ROGER CROFTS

HEALING THE LAND

Map of locations mentioned in the text

Healing the Land

Roger Crofts

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THE STORY OF LAND RECLAMATION AND SOIL CONSERVATION IN ICELAND

Restructured, substantially revised and extended from an original Icelandic text *Sáðmenn sandanna: Saga landgræðslu á Íslandi 1907-2007* by Friðrik G. Olgeirsson

Soil Conservation Service
of Iceland
2011

Healing the Land

THE STORY OF LAND RECLAMATION AND SOIL CONSERVATION IN ICELAND

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Dedication

To
Sveinn Runólfsson and all his past and present
colleagues who have worked diligently to
reclaim the land and improve the soil

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A Century of Inspiring Lessons

A Message from the President of Iceland
Ólafur Ragnar Grímsson

As the global community faces new threats in the form of food insecurity, water shortages and climate change, which could lead to destruction on a scale never before seen and spell the end of lifestyles that have been with us for generations, it is only natural that people ask: What can we do?

Increasingly, attention is turning to the ecosystem services offered by systematic restoration of degraded land and the resistance that healthy vegetation can raise against destructive forces. Iceland's experience in this field is a valuable resource, a reservoir of knowledge on which leaders and academics all over the world can draw.

A century ago, Icelandic visionaries realised that it was necessary to make a stand against soil erosion and land degradation. What, at first, seemed almost a futile gesture soon gave grounds for hope, and in the fullness of time the passionate energies of those pioneers became the basis of a national campaign.

For longer than other countries, Iceland has been working systematically at halting the destructive forces and reclaiming the vegetation cover, creating fertile enclaves in barren areas and turning back the advance of the desert sand. It is a remarkable history of deliberate efforts and scientific work, and the success has attracted international acclaim.

When systematic land reclamation began in Iceland, our people and the forces of nature had encroached on the environment without hindrance for a millennium, devastating a large part of the vegetation and the soils, creating what gradually became Europe's largest desert.

The nation chose to make a new departure, and the results are now, at the beginning of a new century, a cause for national pride; lessons to be shared with others.

What took a century in Iceland must now be globally accomplished in a decade.

Our story provides an inspiration of hope, can help to strengthen the crucial role of soil and vegetation in global sustainability, linking land care with climate, biodiversity, water, food security, poverty reduction and peace.

This instructive saga now appears in an English version, based on the publication, *Sáðmenn Sandanna*, which marked in 2007 the centenary of soil conservation and restoration of land quality in Iceland and coincided with an International Forum on Soil, Society and Global Change held in the country.

This English version, rewritten and edited by Roger Crofts, is particularly welcome, since collaboration between Icelandic specialists and this renowned expert and enthusiast has greatly enhanced the development of successful soil conservation strategies in Iceland.

I hope that the book will prove instructive and inspiring, and serve as a declaration of our desire to collaborate with nations and partners all over the world.

Svandís Svavarsdóttir
Minister for the Environment

100 years of soil conservation in Iceland

Land is a unique asset, being both finite and irreplaceable. We humans derive most of our subsistence and well being from the different attributes of land and, as a result, it is inevitable that there is pressure on land based resources. Different processes of land degradation have been the outcome in many parts of the world, having severe impacts on ecosystems and the services they provide and on human livelihoods. Land degradation is one of the key challenges facing mankind in order to achieve sustainable development, but the quest for sustainability of land management has proved to be a major challenge to most countries.

This book takes the case of Iceland. It tells the remarkable story of more than century combating land degradation.

Iceland has the unique history of being relatively lately colonised by humans, and having a well documented history. On this volcanic northerly island with a cold and windy climate, the 1100 years of human settlement took its toll on the Icelandic ecosystems as society has derived its subsistence mainly from land based activities. In the beginning of the 20th century, human induced land degradation was recorded on most of the Icelandic lands and almost all of its forests and woodlands were lost.

The pioneering legislation from 1907 – the Act on Forestry and Protection against Soil Erosion – ranks as a major milestone in the Icelandic effort to address, halt and later revert land degradation and soil erosion. On the basis of this legislation, the government established specific authorities to work on these issues, one of which gradually developed into the current Soil Conservation Service that is acknowledged as the first such specific authority worldwide still in operation.

The 100 years of organised work to curb land degradation and combat soil erosion is a great story that is well documented and described in this informative book. The journey – from the early work of the soil conservation pioneers with basically nothing except an heroic spirit in a relatively hostile environment, to the great achievements of halting and reversing the land degradation processes, and making land reclamation a major national commitment in Iceland with a widespread participation from all levels of society – is a simply a remarkable story.

Although land governance is inevitably a

country specific and case dependent issue, the story of combating land degradation in Iceland is of great relevance to much wider audience. Land degradation is currently such a threat in a range of countries, not least those developing or in economic transition. In order to share experiences and advance sustainable land management, Iceland has established formal collaboration with United Nations University to offer a specific capacity building programme on land restoration. This successful effort has resulted in exchange and collaboration with institutions and experts from regions in Africa and Asia.

This book by Roger Crofts, a well known expert on Iceland and its environment, will add to this. It is well written and informative and will certainly be of a keen interest to a wide audience within diverse fields of land use and conservation of natural resources. The book also adds greatly to the Icelandic effort to sharing the experience and accumulated knowledge from a century of combating land degradation and healing the land with other countries of the world.

I congratulate the author of the book and, most especially, the people at the Soil Conservation Service for their contribution and this important achievement.

Sveinn Runólfsson
Director, Soil Conservation Service of Iceland

A Time To Remember

The 100 year history of the Soil Conservation Service of Iceland is a story of struggle against virtually insurmountable natural forces, scepticism of the need for action, and an impoverished population. It has long been the good fortune of revegetation efforts in Iceland to have selfless and committed political leaders, and conservation experts steadfastly supported by their staff. This group of pioneers has resolutely waged battle with the sand, the country's ancient nemesis. They saw how nature's erosive forces overwhelmed communities and turned hundreds of square kilometres of fertile land into desert. At the beginning of the 20th century, most felt it an impossible task to stop the destruction. Nevertheless, the work of these impassioned trailblazers in the last century laid the framework for a better and more beautiful Iceland. It is about people of great optimism who intrepidly forged battle with the sand.

There are many indications that soil erosion and desertification have decreased significantly over the past 20 years, and that land reclamation and the ability of the land to heal itself have outpaced land degradation. If this assessment is correct, it is the first time since Iceland's settlement 1100 years ago, signalling that the recovery of land resources has now begun. The main reasons for this change are a warmer climate, diminishing grazing pressure at strategic areas, and revegetation activities representing a blend of practical knowledge, scientific endeavour and political support.

The fateful saga of vegetation and soil has consistently been interwoven with human activities – a close correlation exists between the welfare of the land and the welfare of the nation. There is strong and growing interest among Icelanders in environmental issues. Icelanders today are more knowledgeable and technologically skilled in the field of revegetation. Yet, it is imperative that more assets are earmarked to pay our debt to the land, as much work remains.

The Soil Conservation Service of Iceland has over the century accumulated wide-ranging experience and knowledge. We can share this with other nations that are struggling in their first steps in the battle against soil erosion and desertification.

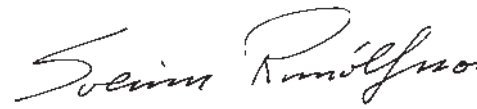
It was decided that the story of the century should be documented by Friðrik G. Olgeirsson, *Saga landgræðslu á Íslandi 1907–2007* (The Story of Soil Conservation in

Iceland 1907–2007). The excellent work of the author, and key staff supporting at the Soil Conservation Service, has been recognised by Upplýsing - the Icelandic Library and Information Science Association with the award for the best non-fiction book of the year 2007.

Roger Crofts has, at my invitation, produced this new version. He is a specialist in environmental and organisational management and has visited Iceland many times. He has transformed the original work into a new book with a structure of history, action, analysis and assessment with a great deal of new material, many insights from his own observations and his deep, practical experience of how organisations work, the role of political processes and the value of science and policy. To him I extend my grateful appreciation for all his excellent work, co-operation and guidance throughout the years and for producing this outstanding English language version of our story.

I hope that readers enjoy the story of determination and struggle of the people of Iceland recounted within these pages and can learn lessons for their own countries.

Help the Land Heal Itself!



Acknowledgements

Having been invited to produce a version of the original Icelandic text of *Sáðmenn sandanna: Saga landgræðslu á Íslandi 1907–2007* (*The Story of Soil Conservation in Iceland 1907–2007*) for the English-speaking community, I would like to thank the original author of the Icelandic version Friðrik G. Olgeirsson for allowing me to quarry his material. The current text is my own with a thematic treatment, together with new material and reflections from my experience of working in Iceland. Thanks to Róbert Mellk for providing an English translation of the original Icelandic text as I am not an Icelandic speaker. David Gislason kindly translated some of the poems.

I would like to thank most especially my colleague and friend Sveinn Runólfsson, the Director of the Soil Conservation Service of Iceland (hereinafter the Soil Conservation Service), for stimulating my interest in soil conservation in Iceland and showing me what has been done on the ground in so many parts of this wonderful country. Thanks to Magnus Magnusson who first introduced me to his native land of Iceland, to former President Vigdís Finnbogadóttir for her wisdom and insights into Icelandic culture, and to President Ólafur Ragnar Grímsson for many interesting discussions. Thanks to Guðríður Þorvarðardóttir for food and friendship on my trips. Thanks to Andrés Arnalds for many stimulating conversations in the office and in the field. Thanks also to Anna María Ágústsdóttir, Guðmundur Halldórsson, Hermann Sveinbjörnsson, Jón Ragnar Björnsson, Kristín Svavarsdóttir and Magnús H. Jóhannsson of the Soil Conservation Service for answering my many questions and providing the new data and information which I have used in the text. Special thanks to Elín Fjóla Þórarinsdóttir of the Soil Conservation Service for providing statistics, maps and photos of reclamation activity and to Guðjón Magnússon for his work on the photographs and other illustrations. Thanks to Ólafur Arnalds and Ása L. Aradóttir of the Agricultural University of Iceland for stimulating debates and guidance on research material. Thanks to the acknowledged authors for permission to use certain diagrams and figures. Thanks to Professors Andrew Campbell, Anton Imeson and Jim Rose for their comments on an earlier version of the text. Thanks to the photographers listed in Appendix 3 for the use of their images. Thanks to Magnús Guðfinnsson and Árni Pétursson of Oddi for the layouts and printing. And thanks to my wife, Lindsay, for being so tolerant and understanding of me spending so many hours in the study working on this book, for allowing it to dominate our conversations and for letting me go on my frequent visits to Iceland.

Edinburgh, Scotland
Roger Crofts
August 2011

Author's Preface

Sand reaches out and finds me,
Sand, with its cruel custom,
Sand that can be so blinding,
Sand overwhelms the landscape,
Sand sifts through every crevice
Sand to the left and right hand,
Sand that consumes the seedlings,
Sand is so unrelenting.

Sand in the hayfield settles,
Sand desecrates our clothing,
Sand separates the districts,
Sand, that constricts your breathing,
Sand in your goblet swimming,
Sand in the bubbles blending,
Sand invokes awe and wonder
Sand is my adversary.[1]

How poignant those words are, written by the Rev. Björn Halldórsson after a severe sandstorm in February 1763. Icelanders and visitors who have experienced the sand storms in the interior and on the coast, and seen farm houses disappearing under the sand and others re-appearing out of the sand after the latest storm, have constantly marvelled that the sand can be captured and its effects quelled. This is the essence of the story of soil conservation over the last century.

Anyone who has crossed Iceland in a small plane or travelled overland between the northern and southern coasts of Iceland will have some understanding of the immensity of the task of conserving soils and restoring the land surface. Indeed, in many cases it is more a matter of aiding nature in the creation of soils which have been lost through a complex interaction between the destructive forces of nature and human activity on the island since it was settled over a thousand years ago.

When the Soil Conservation Service collaborated with the Agricultural Research Institute to undertake an assessment of soil erosion in the 1990s, the scientific team classified the state of the land surface as 6% with extremely severe erosion, 11% severe erosion, 22% considerable erosion, 7% little erosion and 4% no erosion (the remaining 23% were mountains, ice caps, rivers and lakes)[2]. This raised the questions: was soil conservation possible and sustainable in the Icelandic context, and why had apparently so little progress been made over the first 80 years of statutory action for land reclamation and soil conservation. There has been great progress

Photo 0.1 *A typical scene of the desert of black sand in the interior* RC

incrementally throughout the century, but it has to be seen in the context of the scale and extent, and especially the causes of soil erosion.

Soil conservation in Iceland has had to tackle the double challenge of natural forces and human activity. Iceland is one of only two terrestrial places on Earth where the tectonic plates are spreading away from each other. New land is coming into existence all of the time, driven by forces deep in the Earth's crust. The surface is riven apart, mountains appear, and lavas flow over wide areas. A chemical cocktail of material is thrown high into the atmosphere periodically, only to smother the surface when it lands. The ash and pumice - *tephra* - at one and the same time stops vegetative growth and provides the basis for natural generation of soil. Ice caps top many mountains and add another ingredient to the play, as many of these are underlain by volcanoes, and have been active at some stage during the millennium since The Settlement. Any heating up of these volcanoes inevitably releases vast volumes of water, which cascade over the adjacent land in torrents in a manner that no modern engineering has been able to control. The soils and their substrate are readily removed and deposited downstream on the extensive 'sandur' plains and out to sea. Yet, despite all of this water action, the central area of Iceland can be properly described as a desert with low precipitation and extensive drying of the surface layers. The winds induced by the temperature and pressure variations between the ice caps and the surrounding land provide yet another force for removing the soil and depositing it in the water courses, on previously vegetated surfaces and out to sea. It is scientifically legitimate to think of Iceland being on the move, both as the tectonic plates part and as the consequences of the volcanic activity change the land surface fundamentally.

To all of this natural dynamism must be

Photo 0.2 *Rofabörð showing the extent of soil and parent material lost due to erosion* NMI

added the effect of human activity since the first settlers arrived in the ninth century A.D. The old Icelandic annals and other written records tell of humans seeking to conquer the forces of nature. Recent studies of soil profiles and analysis of pollen show that trees were cut down for construction and for firewood, exposing the surface to wind and water erosion. Soil profiles also indicate extensive burning of woodland in the early centuries, to clear land for grazing and to produce charcoal. Attempts to grow crops often failed due to bad weather, sometimes prolonged over many years due to volcanic ash clouds blocking out the sun and reducing the summer season. In more recent times, there have been many examples of over stocking of the land by domesticated animals, especially sheep and horses. A cycle of degradation has resulted, with the removal of the vegetation surface and the exposure of the soil making it more vulnerable to removal by the natural forces of wind and water. The result has been a substantial reduction in the carrying capacity of the land, with land surfaces lowered by many metres as evidenced by the few remaining pillars of soil: the *rofabörðs*.

Icelanders are both immensely proud of their country and greatly concerned at the effect that they and their forefathers have had on the land. Before soil conservation became an issue in other parts of the world, such as the dustbowl of the Dakotas in the USA, the Icelandic authorities, emulating their Danish counterparts, took a major step forward. They recognised that there was a problem and that something must and could be done about it. The Danish government and the Parliament

in Reykjavik agreed, *inter alia,* to the formation of the first soil conservation service in the world. This book tells the story of the century or so from its formation in November 1907 to the present day.

From the perspective of a visiting environmental and organisational management specialist and a great lover of the people and land of Iceland, the story has two major ingredients: learning lessons from good and bad ideas, and having the right people in the lead to drive the process forward.

There are many questions which, in hindsight, need to be addressed. Was it good practice to reclaim the land by dropping seeds and fertiliser from an aircraft without engaging the farmers? Was it sensible or sheer desperation to use non-native and highly invasive species as part of the reclamation effort without thinking of the longer term consequences? Was it the best practice to operate from a central base without engaging with all of the key players locally? Was it appropriate to operate without knowing the extent and severity of the problem over the whole country until quite late in the work? Was it reasonable not to deploy the scientific knowledge of soil conservation gathered from around the world? The material provided in text and the overview in the final chapter seeks to address these and other questions.

The story told in this book is testimony to the work of many individuals on behalf of a whole nation. It is not a parochial story. If there is one clear message from Iceland it is that lessons must be learned from past successes and failures, new methods applied, new ideas garnered from interacting with the wider scientific community, and ensuring that the public both benefit from the activity and engage in it. Anyone involved in improving the stewardship of the world's natural resources for the benefit of present and future human generations can learn from the Icelandic experience. The title *Healing the Land* is recognition of the need for action in Iceland after centuries of destruction and provides lessons and messages for other countries where management of this inestimable resource is inadequate. I hope readers will be inspired by the triumph of human ingenuity and fortitude over the relentless, and at times, overwhelming power of natural processes and poor human stewardship of one of the most vital natural resources of the world: the soil.

The book is in 4 parts.

1. Chapters 1 and 2 set the scene for the centennial story by providing an account of natural and human history since The Settlement and the early reclamation efforts.
2. Chapter 3 documents reclamation action on the ground over the century to demonstrate what has been achieved and the evolution of activity through different periods.
3. Chapters 4 to 7 discuss the development of the essential ingredients for conservation and reclamation: public views, policy, law, resources, organisation, science, experiment and demonstration, reclamation techniques, awareness raising, working with farmers, and motivating civil society.
4. Chapter 8 assesses the progress made, the barriers and the successes, sets out the lessons learnt for Iceland and elsewhere, and provides some thoughts for the future.

Endnotes

[1] Rev. Björn Halldórsson wrote this poem on 17 February 1763 after a very bad sandstorm. Translated by David Gislason

[2] Arnalds, Ó., Þórarinsdóttir, E.F., Metúsalemsson, S., Jónsson, Á., Grétarsson, E. & Árnason, A. 2001. *Soil erosion in Iceland*. Soil Conservation Service and Agricultural Research Institute. 121 pp.

Setting the scene

Chapter 1

A little history – natural and human

Any account of the story of soil conservation in Iceland must begin by recognising the history of the land: the forces of nature and their effects, and the human endeavour over a millennium of superimposed on them and interacting with them. This chapter provides a brief natural and human history of Iceland over the period from The Settlement as an essential context for the story of soil conservation.

The current Director of the Soil Conservation Service, Sveinn Runólfsson, puts the issue into context as follows:

> "The strong link between the health of the land and human living conditions has been amply demonstrated over the 1100 years of Icelandic history. I come from an island in the North Atlantic Ocean, where there lives a nation that was rated amongst the poorest on Earth until less than a century ago. Massive land degradation and soil erosion contributed to the collapse of the once prosperous nation; a nation that developed the legacy of scholarly knowledge and literacy - and the Sagas. We are well aware of the importance of knowing and using resources with care and skillfulness. A combination of natural processes and human activity has resulted in the loss of most of the original tree cover and more than half of the soil cover in Iceland. Extensive areas formerly covered by fertile soil, supporting shrub and tree cover, are now barren land. Forty percent of the land area has been surveyed as deserts, and vast areas are severely degraded rangelands. Under extreme poverty, Iceland established the Soil Conservation Service more than 100 years ago, which may be the oldest of its kind in the world. I must say that we Icelanders have a deep understanding of the need to combat the destructive forces on the soil at home and on a global basis And the present day aims remain the same – to regain, conserve, and ensure sustainable use of Icelandic soil resources."[1]

The raw power of nature

Examination of the catalogue of volcanic eruptions and weather conditions since The Settlement provides a poignant reminder of the power of nature and its effect on the land and the ability of the farmers to continue to grow crops and breed livestock. Eruptions, and in particular large clouds of ash and superheated steam, substantially lowered the temperature locally and regionally. Noxious gases from the early phases of eruptions often proved devastating to livestock, especially as fluorine and sulphur gases were so pungent and their high density meant they remained close to the land surface. Fluorine is a particular problem as it poisons the vegetation and causes loss of teeth and deterioration of bones in livestock. Floods – *jökulhlaups* – from those ice caps resting over the magma chambers devastated the lower lying areas, stripping off the vegetation and soil, and leaving immense deposits of material which took time to become naturally fertile and suitable for cultivation. Large quantities of ash were

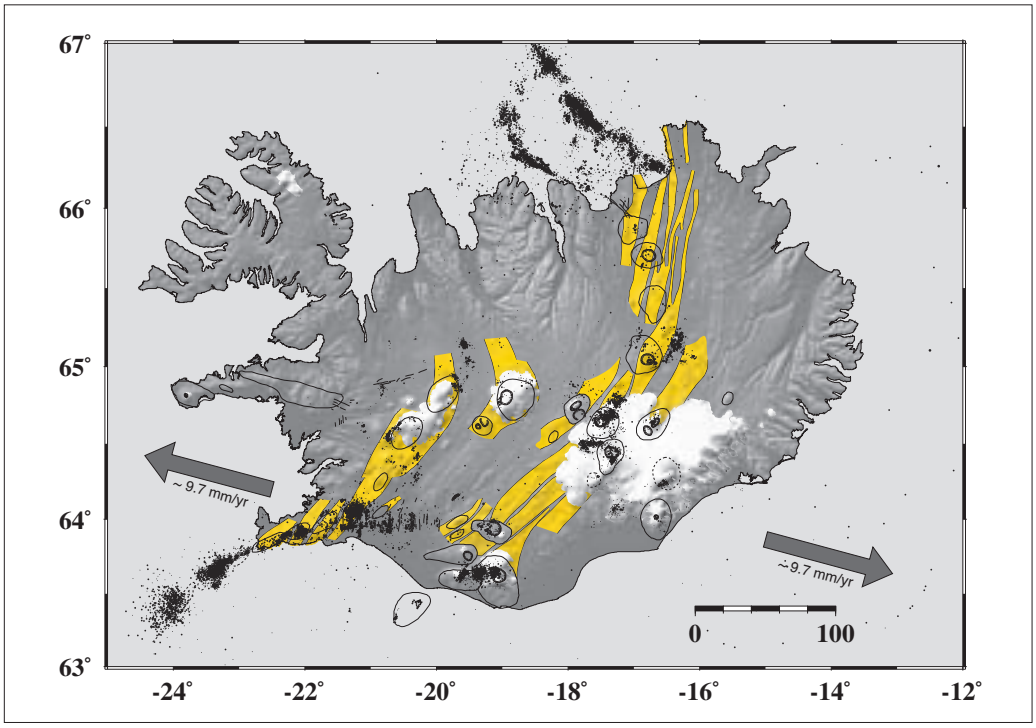


Figure 1.1 *Central volcanoes, tectonic plate boundaries and earthquake locations*

Source: Einarsson, P. and K. Sæmundsson 1987. Earthquake epicenters 1982–1985 and volcanic systems in Iceland. In: Þ. I. Sigfússon (editor), *Í hlutarins eðli*. Map accompanying Festschrift for Þorbjörn Sigurgeirsson. Menningarsjóður, Reykjavík. With kind permission.

deposited over previously vegetated land causing it to die back and become unsuitable for cropping or for livestock grazing for some time. Cold (katabatic) winds from ice caps in the Highlands and winds associated with deep cyclonic depressions in the North Atlantic brought intense air currents and large falls in temperature. As a result, sand was blown from the uplands onto inhabited areas, filling the coats of sheep and the lungs of all animals so that they were neither mobile nor could breathe, and quickly died. The rapid falls in temperature also caused trauma for the livestock, resulting in death and lowering of fecundity, as well as making food sources inaccessible to them.

