RESTORATION OF BOREAL AND TEMPERATE FORESTS

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chapter twelve

Restoration of birch woodlands in Iceland

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12.1 Introduction

Land degradation and soil erosion have drastically changed Icelandic ecosystems since human settlement: vegetation cover has decreased, most of the woodlands have disappeared, and the remaining vegetation is severely degraded. The result of the degradation processes is often sparsely vegetated land with shallow and poor soils and in other cases barren land, a desert (Arnalds and Kimble 2001). Once extensive, birch woodlands and shrublands now cover about 1% of the country. Downy birch (*Betula pubescens* Ehrh.) is the only species that has formed woodlands in Iceland during the Holocene (Hallsdottir 1995).

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Preservation of the remaining native woodlands and restoration of productive birch ecosystems on degraded landscapes are important conservation goals in Iceland. Traditional landuse, however, is a major obstacle to large-scale restoration efforts, particularly sheep grazing. Birch woodland restoration must also compete for funding and popularity with other forms of reclamation such as seeding with grasses to improve grazing or planting of exotic tree species.

In this chapter, we discuss the ecological and socioeconomic context of restoring birch woodlands and describe potential restoration strategies.

12.2 Natural birch woodlands

12.2.1 Physiography

Iceland is a 103,000 km^2 island in the North Atlantic Ocean, situated between 63°23′N and 66°32′N. The island is mountainous: only 24% of the land is below 200 m elevation, 58% is above 400 m elevation, 37% is above 600 m, and glaciers cover about 11% of the country (NLSI 2002). Iceland is where the Mid-Atlantic Ridge is elevated above sea level by a mantle plume or "hot spot." Volcanic activity is frequent, with one eruption every 3 to 4 years (Guðmundsson 1996).

The climate of Iceland is maritime, cool-temperate to sub-arctic. July mean temperatures are 9 to 11°C for most lowland weather stations, but January mean temperatures drop to −2 to +1°C (Einarsson 1976). Long periods in winter with temperature fluctuating around the freezing point and numerous freeze–thaw cycles contribute to intensive cryoturbation (movement caused by frost action) of Icelandic soils (Arnalds 2004). Annual precipitation ranges from 400 mm in the northeastern part to 4,000 mm in the southeast highlands (Einarsson 1976). Important characteristics of the climate in Iceland are a high frequency of strong winds and frequent changes in the weather.

Icelandic soils are formed in parent materials of tephra layers and aeolian sediments consisting mainly of volcanic glass (Arnalds 2004). Substantial soil has been removed by large-scale erosion, leaving desert areas with unstable surfaces covering 35 to 45% of the country (Arnalds and Kimble 2001). The Vitrisols of these barren deserts are sandy and shallow and have low (<1%) organic C content (Arnalds and Kimble 2001). Brown Andosols are the main soils of freely drained sites; wetlands are chiefly gleyic Andosols with a relatively high mineral content due to a steady influx of aeolian materials from erosion areas (Arnalds 2004).

Classified satellite images show that 14% of the country has a continuous vegetation cover, 13% is fairly well-vegetated, and 23% has poor vegetation cover (NLSI 1993). The most common vegetation communities on dryland soils include moss heath dominated by *Rhacometrium* mosses, dwarf shrub heath dominated by one or more of *Empetrum hermafroditum*, *Vaccinium uliginosum* and other dwarf shrub species, shrub heath dominated by *Salix* species and *Betula nana*, sedge or rush heaths characterized by *Carex bigelowii*, *Juncus* species or *Kobresia myosuroides*, and grasslands (Steindorsson 1980). Most of the wetlands are characterized by *Carex* species, but *Salix* shrubs and *B. nana* can also be important components in some bog types (Steindorsson 1980). All these communities are influenced to some extent by long-term grazing, mostly by sheep.

The desert areas have low vegetation cover (1 to 10%) characterized by mosses, lichens, and vascular plant species such as *Armeria maritima*, *Cardaminopsis petraea*, *Cerastium alpinum*, *Festuca richardsonii*, *Poa alpina*, *Poa glauca*, and *Silene uniflora* (Arnalds et al. 1987). Many of these surfaces were once covered with fertile, brown Andosols that were eroded away, mostly after human settlement. The deserts have been classified by surface geomorphology; sandy lag gravel is the most common, followed by lag gravel, sandy fields, and sandy lava surfaces

(Arnalds and Kimble 2001). Intensive cryoturbation, wind and water erosion, and sand accumulation make these surfaces unstable and hostile environments for plants.

