged 70% across all species (see Fig. 8.5), and growth rates have been similar to those from less-disturbed areas (Figs. 8.8–8.10).

Program Results

During 1978–1993, 3070 ha of barren land were reclaimed by grassing. During this period, 1,692,000 trees were planted on previously grassed sites (Fig. 8.11).

Total cost of the reclamation program during 1978–1993 has been approximately $15 million Canadian, with about 80% of the funds spent for salaries of the employees. Given the rough topography in which restoration was needed, manual grassing and tree planting techniques appeared to be the most cost-effective means of restoring the landscape. On average, treatment of a hectare of land costs less than $5000.

FIGURE 8.8. Cumulative growth of jack pine planted in 1979 compared with a non-polluted reforestation stand planted in the same year (n = 100 at each site). (Unpublished data of P. Beckett and J. Negusanti.)



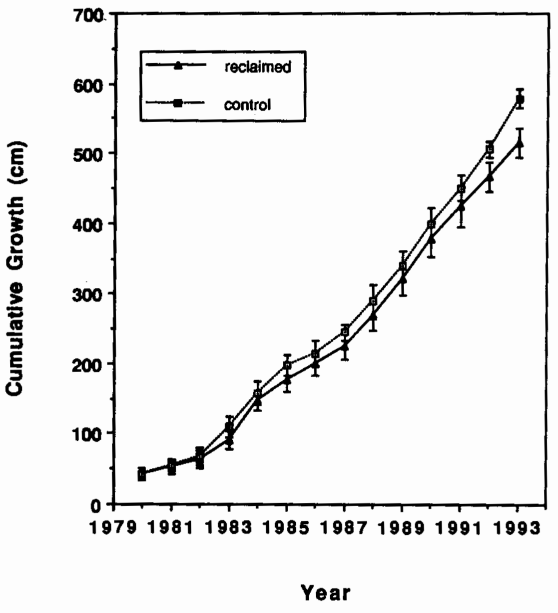


FIGURE 8.9. Cumulative growth of red pine planted in 1979 compared with a non-polluted reforestation stand planted in the same year (n = 100 at each site). (Unpublished data of P. Beckett and J. Negusanti.)

In comparison with many mechanized restoration techniques, the program has the added benefit of providing needed employment, being labor- rather than capital-intensive. More than 3340 individuals have been directly employed through the municipality's land reclamation program over the past 15 years. This has included 1600 students and 1740 individuals who were unemployed or on social assistance.

Future Initiatives

Considerable barren land and many other challenges remain for the municipal reclamation program. As the areas near road corridors are completed, additional costs and perhaps new approaches are needed to treat the more-remote areas. The newly forested areas are also potentially vulnerable to insect pests, fire, and expand-