The most conspicuous evidence of natural processes is the presence of bare sand in many areas. For example, ancient sources refer to sand along wilderness trails. A sand route is cited in both the *Saga of Reykdæla* and the *Saga of Hrafnkell*[2], where reference is made to the Sprengisandur Route. In the *Saga of Grettir the Strong*[3], a reference is made to Stórisandur when Þorbjörn rides "the sands south" on his way to the Parliament at Þingvellir after having defeated Grettir in battle and buried his head in a sand mound. Thus both of the country's most famous highland sand plains are mentioned during the first centuries of Icelandic history. Place names also demonstrate that sand was found alongside good land in the lowlands: Sanddalur (sand valley), Sandfell (sand hill), and Sandvatn (sand lake), being examples.

The volcanically active areas of the spreading centre between the North American and Eurasian tectonic plates, which cross the

Table 1.1 Eruptions since The Settlement

Volcano/volcanic system	Eruptions since 870AD	Most recent eruption	Principle hazards
Katla	21	1918	Jökulhlaup Tephra fall Lava flows
Grimsvötn/Laki	c70	2011	Jökulhlaup Tephra fall Lava flows
Hekla	23	2000	Tephra fall Lava flows Fluorine gas
Bárðarbunga/Veiðivötn	23	1910?	Jökulhlaup Tephra fall Lava flows
Öræfajökull	2	1727	Pyroclastic flows Jökulhlaup/lahars Tephra fall
Askja	>2 episodes	1961	Tephra fall
Krafla	2 episodes	1984	Lava flow
Eyjafjallajökull	4	2010	Jökulhlaup/lahars Tephra fall
Vestmannaeyjar	2	1973	Tephra fall Lava flow
Reykjanes peninsula	4 episodes	c1340?	Tephra fall Lava flow
Prestahnúkar system	1	c950	Lava flow
Þeistareykir submarine	1	1867	Tephra fall
Snæfellsnes	1	c900	Tephra fall Lava flows

Source: Based on Gudmundsson, M.T. et al. 2008. Volcanic hazards in Iceland. *Jökull,* 58, page 254 with kind permission.

centre of Iceland, are the source of much of the sand (Figure 1.1). Two basic types of volcanic material are found: an alkaline type is comprised of largely basaltic rocks which have good moisture retaining characteristics, and an acidic type of silica based rocks which are prone to drought and are very easily moved by the wind.

Volcanic eruptions have always been considered major events, and are the reason why their impact on vegetation, livestock and economic life has been well chronicled over the centuries. An estimated 217 eruptions have been recorded since Iceland was first settled[4]. Eruptions have had enormous consequences, both direct and indirect. South central Iceland, in particular, has been the victim of frequent eruptions of Hekla and Katla (Figure 1.2). Many other volcanoes have spewed out lava and tephra over the land, destroying ground vegetation and forests, such as,

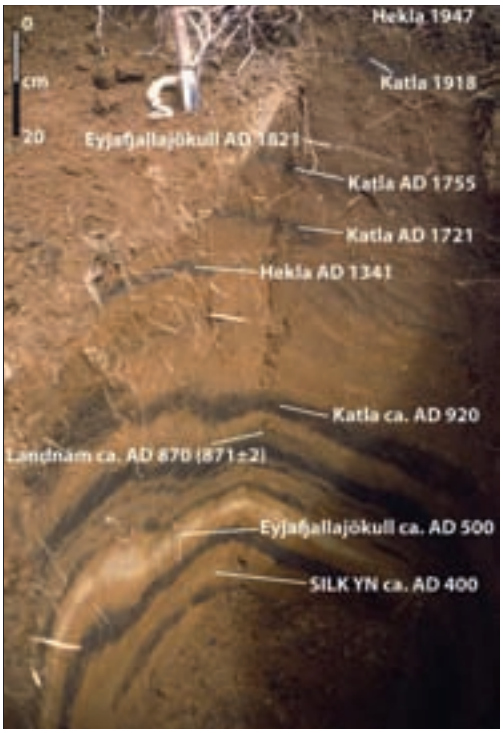


Figure 1.2 *Soil profile illustrating the instability of the surface, showing the Settlement (Landnám) layer and later tephra layers from eruptions of the Hekla and Katla volcanoes*

Source: Dugmore, A. J, Gísladóttir, G, Simpson, I. A. & Newton, A. 2009. Conceptual models of 1200 years of Icelandic soil erosion reconstructed using tephrochronology. *Journal of the North Atlantic* 2, 1-18.

Leirhnjúkur in the north east, Askja, Lakagígar and Kverkfjöll in the central highlands, and Öræfajökull and Dyngjufjöll under the Vatnajökull ice cap (Table 1.1).

It is no exaggeration to state that the natural environment of Iceland over the millennium or so since The Settlement was often inimical to the continuation of human settlement and the production of food. Indeed, it is a great surprise that Icelanders continued to inhabit the island at all.

A few descriptions over the years since The Settlement will give the reader some idea of the effects of eruptions and associated flooding from these natural events.

- Remains from 20 farmsteads in the Þjórsárdalur valley in south central Iceland show that there were flourishing settlements and vegetated land throughout the valley until the massive eruption of Hekla in 1104 (see figure 1.3).
- A deep ash and pumice layer was deposited from the Hekla eruption of 1510. Subsequently, wind activated the deposits causing sand drifting and soil erosion which was not effectively halted until the 20th century.
- In 1362 the Öræfajökull volcano erupted under the southern part of the Vatnajokull ice cap and destroyed all 40 farms on the low ground to the south.
- The floods on the Jökulsá á Fjöllum in the 18th century, resulting from volcanic eruptions under the northern part of the Vatnajökull ice cap, destroyed large tracts of vegetated land.
- On 17 May 1724, a black cloud of ash appeared over the mountains to the northeast of Lake Mývatn in north Iceland. Accompanying lava flows destroyed four farms, killed off the vegetation, covered the land surrounding the church at the village of Reykjahlíð and came to a halt at the cemetery.
- Without doubt the most significant natural event with devastating effects on people, land and farming since The Settlement was the Laki eruptions in the 1780s. A 27 km long fissure with 140 vents and craters was active for 2 years from the summer of 1783. Tephra was spread over about 8% of the Icelandic land area. Noxious gas clouds, river diversions, and lava flows over highland pastures devastated 20 farms. Over 50% of the Icelandic domestic livestock were killed and around 20%, some 10,500, of the Icelandic people

died. Vegetation was poisoned by the fluorine gas emitted in the early phases of the eruption. Later around 100 million tons of sulphur dioxide was ejected into the atmosphere; it reached the Arctic and Europe, causing an estimated reduction in temperature of 1.3°C for 2-3 years.

– The Eyjafjallajökull eruptions of 2010 resulted in substantial quantities of ash being deposited onto high quality farmland, reducing production for a few weeks and rendered the highland commons useless for the summer grazing. Roads were closed and river valleys filled with ash. Ash continues to be deposited into the valleys and is blown onto the land. There remains a great deal of ash still to reach the lower ground.

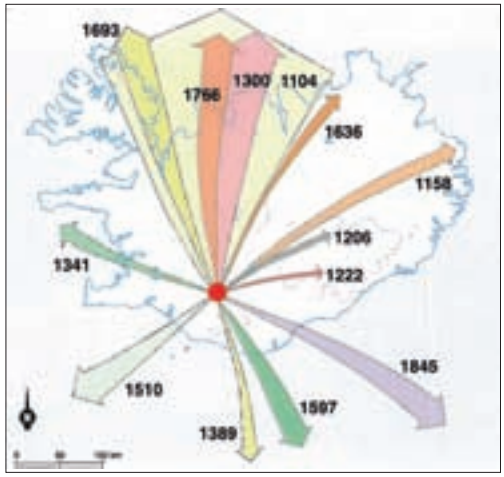


Figure 1.3 *Ash dispersal from Hekla volcano eruptions 1104–1845*

Source: Published in Ari Trausti Guðmundsson. 2001. *Íslenskar Eldstöðvar.* Vaka-Helgafell, page 136 with kind permission.

Icelandic soils

The characteristics of Icelandic soils are a major determinant of their susceptibility to erosion, especially by wind, and also to the speed of development and vegetation formation. Icelandic soils are mainly formed from eruptive volcanic parent material and material derived from it such as glassy sands. They are predominantly of basaltic type with high alkalinity, and readily decompose, even in the harsh high latitude climates of Iceland. They are generically known as *andosols*. Ólafur Arnalds has led the work on defining the characteristics of the soils and determining the classification according to world systems[5]. He identifies 2 main types: *andosols* comprising over 50% of the total and *vitrisols* comprising over 30%. The former are alkaline, freely drained and form over the lower ground. The latter are more alkaline with virtually no carbon and a high nitrogen composition. The parent material is the stone pavements and lag deposits of the interior deserts. They are now bare of vegetation, but it is considered that they were vegetated at the time of Settlement and have since been over grazed leading to the loss of the vegetation cover and the finer particles.

Icelandic soil profiles illustrate the dynamics of the environment. A great deal of additional material is added either from tephra deposition after eruptions or from sand blow (Figure 1.4). The sources of sand are a critical factor in the development of strategies for reducing sand drifting and vegetation loss. The principle sources are: decomposition of lavas, deposition of tephra, river flood deposits or advancing sand fronts.

The effect of changing climate and weather

Iceland's climate is classified as predominantly cool temperate maritime, with a subarctic regime in the highlands and many freeze/thaw cycles in winter. Annual precipitation is in the range 400 mm to 4,000 mm. The interior can be reasonably classified as a cold desert due to a combination of

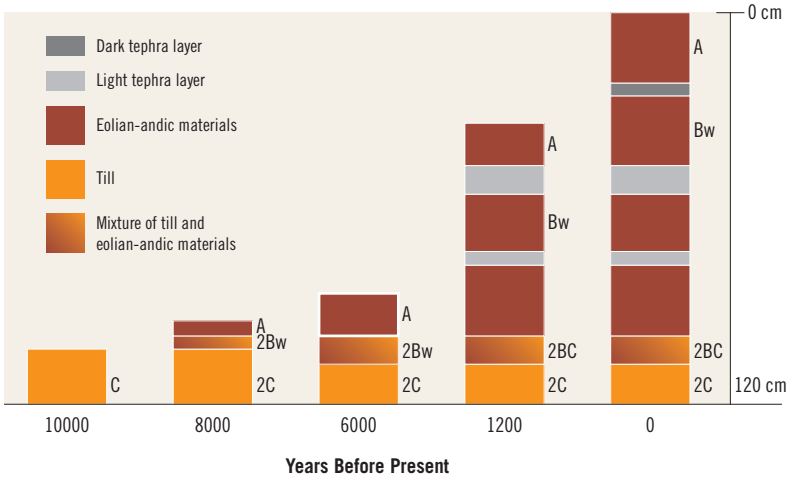


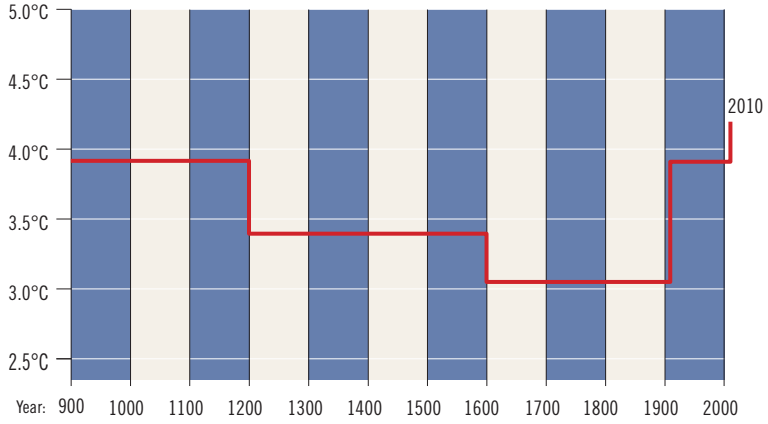
Figure 1.4 *Typical soil profile development: an andosol formed from tephra and aeolian materials from a type site in north Iceland*

Source: Arnalds, Ó. 2008. Soils of Iceland, *Jökull, 58, figure 4* with kind permission.

moderate precipitation, drying winds and freely drained surface materials

Weather conditions have changed dramatically since The Settlement with long periods of cold weather and shorter interludes of warmer weather (Figure 1.5). Inevitably, these have a marked effect on the speed of soil formation, the development of vegetation, and the amount of erosion by wind and water. Cycles of freezing and thawing, and the process of cryoturbation, damage the surface vegetation layer by creating unvegetated spots which are prone to erosion and accelerate the removal of the surrounding vegetation. The effect of climate and weather changes on the human population have been dramatic. Human ability to survive and to gain a livelihood from the land in the traditional manner of livestock production has placed great strains on the vegetation resulting in much of its removal.

In the 12th century, Iceland's climate



The graph shows the average temperature over four periods in time. From the time of Settlement until 1200 it was usually warm, but much colder over the period 1200 to 1600. The coldest period was 1600 to 1920, but since then weather has mostly been mild with rising average temperatures.

Figure 1.5 *Estimated average temperatures since The Settlement*

Source: Páll Bergþórsson with kind permission.

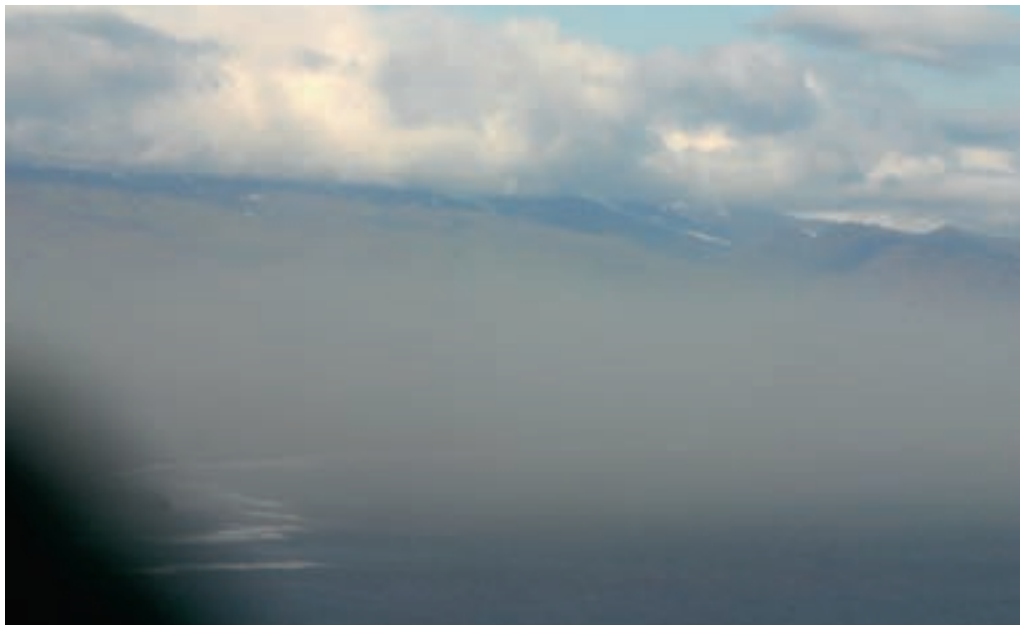


Photo 1.1 *Sand blowing darkening the sky, covering the ground and irritating the nostrils* RC

began cooling. The period from 1900 to 1920 was particularly cold (Figure 1.5). Cooler weather naturally impacted upon the vegetation, especially during the hardest years. It is no coincidence that travel over the highland routes largely ceased in the 17th century. Iceland's climate began to deteriorate after 1860, and some of the harshest years in the nation's history began around 1880. The situation was particularly severe in north and east Iceland where livestock in many districts were devastated, agriculture collapsed and fishing declined.

Dust storms

Dust has been and remains a major problem[6]. Dust covers the surface with fine, often glassy, particles and reduces the sunlight sometimes for days on end. As a result, vegetation growth is retarded. The main sources of dust are from newly deglaciated land at the ice margins and where rivers emerge from the ice, areas where floods have occurred due to seasonal snow melt or from the after effects of eruptions under ice caps, areas of bare soil and areas of bare sand especially in the highlands. Dust has been traced for long distances, for example for 400 km out to sea. With the retreat of glacier and ice cap fronts resulting from global climate change exposing more bare sand areas, it is likely to be more problematic in the future. However, much of the material, derived from basaltic tephra and with its high alkalinity, is a soil improver.

The black sandstorm

The problem of sand blow, soil erosion and the loss of lives, livestock and livelihoods in Iceland are graphically illustrated by a huge sand storm in 1882. It particularly affected south central Iceland around Rangárvellir, near Hekla.

The winter of 1881–1882 was variously called *The Hard Winter*, *The Sand Year* or *The Winterkill Year*. During the Easter holidays the temperature dropped below freezing and a blizzard blew from the north for 10 days

bringing some of the coldest weather ever known. Severe sandstorms blew relentlessly over inhabited areas nonstop for three weeks in a way that is hard to imagine. The blowing sand pulverised grasslands, ripped turf roofs off houses, and flattened walls and embankments. Many farms were abandoned. Nine farms were completely buried under sand and almost nothing was left standing. The sandstorm killed large numbers of livestock, their lungs filling with sand, while others became diseased and died. Of the 1400 sheep taken to one of the highland pastures for the winter, only 100 were found alive after the weather moderated. Large numbers of sheep died as their wool filled with sand to the point where they could no longer stand and could do nothing to save themselves. Sheep housed in barns suffocated from drifting sand, while dead trout lay scattered on sand that was once a lake. Horses met a similar fate.

The summer of 1882 was extremely cold – more like winter. In many regions, famine struck and people gave up. Some travelled to North America, others moved to different districts, but some just moved their turf houses onto the remaining patches of grass. One of the farms abandoned because of sandstorms was Kornbrekkur in the Rangárvellir district of south central Iceland. Its name refers to a time when corn grew there, the land being fertile and well suited for cultivation. Around 1880, wind erosion north of the farm had become so severe that the black sandstorm of 1882 ruined this once prosperous estate. The Rev. Matthías Jochumsson, the parish priest, visited Kornbrekkur after the storm abated and later wrote "I came and stared / everything a wasteland / and no one home". His poem *Did you go to Kornbrekkur?* tells the story.

> An earlier time I was there:
> Sun bathed the countryside,
> summer in the grounds.
> The fields were merry
> and in hundreds of groups
> the sheep marched
> on sun drenched ground.