12.2.2 History of the birch woodlands

During the Holocene, birch woodlands were common in lowland areas of Iceland, but their extent varied with fluctuations in the climate (Einarsson 1963; Hallsdottir 1995). Birch woodland and shrubland cover has been estimated as > 20% of the country at the time of settlement in the 9th century AD, perhaps over 30% (Figure 12.1A) (Bjarnason 1974; Sigurðsson 1977), based on historical records, pollen analyses, old place names, and the current distribution of the woodlands (Thorarinsson 1961; Einarsson 1963; Arnalds 1987; Hallsdottir 1995; Kristinsson 1995). Extensive clearing, burning, and cutting for fuel rapidly reduced woodland area after settlement, and grazing by domestic herbivores inhibited regeneration (Thorsteinsson 1986; Arnalds 1987).

Widespread ecosystem degradation and soil erosion likely started soon after settlement (Thorarinsson 1961; Sigbjarnarson 1969). Woodlands are more resilient following natural disturbances than the heathlands or grasslands that replaced them, and woodland deterioration probably contributed to accelerated soil erosion (Aradottir and Arnalds 2001). Birch woodlands can withstand substantial volcanic ash deposition, as demonstrated by woodland remnants near active volcanoes such as Mount Hekla. Woodland cover reduces wind speed at the soil surface, thus stabilizing ash falling on woodland and enabling vegetation to regenerate. Lower wind speed under woodland cover also reduces abrasion of the vegetation by blowing ash. Woodlands accumulate snow, which insulates the soil surface and reduces the intensity of cryogenic processes. Hillslope erosion has been common in the mountainous landscapes of Iceland (Arnalds et al. 2001). The woodlands contribute to slope stabilization not only through their effects on solifluction (soil creep) and other cryogenic processes, but also because woodlands have higher infiltration rates than other vegetation types (Orradottir 2002), which limits the risk of running water on the slopes.

Birch woodlands in Iceland probably reached a postglacial minimum at the beginning of the 20th century of about 1% cover of total land area. Legislation was approved in 1907 to protect the remaining woodlands and to create new forests. For the next few decades, emphasis was on enclosing some remaining birch woodlands to protect them from sheep grazing. The purpose was to prevent further degradation and promote restoration of the woodlands, and in many cases this led to new expansion (Blöndal and Gunnarsson 1999).

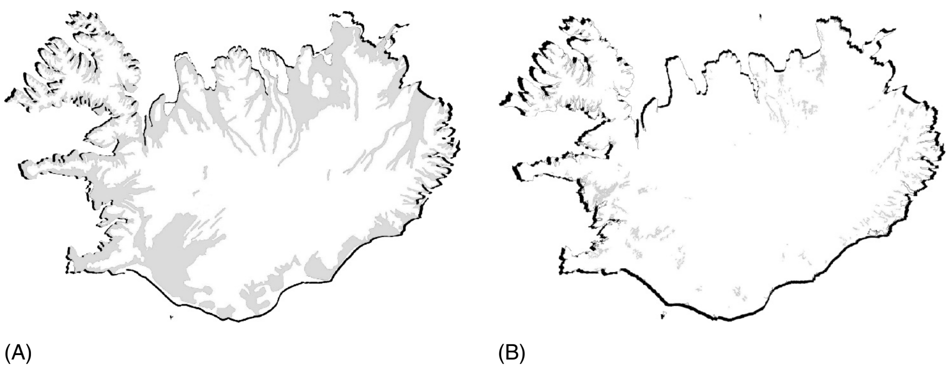

Figure 12.1 (A) Estimated cover of birch woodlands in Iceland at the time of settlement, A.D. 870, based principally on elevation limits of birch distribution today (by Sherry Curl, Iceland Forest Service). (B) Cover of birch woodlands in 1990 based on a survey of birch woodlands conducted in 1987 to 1991. (By Daði Halldórsson, Iceland Forest Service. With permission).