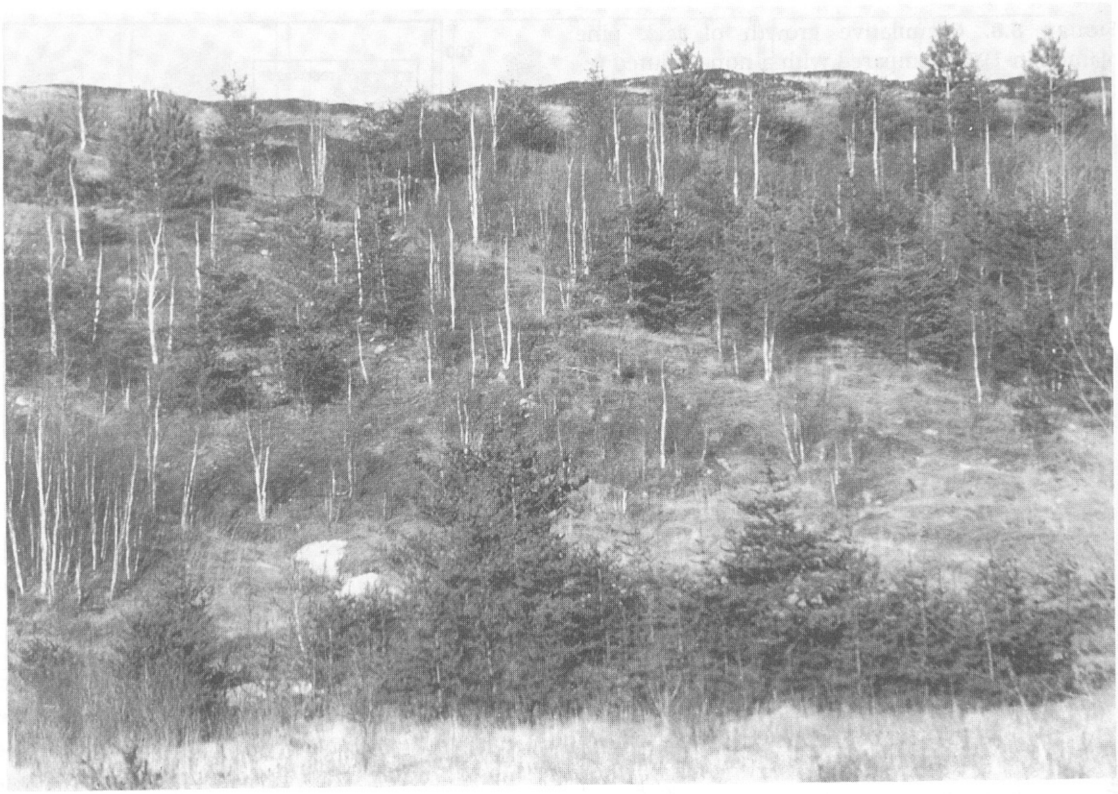


FIGURE 8.10. Picture of reforested area near Hannah Lake (1994) showing natural-type placement of trees. (Photo by P. Beckett.)

ing urban development and need to be protected.

One of the potential benefits of large-scale land reclamation activities that was not recognized at the start of this program is the improvement in the quality of drainage water from the treatment areas (Skraba 1989). To date, watershed liming treatments have contributed to increased pH and alkalinity in two area lakes (see Chapter 15). This discovery has prompted the Technical Advisory Committee to look at reclaiming several whole watersheds in the municipality to achieve the added benefit of improved aquatic environments. Similar watershed liming is being used on an experimental basis in the United States (Gubala and Driscoll 1991), United Kingdom (Howell and Dalziel 1992), and Scandanavian countries (Olem et al. 1991).

The Technical Advisory Committee is also pursuing the idea of conserving or setting aside a major barren area as a reminder of the environmental changes the community has made. Such a preserve will also provide scientists with the opportunity to study natural succession and barren land ecology (Watson and Richardson 1972; Jordan et al. 1987).

Socio-Economic Benefits

The municipality's and mining companies' land reclamation programs have fundamentally changed the physical appearance and psychological "mindscape" of the community. It is now increasingly difficult to find completely barren landscapes within public view corridors. This transformation (see Plates 9–11, following page 182) and the process used to achieve this success have been widely published, and the municipality has been the recipient of several prestigious environmental awards (Table 8.2).