In the third and fourth verses, the poet describes his visit after the devastation:

> I visited once again.
> I saw a sand plain
> and black ruins.
> Outside awaiting guests
> was wasteland and coldness,
> and wafts of mourning
> filled all within.
>
> Hell had
> in the district all around
> gone looting
> leaving nothing behind.
> Struck the master
> and then one after the other,
> house and fields,
> flock and pastures.[7]

Icelanders believed that this was nature at work and that nothing could or should be done. Man was powerless against the forces of nature. This was hardly surprising when those visiting these areas found the ground buried in sand, the farm buildings on the

Photo 1.2 *Farm buried by a sand storm and recently excavated, near to Gunnarsholt, south central Iceland* SR

verge of collapse and few livestock to be seen. Inland were huge waves of sand ready to engulf farms and farmland when the next storms began in 1885. Many farms were overwhelmed, including Gunnarsholt (see Chapter 3). In Rangárvellir at least 75 farms have been destroyed by drifting sand in the last three centuries. A local farmer noted that "It was midsummer and not a cloud in the sky. Just for fun, I tried long and hard to find where the sun was hiding. But it just wasn't possible. The sandstorm was that black."[8]

Iceland: always loved yet abused

The vegetation cover

The vegetation of Iceland has changed dramatically since the original settlers first stepped ashore. Observers regarded Iceland as a beautiful country, to the extent that they considered the name 'Iceland' to be a misnomer and that is should have been called 'Greenland' (and *vice versa*). But, since then, human activity has had a profoundly detrimental effect on the land. Colonisation disrupted the delicate balance that existed between sensitive vegetation, harsh growing conditions and slow soil formation. Woods and vegetation were removed, providing ideal conditions for wind and soil erosion. This is not a purely Icelandic phenomenon. Examples of land overexploitation and soil erosion are found throughout the world, but the extent of desertification that has occurred in Iceland since colonisation has few parallels in the northern hemisphere.

The words of Ari "the Learned" Þorgilsson in the *Book of the Icelanders*, that Iceland was "lushly vegetated from mountain to sea" when settlers arrived in the 9th century, have often been quoted[9]. Although some have disputed this description recorded three centuries later, recent research indicates that they were basically accurate with the extent of vegetation at least twice what it is today (Figures 1.6 and 1.7). Woodlands and shrub vegetation are considered to have been reduced from almost 40% of the land area) to 1%, vegetation cover as a whole has been reduced from 60-70% to about 40%, and between 50 and 70% of wetlands have been drained[10]. Barren land most certainly existed as can be deduced, for example, from place and topographic names appearing in the ancient records.

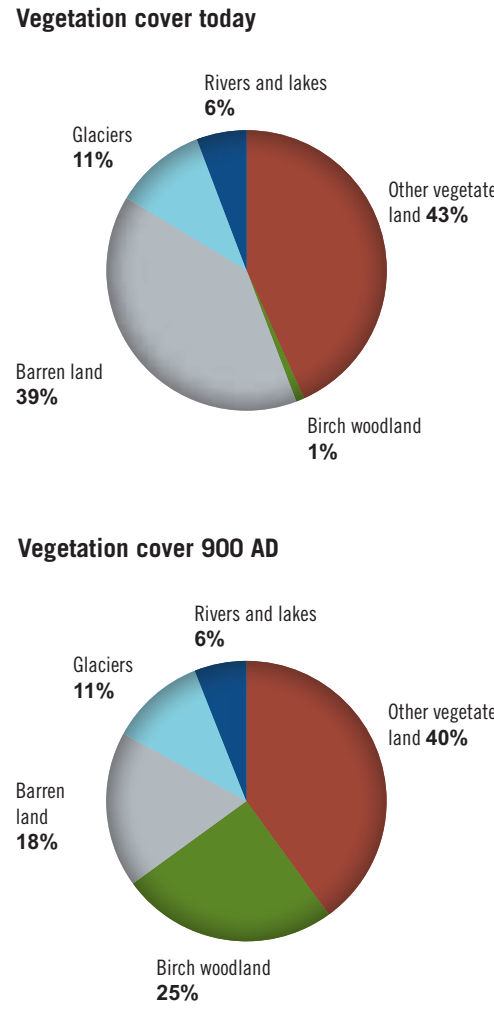


Figure 1.6 *The vegetation cover at The Settlement in the 9th century and in the 20th century*
Source: IINH

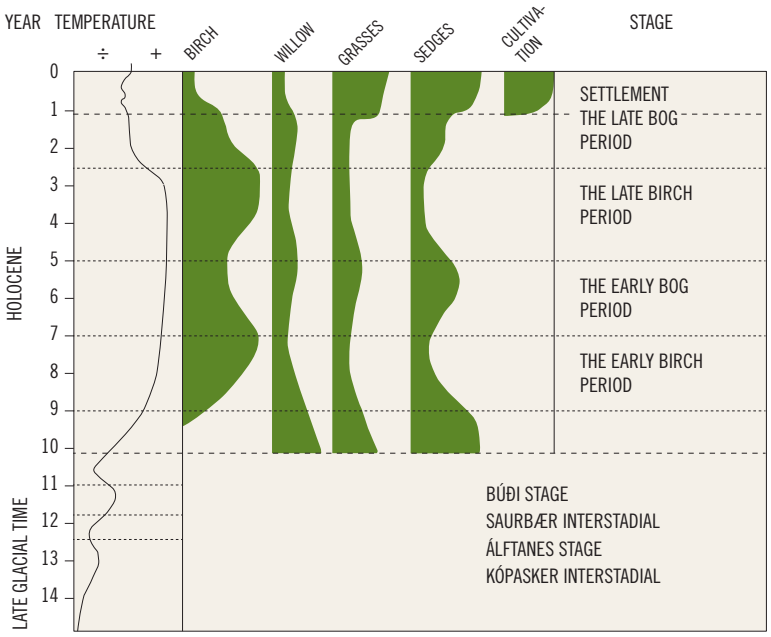


Figure 1.7 *Changes in the pollen curve illustrating the dramatic effect of The Settlement with reduction in the occurrence of downy birch and the growth of grasses (Poa) and sedges (Cyperacia) and cultivated species*

Source: Gísladóttir, G., Erlendsson, E. & Lal, R. 2011. Soil evidence for historical human-induced land degradation in West Iceland. *Applied Geochemistry*, 26, page 530, with kind permission.

There are many written records of the existence and extent of vegetation cover during the first centuries after colonisation. Sources from the Independent Period, 875 to 1265, indicate frequent travel between the Icelandic regions. These highland routes would not have been as busy and as passable unless good meadows were found at regular intervals to feed the horses. The Sagas mention large areas of woodland in southern and northern Iceland. For example, the *Book of Settlements*[11] records that the forest at Botnsdalur on the west coast had been so large that ocean-going ships were constructed from the timber. The ancient manuscripts also mention that domestic animals sometimes got lost in the woodlands, only to be found some years later, along with their many offspring. In many areas, place names refer to woodlands and to the making of charcoal, (skógur=woods, timbur=timber). Also the Icelandic word eyðimörk is used to describe a desert. It has two components eyði meaning empty or deserted, and, significantly, mörk meaning woodland, testifying to the long held historical viewpoint that many now barren areas were wooded. Remains of the climax vegetation from the early centuries of colonisation can still be seen, for example, on islands in rivers and lakes which neither livestock nor lava could reach. Relict soils have also been discovered in many places during recent scientific investigations indicating periods of surface stability[12].

The *Book of Settlements* names about 415 settlement sites. Most of them still exist, but there are also many that are deserted. Moreover, research shows that in the first centuries of colonisation farmsteads were situated at much higher altitudes than today.

What caused the changes?

Wood had been a major raw material in the first centuries after The Settlement. Timber was felled for building homes and boats, for fuelling fires for cooking and tool making, and for producing charcoal. Large tracts of forest were burned to create grazing land. A layer of charcoal below ground from the time of The Settlement bears witness to this practice[13]. There are also 38 placenames around Iceland which include the word Svíðingar, indicating the practice of burning woodland to produce grazing land.

Attitudes to forest management are well described by Þorvaldur Thoroddsen writing in the late 19th century[14]. The early settlers would burn a neighbour's forest to avenge a wrongdoing, and chop down everything they could to make charcoal; many shrubs were sacrificed to the scythe in the name of firewood.

Deforestation proceeded more rapidly in the north than in other areas of the country. When the Icelandic sagas were written in the 13th century, forests in the north were much smaller than they had been in earlier times. From historical sources, it is possible to infer that woodlands had been ten times more widespread at the start of the 18th century than today. When naturalist Sveinn Pálsson travelled the country at the end of the 18th century, he judged Hallormsstaðaskógur in eastern Iceland (a major centre of the Iceland Forest Service) as being the largest and most beautiful forest in Iceland, but feared it would suffer the same fate as other forests. He wrote:

> "And, so this beautiful district will experience the same fate as other forested areas of Iceland. It will be a mark of shame for the old, and disservice to the yet unborn! Everywhere, yet particularly at Hallormsstaður and the innermost valleys, is there evidence of rueful destruction. The beautiful birch trees have been decimated in these parts, but not from the roots; rather, they have been chopped down at heights as high as man, so the area looks like swarming phantasms, erect ghosts, which at first terrified my horses."[15]

Apart from the rapid decline of woodlands immediately following The Settlement, deforestation probably occurred most rapidly after the mid 19th century as trees were particularly in demand for fires to make charcoal and to heat the blades of scythes so they could be sharpened for grass cutting. For example, farmers near the coast in the Rangárvellir district of south central Iceland exploited a woodland, Landskógar, which had always protected the sensitive volcanic soil from soil erosion. The forest had begun significantly declining in the 17th century, but records show that it was still so tall and dense in the mid 19th century that it obstructed the view to the mountains, and it took two hours to walk through it in any direction. However, overexploitation and excessive grazing during poor weather nearly destroyed the forest in a few decades. By the early 1880s it had disappeared, with the only remnants being some shrubby birch. With the trees gone, the soil was readily stripped away by the wind exposing bare lava. The 'Black Sandstorm' described earlier in this chapter was, in part, a consequence of this forest no longer existing.

Agricultural publications from the latter part of the 19th century and the early 20th reported how many horse loads of wood for kindling fires farmers collected; this was often considerably more than horse loads of hay from the same farms. Birch and shrub vegetation were sacrificed when farmers needed firewood to survive. Birch and willow have a great propensity for rejuvenation, so that felling trees and ripping up brushwood were not completely responsible for destroying forests. There were other factors as well.

Large quantities of charcoal were needed

to extract iron from limonite, which Icelanders did until the 15th century, and to heat the forges where tools were made until the end of the 19th century. The practice of chopping down trees for charcoal making is an Icelandic tradition. The charcoal was made in large hollows, and the relics can still be found around the country. Vestiges of some charcoal pits have been found in former highland pastures. For example, the place name Smiðjuskógur (=smithie) on the Sprengisandur Route indicates a forest which no longer exists, but some molten metal waste found in the sands bears witness to charcoal production. The holes were filled with wood and covered with turf, and a fire lit above. There are stories of men losing control of fires, resulting in large areas of forest being burned to the ground. Initially, high quality wood was burned to make charcoal, but as these sources diminished willow and other shrubs were used.

Grazing by domesticated animals also played its part in the destruction of vegetation. It is thought that vegetation had developed, free of grazing, for almost 9,000 years from the end of the last Ice Age. Sixty years after The Settlement livestock ownership grew rapidly and became the foundation for human survival. The colonists introduced cattle, sheep, horses, pigs, goats, fowl, dogs and cats. Interpretation of ancient manuscripts puts cattle numbers, particularly cows, as proportionally much greater than in later centuries, while the number of sheep was lower (Figure 1.8). There were a large number of domesticated, free-range pigs during the first centuries after colonisation, but they died out around 1600, because of the damage they caused to the land and poor weather conditions. There were fewer livestock throughout the 18th century, particularly after an outbreak of scabies disease in 1760 and the effects of the Laki eruptions in the 1780s.

There is no doubt that livestock had a

Photo 1.3 *Trees being carried on horseback from Þórsmörk for charcoal making and other domestic uses in the late 19th century* IFS

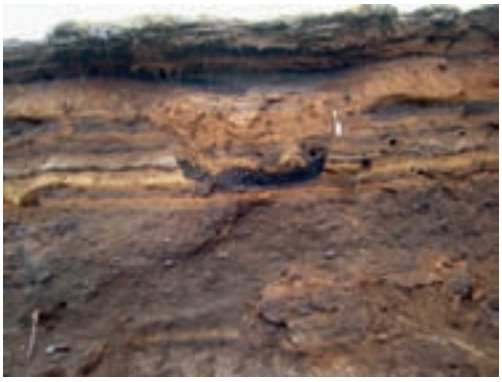


Photo 1.4 *A charcoal pit exposed in a river bank in Þórsmörk* IAI

Photo 1.5 *Over twenty charcoal pit impressions can be identified from this aerial photograph in north Iceland* ÁE

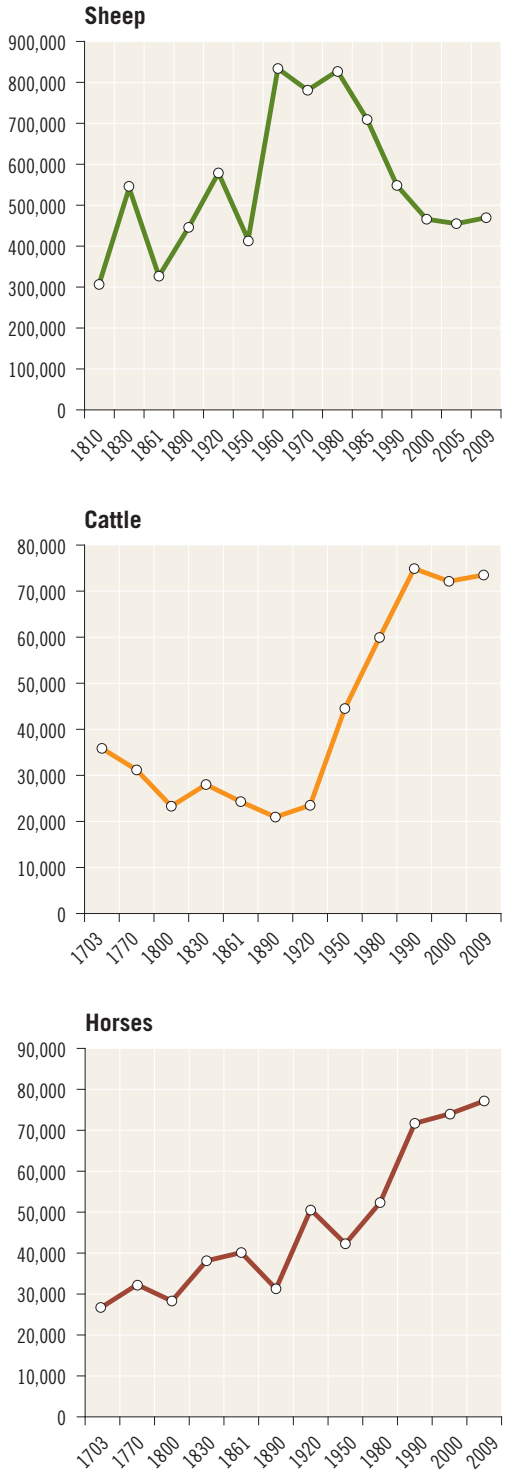


Figure 1.8 *Sheep, cattle and horse numbers*
Source: Farmers Association of Iceland

seriously negative impact on vegetation in the first centuries of colonisation, especially if several years of harsh weather came in succession. Longstanding grazing by sheep and horses, particularly in winter and spring, impeded woodland renewal. Sheep, for example, ate the new buds and the branches protruding above the snow, so arresting tree growth. With growth in the numbers of grazing animals and continuing lack of management by farmers, who allowed animals to roam, vegetation was easily consumed and new growth significantly impeded.

Four main factors saved the remaining woodlands around the turn of the 20th century. Coal was imported. In 1867, Scottish scythes were imported which did not require the use of charcoal to heat the metal for sharpening the implement. Sheep grazing outdoors in winter and spring reduced as haymaking increased. And, education opened the way for new attitudes. People in the 20th century viewed forests as beautiful and worth saving. Remains of the forests were therefore widely protected.

Overview: human incompetence alongside overwhelming natural forces

The main reasons for soil erosion – inclement weather, human mismanagement of woodlands and overgrazing, and the effects of volcanic eruptions – were all present simultaneously, with cumulative effects on vegetation. Although it is difficult to disentangle the precise causes of the changes, and the relative weight to be given to natural and human factors, all recent studies have come to the same conclusion: there has been an acceleration of degradation due to human mismanagement. This is well illustrated in the sequence shown in Figure 1.9. Estimates of the loss of soil mass have been estimated at between 7 and 9 fold in the Reykjanes peninsula in south west Iceland

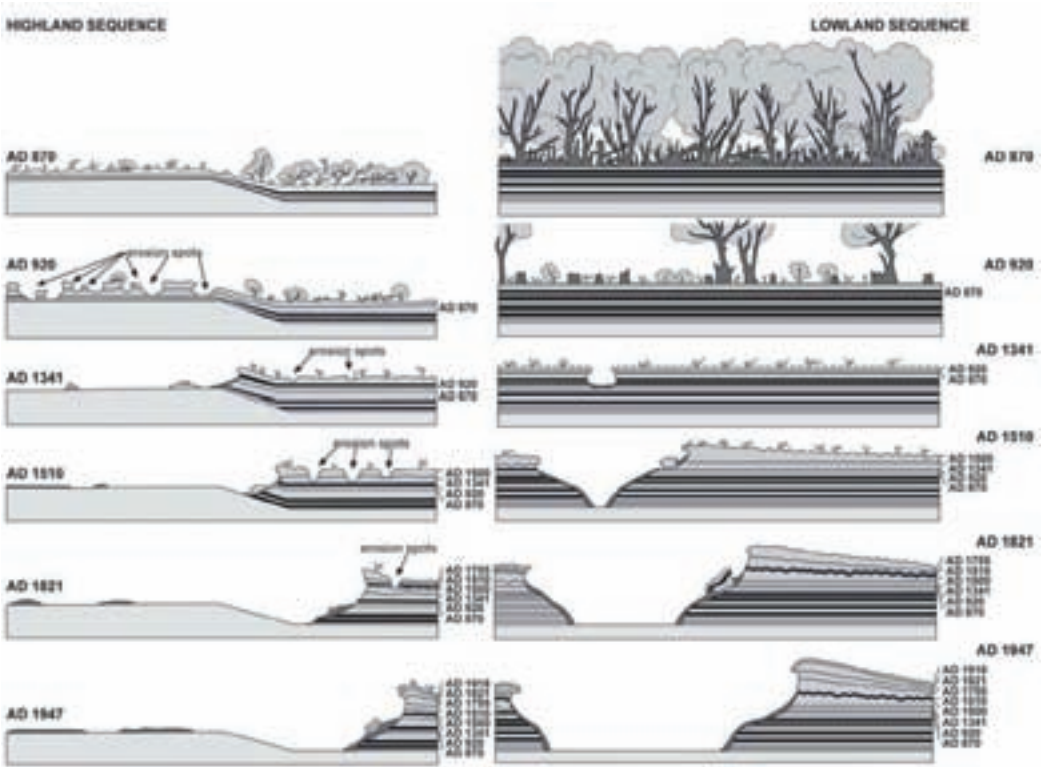


Figure 1.9 *How the landscape has changed since The Settlement: reconstructions of landscape change at Seljalandsheiði south Iceland A.D. 870–1947*

Source: Dugmore, A.J., Gísladóttir, G., Simpson, I.A. and Newton, A. 2009 Conceptual models of 1200 years of Icelandic soil erosion reconstructed using tephrochronology, *Journal of the North Atlantic* 2, page 11 with kind permission.

for example[16], and the retreat of erosion fronts in south central Iceland has been estimated at 20 cm per year[17]. Other estimates suggest that some 3 million ha of soil and vegetation have been lost equivalent to 1.6 billion tonnes of CO_2[18]. We now know that birch withstands ash-fall much better than undergrowth, so desertification increased in relation to the depletion of birch woodlands.

At the start of the 16th century, people began predicting that the land would be completely devastated. This reflected their fear not only of desertification, but also of a waning economy. This view is reflected in the poem *Stúfur* by Þórður Magnússon at Strjúgur:

"Indeed it be but a moment before Iceland is no longer."[19]

Understanding the sequence of changes that occurred from a combination of natural and human activity is an essential prerequisite for defining strategies and action for soil conservation and land reclamation. Two valuable, complementary approaches have been developed from detailed scientific observations and analysis. Six stages of desertification have been identified by Aradóttir as follows: 1. continuous cover of birch, willows, grasses and forbs; 2. replacement by heathland; 3. development of erosion spots and patches resulting from grazing and vegetation removal; 4. formation of erosion fronts and escarpments, and isolation of remnants of original soil and vegetation in the form of rofabarð; 5. increasing disappearance of vegetation and soil; and 6. the end point

of bare glacial till or sand: the true desert surfaces, with no organic matter, low nutrient status, no seed sources, and poor water retention capacity[20]. A sequence developed by Dugmore and co-workers is illustrated in Figure 1.9 from detailed analysis in south central Iceland. The highland and lowland sequences differ because of natural factors, such as the effect of altitude, original soil depth and nutrient status, and most especially because of the effects of human activity: with heavy grazing in the uplands and tree removal in the lowlands respectively triggering the degradation of the land[21]. The accretion of new material from volcanic eruptions (the dated black lines on the diagrams) and from sand blow is a major feature, alongside degradation.