Even though improvements in agriculture during the latter part of the 20th century reduced the need to use birch for fodder, most native birch woodlands are open for summer sheep grazing, which has continued to prevent natural expansion of woodlands outside of protected areas.

Planting exotic conifers started around 1935, and planting of conifers in birch woodlands was encouraged and continued until the 1980s. Although these plantations are not extensive, less than 2,000 ha in all, they have affected many birch woodlands. Conifers usually grow taller than birch and planting them in birch woodlands can result in replacement.

12.2.3 Characteristics and distribution of the birch woodlands

Information about the birch woodlands is based on a qualitative survey in 1972 to 1975 (Sigurõsson 1977) and a quantitative survey in 1987 to 1991 (Aradottir et al. 2001). Natural birch woodlands in Iceland occupy 1,165 km^2 (Figure 12.1B). Small, scattered woodland units form a large portion of the woodlands, which are unevenly distributed over the country. Most of the woodlands are in west Iceland and the western fjords (about 47%) and southwest and south Iceland (23%), but hardly any natural woodland can be found in northwest Iceland. Most of the woodlands are in the lowlands, below 300 m elevation, but vigorous woodlands are found at higher elevations. The highest elevation where birch forms continuous stands is at 500 to 550 m, although groups of scattered trees or shrubs may exist at higher elevations.

Low-growing trees ($<$4 m) and a shrubby, multistemmed growth form characterize most birch woodlands, although woodlands with taller trees and one to four stems are also found (Figure 12.2). The multistemmed shrub form of birch is especially prevalent under

(A) (B)

Figure 12.2 (A) Straight, single-stemmed birch tree in a North Iceland birch woodland. (B) Remnants of a shrubby, low, and multistemmed birch woodland adjacent to eroded landscape (front) near the volcano Hekla in South Iceland. (Photos: A.L. Aradottir.)

strong oceanic conditions and at higher elevations. The taller trees are more common inland at low to mid-elevations, especially in northern, eastern, and southeastern Iceland.

Other tree species include scattered individuals of *Sorbus acuparia*, which are found in many woodlands but never form pure stands. A limited distribution of clones of *Populus tremula* has been found in eastern and northern Iceland (Blöndal 2002).

Willows commonly form shrub layer in woodlands. *Salix phylicifolia* is the most frequent species, and may form shrublands on its own. The lower-growing *Salix lanata* and the prostrate *Salix arctica* are also common in the shrub layer of birch woodlands. Where the birch is especially low growing, *S. phylicifolia* and *S. lanata* can be codominant or even dominant over the birch. Dwarf shrubs, such as *V. uliginosum*, *V. myrtillus*, and *E. nigrum*, often dominate the understory of birch woodlands, but grasses, tall forbs, and *Equisetum* species can also occur in the understory (Steindorsson 1980; Aradottir et al. 2001).

12.2.4 Economic importance, past and present

Throughout history, birch woodlands have been valuable for fuel, building material, and animal fodder (Thorarinsson 1974). Charcoal from woodlands was used for iron working and they were extensively grazed (Thorarinsson 1974). These uses of birch woodlands declined in importance after the 1930s when they were replaced by geothermal heat, imported fossil fuels, and cultivated hayfields.

Presently, the wood products of birch are not economically important, although a small amount (less than 500 m^3) is felled each year and sold for firewood and handicrafts. On the other hand, birch woodland properties are in high demand for summerhouses and some of the woodlands are popular recreation areas. Birch woodlands are also valued as representing ecosystems that once covered large areas but today are limited in extent.

The most common use of birch woodlands is still grazing by sheep, although winter grazing and browsing has declined due to increased haymaking and housing of the animals during winter. Farmers used to have a negative attitude toward the woodlands, as wool, the most valuable farm product, got tangled in branches of the birch and was lost. Some sheep farmers now consider birch woodlands an important part of their grazing lands and they are trying to increase the woodland cover on their land through management actions.

12.2.5 Land ownership and land tenure

Land suitable for restoration of birch woodlands can be divided into farms, grazing commons, state-owned or managed land, and land owned by municipalities. Farms usually include cultivated areas and uncultivated home grazing areas. About 90% of Icelandic farms are privately owned and the state or the national church own most of the rest (Icelandic Agricultural Statistics 2000). Although the majority of land best suited for reestablishing birch woodlands is on farms, the greatest competition with other types of landuse, especially livestock grazing, is also here.