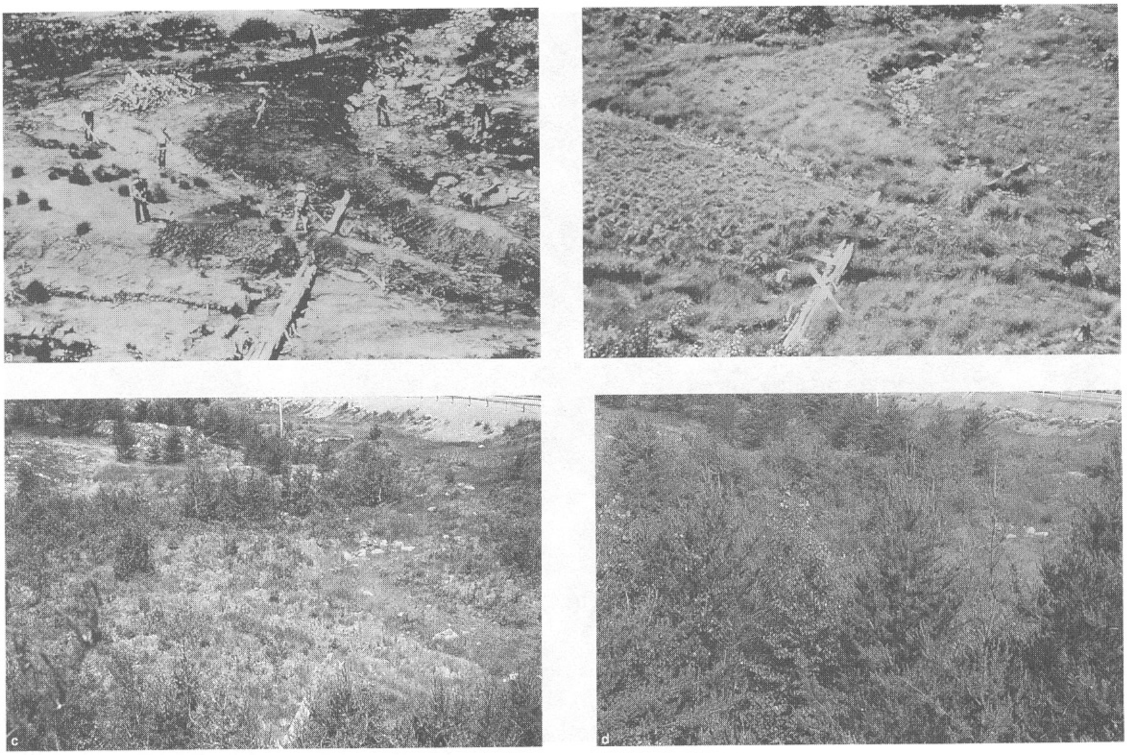


FIGURE 8.11. *(a–d)* A site in Sudbury before and after liming, grassing, and tree planting.

International program recognition and landscape transformation have been a tremendous source of pride for area residents and municipal officials. As the municipality reclaimed barren sites, the community in turn placed a greater emphasis on vegetation enhancement throughout all neighborhoods. This has led many private citizens to improve and green their own properties.

TABLE 8.2. Program awards

1992 United Nations Local Government Honours Award, presented to 12 municipalities at the Earth Summit in Rio de Janeiro in June 1992
1992 Chevron Conservation Award, presented in Washington, D.C.
Government of Canada Environmental Achievement Award for Municipal Leadership 1990, presented in Ottawa by Governor General Ray Hnatyshyn
1990 Lieutenant Governor's Conservation Award from the Conservation Council of Ontario, presented in Toronto by Lieutenant Governor Lincoln Alexander
1990 Arboricultural Award of Merit, presented by the International Society of Arboriculture Ontario Inc.
1986 Community Improvement Award, presented by the Ontario Horticultural Association

Although a direct linkage is difficult to establish, the land reclamation appears to have had a major influence in the economic diversification of the area over the past 15 years. The visual improvement of the area has been significant enough to allow the municipality to now market itself as a summer and winter tourism destination based on the establishment of a northern science center (Fig. 8.12). It has also made it easier to market the community to prospective businesses that are looking to establish facilities in northern Ontario. Land reclamation has removed a negative community stigma that formerly affected some corporate decisions. This program is an important example of how environmental improvement can contribute to economic development.