Sveinn Pálsson, travelling in the east and north east Iceland in 1794, experienced at first hand the drifting sand. He wrote the following account:

> "The farm buildings are in large part buried because of continuous, overwhelming sand drifting, but they have the advantage that the heat inside the buildings is almost unbearable so there is no humidity or stink, because the sand absorbs it all. The roofs are mostly made from lyme grass or stems, covered with sand and earth from which grows beauteous grass. Since the district is so utterly enveloped in sand, haymaking outside the small pasture is simply a matter of cutting the blades of lyme grass which is excellent feed." [22]

A century later this area had become a desert.

The expansion of fishing based in the villages of the south coast had serious consequences for local vegetation. People moving from rural areas to coastal communities generally brought livestock with them. They were grazed all year round without management. Settlers also used whatever brushwood, especially birch, they could find for firewood. This resulted in enormous vegetation loss, for example on the Reykjanes Peninsula and areas around most fishing villages. The settlers also created sheilings in the highlands for summer grazing, destroying the fragile vegetation as a consequence.

Analysis of vegetation history shows that vegetation loss and soil erosion has been greater in the 19th century than in any other century, with the possible exception of the 13th century. The period 1830–1836 and the years after 1881 were particularly ill-fated. A succession of hard years began in 1881 and triggered widespread desertification, mostly in south Iceland and especially in the upper regions of Rangárvellir. The last quarter of the 19th century is undoubtedly the worst period in the nation's vegetation history. Sand storms did not spare anything. While this desertification was primarily the result of violent sub-polar storms and many years of cold caused by pack ice off the north of Iceland, sheep also played a substantial role by grazing relentlessly on a limited area of impoverished and environmentally sensitive land. Lucrative sales of castrated male sheep to Britain for human consumption as mutton partly contributed to the large increase in numbers towards the end of the 19th century. During these cold years, many farmers were incapable of making sufficient hay, so sheep were forced to survive by grazing on the natural vegetation. Serious overgrazing resulted and farmers were unsympathetic to and did not really understand what overgrazing was all about, as livestock grazing was the only means for their survival.

These high levels of destruction, widespread throughout the country, and their debilitating effects of human survival began to suggest the need to change practice from exploitation to conservation. This awakening is described in the following chapter.

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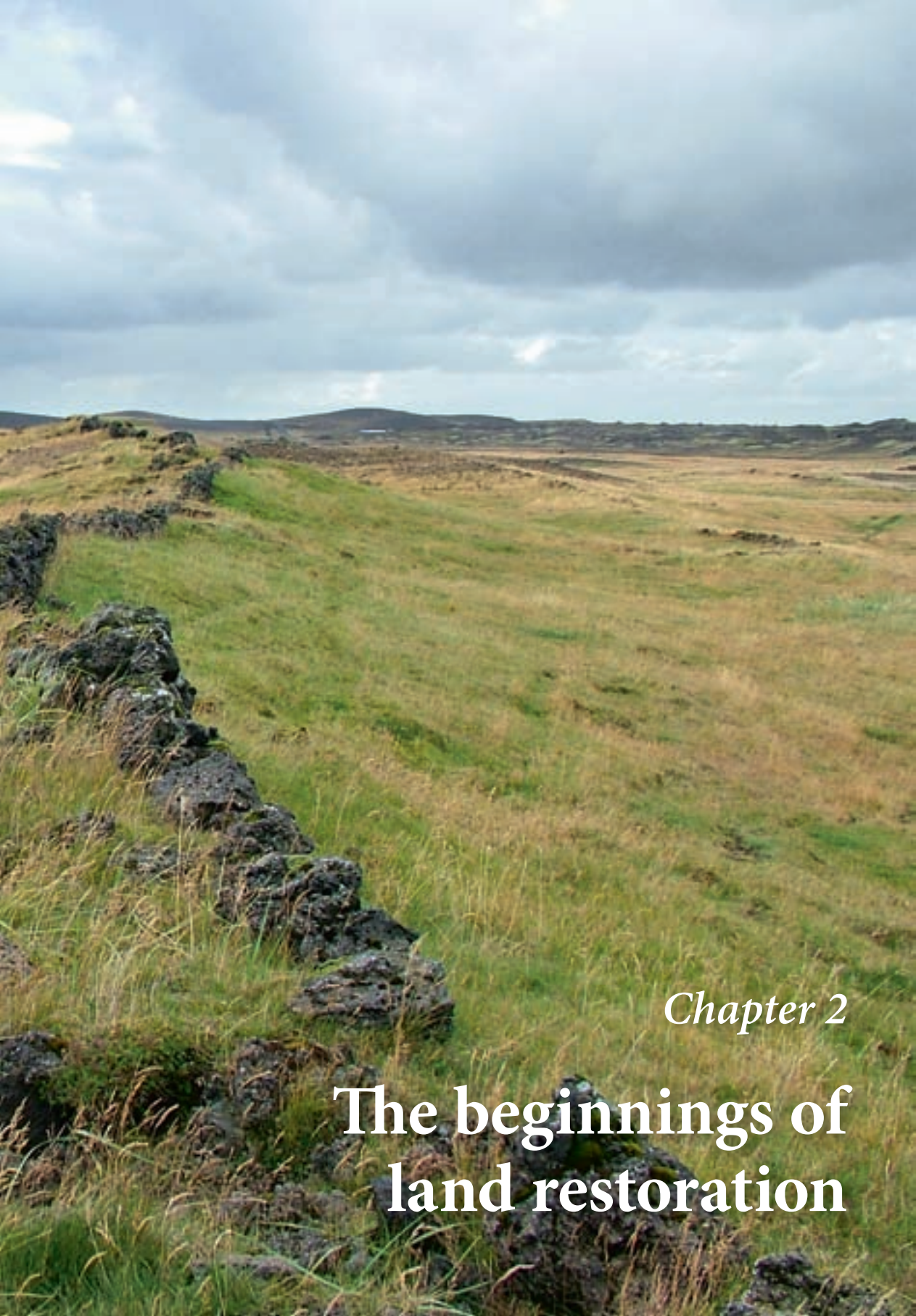


Chapter 2

The beginnings of land restoration

Inexorable natural forces and insenstivity of land use by farmers set the scene for the awakening of consciousness about land degradation and the beginnings of efforts to reclaim land and restore soil. But, as in many aspects of human endeavour, the awakening in Iceland began gradually and owed its origins to a few farsighted and practical individuals. Early ideas, trials and experiments, gathering experience from elsewhere, and developing the legislative framework and the implementation structures, complete the scene-setting for the more detailed review of a century of formal land restoration and soil conservation.

Soil stabilisation efforts 1700–1880

The oldest known evidence of defences against drifting sand are stone walls built in south west Iceland. Some of these walls had been constructed on erosion ridges facing the direction of drifting sand. It is not known with certainty when or who constructed them. There is documentary evidence in the 13th century, but it is more likely that the walls were constructed when the area was being covered with sand at the end of the 17th century.

In 1745, a Royal command was issued to prevent sand from drifting because of the need to dry fish outdoors in Vestmanneyjar (islands off the southern coast). This was to be accomplished by building a stone wall and sowing lyme grass, but it was not successful. It is noteworthy that this first order should be to protect fish drying, rather than safeguard agricultural land or vegetation from drifting sand.

Photo 2.1 *The Rev. Björn Halldórsson, the first recorded pioneer of land protection*
Source: NMI

The Rev. Björn Halldórsson, an expert on farming, was the first to initiate protection of his hayfield in north west Iceland, even though the results of his efforts were not permanent. He probably copied the design of the stone walls from those in his native area in south west Iceland. He also arranged for the government to order his parishioners to help in building a wall along the periphery of the hayfield most threatened by sand drifting. This compulsory work was rather unpopular, the wall was called "Unrighteous", and

Photo 2.2 *The white shell sand of Sauðlauksdalur, north west Iceland where Halldórsson farmed*
MTH

perhaps prophetically did not provide adequate protection. There was a major storm on 16 and 17 February 1763 which caused serious damage and, in consequence, Halldórsson wrote the poem *Sand Everywhere* quoted in the Author's Preface.

Despite his lobbying of the District Governor to take action to reduce sand drifting, Halldórsson spent the equivalent of a quarter of his income removing sand from his hay field. His successors for the next 150 years were in the same position. Indeed, there is still a great deal of sand drift in the area.

Halldórsson's agricultural publication *Atli,* published in 1780, was a textbook on husbandry. In the book he quotes an old, experienced farmer saying to a young man wanting to become a farmer: "September is the time that lyme grass drops its seeds. They may now be gathered. Sow them immediately in sandy land and cover with earth. It sprouts next spring." This is the first reference to sowing lyme grass seeds for land stabilisation.

Similar work was undertaken by the naturalist Þórður Þóroddsson, on behalf of the government, to encourage farmers to practise soil reclamation and sow lyme grass. He presented proposals to the Governor in May 1784 explaining that lyme grass was the only solution to preventing drifting sand in the Rangárvellir, and that the entire sand covered area needed to be sowed simultaneously. However, almost no seed was available, and the matter faded into endless red tape and speculation. Decades passed and nothing happened, despite the fact that, periodically, farms were abandoned.

Pioneers blaze a trail

In the 19th century, Danish authorities were concerned about drifting sand in Iceland and sent seed varieties, such as lyme grass (*Leymus arenarius*) and canary grass (*Phalaris canariensis*), to help in the battle. It is likely that the seeds were collected in Jutland, although they could have been lyme grass seed from Greenland where a related

variety called American dune grass (*Leymus mollis*) grows. The experience in constructing windbreaks and sowing lyme grass increased and created the foundation for revegetation work which is still valid today.

The enormous destruction of the 1882 storm in south central Iceland, described in Chapter 1, led people to rethink and look for ways to reclaim the land. The time of systematic revegetation had not yet arrived, but during the final years of the 19th century, a few dynamic men were the pioneers of land restoration.

The Danish authorities, concerned about the problems of drifting sand, commissioned a report from the poet Grímur Thomsen. His findings for the Governor-General included arguments for providing government money for soil reclamation.

The Suðuramt Agricultural Association in southern Iceland was instrumental in identifying the problems and what might be done to alleviate them. In the 1880s, they hired Sæmundur Eyjólfsson, a farmer's son, an agricultural graduate and a school teacher, to educate farmers about soil conservation during his long summer holidays. Like many Icelanders, Eyjólfsson had a deep knowledge of the Sagas. All of these proved to him that deforestation had led to soil erosion, whereas protection of woodland and planting the seeds of birch provided shelter from destructive winds. He also learnt from others. He visited Denmark in 1892. On his return, he pointed out that Icelanders must learn to work in harmony with nature and he called for legislation to support soil reclamation, as was done in Denmark.

He wrote prolifically in newspapers and magazines on the need to prevent overgrazing, and to preserve woodlands, and to undertake revegetation. Significantly, he realised that working with farmers was the way forward – an approach not adopted comprehensively until the late 20th century. One of Eyjólfsson's key observations was the effectiveness of lyme grass in revegetating sandy areas through its capacity to bind sand. He instigated what proved to be successful trials using lyme grass for stabilising sand in south Iceland. This was undoubtedly his greatest achievement, as lyme grass has proved to be the most effective stabiliser of sand for land reclamation ever since.

From slow beginnings, the work stimulated by Eyjólfsson gradually gained ground and others, such as Eyjólfur Guðmundsson, took up the case when they saw the success of the measures. Eyjólfsson's trials in southern Iceland also led him to the conclusion that much of the problem resulted from poor management through thoughtlessness and greed rather than the effects of nature. This was a very significant breakthrough in thinking if efforts on stabilisation and reclamation were to gain credibility and become effective.

Many techniques were tried. Stone walls

Photo 2.3 *Sæmundur Eyjólfsson an early pioneer* NMI

and banks of turf and hay were used as buffers against wind blown sand. Old hay and turf were spread over the fields as land stabilisers. Bare sand was removed from cultivated fields to allow grass to grow to yield hay. Irrigation by diverting water from rivers to the fields was also tried out to aid the revegetation of the sands. Rivers were also diverted to reduce the risk of erosion. Eyjólfsson and Guðmundsson persuaded the Agricultural Society of Iceland to support sand stabilisation and soil reclamation by allocating grants to farmers.

Lack of interest, even ignorance and prejudice, by farmers and the public remained. People were generally sceptical, thinking there was not much sense in "working against God's will". Many disapproved of spending money on such "pointless efforts". A sceptic, using the pseudonym "Tófi", wrote an article in 1895 telling the story of a worker on social benefits who placed horse manure on the bare sand, and then put lyme grass stems into each pile saying "I receive praise and glory for working hard at soil reclamation, and then receive a substantial grant every year to continue these trials"[1]. Tófi particularly mocked the grants that the Agricultural Society awarded to Eyjólfsson's group and the latter responded as follows:

> "It is patently clear that there are extreme difficulties involved in preventing destruction from drifting sand, but what is worse is that it is not only the forces of nature that are opposed to such endeavours. Blindness and weakness are so pervasive that many think it a stupid pipe dream to consider any kind of defence against the destruction of land … and is the path many have taken who believe it their duty to destroy any attempt to heal the scourge".[2]

Eyjólfsson played a key role in developing a statute enacted by the Icelandic Parliament in 1894 granting county councils authority to declare an area as protected: *Statute to preserve woodlands and lyme grass*. A year later a new law was passed *Statute to impede drifting sand, and to reclaim soil*, but it was little used and came to no avail.

Eyjólfsson was a lone voice, far ahead of his time. Although he was the true pioneer of land reclamation and forest preservation in Iceland, so few of his contemporaries shared his passion and his efforts produced fewer results than might be expected.

Others wrote about desertification and land use, in particular the naturalist Þorvaldur Thoroddsen whose writings heightened the interest of thinking people. The number of those who understood the effects of how the land was managed and its impact on nature, and how natural forces by themselves could endanger vegetation and ecosystems, grew yearly. Concerns about soil erosion were well known to Icelanders who had emigrated to the New World, with a pastor in Winnipeg, Canada lecturing in 1888 to the title "Iceland is blowing away."

The years of the pioneers were soon over. Despite their good intentions, these years proved disappointing. Farms were still being devastated, while many others around the country were in constant danger from wind erosion and drifting sand. Advocates of conservation had their hopes tied to irrigation, but the trial sites were severely damaged due to lack of maintenance and overgrazing. Yet there was still hope as the new century brought with it changing times.

Stirring the national conscience

Iceland's ecosystems changed enormously from The Settlement to the end of the 19th century. Habitation had disrupted nature's delicate balance. The decline was considerably greater than most Icelanders realised,

and not only affected traditional agriculture, but other areas of national life. Something had to give. But, the Icelandic nation refused to confront this reality until the turn of the 20th century. It was then that people finally began to understand the connection between poor stewardship of the land and land degradation. An awakening on this issue coincided with a reawakening of the nation stimulated by poets and then by politicians. The 'Black Sandstorm' of 1882 was a milestone event. There were now enough people who wanted something done, following the efforts of pioneers like Sæmundur Eyjólfsson.

Hannes Hafstein was both a poet and politician. In July 1895, he gave a speech at the dedication of the bridge over the Þjórsá river in south central Iceland during which he referred briefly to desertification and destruction caused by sand; perhaps the first time ever by an Icelandic politician. In his speech, Hafstein discussed the country's future, and proved to be prophetic in the closing lines:

Photo 2.4 *Hannes Hafstein: poet and politician, and founder of legislation on soil conservation and land reclamation* NMI

> "Perhaps, it will not be as long to wait, as some believe, before Iceland partakes in the progress and implementation of modern trends, just as other countries. Perhaps, it will not be very long to wait before we, as other nations, think beyond just getting across rivers in one piece, and instead think of harnessing our powerful and untamed rivers and waterfalls to work for us and to heat and to illuminate. Perhaps the time will come when we will have succeeded in impeding soil erosion and land degradation by sand – perhaps the valley becomes covered in woodlands."[3]

Hannes Hafstein was genuinely interested in land reclamation. On New Year's Day 1901, his toast to Iceland was a new poem entitled *Poem of Iceland*.

> That time will come, when earth
> wounds heal,
> countrysides mature, fields envelop
> emptiness,
> sons receive bread from fertile Mother
> Earth,
> culture grows in the bosom of new
> forests.
>
> I see in my mind our fleets all self-
> propelled,
> power from the beauty of your
> waterfalls compelled,
> engines employed, and workers
> who excelled,
> a nation in charge with democracy
> upheld.
>
> Many the tasks, but your people are
> united,
> the edict is this: all citizens invited
> whatever role, or task that has been
> cited:
> to cherish, build and trust your
> country unrequited.[4]

Poetry like this had an influence. The work of Sæmundur Eyjólfsson and the farmers in south Iceland had an influence. The campaign for independence and increased political rights that came with Hannes Hafstein, the first Icelandic minister, in 1904 had an influence. According to an old Icelandic proverb, *The droplet hollows out the stone*. An Agricultural Congress convened for the first time in 1899 led to advances in agricultural education, and the founding of interest groups by farmers. Moreover, the public became mobilised, and at the start of the new century, youth associations were formed throughout the country with improvement of the land and people as their main objectives. Each association had land where members grew flowers, perennial plants and trees. Although these youth associations had little to do with soil reclamation, they all had the same motto *Cultivating people and land – all for Iceland.*

All of this description illustrates that land reclamation, soil conservation, afforestation and vegetation conservation had greater support from the public at the start of the 20th century than previously. Land reclamation was now on the agenda.

Endnotes

[1] Tófi. 1895. *Ísafold* 24. In Icelandic.
[2] Sæmundur Eyjólfsson. 1895. *Hepting sandfoks*, 183. In Icelandic.
[3] Hannes Hafstein. 1895. *Ísafold* 31. 7. In Icelandic.
[4] Quoted in Guðjón Friðriksson. 1901. *Ég elska þig stormur*, 301. In Icelandic translated by David Gislason.

Reclamation Action

Chapter 3

A century of reclamation activity

The devastating effects of natural and human activity described earlier have been subject to an intensive effort since the establishment of the formal land reclamation arrangements in 1907. This chapter sets out what has been achieved for the country as a whole, and highlights particular projects as exemplars of different problems and solutions. Particular attention is given to the range of work undertaken at Gunnarsholt, the farm owned by the Soil Conservation Service since 1926.

A century of reclamation activity

Activity over the century can be ascribed to four periods. Each of these is described briefly and maps of the activity around Iceland presented.