Farmers jointly manage communal grazing areas in each municipality or local community for sheep grazing and sometimes horse grazing. Ownership is often unclear and is sometimes contested. Large areas of the grazing commons are above the tree line, but there are also some areas at lower elevations that could support birch and willow scrublands or woodlands.

The Iceland Forest Service (IFS), the Environment Agency (EA), and the Soil Conservation Service (SCS) manage nonfarm land owned by the state, including about 15% of Icelandic birch woodlands as well as areas suitable for their restoration. Land managed by the IFS includes remnant birch woodlands and surrounding areas that are protected from grazing and land for afforestation. About 4% of the birch woodlands in Iceland are under the supervision of the IFS. The EA manages national parks and reserves that include over 10% of birch woodlands (NCC 1996). Most of the land managed by the SCS has been badly degraded or has active erosion and is under reclamation. Land owned by municipalities includes mostly towns and their surroundings. Because of public interest and availability of both volunteer and paid labor, afforestation is commonly practiced in these areas. However, restoration of the birch woodland ecosystem is rarely a specific goal of these afforestation efforts.

12.3 Afforestation and restoration of birch woodlands

12.3.1 Afforestation in Iceland

Organized forestry began in Iceland early in the 20th century and focused on protecting the birch forest remnants. The IFS acquired several forest areas for protection. From 1935 to 1951, native birch was the most planted species in Iceland, with planting ranging from a few thousand to over 150,000 seedlings per year.

After 1950, emphasis has been on afforestation through increased planting of exotic conifers, principally *Picea abies, Picea sitchensis, Pinus sylvestris, Pinus contorta*, and *Larix sibirica* (Blöndal and Gunnarsson 1999). Planting was at 500,000 to 1.5 million seedlings annually until 1989. During this entire 40-year period (1950 to 1990), native birch planted was 5 to 15% of the seedlings planted annually or 50,000 to 150,000 seedlings per year (Petursson 1999, unpublished data).

Afforestation has increased again since 1990 to about 5 million seedlings planted annually, which corresponds to a planted area of 1,200 to 1,500 ha per year. Planting of native birch has increased as a proportion of the total, comprising almost 30% of seedlings planted in 1999 to 2001. *Larix sibirica* is planted to almost the same extent as native birch (30%), followed by *Picea sitchensis* (12%), *Pinus contorta* (10%), and *Populus trichocarpa* (6%). Over 20 other species comprise the remaining 12% of trees planted in Iceland (Petursson 2002).

Today, the main actors in Icelandic afforestation are government-funded regional farm afforestation projects and forestry societies (NGOs). Since 1990, many forestry societies have participated in the Land Reclamation Forest (LRF) project, a government-funded program with the aim to afforest eroded or degraded land. Numerous private individuals also participate, but usually on a smaller scale. The IFS, once active in afforestation, now manages the National Forests and plays a leading role in research, planning, and policy.

The LRF project is the first large-scale program of planting tree seedlings for reclamation of eroded and degraded sites in Iceland. About 1 million seedlings are planted annually in this program, of which 40 to 75% are native birch (Figure 12.3). The survival and condition of the first plantations have been surveyed on several occasions in order to learn from mistakes and successes (Table 12.1). There was large variation in the survival of all species at individual sites reflecting differences in environmental conditions, vegetation cover and surface characteristics of the planted areas, and different fertilization treatments. The survival of birch was overall better than that of larch and pine, even though pine was consistently planted at more favorable sites than the other two species.

Multiple-use objectives underlie Icelandic afforestation planning and management of cultivated forests (Eysteinsson 1999a). Most farm afforestation plans emphasize timber production for areas where it is feasible, accounting for roughly 60% of the seedlings planted annually (Petursson 2002). In peripheral areas, emphasis is on protective functions, shelterbelts, and sometimes wildlife value, improved grazing for livestock, and outdoor recreation (Eysteinsson 1999b). Indirectly, afforestation projects promote substantial natural regeneration of birch in grazing exclosures.