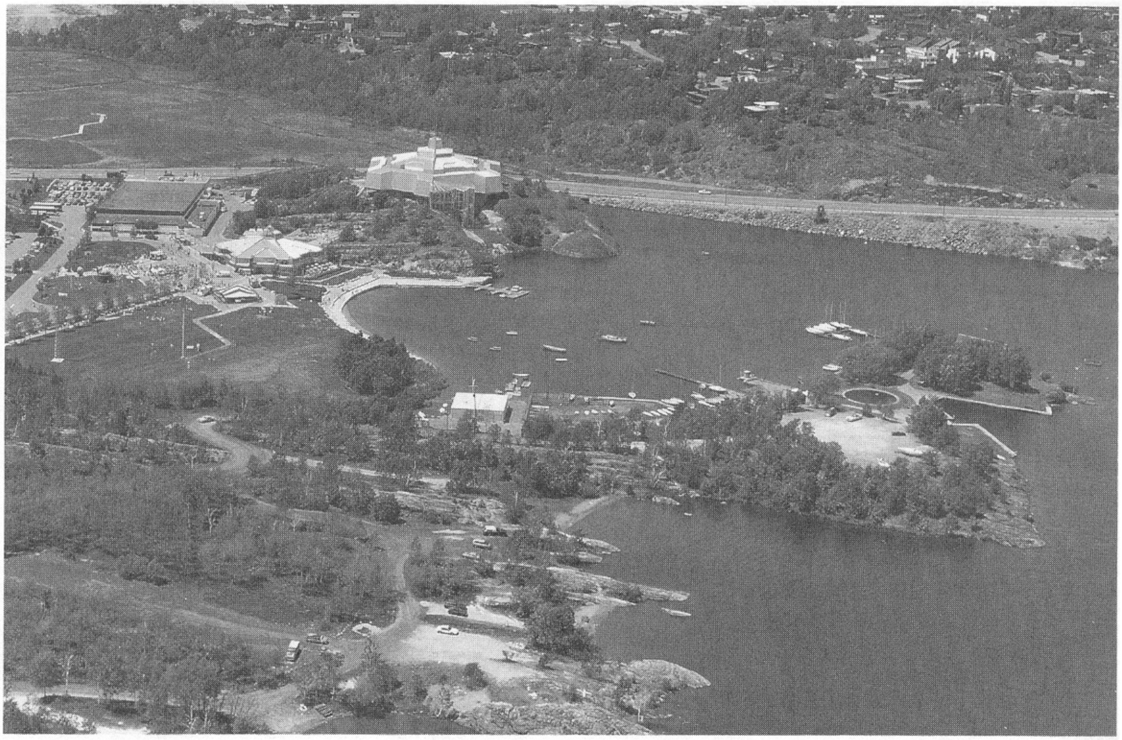


FIGURE 8.12. Aerial view of Science North, with the Lily Creek wetland in the background and the sailing club in the foreground.

Lessons Learned

Overall, the program has been successful because most program activities drew on the lessons learned from pilot test plots and small demonstration project findings. This has led to a very simple treatment recipe being adopted (see Table 8.1). With continuous monitoring of performance, adjustments have been made as the need arose (e.g., seed mixture altered, and supervisor/field crew ratios adjusted).

The existence of a volunteer Technical Advisory Committee has also demonstrated the value of having a broadly based community support group spearheading problem-solving assignments. This group has also been able to focus on many other vegetation enhancement initiatives in the community.

However, in addition to having the volunteer advisory committee spearheading the problem-solving aspects of the program, it was essential to have a host organization (in this case, the municipality) to carry it out. The municipality, in effect, became the general contractor to ensure that required reclamation tasks occurred. In this role, the municipality provided logistic support for the program and was responsible for hiring and supervising all the program's employees, for purchasing or acquiring all support materials, and for all payroll and accounting functions. It also appointed a land reclamation co-ordinator to oversee each year's program. For the program to progress as far as it has, this organizational and catalytic role was essential.

Finally, this program demonstrates the benefits of being committed to achieving stated goals and objectives and rigorously pursuing them. These goals have included the rehabilitation of barren land, improvement of a negative regional image, and a commitment to a labor-intensive approach. In the process, time was not wasted on attributing blame but on solving a community problem and in providing the necessary community leadership to achieve this. This program also demonstrates the benefits of an ecosystem approach underpinned by scientific principles in recreating a self-sustaining local environment.

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