The first period 1907–1946

Action during this period was constrained by the lack of people and resources to undertake the work. Inevitably, the greatest effort

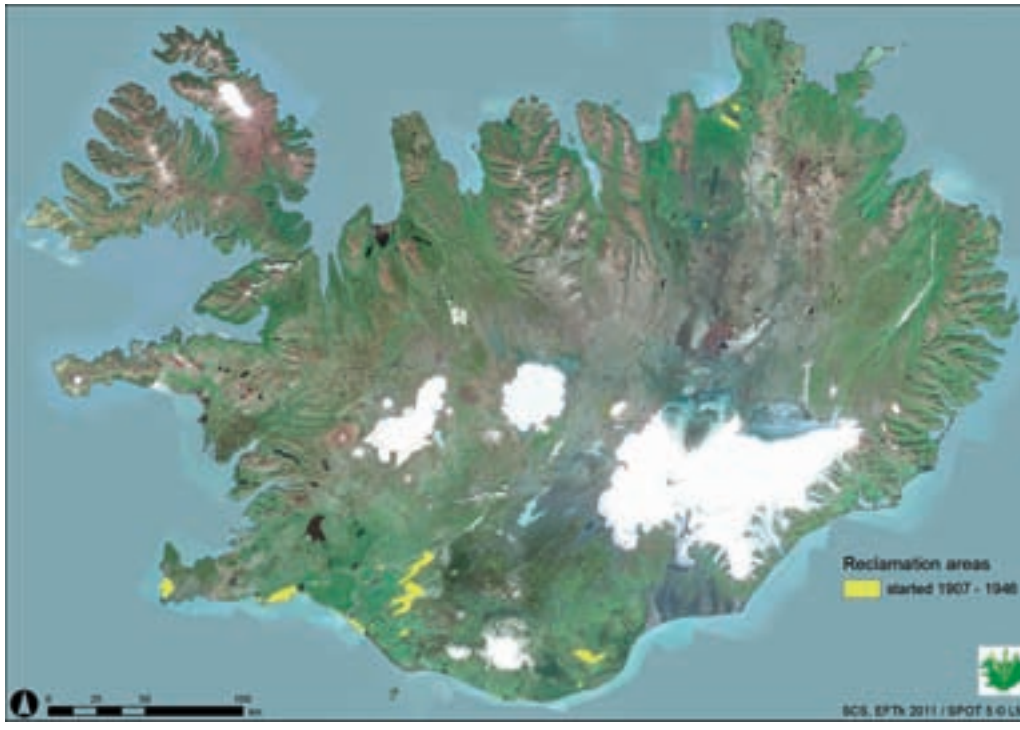


Figure 3.1 *Reclamation activities around Iceland 1907–1946*
Source: Soil Conservation Service

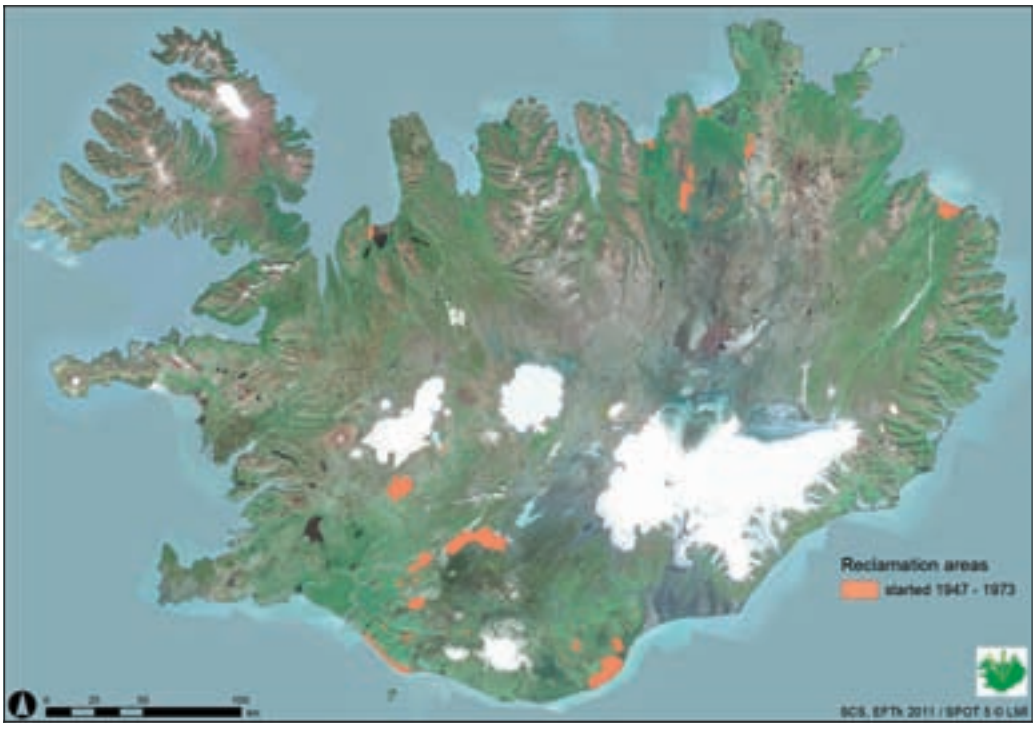


Figure 3.2 *Reclamation activities around Iceland 1947–1973*
Source: Soil Conservation Service

was in south and south west Iceland where the problems of drifting sand were most evident as farms were regularly being overwhelmed (Figure 3.1). It was also the area closest to the main urban population centre of Reykjavík where key politicians and reclamation workers were based. It is no coincidence that the work extended inland from Gunnarsholt, the farm purchased as the base for reclamation in 1926, as this was where the key sand reclamation workers were based throughout the summer and there was early recognition of the need to stabilise drifting sand up-wind. Three coastal areas – on the Reykjanes peninsula in the south west corner, around Þorlákshöfn and between the mouths of the Rangá and Þjórsá rivers – also received attention as drifting sand from coastal dunes was threatening the fishing villages and other settlements in these areas. In addition, there was some modest effort in the north east coastal areas of Kelduhverfi and Öxarfjörður where the major river Jökulsá á Fjöllum reaches the sea and further inland at Hólssandur.

The second period 1947–1973

During the second period, with greater resources of finance and manpower, the reclamation effort was spread more widely (Figure 3.2), but still with a concentration in south central Iceland. Primary activity was on the Þjórsá river, in the Sandvatn area south of the Langjökull ice cap, and along the coast between the Rangá and Markarfljót river mouths. Significantly, activity began further east where large rivers from the eastern side of the Mýrdalsjökull ice cap and from the Skaftá system on the west side of the Vatnajökull ice cap deposited sand on the sandur plains. In the north, the earlier

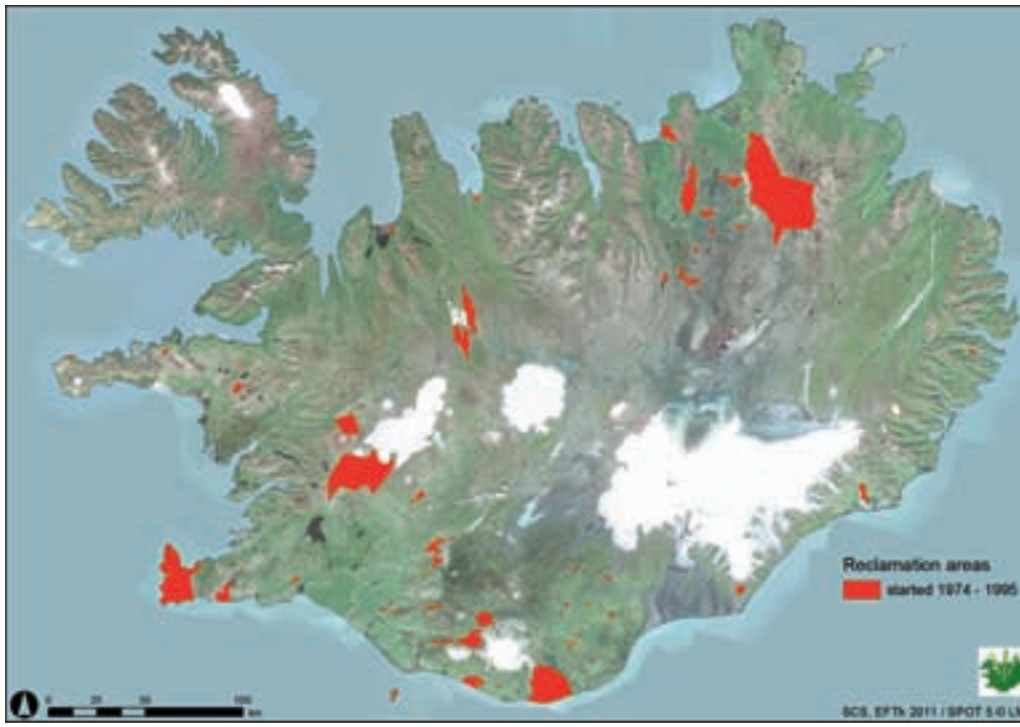


Figure 3.3 *Reclamation activities around Iceland 1974–1995*
Source: Soil Conservation Service

work was extended inland and also included sand drift areas around Lake Mývatn and the mouth of the Lagarfljót in the north east. Knowledge of the situation around the country enabled effort to be concentrated on the most problematic areas.

The third period 1974–1995

This was the most intensive period of activity stimulated primarily by a substantial addition to the resources available. The most notable changes (Figure 3.3) were the extension of reclamation activity to many inland locations, either near to the outlets of rivers from ice caps or along the courses of major rivers, as both of these were prime sources of sand which covered the sparse vegetation of the highland commons. The distribution of activities also reflects the relative ease of access through greater use of off-road vehicles and, most particularly, the use of aircraft for seed and fertiliser application.

The fourth period 1996-present day

The most notable features of reclamation activity during this final period (Figure 3.4) were the wider spread of activity and the concentration in the valleys of major rivers flowing north from the Vatnajökull ice cap. The latter are major sources of drifting sand affecting the quality of the highland commons grazing areas. Also, the effort was much more selective and targeted as a result of the detailed information acquired from mapping of erosion severity and its association with different forms of the land surface. The report on which this activity was based revolutionised the planning and execution of reclamation activity throughout the period[1].

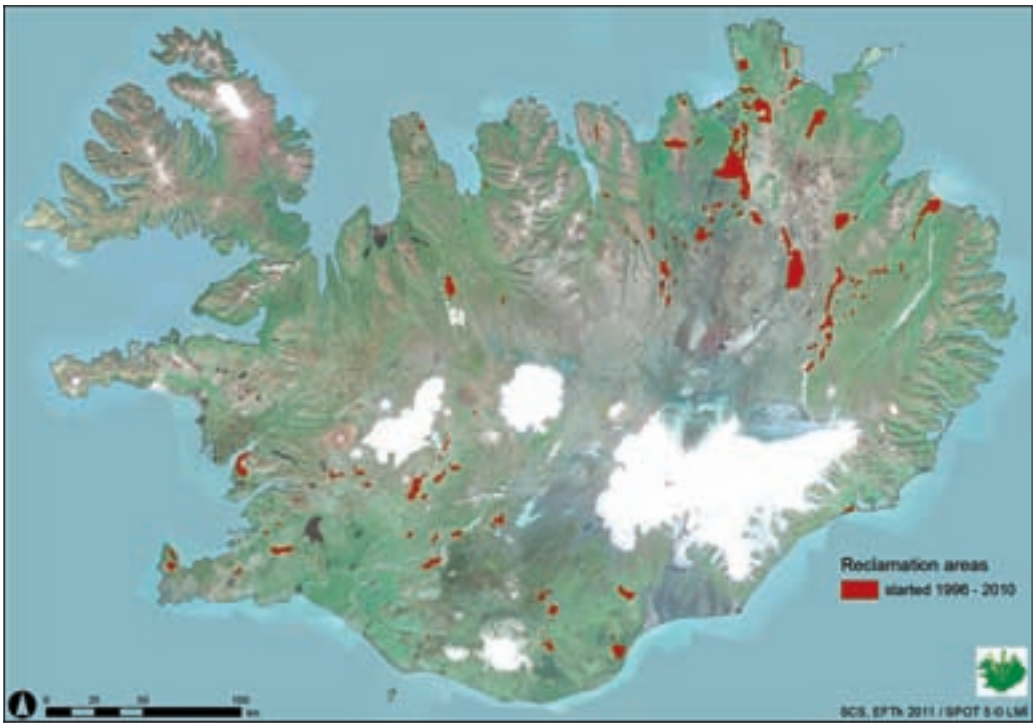


Figure 3.4 *Reclamation activities around Iceland 1996–2010*
Source: Soil Conservation Service

Photographic examples of reclamation effort

The following selection of photographs provides the reader with some idea of the type and extent of erosion and degradation, the improvements made and the successful outcomes over the century.

Degraded land

Photo 3.1
Birch roots exposed by wind erosion AA

Photo 3.2
Four metres depth of soil erosion leaving only a remnant of the orginal surface
SR

Photo 3.3
A devastated land due to overuse and wind erosion AA

Photo 3.4
A dramatic example of wind erosion and airborne dust SR

Photo 3.5 *The remnant gravel desert after the soil has been eroded* SCSI

Photo 3.6 *Vehicle tracks breaking the vegetaiton cover and adding to the existing erosion* JE

Improving land

Photo 3.7
Lyme grass capturing sand in dunes and on sand plains as an early step in the stabilisation process RC

Photo 3.8
Recently seeded and fertilised area surrounded by bare sand RC

Photo 3.9
Pumice from the 1973 eruption on Heimaey stabilised with red fescue RC

Stabilised and vegetated land

Photo 3.10
Stabilised coastal area at Vík in Mýrdal
MWL

Photo 3.11
Stabilised dunes on the south coast following seeding with lyme grass GM

Photo 3.12
Drained wetland intensively farmed
OS

Stabilised and vegetated land

Photo 3.13
Combination of different plants in land reclamation
JRB

Photo 3.14
Trees and shrubs providing the highest level of resilience to erosion SCSI

Examples of reclamation activity around the country

The Gunnarsholt story

By far the most significant area of land owned by the Soil Conservation Service is at Gunnarsholt. Farms which had been abandoned by their owner in the Rangárvellir District of south central Iceland were purchased in 1926. Gunnarsholt and two adjacent farms were in an area covered with sand and with little or no cultivable land remaining. From the 1930s, it was, *de facto,* the centre of operations. It formally became the headquarters of the Sand Reclamation Service in 1947 where the Director and farm manager worked. Sixty four years on Gunnarsholt is still the headquarters.

More significantly, it is the centre of reclamation science and technological innovation; it is the place of experimentation in the laboratory and in the fields; it is the source of seeds for reclamation activity around Iceland and for export to other countries; it is the demonstration hub for all who wish to see the art of the possible, and to view the practice of what many thought was the impossible. It is, therefore, the demonstration centre for all aspects of land reclamation and soil conservation. It is a place to be visited by farmers from around Iceland to help them

Photo 3.15 *Gunnarsholt central building and land in 1944* HO

Photo 3.16 *Gunnarsholt from the same point as Photo 3.15 in 2011* JRB

change their minds and their practices and to give them ideas and encouragement. It is the place visited by Icelandic Ministers and politicians to judge the value of the public investment. And, it is the place visited by overseas guests to be given tangible evidence of how to tackle and succeed in the battle against land degradation and soil erosion.

The story of the evolving role of Gunnarsholt is, in microcosm, the story of land reclamation and soil conservation in Iceland.

A challenging location

Gunnarsholt was an ancient farmstead first mentioned in the *Book of Settlements* where it is stated that Gunnar Baugsson settled the farm, presumably just before 900 A.D. The oldest contemporary source is the church register of Bishop Páll Jónsson from around 1200 indicating the existence of a church. Slightly more recent references are found in two sagas *The Tale of Oddaverjar* and *The Saga of Guðmundur the Expensive*. Gunnarsholt was initially located about 300-400 metres north of the current site. The land, farm buildings and church were abandoned in 1836 due to sand drifting, but the farm was resettled three years later and new farm buildings erected. They remained there until 1854 when the farm was moved once again because of drifting sand and rebuilt on a hill. After the sandstorm of 1882, Gunnarsholt

was almost abandoned, but the farmer managed to survive. In 1925, the farmer was not so fortunate as wind erosion forced him to abandon the farm. The farmland would have been lost forever if something radical was not done.

Many farms in the Rangárvellir area had suffered periodic overwhelming by drifting sand and were again suffering in the 1920s. Records show that at least 75 farms in the area were buried under the sand. On other farms, houses were being moved again and again to find shelter from the drifting sand and allow the livestock to survive on the last strips of vegetation. So it was most appropriate for the government to purchase land in a devastated area to experiment and demonstrate new techniques.

Early action

The primary activity was to stop the scourge of drifting sand. Hay fields and some of the worst sand drift areas were fenced off. In 1928, construction began on a new farm house and outbuildings comprising residential accommodation, tool shed, a barn with a capacity of 800 horse-loads of hay, two silage pits, a cowshed for 20 animals, and other facilities. The cowshed had a seed loft where lyme grass and other types of seed were stored. An experimental farm was planned. This construction work was a cooperative effort with the South Iceland Agricultural Society. As a result, drifting sand and land degradation was halted, the sand and gravel plains revegetated and pastureland recreated. For example, approximately two thousand horse loads of hay were produced annually from the fields and used by farmers in the district. However, the experiment to breed musk oxen of Greenlandic-Norwegian extraction failed and the animals died.

A decade later, birch seed collected from woodlands in south east Iceland was sown. This effort proved quite successful. A shrub form of birch grew in abundance and, through self seeding, it gradually grew into what is now called *Gunnlaugsskógur (Gunnlaugs Woodland)* – a delightful place for visitors to see the transformation.

Gunnarsholt becomes a large scale operation

The next stage was to transform Gunnarsholt into a profitable farm land. In the later 1940s cultivation of bare sand areas was substantially expanded to demonstrate that farming and land revegetation could be compatible, if managed properly. Cattle breeding was begun in 1948, at first for milk production, and later for beef. Beef cattle from various parts of Iceland were purchased: a Scottish Galloway/Icelandic cross, as importing livestock was prohibited because of the risk of livestock diseases as the native herds had no immunity. A hydro power plant in 1951, which operated until the late 1990s, provided all of the energy needed at Gunnarsholt in the first few years, and provided a significant proportion throughout its life.

Sheep farming was introduced in the early 1950s. Beef cattle and sheep grazed on the newly revegetated land as soon as the fields turned green. For a time, Gunnarsholt was the largest farm in the country with 1,578 ewes and 600 beef cattle on the former sand desert. It is no wonder that the entire operation was viewed as a model for others. Cattle could be outside all year, but shelter and feed were provided in the winter. They were slaughtered at 18 months old when their carcass weight was generally 200 kg. All stock was carefully monitored and the information recorded. The work demonstrated that it was possible to raise animals using considerably less manual labour than was usual. A large stock of horses was purchased for breeding and to make use of the grass.

At a time when machinery owned by farmers was far too small to undertake revegetation work outside cultivated land, aircraft were used from 1958 for top dress-

Photo 3.17 *Harvesting seed at Gunnarsholt for future reclamation* ÞK

ing hayfields at Gunnarsholt. In 1973 two airstrips were created on the former sand plains. Planting of shelterbelts was another innovation. Apart from effectively breaking the wind, they proved to be good habitats for birds and their prey, and improved the look of the area considerably. As they grew the hedges provided excellent shelter to allow seed production in adjacent fields. A major grain farming experiment began at Gunnarsholt in 1961. It covered 200 hectares by 1963, but a subsequent cold spell put an end to the project. The biggest single innovation was the Fodder and Grass Seed Production Centre established in 1963–1964 to produce grass pellets and seed. It operated successfully until 1986 when it closed due to lack of markets arising from declining livestock numbers. It never produced seed as this was done at the nearby Sámsstaðir experimental farm of the Agricultural Research Institute. However, a seed processing operation was established in the old factory in 1988.

When production quotas for sheep farming were introduced, the Minister of Agriculture issued a directive to end sheep farming at Gunnarsholt. This was very unfortunate as there was so much more that could have been learned. Cattle and horse breeding were ceased in the late 1980s in order not to compete with local farmers. The success of combining livestock farming and land reclamation had already been proven and, as with any experimental farm, new techniques needed to be trialled and demonstrated.

A measure of the success of the farming operation was that the last farmer in the early 1920s could only grow enough hay for a quarter of a horse load, whereas in the 1960s 18-20,000 horse loads of hay were produced each year (a horse load is 100 kg). Another measure is that from a bare sand plain between Gunnarsholt and Hella in 1954, the whole area was vegetated and produced grass, hay and silage within 15 years.

A demonstration farm for visitors

Gunnarsholt was a very popular place to visit. Leaders in the agricultural sector proudly showed their foreign guests around

the area, explaining the various projects. This is clearly illustrated by Halldór Pálsson, Director of Agricultural Affairs:

> "A proverb says "Keen is the visitor's eye". This I often noticed when taking foreign agricultural scientists to Gunnarsholt. In the summer of 1960, Dr. C. P. McMeekan from New Zealand, one of the world's foremost figures in international agricultural policy, was a guest of the Agricultural Society of Iceland. I, along with a few colleagues in the agricultural sector, took him to Gunnarsholt. I'll never forget how impressed he was when he saw a large herd grazing on green grass growing amid windblown lava and black sand. Many ewes had two offspring, sheep and cattle looked relaxed standing about here and there on the pastures, while at home hayfields are mowed, and half-grown green fodder intended for fall grazing and silage. McMeekan felt this to be an impressive achievement and one of the most significant examples of the importance of plant growth and livestock grazing synergy that he had witnessed."[2]

The demonstration effect of Gunnarsholt steadily grew. Visits for Icelanders were no less impressive. The young and the old, the sceptics, as well as the staunch enthusiasts of vegetation conservation and all kinds of cultivation, had their interest in the issue bolstered by seeing the results.

The success of Gunnarsholt resulted in it becoming such an integral part of the Sand Reclamation Service so that no-one thought it should be otherwise.

The work expands further

In the early 1980s, the position of Gunnarsholt as the headquarters of the Soil Conservation Service was consolidated with a new building to accommodate the growing numbers of staff based there, allow visitors to stay and to act as a show case for the work on the land and in the wider area. The building was extended in 1991, with a pyramid-shaped structure called Little Hekla (as it mimics the shape of the nearby volcano of that name), to accommodate the library and archives, and to provide exhibition space to benefit visitors. Houses for staff to lease were also provided to meet the housing shortage in the area and to ensure that there were always staff on site.

The Icelandic horse breeding programme leased a building at Gunnarsholt in 1981 for the selection and breaking of young stallions. A new building was constructed in 1992 for the breeding programme. This added to the variety of research and development work at Gunnarsholt. It ceased operation in 2000 when artificial insemination became more popular amongst horse breeders. It has been refitted to house the new visitor and interpretation centre for the Soil Conservation Service opened in April 2011.

Facilities for research had been limited, but when the Fodder and Seed factory ceased operation in 1986, the space was refitted as a conference area, offices for specialist staff, joint office space for researchers from the Soil Conservation Service, the Agricultural Research Institute and the Iceland Forest Service, workshops and a seed processing unit. Further expansion of activities and staff lead to more renovation work on the old factory in 2001 to accommodate the growing numbers of technical experts, as well as the seed processing machinery and seed storage. In 2003, all the buildings in the Gunnarsholt complex were linked into the district geothermal heating system funded through a special state grant. In 2007, houses previously used as an alcoholic sanatorium, were acquired; some were demolished, and those rebuilt now house UN University Land Restoration Training course students and research students (Figure 3.5).