Figure 12.3 A 10-year-old Land Reclamation Forestry plantation in South Iceland. Birch interplanted with Nootka lupin as a nurse crop. (Photo: A.L. Aradottir.)

Table 12.1 Survival in 1996 of the Most Commonly Planted Species in the LRF Project During 1991–1992 (Native Birch, Siberian Larch, and Lodgepole Pine)

Three Species	Planting Year	No. of Sites in Survery	Survival of Planted Seedlings		
			Mean of all Surveyed Sites	Lowest Site Average	Highest Site Average
Birch	1991	9	69	32	94
Birch	1992	4	72	55	89
Larch	1991	6	41	39	83
Larch	1992	4	48	11	89
Pine	1991	2	64	10	90
Pine	1992	3	63	60	68

The numbers are based on a survey of over 3,200 tree seedlings at nine sites, selected in a randomly stratified manner from more than 80 planting sites (Aradottir and Gretarsdottir, unpublished data). Not all species were represented at all sites.

12.3.2 Restoration of birch woodlands

12.3.2.1 Goals

Afforestation with birch can have several different objectives, including restoration of native woodlands, ecosystem functions, and biodiversity. Other objectives include carbon sequestration and improved options for future landuse. Although using exotic tree species can meet many of these objectives, only the use of native birch and willows can restore the native woodlands.

Birch is useful for the rehabilitation of degraded land. It is an early colonizer in both primary and secondary succession in Iceland (Persson 1964; Aradottir 1991; Gretarsdottir 2002), and can be a key species in ecosystem development. It performs relatively well in plantations on degraded and eroded sites (Table 12.1), where restoration of birch woodlands also means restoration of ecosystem structure and function and increased options for land-use. Restoration of birch woodlands on sites with low soil organic matter has the potential to sequester considerable carbon by increasing carbon in the soil, understory vegetation, and in the trees (Arnalds et al. 2002).

12.3.2.2 Extent of restoration needs

Somewhere on the order of 100,000 ha (about 1% of Iceland) are now available for birch woodlands restoration, or could be within a short period. However, active restoration of birch woodlands is currently limited in Iceland. Current opportunities for the restoration of birch woodlands may be the greatest on public land, which is largely managed by state agencies. These agencies have similar goals of protecting existing woodlands and increasing woodland area where appropriate.

Potentially, 1 to 2 million ha of additional land could be available for woodland restoration, but this depends on developments in landuse and farm economy, factors largely beyond the control of foresters or ecosystem restorationists. Most of this land is located within the home grazing areas of farms and some grazing commons include large areas at 200 to 500 m elevation. Many of these areas are badly eroded and in need of reclamation, but for most summer grazing currently limits birch and willow woodland or shrubland restoration.

Sheep numbers in Iceland declined by 50% from 1978 to the 1990s due to market conditions and government initiatives, but production still exceeds home market demand (Arnalds and Barkarson 2003). Farmers are, however, reluctant to change landuse and seek to maintain landuse rights for fear of losing certain traditions, such as the fall roundup of the commons that serves as an important social function in rural communities. Nevertheless, there should be opportunities for changes in landuse such that large areas could be managed or protected from grazing by sheep in order to enhance the restoration of birch ecosystems.

12.3.2.3 Restoration techniques and strategies

Restoration of birch woodlands can take a long time and will often require cultural inputs, even on sites previously covered by birch. Reintroduction of birch may be necessary in areas where birch has disappeared or has low abundance. Planting of seedlings is the most common method for restoration and direct seeding is only used on a small scale. Spread of birch can be effective through natural recruitment in the vicinity of birch woodland remnants or established birch stands.

Research on birch woodland restoration in Iceland has focused on methods for establishing birch as a key species in woodland development and the dynamics of birch colonization. Establishment can be especially difficult on eroded sites, where it is impeded by factors such as frost heave, low nutrient status, low water holding capacity of the soil, and active soil erosion (Arnalds et al. 1987; Magnusson 1997; Arnalds and Kimble 2001).

12.3.2.3.1 Planting The 1.4 million birch seedlings planted per year are almost all container seedlings grown in 50 or 100 ml multipot containers. The seedlings are usually 1 year old at planting and 10 to 25 cm in height. Most of the seed comes from seed orchards of select material or identified seed stands of birch originating in southeast Iceland. Seedlings are produced in private nurseries.