Figure 3.5 *The arrangement of the central buildings complex at Gunnarsholt*
Source: Soil Conservation Service

Land at Gunnarsholt has been devoted to research plots since 1947, with a few hundred hectares devoted to trials and experiments: for instance, 50 plots of a hectare each were established to observe vegetation succession after seeding. An experiment comparing the nutrient value of different organic and waste material for reclamation was undertaken, as well as research on the flow of water in gravelly sands and the survival of seedlings under different conditions. Scientists from cooperating agencies in Iceland and from overseas are now using extensive areas for short term and long term research plots. The results are reported in Chapter 6.

Gunnarsholt pastureland has also changed over the years. In early 1980s the total acreage of cropland was around 1600 hectares, harvested for grass pellets, seed and hay full stop In autumn 1989, work began on the Poplar Project, a cooperative effort between the Soil Conservation Service and the Agricultural Research Institute, Forest Service, Queen´s University, Kingston, Ontario, Canada and later the Weather Bureau to determine the environmental impact of the local woodlands: the interplay of weather, soil, sunlight and trees. The project was initiated by Alexander Robertson, formerly of the Canadian Forest Service and Harry McCaughey from Queen's University. Some 145,000 poplars from one clone were planted at 1m intervals. More than 40 scientific papers, 4 Ph. D. dissertations and a number of Masters theses have resulted from this work.

The Agricultural Bank of Iceland and Toyota in Iceland sponsored exhibition gardens at Gunnarsholt where all vegetation used in land reclamation was grown. Over 100,000 trees have been planted in various areas of the farm to aid the restoration of the land. The windbreaks of willows and poplars grow well, are very effective and now total 85 km in length.

The use of land on the Gunmarsholt estate

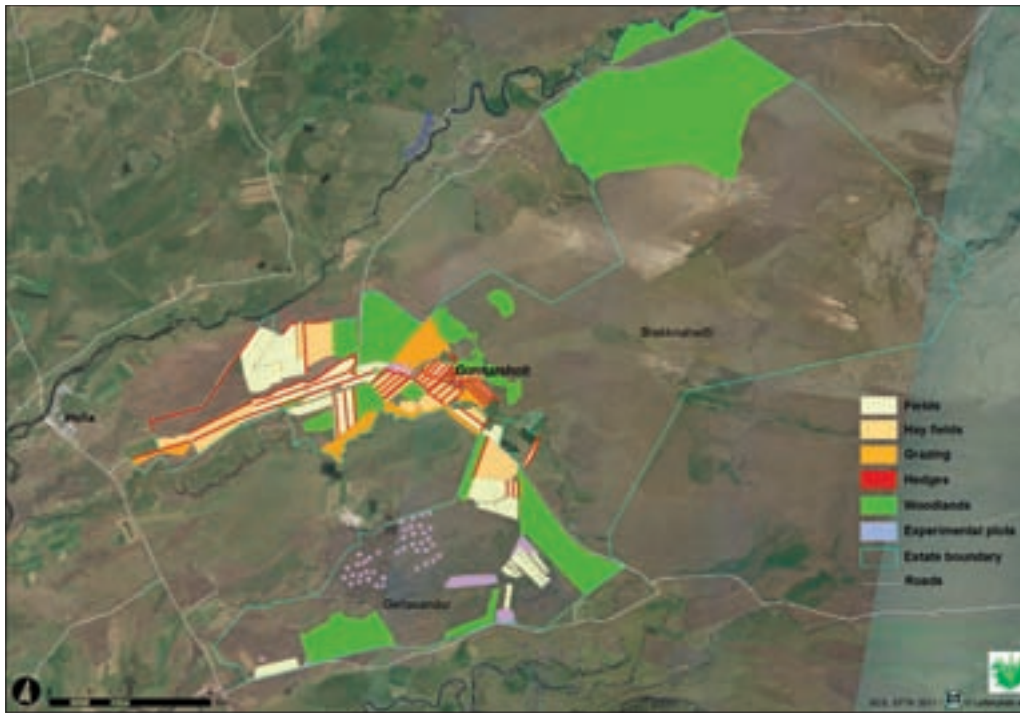


Figure 3.6 *The allocation of uses on the Gunnarsholt estate*
Source: Soil Conservation Service

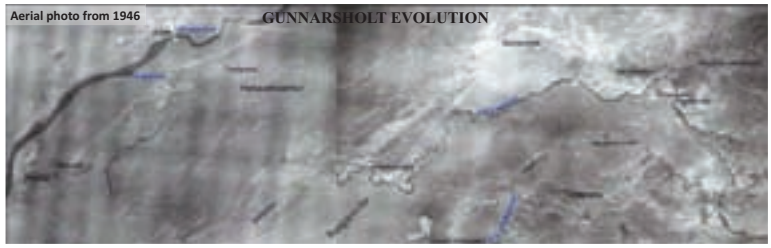


Photo 3.18
Gunnarsholt in 1946

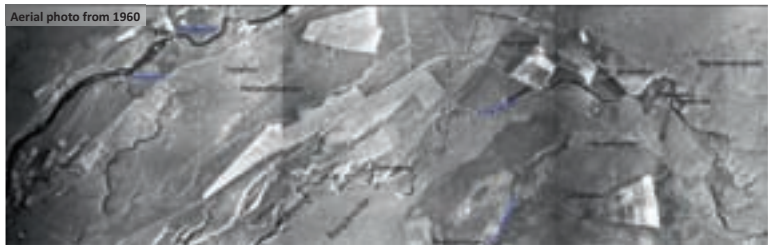


Photo 3.19
Gunnarsholt in 1960

Photo 3.20
Gunnarsholt 2006–8

Photo 3.21 *Trial plots at Gunnarsholt in 1958* BS

has changed over time. The current land uses are shown in Figure 3.6, notable points being the extent of the woodlands and hedges, and the continuation of the experimental plots. Much of the land is leased out to farmers for hay production.

The central buildings (Figure 3.5) have a wide range of uses reflecting the evolving needs of the work based there. Buildings have been converted to new uses when their original purpose has ceased, such as the seed station conversion to specialist staff offices, laboratories, a conference area and briefing rooms.

The best evidence of the success at Gunnarsholt can be seen from the sequence of photographs opposite. The amount of bare ground has reduced substantially and most of the land is now either in productive use or the vegetation succession is developing towards a stable position.

The total area of Gunnarsholt and adjacent farms is over 12,000 hectares.

Stopping sand drifting: Landsveit and Rangárvellir south central Iceland

The area around Gunnarsholt and inland along the courses of the Rangá and Þjórsá rivers received a great deal of sand drift stabilisation work, especially during the earliest phase of activity given its close proximity to Gunnarsholt (Figure 3.7). Later periods of activity were up-wind in recognition of the need to halt sand drift from source areas close to the glaciers and also around the banks of major glacial rivers, such as the Þjórsá. The most recent reclamation effort coincides with the western limits of the major Hekluskógar (Hekla) forest project described later in this chapter. The work illustrates the need to monitor the effectiveness of earlier reclamation activity and return to repair damage and stabilise unstable areas.

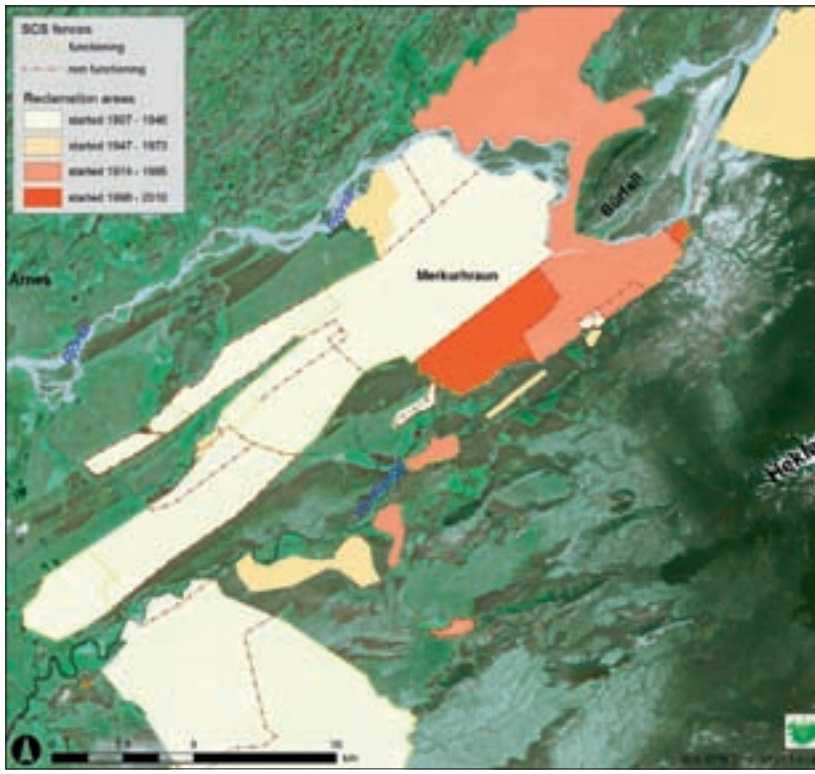


Figure 3.7 *Reclamation activity in the Landsveit and Rangárvellir areas, south central Iceland*
Source: Soil Conservation Service

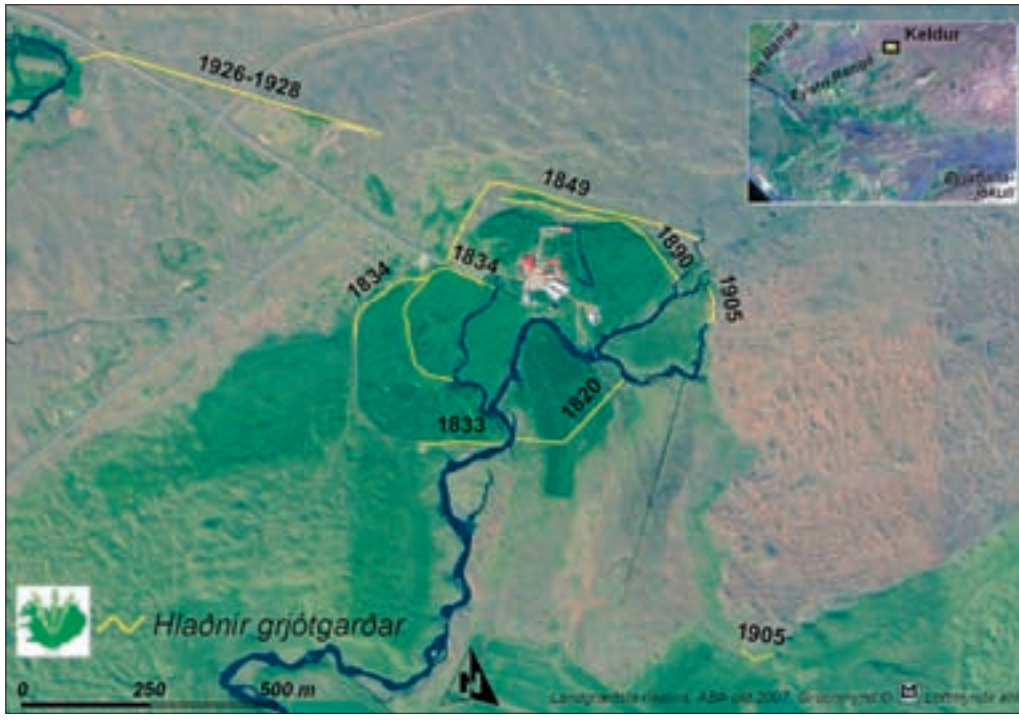


Photo 3.22 *Stone walls protecting farmland at Keldur from drifting sand* SCSI

Photo 3.23 *Almost a century of reclamation at Reykir* SCSI

Protecting an important harbour and town: Þorlákshöfn, south west Iceland

The south coast of Iceland is the recipient of large quantities of a sand and finer material from a number of glacier rivers: Ölfusá, Þjórsá and Markarfljót, in particular. At the mouth of the Ölfusá, the accumulation has been formed into mobile coastal dunes which have periodically threatened the town and harbour of Þorlákshöfn. This is an important harbour as a fishing port and the ferry port for Heimaey in Vestmannaeyjar. It was replaced recently by a new harbour, but is still often used when excessive sand accumulation in the new harbour from the Markarfljót river causes it to close. The extent of the unstable sand and the need for continued applications of fertiliser has meant that a combination of ground and aerial seeding and fertiliser application has been the most effective (Figure 3.8). This continued until a few years ago. Ground based application has been used nearer the settlement.

Stabilising a highland common grazing: Biskupstungur common

Reclamation activity on the Biskupstungur common has been ongoing for the last quarter of the century (Figure 3.9). Sand is frequently deposited by rivers emanating from the Langjökull ice cap to the north. The area to the south of Sandvatn was one of the first sites for experimental irrigation to keep the sand under water and therefore reduce the potential for sand blow.

During the 1970s and 1980s, land reclamation was undertaken along the Sandá river. Local farmer Arnór Karlsson recounts:

> "This work probably began with a small incident that I recall happened in early summer 1972 at a rocky area southeast of Sandvatnshlíð. There were a few council members and others from Biskupstungur who were interested in revegetation, along with the Director of the Soil Conservation Service at the time, Páll Sveinsson. Páll scraped the sand with his feet to expose soil and

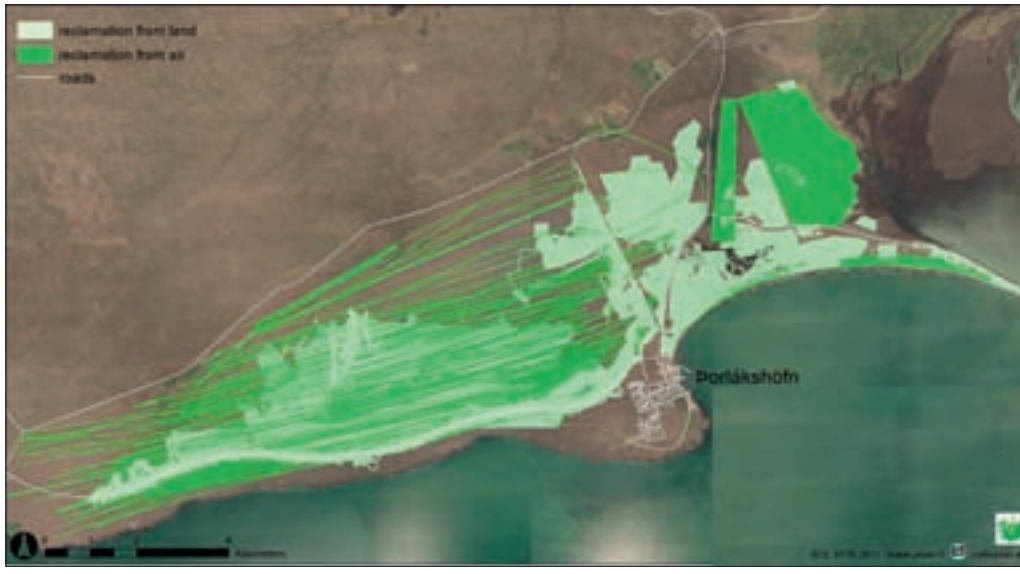


Figure 3.8 *Reclamation around Þorlákshöfn using aircraft and tractors*
Source: Soil Conservation Service

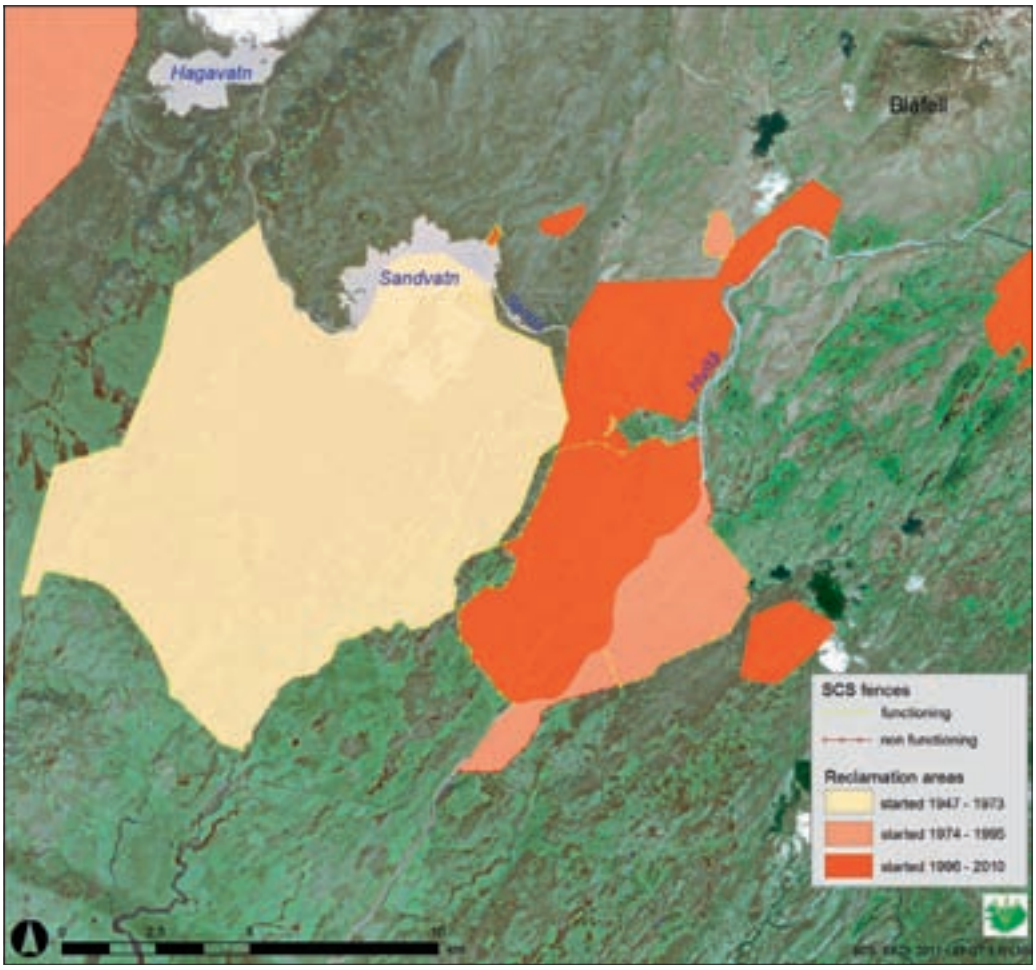


Figure 3.9 *Biskupstungur common reclamation activity in south central Iceland*
Source: Soil Conservation Service

said 'This is earth. This we will vegetate.' These words were said with such passion that everyone there was convinced that this work must be carried out."

"An agreement was made to spread 100 tons of fertiliser and a suitable amount of seed every year over this barren land. The Soil Conservation Service took care of distribution costs and paid for all the seed and half of the fertiliser. Biskupstungnahreppur district (the local municipality) paid for one-fourth of the fertiliser and sheep owners the other one-fourth. Each farmer paid according to how many sheep he grazed on the common. This cooperation is still continuing in many parts of the common, and now there are hundreds of hectares of grassland that before were just scree and rocks."[3]

Stabilising blowing sand: Öxarfjörður and Hólssandur, north Iceland

Reclamation activity in this area of north Iceland has been ongoing throughout the

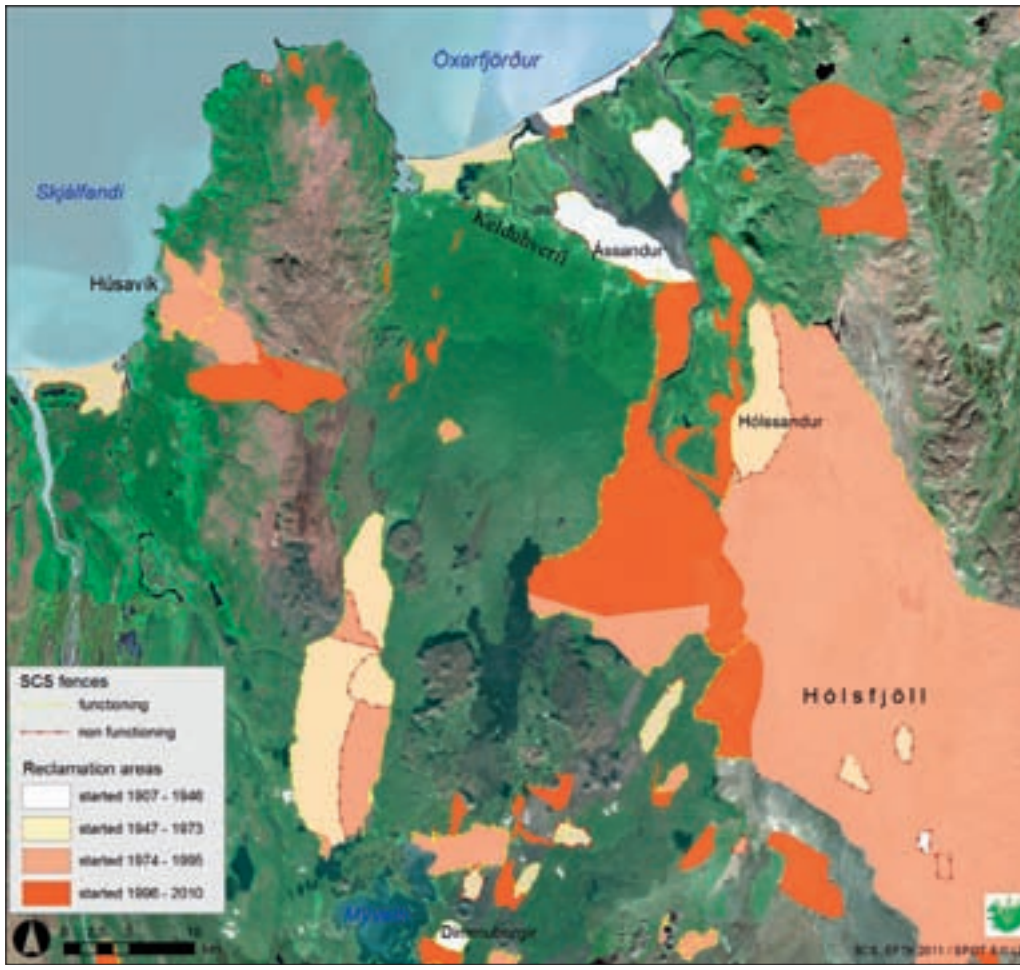


Figure 3.10 *Reclamation activity around Öxarfjörður and on Hólssandur*
Source: Soil Conservation Service

century as a result of large areas of bare sand at the coast in Öxarfjörður at the mouth of the major glacial river Jökulsá á Fjöllum, further west in Skjálfandaflói bay and continual sand blowing onto the lower ground from the south. The earliest work focussed on sowing lyme grass. In the middle of the last century, with recognition of the need to reduce grazing, large areas were fenced (Figure 3.10).

Hólssandur, a sand area in Norður-Þingeyjarsýsla in north east Iceland, was one of many eroded areas that should have been protected and revegetated 20–30 years earlier, but were not because of limited finance. The source area of the sand was Hólsfjöll, an expansive mountainous area with little or no vegetation, which was generally regarded as having greater degradation than any other part of the country. Hólssandur is over 300 metres above sea level, and the Sand Reclamation Service had never before attempted to revegetate at such an altitude. At first, about 6,000 ha were enclosed, and later expanded. Lyme grass and red fescue seeds were sown with good results. These first projects were an important step in guiding future efforts to restore the highland commons.

Figure 3.11 *Dimmuborgir showing encroachment of sand into the site from the south and the fence to keep out grazing animals*
Source: Soil Conservation Service

Safeguarding a natural and cultural heritage site: Dimmuborgir, north Iceland

Part of the sand drift from the sand deserts north of the Vatnajökull ice cap has been threatening to overwhelm the notable natural heritage site at Dimmuborgir on the east side of Lake Mývatn in north Iceland. The site is a series of collapsed lava tunnels and caves creating grotesque forms, which with typical Norse imagination has made this one of the important cultural sites of the country. The sand waves, obvious on the satellite image in Figure 3.11, have been the focus of stabilisation efforts for a long time.

The whole area was taken into the ownership of the Sand Reclamation Service and fenced in 1942. Despite this, it was not until the 1990s that significant progress was made. In the final months of 1993, Mývatn farmers collected 140 spoiled bales of hay and used

them to blanket sand dunes that had been sown with lyme grass seed. The Association of Savings Banks generously subsidised the project for three years. Later in the summer, work continued on many fronts, including helicopters transporting bales of hay, birch planted, fertiliser spread, and walking paths lined with gravel. Adjacent land was declared protected after agreements were made with the owners. From 1992 to 1997, the Soil Conservation Service, along with volunteers, sowed lyme grass and spread fertiliser. Good progress has been achieved, but the battle is not yet won and further effort to control sand drifting from further south will be needed to safeguard the site and areas to the north. Almost 300,000 people visit the area every year. Attendance is expected to double in few years time, which will create a greater threat to this extremely fragile ecosystem than the encroachment of the sand dunes.

Protecting the main road: Mýrdalssandur, south central Iceland

A section of the Icelandic ring road, Route 1, across the Mýrdalssandur in south central Iceland was for many years closed to traffic for 15-20 days each year due to drifting sand. The sand also causes considerable damage to vehicles. The sand source is from the rivers flowing from the eastern side of the Mýrdalsjökull ice cap (the source of some of the largest glacial floods in Iceland when the Katla volcano erupts: see Table 1.1 for its frequency). An agreement was concluded with owners of the sand plains to revegetate the area. This work has continued to the present day (Figure 3.12). The area covers about 40,000ha, but only a small part has been stabilised. The Icelandic Road Administration funded half of the work.

Work under Land Reclamation Programme III (see Chapter 4 for details) was, in

Photo 3.24 *Encroachment by mobile dunes into Dimmuborgir* SCSI

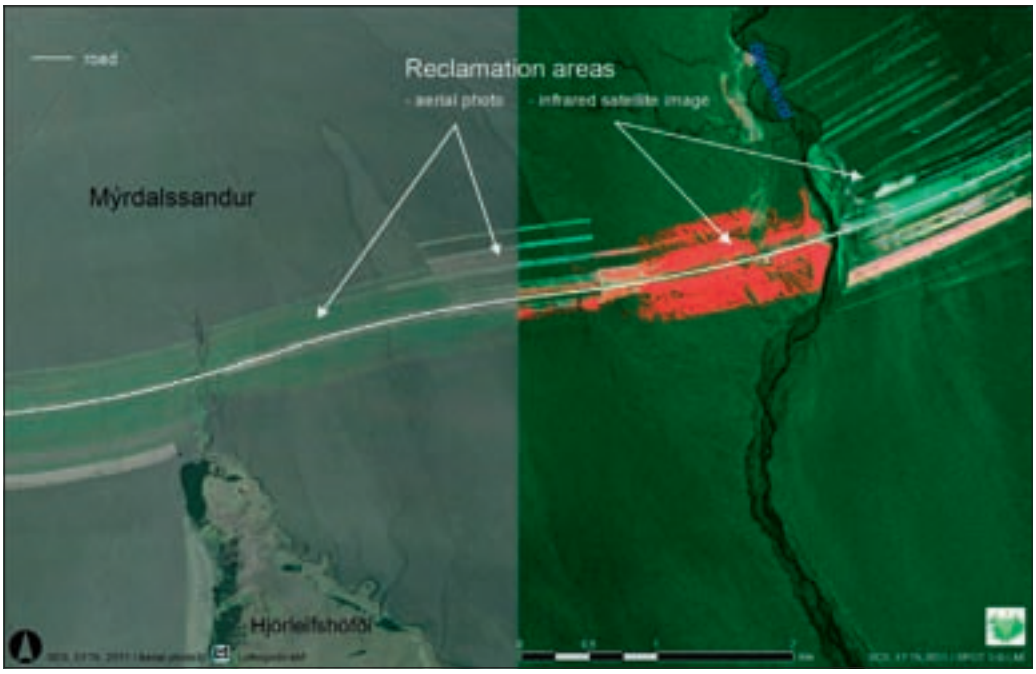


Figure 3.12 *Reclamation alongside Route 1 across the Mýrdalssandur seen from infrared satellite and aerial images*
Source: Soil Conservation Service

part, intended to halt the sand drifting problem by revegetating sand alongside the road. In 1987, a 40m wide and 3,000m long strip of land was sown north of the roadway, and the carriageway was to be moved to the south. In 1988, two similar tracts of lyme grass were planted and fertilised, one on the north and the other on the south side of the strip previously planted. This work was undertaken by local farmers. Lyme grass and lupin were the main species used to revegetate the sands. An aircraft was also used to sow red fescue and Bering's tufted hair grass in narrow tracts. Work still continues on Mýrdalssandur and some 5% of the sand plain has been sown, resulting in significantly reduced drifting sand onto the road. The Soil Conservation Service sowed in spring and autumn, and local contractors spread fertiliser.

Photo 3.25 *Successful roadside stabilisation of sand by Nootka lupin* ÞK

Stopping rivers flooding the land: Hornafjarðarfljót, Skógeyjarsvæði, south east Iceland

The amount of land lost from seasonal flooding or from a glacier burst flood can be substantial. Without entrainment, the rivers flow

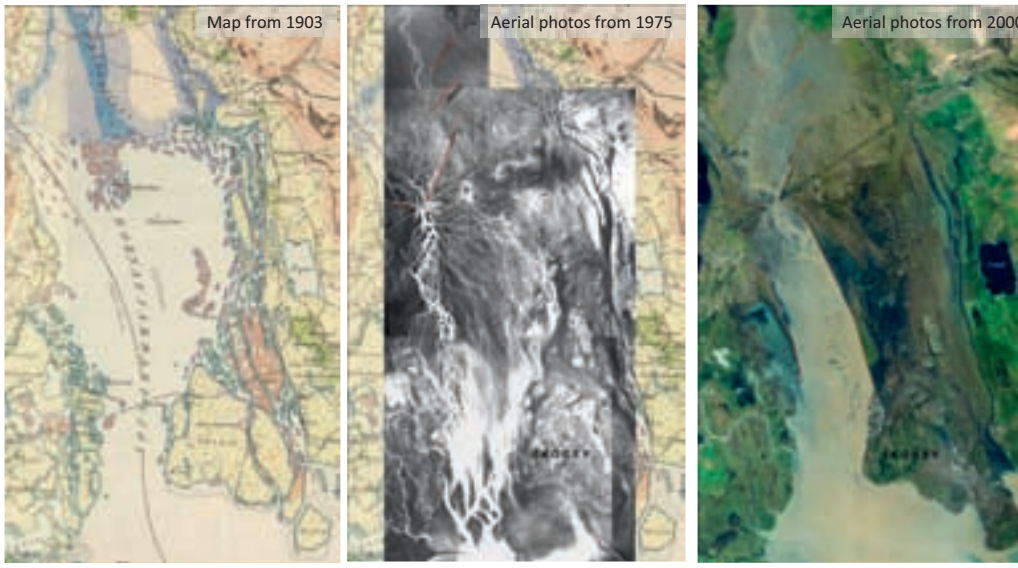


Figure 3.13 *Three phases of river entrainment and land reclamation at Skógey on the Hornafjarðarfljót*
Source: Soil Conservation Service

over farmland. An excellent example is the entire area of Austur-Skaftafellssýsla County, where numerous flash floods devastated most of the vegetated lowland in the 18th to 20th century, when the ice caps were reaching maximum size and then receding. The area around Hornafjarðarfljót in the south east corner of Iceland is a show case site. The map and aerial photograph sequence (Figure 3.13) show the changes made over a century. In 1903 there were no formal roads and no management of the river. By 1975, a road and bridge had been constructed and levees created immediately up stream of the bridge to channel water under the bridge and reduce the risk of flooding. Below the road bridge there was a great deal of naturally flooding land: a classic river estuary situation, resulting sandstorms every year during dry spells threatened the village of Hornafjörður. Given the desire to halt the sandstorms, levees were constructed during the last quarter of the 20th century on either side of the river to entrain its course and allow reclamation of land behind them for the first time. This was one of the most successful projects the Soil Conservation Service has ever undertaken. Fertiliser and grass seed were distributed over 4000 hectares of bare sand, mostly by aircraft, resulting in restoration of a unique wetland with high biodiversity.

Major ecological restoration: the Hekla Forest Project

An example of building resilience and restoring the functions of the natural ecosystem is the Hekla Forest (Hekluskógar) project developed over the last few years and to continue for some decades to come. Experience has shown that treeless land is not able to withstand tephra deposition from an eruption, while birch woodlands, with a shrub layer of willow and other dwarf species, restrain the

tephra and over time it forms part of the forest floor. The area to the south west of Hekla is badly eroded, has poor soils, limited soil nutrients, and is subject to drought. The land downwind has been revegetated and some of it is now good agricultural land. The Soil Conservation Service, Iceland Forest Service, local land owners and many other partners are developing a major birch woodland near the Hekla volcano, using natural defences to protect against natural disasters. The aim is to stabilise the drifting sand, reclaim the eroded area and to protect the already reclaimed area from the consequences of tephra falls from future eruptions of Hekla. The intention is to cover up to 600 km² of a total area of 1000 km² (almost 1% of Iceland) over a 50 year period with predominantly locally sourced birch and willow (Figure 3.14). Key archaeological and nature sites, recent lavas and currently used common grazing lands will be safeguarded from planting.

The species being used are known to have withstood tephra deposition in the past more successfully than other species, allowing rebuilding of the ecosystem and stimulating natural succession without high levels of seed and fertiliser inputs. The first step is to plant grasses, legumes and mycorrhiza species on bare areas with minimal fertiliser application to provide favourable conditions for tree and shrub growth; the species used will depend on the degree of instability of the surface (see Table 3.1). The preferred approach is to establish small groups of trees and shrubs either as seeds or cuttings with added fertiliser and mulching. The seeds of these trees and shrubs, once established, will be dispersed

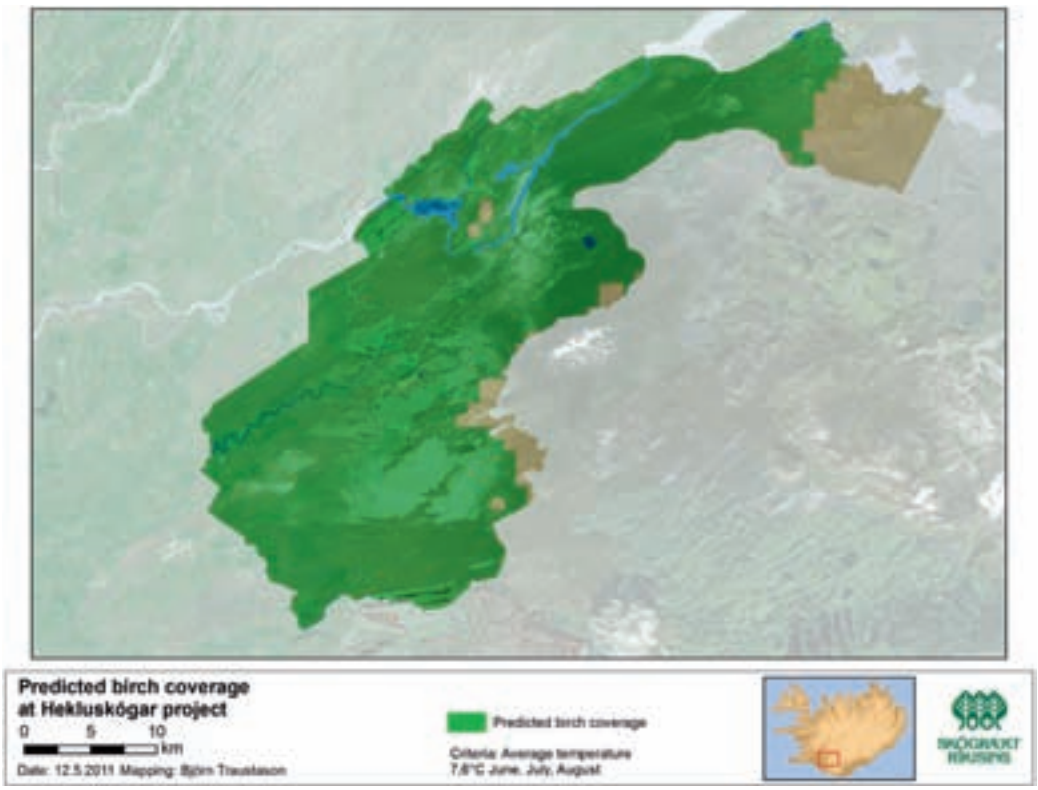


Figure 3.14 *Hekla Forest Project: estimated vegetation cover by 2050*
Source: Hekluskógar project

Table 3.1 Hekla Forest plans

Erosion class	Vegetation cover	Area km²	Reclamation Measures	Afforestation measures
Very active	≤ 33%	150	c50% seeded with *Leymus arenarius*. Whole area fertilised 3-4 times	Planting of birches, willows & native legumes as islands after 8-10 years
Some	≤ 33%	190	c75% seeded with *Poa* and *Festuca*. Fertilised 3 times	Planting of birches, willows & native legumes as islands after 2-3 years
Limited	34-66%	115	c70% fertilised 3 times	Planting of birches, willows & native legumes as islands
None	≥67%	170	No revegation needed	Planting of birches &/or willows as islands

Source: Aradóttir, Á.L. 2007. Restoration of birch and willow woodland on eroded areas. In Halldórsson, G., Oddsdóttir, E.S. & Eggertsson, O. Eds. *Effects of afforestation on ecosystems, landscape and rural development,* TemaNord 2007: 508, Reykholt, Iceland, June 18–22, 2005, page 73 with kind permission.

naturally downwind and stimulate growth on adjacent areas, therefore attempting to mimic natural processes of vegetation succession and seed dispersal as much as possible. The Hekla Forest will, over time, improve land resources, sequester carbon, contribute to improved water management, provide recreational areas and land improvement, and increase land values. In the spring of 2007, contracts were concluded with the government to fund the Hekla forest project for the first 10 years.

The essential ingredients for the century of reclamation effort described in this chapter are analysed in Chapters 4-7.

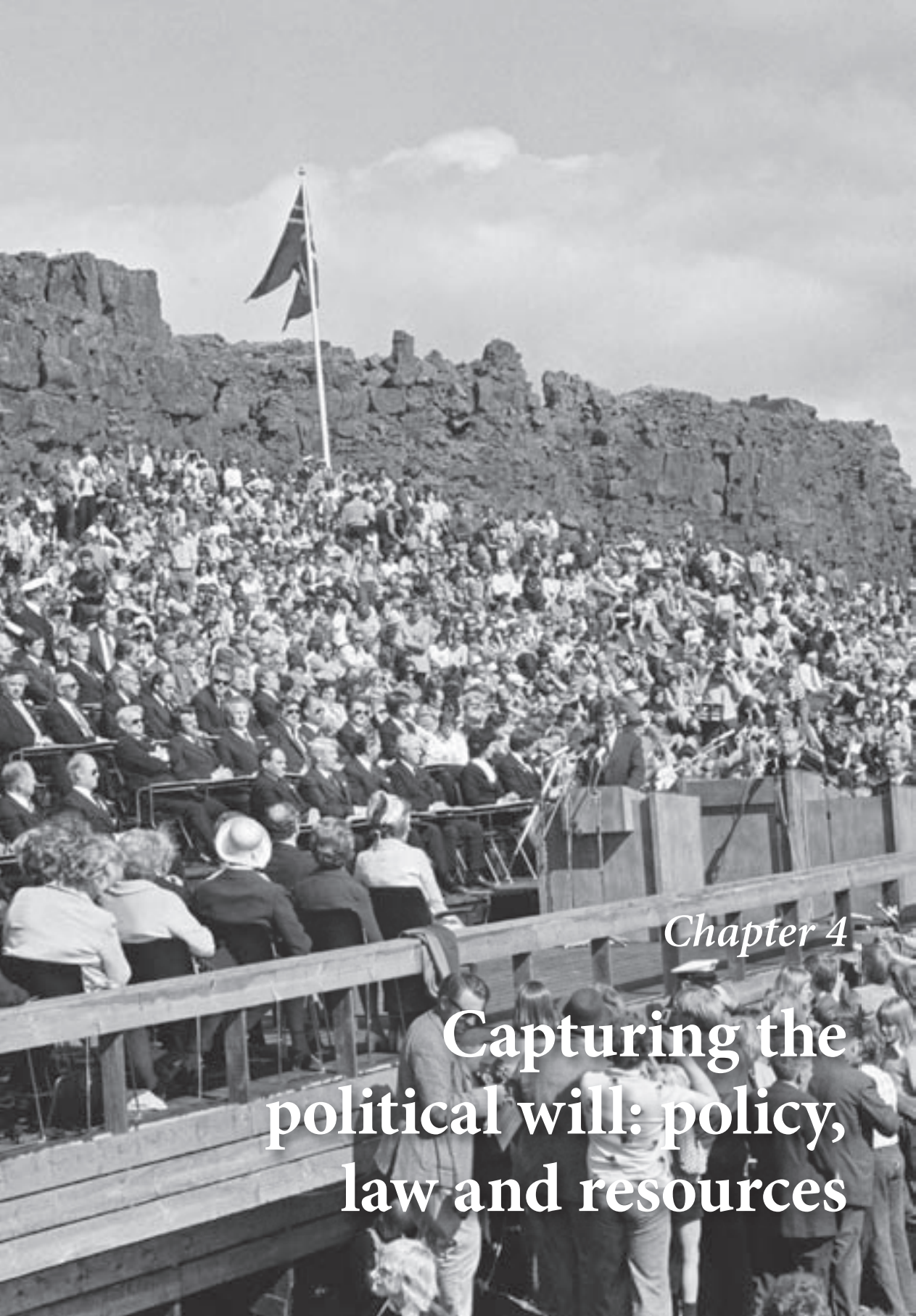
Endnotes

[1] Arnalds, Ó., Thorarinsdóttir, E.F., Metúsalemsson, S., Jónsson, A., Grétarsson, E. & Árnason, A. 2001. *Soil erosion in Iceland.* Soil Conservation Service and Agricultural Research Institute. 121 pp

[2] Halldór Pálsson. 1972. *Páll Sveinsson landgræðslustjóri,* 13. In Icelandic.