Frost heaving is one of the main causes of mortality during the first years after planting (Aradottir and Gretarsdottir 1995; Oddsdottir et al. 1998). The extent of cryoturbation depends on factors such as differences in soil texture, snow cover, and frequency of frost–thaw cycles (Bergsten et al. 2001; Matsuoka 2001), but is most serious where seedlings are planted in spots with little or no vegetation cover. This can be reduced by sowing annual grasses and fertilization at planting (Oddsdottir et al. 1998), by using nurse crops such as lupine (*Lupinus nootkatensis*) (Figure 12.3) that can improve growing conditions

Figure 12.4 A group of children assist with seeding of birch at a reclamation area in South Iceland. Individuals and groups have the opportunity to participate in excursions organized by SCS, IFS, or other agencies, where environmental education and recreation are combined with reclamation and afforestation. (Photo: O. Arnalds.)

at harsh sites (Aradottir 2004), or by mixing organic fertilizer with the soil before planting (Aradottir, unpublished data).

Fertilization increases birch seedling vigor and growth, but nitrogen fertilizers may increase mortality in the first year after planting due to salt stress and competition by other vegetation (Oskarsson et al. 1997; Oddsdottir et al. 1998). Fertilizer-induced mortality in young plantations can be avoided by using slow-release or low N–high P fertilizers (Oskarsson et al. 1997). The increased vigor and long-term survival of fertilized seedlings, as well as reduced mortality from frost heaving, may compensate for early mortality on poor and eroded soils (Oskarsson et al. 1997; Oddsdottir et al. 1998), at least if stocking density is less important than survival. Furthermore, birch is likely to seed into any gaps within 20 years.

Salix lanata and *Salix phylicifolia*, the native willows that form the shrub layer in many birch woodlands, can be propagated from fresh cuttings (Svavarsdottir and Aradottir 2004). Because these species are found in most parts of the country, local populations can be used in restoration programs.

12.3.2.3.2 Direct seeding Direct seeding of birch has been used on a small scale; a few small stands were established in the first half of the 20th century by this method (Magnusson and Magnusson 1990). During the last 10 to 15 years, there has been renewed interest in direct seeding of birch. Birch seed can be easily collected. In most years seed is readily available, although viability can vary greatly between stands and between years (Thorarinn Benedikz, unpublished data). Simple instructions on seed collection and seeding are available; also, a demonstration video has been made. Volunteer groups have collected seed for their own use or donated to the SCS or the IFS. Direct seeding is often used in small reclamation projects involving volunteer groups or school children (Figure 12.4). In many cases, the seed collection and seeding are done in the same field trip, providing an opportunity for educating volunteers about reclamation work, soil, and nature conservation.

Characterization of safe sites for birch seedling establishment is useful for targeting suitable areas for direct seeding. Seedling emergence of birch is generally much higher in open microsites where the seeds have good contact with the mineral soil than in microsites with dense vegetation cover (Kinnaird 1974). Greatest seedling emergence is on microsites of mineral soil, but lowest emergence is where the sward thickness exceeds 1 to 2 cm (Aradottir 1991; Magnusson and Magnusson 1990). Winter survival, however, is lower in open microsites due to cryoturbation (Magnusson and Magnusson 1990; Aradottir 1991, 2003), but this can be ameliorated by low-level fertilization (Aradottir 1991). Fertilization can also stimulate the formation of biological soil crusts (Elmarsdottir 2001; Gretarsdottir 2002) that stabilize the soil surface and are favorable for seedling establishment of many species (Aradottir 1991; Elmarsdottir 2001).

Direct seeding of birch is sometimes used with fertilization and grass seeding to revegetate severely degraded areas. A sufficient vegetation cover has to be established in order to stabilize the soil surface and reduce cryoturbation, but the vegetation should not be so dense that it will curtail birch seedling establishment. Conditions for birch establishment are often most favorable on older revegetation sites where the seeded grasses have declined (Aradottir 1991; Gretarsdottir 2002).

The main problems associated with direct seeding are limited seedling emergence and slow growth for the first several years. Using seeding shelters (cones and tubes) to establish birch can improve seedling emergence and growth (Aradottir 2003; Aradottir unpublished data), but it has not been evaluated whether these are practical to use on a large scale. Nevertheless, they may be useful for small projects to avoid discouragement from the lack of visible results.

12.3.2.3.3 Natural expansion Substantial natural expansion of birch can occur in the vicinity of established birch stands, especially in areas protected from sheep grazing. However, only a few examples have been well documented. For example, aerial photographs and field measurements documented extension on a disturbed site in southern Iceland. The birch was initially established by seeding several small plots. After 20 years, birch cover had extended to 9,000 m^2; during the following 24 years, birch cover expanded to 30,000 m^2 (Aradottir 1991; Aradottir and Arnalds 2001). Some of the extension was due to early transplants from the initial birch clusters to new sites, but most was by natural recruitment of birch around the edges of established clusters and the establishment of new clusters that subsequently served as foci for additional colonization (Aradottir 1991).

Two factors govern natural regeneration from seed: availability of safe sites and density of seed rain. Seed rain decreases in a log-linear manner with increased distance from the seed source (Hughes and Fahey 1988; Aradottir 1991); closer to the seed source, recruitment is primarily limited by the availability of safe sites. The direction of seed dispersal is correlated with strong prevailing winds (Aradottir et al. 1997).

12.3.2.3.4 Restoration strategies The potential area for restoring birch woodlands in Iceland is on the order of thousands of km^2. Planting can successfully establish birch, but it is costly and labor intensive and therefore not well suited for woodland restoration of extensive areas. Direct seeding is relatively inexpensive, but is more sensitive to environmental conditions and initial growth is slow; thus, results are not immediately visible. Natural expansion of birch is limited to areas close to seed sources, such as planted birch stands and woodland remnants. As existing birch woodlands are of limited distribution (Figure 12.1B), the lack of seed sources limits colonization of birch in large areas of the country. Furthermore, safe sites for seedling establishment may be limited even when seed sources are available.

Natural expansion can be encouraged by establishing islands of birch and willows by planting or seeding at strategic locations across landscapes, thus forming seed sources from which trees can gradually colonize the whole area (Aradottir 1991; Ludwig and Tongway 1996). Such a strategy would concentrate resources (plants, seeds, fertilizer, etc.) at selected

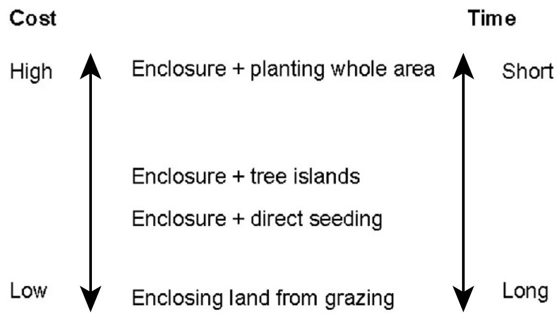

Figure 12.5 The cost of restoration strategies is probably inversely related to the time until woodland cover is restored, other factors being equal. The success of enclosing land from grazing without introduction of birch will depend on available seed sources. If they are plentiful, this method may give faster results than direct seeding or planting of tree islands.

locations to enhance the probability of local establishment. Stands serving as seed sources should be established close to areas that have a high density of potentially safe sites for seedling establishment, or where the availability of safe sites can be increased by strategic fertilizer applications after good seed years. This strategy will cost less than wholesale planting of large areas, but should give quicker results than unassisted natural expansion in areas where birch is absent or has a very limited distribution (Figure 12.5). Planting birch islands for seed sources is not likely to be effective at high elevation sites because availability of viable seed decreases with increasing altitude (Kullman 1984).

12.4 *Economic, social, and political contexts*

Although afforestation and reclamation activities are widespread in Iceland, restoration of birch ecosystems is not emphasized. The main obstacles are lack of interest among landowners and others who practice afforestation and lack of specific goals in reclamation and afforestation projects. Landowners do not generally consider birch woodlands as a potential economic resource in the same way as plantations of exotic species that grow faster and yield timber. Many landowners also prefer planting for variety, and they tend to use exotic species or species mixtures, even for plantations that are not particularly aimed at timber production. Extension service personnel in forestry have traditionally promoted the use of exotic species, although this is changing.

Many Icelanders agree with the goal of restoring land to birch woodlands. However, those individuals or organizations involved with afforestation generally plant a number of exotic tree and shrub species along with birch, most often in mixed stands. Vague objectives, for example, to bring back woodland, rather than to restore a certain type of woodland or ecosystem, or to just simply plant trees because it is fun to plant trees, are the main reason for this. For example, participants in a recently completed afforestation grants project (Eysteinsson, unpublished data) were given seedlings to plant, if they provided an equal number of seedlings. Participants were able to choose from among the seven most planted tree species in Iceland (native birch and six exotic species). Although most participants had nothing against planting birch, only 5 out of 127 participants chose to plant only native birch. Some wanted only one or another exotic species. Most participants wanted two or more species, indicating interest in variety when planting trees for amenity. The commonly slow growth and low, scrubby habit of Icelandic birch is perceived by many to be less desirable than forests of taller, straighter trees.

Soil erosion and land degradation are more active and widespread in Iceland than in other European countries. In a Western democracy with a high standard of living and a well-educated population, there should be strong incentives to reclaim some of what has been lost, including the woodlands. The SCS historically has emphasized soil conservation and reclamation of eroded land for various uses, including grazing, but restoration of birch woodlands has not been an important goal. This has changed in recent years, and success stories of establishment and spread of birch stands on reclamation sites (Aradottir 1991) show that restoration of birch woodlands on eroded sites can be a feasible option.

The Icelandic Forest Service has emphasized exotic tree species rather than native birch (Blöndal and Gunnarsson 1999), although this is changing somewhat. Recently, the IFS obtained areas with the aim of protecting relatively intact birch forest ecosystems as well as land with birch scrub remnants to promote natural invasion. Government subsidies for afforestation on farms through Regional Afforestation Projects have increased, mainly for timber production, but carbon sequestration and soil protection are also important objectives. Native birch is often a component of these plantations, either as a nurse species or in plantation edges, but is rarely planted for wood production due to slow growth and poor form.

The environmental sector, including both NGOs and state agencies, has not emphasized restoration of birch woodlands. To be sure, afforestation with native birch is less controversial than afforestation with exotic species, but there has been no organization that specifically promotes protection and restoration of birchwoods. The lack of interest by the general public and other stakeholders is reflected in the political arena. Despite increased government appropriations for afforestation in recent years, support has been limited for ecological restoration, except for a few projects to restore drained wetlands. However, grants schemes could be set up to encourage restoration of birch woodlands and other important ecosystems, just as farmers are subsidized for producing meat and dairy products or as a part of Regional Afforestation Projects. The need for afforestation projects with a primary goal of restoring birch woodland is increasingly recognized and there are currently several small restoration projects and at least one large-scale project under way (Land Reclamation Forest Project).

12.5 Conclusions

Despite a general lack of interest in Iceland in ecosystem restoration and hindrances resulting from conflicting landuses, there is reason for optimism. Native birch is increasingly used in afforestation, making it the most planted tree species in Iceland. Large-scale birch woodland restoration projects are under way, which will serve as demonstrations and may evoke interest in further restoration activities. Sheep farming seems likely to decline, which may alleviate some problems with conflicting landuse and make more land available for restoration. Birch is regenerating naturally within enclosures wherever a seed source is available. In some cases, birch woodland is expanding by natural recruitment as fast or faster than planting, resulting in mixed woodlands or even abandonment of plans for planting (Skúli Björnsson, pers. com.). Birchwoods being planted today will be seed sources for further expansion in the future.

Techniques for establishing birch under various conditions are fairly well known, and lack of knowledge should not be a limiting factor for woodland restoration. Nevertheless, further development of methods for large-scale operations is needed. The necessity to introduce other components of the birch ecosystem in order to ensure ecosystem recovery is also unknown.

In order to increase interest in birch woodland restoration, stakeholders for afforestation and reclamation must be better informed about the need to focus on this objective in individual projects. Governmental agencies, such as the IFS, SCS, and EA, can encourage others to work on birchwood restoration by increasing emphasis in their own projects on this objective. A change in policy such that some governmental funding for regional afforestation programs would be earmarked for restoration projects would greatly stimulate birchwood restoration in Iceland.

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