[3] Arnór Karlsson. *Biskupstungnaafréttur með augum bónda* (*Biskupstungur Common, Through the Eyes of a Farmer).* In Icelandic, page 90.

The Ingredients of the centennial story



Chapter 4

Capturing the political will: policy, law and resources

The first ingredient of the centennial story rests with politicians. Their understanding of the issues and their willingness to make changes to policy, legisation and to increase the level of resources devoted to land restoration and soil conservation is crucial. Politicians listen to the messages they receive from their constituents and the voters, and learn from evidence of success on the ground by trusted practioners.

Changing political will and evolving legislation

At the beginning of the 20th century, Iceland's economy operated virtually without technology. There were no roads, few rivers had been bridged, and manual human labour and horses were the main source of motive power. There was very little industry, and trade and services were still largely in the hands of foreigners. Virtually everyone was employed in agriculture and fishing in one way or another. Culturally Icelanders loved books, and almost everyone was literate. Interest focused mainly on early and contemporary literature, and on history. There was less interest in natural history or technology. This was understandable. Literature has deep roots in Icelandic culture, but natural science and technical skills were relatively new and often viewed as exotic disciplines, and few Icelanders could read books in Danish or German.

Agriculture had been the lifeblood of the country since colonisation, and still was in 1900, although the fisheries were growing in importance. It was remarkable how few changes there had been in meat, wool and milk production over the previous millennium. Hay fields were largely on uncultivated land and the hay was cut by hand with scythes, then dried on the ground, raked into bundles and carried to farmsteads on horseback. Sheep and horses grazed freely throughout the country, and there was little attention to the quality of grazing. No one seemed to care if the grazed land was scraggy or lush. Self-sufficiency farming still prevailed. But, during the last two decades of the 19th century live sheep were exported to Britain, resulting in a rapid increase in the stock numbers and subsequent over grazing during successive years of inclement weather.

The sand reclamation pioneers who began seeding the sands and the eroded areas at the turn of the 20th century had to tolerate a lack of understanding, even ridicule, from people with little or no belief in their work. Icelanders were accustomed to drifting sand and damaged vegetation, and generally thought that little could be done to stem the tide of nature. This attitude gradually changed as the nation became more educated, and as efforts by the 'seeders of the sands' bore fruit. Eventually, the public became convinced of the need for land reclamation, vegetation conservation and sensible land utilisation. A new century had barely begun, but it was to be a century when national attitudes towards land utilisation and environmental protection began a fundamental shift away from the mind set that had prevailed since The Settlement.

The 1907 Act

It is significant that the first legislation on land reclamation and soil conservation was enacted 3 years after the Danish government had agreed that Iceland should have home rule over its domestic affairs.

During the opening years of the 20th century, the focus of attention was on afforestation and the protection of the remaining relic forests. The technical turning point came through the visits of Danish specialists on afforestation and land reclamation - Carl Vilhelm Prytz and Carl Hartvig Ryder, and later C. F. Dahlerup. They proposed new legislation. Politically, the proposals were led by Hannes Hafstein, who was the first Minister of Iceland in the Danish Cabinet after home rule was granted in 1904. He introduced the *Bill on forestation, soil reclamation and defences against desertification* with the following comments:

> "This bill may be viewed as a kind of yardstick of belief in the future of this country and the willingness to make an effort on behalf of those yet to be born. It cannot be expected that the issue which is being established here will bring any dividends today or tomorrow. What we are asking is to take on the cost of endeavouring to improve the country, to make it more hospitable and attractive for our children and theirs. It is founded on the desire that vegetation in this country be not just maintained, but rather increased and proliferated in years to come, based on the belief that what has been here could come again." [1]

The costs of implementation of the measures in the bill were regarded as too great an imposition on farmers and their representatives were not prepared to support it. After a good deal of negotiation, an amended bill without financial imposition on farmers was passed unanimously on 11 September 1907, confirmed by the King of Denmark on 22 November and came into effect on 1 January 1908. The predecessor of the Soil Conservation Service of Iceland, curiously named the Director of Forestation (a common approach to naming government institutes in Iceland in the early 20th century), had been established. It is generally recognised that 22 November 1907 is the date of the establishment of formal soil conservation in Iceland and hence the centenary was celebrated in 2007.

The statute was short and demonstrated that Icelanders had greater interest in afforestation at the time, rather than a firm resolve to impede drifting sand or for the preservation of the remaining native woodlands. Responsibility for implementation lay with the Director of Forestation. A critical provision stated that "Forest wardens may be assigned the tasks of inspecting and recording drifting sand areas, and supervising implementation of drifting-sand measures that may be carried out."[2] This is the only reference in the Act to land reclamation and, in consequence, the legislation was considered a constraint on revegetation for years to come and delayed many important projects.

The 1914 Act on Sand Reclamation

By 1913, the 1907 Act was considered to be functioning successfully, but there was a desire that the State should have tenure over all lands being reclaimed because farmers were not regarded as adequate stewards and allowed degradation of vegetation to occur. The government drafted a *Sand Reclamation Bill*, in collaboration with the Director of Forestation and the Agricultural Society of Iceland, and introduced it to Parliament in April 1914. The committee appointed to study the bill proposed that its administration be transferred from the Director of Forestation to the Agricultural Society of Iceland, as the Society's advisors were in the best position

to monitor the work. The revised Bill was approved by Parliament in early November 1914 as the *Act on Land Reclamation*. This was the first Parliamentary legislation devoted to land reclamation, and marked a significant turning point.

The Act was mainly concerned with changes to land reclamation administration and the tenure of land reclamation sites. The most significant provisions were that the government accepted ultimate responsibility for "eroded land reclamation", and the Agricultural Society of Iceland replaced the Director of Forestation as administrator of land reclamation with authority to fence wind eroded areas, and with full legal rights over the land. Areas where landowners were prepared to supply funding and fencing were to be given priority. National and local government would determine where land reclamation fences should be erected; 75% of costs would be paid by the Treasury and 25% by the local councils. There were clauses on how farmers were to treat revegetated areas after they were returned to them, and on fines if the law was infringed. The Act also stated that roads through reclamation areas and those close to them where traffic was likely to cause erosion should be closed.

Changing the mindset

A telling incident at the outset of land reclamation illustrates the barriers which sand stabilisers had to overcome with high level officials in Reykjavík and in the field. The first revegetation fence erected at Reykjasandur, in south central Iceland, was cut and horse-drawn wagons driven over newly planted ground as it had previously been a track. The damage was repaired. But three days later Gunnlaugur Kristmundsson, the leader of soil conservation, received a letter from the Government Chief Secretary informing him that the chairman of the local council had complained that the fence would stop necessary travel. He directed Gunnlaugur to take particular care to erect the fence where it would not hinder traffic, either by including a gate or by postponing fencing in those areas that conflicted with the road. Gunnlaugur was quick to realise that this complaint and the government's response could put an end to the reclamation work and went to see the official in Reykjavík to explain the problem. The immediate reaction from the Chief Secretary was the absurdity of putting a fence across a public road and prohibiting people from going about their business. Gunnlaugur argued the opposite. Fencing off land to halt further grazing and stabilise the drifting sand would benefit travellers, farmers, and nearby communities. However, planting seed in unfenced areas would not achieve the desired results since seed would be trampled and eaten, and the sand drift area would extend.

The longer they talked the more open the Chief Secretary appeared, until finally he told Gunnlaugur to return in two hours, by which time a letter to the road works foreman instructing him to build a new road outside the proposed enclosure would be ready. The battle had been won and the outcome made a huge difference to the future of revegetation work in Iceland. The clear message is that tenacity in the teeth of opposition and going to the top to seek the solution, backed by practical experience and a well argued case, are likely to win the day.

Refreshing the law in the 1920s

A review of the legislation was undertaken in the early 1920s, recognising that lessons could be learnt and improvements made in the light of experience. The *Sand Reclamation Act* was approved by Parliament in June 1923. It had three key provisions. The Agricultural Society continued to manage sand reclamation, but the government would appoint a sand reclamation specialist to work with the

Society. Local councils were given power to expropriate wind eroded areas if the owners would not or could not finance their share of land reclamation. Land would be returned to the owners after successful revegetation, but they were to be held responsible for wind erosion not recurring. Until that time, farmers believed that, as land owners, they had an inalienable right to use fenced land reclamation areas. The new act changed the position. The third significant change was that the costs of fencing, revegetation and maintenance of eroded areas shall be evenly divided between the Treasury and the respective landowner; this was amended in 1927 to reduce the landowners share to one third. Local councils were to ensure that payment was made by the landowners. During the depression of the 1930s, farmers often handed over large areas of what at that time was worthless land to the government.

The 1941 Act: the formal establishment of the Sand Reclamation Service

Towards the end of 1940, the Prime Minister decided to review the legislation on sand reclamation. Maybe the time was ripe, or maybe he was thinking ahead to securing independence from Denmark in 1944, or maybe Gunnlaugur wanted an official title and a more formal position for the organisation; it is not at all clear. Gunnlaugur Kristmundsson was one of a three person group assigned the task. The draft *Bill Concerning the Icelandic Soil Reclamation Service and the Prevention of Drifting Sand* was supported by the Agricultural Congress and had its first reading in Parliament on 4 April 1941.

The most notable feature of the proposals was the need to make substantive legal changes to land reclamation and to sheep grazing. Three issues were highlighted. First, there should not be more sheep than is suitable for both the land and the sheep, and grazing in sandy areas should be limited to halt destruction of vegetation. Grazing capacity as a practical measure came to the fore for the first time. Second, soil reclamation areas that are enclosed and being revegetated should be protected from grazing by sheep to improve the chances of success and to avoid negative reactions from farmers if grazed too soon. Third, the State needs to own the land reclamation areas and finance the reclamation work as farmers have not the resources to undertake this activity.

The sea change in political attitudes towards public expenditure on soil stabilisation can be judged by the statement by the Minister when introducing the Bill in Parliament. Praising the work of Gunnlaugur Kristmundsson he said: "I don't think it is an exaggeration that more results have been achieved with the funds expended on soil reclamation, than on the funding of most other matters in the country. This success is primarily accredited to the unusually hard-working and vigilant man who has headed soil reclamation efforts. He has produced incredible results from limited funding. Entire districts have been saved from destruction."[3]

The Minister suggested that the Bill be amended in four ways. First, he proposed that the State be permitted to take complete control of soil reclamation work, in effect to allow the State to expropriate land requiring revegetation, replacing the current law which placed the initiative for land reclamation in the hands of individuals. The reason for this proposed change was that, too often, farmers began grazing reclaimed land before it was adequately revegetated. Farmers could, however, request that their land be revegetated without the need for expropriation. Second, the Director of the Icelandic Sand Reclamation Service should have power to remove sheep that repeatedly found their way

into land reclamation enclosures. The third change authorised limiting sheep access to pastures and commons by setting maximum livestock numbers where land was being overgrazed. The fourth change was to establish the position of Director of the Icelandic Sand Reclamation Service to be appointed by the Minister of Agriculture. The Bill was approved in May 1941, albeit with a shorter title: *Act Concerning Soil Reclamation and the Prevention of Drifting Sand*.

The Minister of Agriculture appointed Gunnlaugur Kristmundsson as Director of the Sand Reclamation Service, but the Agricultural Society of Iceland continued to supervise its activities on behalf of the Minister. The 1941 Act gave the Icelandic Sand Reclamation Service the status of an independent government institution. The relationship with the Agricultural Society of Iceland became less evident, although effective cooperation between the two continued.

Independence means funding for land reclamation

When Icelanders voted on establishing a Republic in 1944, funds raised at the polling stations provided the initial capital for the Land Reclamation Fund set up later in the year. The organisers of the fund raising published an address to Icelanders in the national daily newspaper, Morgunblaðið, on 12 May 1944: "At the same time as the nation is encouraged to decide on founding a Republic, the idea emerged of initiating some kind of project that everyone could participate in, and would live on long beyond our lifetimes. It was decided to found a Land Reclamation Fund". An article written by a reporter appeared on the same page headlined *Land Reclamation is an Issue of Independence* which included the following statement:

> "While much has been accomplished over the last 40 years in both land reclamation and the protection of forests, knowledgeable people believe that the benefits of this revegetation and land conservation work does not amount to more than the average land degradation that would have resulted from man made and natural causes for each of those 40 years, since the time of Settlement. Based on the same progress, the nation should be able to recoup the original land resources over the next 1000 years."[4]

The challenge was clearly made to the public and to politicians to take land reclamation seriously. It was a central component of the national psyche to treat nature more gently and to reverse the devastation caused by human activities since The Settlement. Despite this pressure, there was no new legislation and, although the Land Reclamation Fund was established and still exists, there is very little money in it and the annual interest is donated to forestry societies.

A review of the first half century

At the 50th anniversary of land reclamation in Iceland in 1957, Páll Sveinsson, the Director of the Sand Reclamation Service, wrote the following:

> "The need for land reclamation has been and still is so great for this land of ours that it has perhaps led to undertakings overly ambitious for the money available for land reclamation. ……After 50 years of tireless work, we do not stand at any turning point; we need to protect and revegetate many large areas throughout the country. These vast deserts cover hundreds of thousands of hectares."[5]

Nothing further happened on the legislative front until 1957 when the Minister of Agriculture appointed a commission to coordinate soil reclamation statutes, and explore possibilities for expanding the operations of the Sand Reclamation Service. Following a tour of the country, the Commissioners reported

> "In some places the sand was black as coal, where before had been such beautiful vegetation. At other places, however, the Sand Reclamation Service had succeeded in completely halting desertification, and helped nature to cover large areas with vegetation, areas that a few years before had been barren."[6]

The commissioners confirmed that the work of the Sand Reclamation Service was effective, and more could be done to revegetate land if funding was increased. They also supported the publication of a book on the history of soil reclamation in Iceland *Land reclamation: fifty years of the Sand Reclamation Service of Iceland remembered*. This was published in 1958 by the Agricultural Society of Iceland and the Sand Reclamation Service. It was considered the most noteworthy publication of its kind in Iceland at the time. For example, the article by Gunnlaugur Kristmundsson, Director of the Sand Reclamation Service, *The dawn of organised land reclamation*, is regarded as an invaluable source on revegetation work. The book was included as reference material for the bill.

Failed attempts to update the legislation

The commission submitted a new soil reclamation bill in March 1958: *Bill to impede drifting sand, and land reclamation*. It comprised sections on: objectives and management of the Sand Reclamation Service; impeding drifting sand and land reclamation; revegetating grazing lands; surveying and supervising communal grazing areas; experimentation and research; and raising funds for soil reclamation. The bill contained a variety of innovations, for example the supervision of livestock numbers on communal grazing areas, systematic research on soil erosion and new methods of revegetation. Also, the Sand Reclamation Service's working capital was to be increased significantly. As in the past, most of the funding was from the Treasury, but provisions were also made to tax livestock, imported feed supplements and tobacco. These levies on the agricultural sector for all livestock would increase the budget by 12%.

Debate on the means of funding sand reclamation, revegetation and fencing between 1959 and 1965 meant that the original ideas had to be scrapped and a new framework presented in 1965. There was reluctance on the part of the government to vote additional resources and strong resistance on the part of farmers to have a livestock tax. Other options, such as an alcohol tax, were opposed by other interests. The consensus building which had been evident in previous debates had been temporarily lost due to failure to agree funding mechanisms and, in particular, to the unwillingness of farmers to provide the necessary funds.

The ground breaking 1965 Act

Finally in 1965 a new bill, without provisions on funding was introduced by the Minister of Agriculture:

> "I believe that there is reason to celebrate that attitudes have changed, that people now understand the communal necessity of working against the forces of destruction and erosion… . It is certainly an important project over the following years, and I think that there are few who would now challenge its necessity." [7]

Despite concerns expressed in debate about lack of funding, the Bill was approved in April 1965 as the *Act on Land Reclamation*. It is still the principle statute on soil conservation with only minor amendments made in 1975, 1979, 1982 and 1983; a review is currently underway.

The 1965 Act marked a major turning point. The previous objective of retarding drifting sand was broadened to "… prevent vegetation degradation and soil erosion" and "… to revegetate eroded and poorly vegetated land". The Act formally established the Soil Conservation Service of Iceland as the successor to the Sand Reclamation Service. It also permitted the establishment of Vegetation Conservation Committees in all administrative districts, elected for four year terms; they became a requirement in 1975 and applied to all towns from 1982. These committees, whose members were nominated by local municipalities, were elected for four year terms, and given the role of monitoring the utilisation of communal grazing areas in their local communities, in cooperation with the land utilisation advisor at the Agricultural Society of Iceland, a position established in 1977. The committees were later replaced by ones with clearer objectives and more transparent procedures for selecting members.

Surprisingly, the newly appointed Director, Páll Sveinsson, considered that the 1965 Act would result in virtually no changes; rather it was primarily aimed at integrating the various tasks already being carried out. The primary emphasis would continue to be retarding desertification, although vegetation conservation would be increased, aided by the appointment of a specialist consultant.

A renewed public awareness and a new national consensus

In the late 1960s, Iceland was undergoing major economic changes with the construction of hydroelectric power plants. At the same time, there was extensive land drainage for agriculture. Inevitably, there were negative effects on the land and a growing number of people wanted more consideration to be given to the potential effects of large-scale projects on nature. Land reclamation and vegetation conservation became common topics of conversation. Many spoke out publically. An article *The campaign against the land* by Nobel Laureate in Literature Halldór Laxness in *Morgunblaðið* in December 1970 was probably the most influential. He discussed the abuse of nature, and the enormous land degradation that had occurred during the country's 1100-year history. He criticised irrigation ditches dug by farmers to drain land, which he said impaired the ecosystem. He strongly disapproved of imprudent power plant construction and unrestrained industrialisation. Laxness reserved his most vitriolic

Photo 4.1 *Halldór Laxness: environmental visionary and campaigner* NMI

Photo 4.2 *Draining of wetland for agriculture use was strongly criticised by Halldór Laxness* RC

attack on those who were rewarded for making the problem worse, stating that

> "In recent decades people have been awarded civic honours for draining marshes, the hardiest vegetated areas of the land, under the pretext of cultivating meadows.…Isn't it about time that people were awarded civic honours for filling them in again? Draining the marshes is an assault on the land's sensitive flora and fauna."[8]

Another influence on the views of politicians was the eruption of Hekla in 1970 with ash and lava spread over newly vegetated areas. There is no doubt that the broad public interest in land improvement, tireless efforts of an NGO, Landvernd, in conservation, and the Soil Conservation Service's successful results in land reclamation convinced politicians that the time was right to join the struggle to restore and conserve the land. The foundations for the National Endowment Gift had been laid. The Nobel Laureate's wake-up call, along with writings by many others, contributed to growing environmental awareness, and no doubt stimulated the government to appoint a Land Utilisation and Land Reclamation Committee. Its remit was broad ranging: to develop the plan for celebrating the 1100th anniversary of Iceland's Settlement by implementing a major land reclamation and vegetation conservation campaign, and developing a comprehensive land utilisation strategy. The committee's report (in Icelandic) *Soil Conservation Plan 1974–1978: Findings of the Land Utilisation and Land Reclamation Committee* was submitted in 1974 after 2 years work with extensive consultation. The committee concluded that the following should be objectives:

"a) to stop desertification, wind erosion, drifting sand and other forms of soil erosion,
b) to prevent damage to, and weakening of vegetation,

Photo 4.3
Meeting of the Icelandic Parliament at the original site at Þingvellir to approve a declaration on soil conservation in 1974 on the 1100th anniversary of the settlement of Iceland
KM

c) to organise vegetation utilisation and grazing to ensure that vegetation thrives,
d) to protect woodlands as necessary and ensure that they do not decline,
e) to create new woodlands for beautification, utilisation, shelter, and outdoor life as appropriate,
f) to promote the reclamation of suitable barren lands, and
g) to strengthen research in these areas in order to develop the best possible foundation for all efforts aimed at achieving these objectives."[9]

The committee also submitted proposals to amend the law on communal grazing and sheep gathering, on revegetation, and on retarding land loss and defending against encroachment by rivers.

Political agreement on the proposals was reached and approved at a celebratory session of Parliament at Þingvellir National Park on 28 July 1974. The only business on the agenda was *"A resolution by Parliament regarding land reclamation and land conservation commemorating 1100 years of settlement in the country"*. It was passed unanimously. This resolution is called the National Endowment Gift and resulted in the additional allocation of 1 billion ISK (US$ 8,500m) for vegetation restoration and conservation for the 5 years 1974 to 1978. The Soil Conservation Service was awarded 75%, the Forestry Service 16.5% with the remainder to the Agricultural Research Institute and others. A legal provision was included to ensure that the effects of inflation were taken into account in determining the money available each year.

The National Endowment Gift included a codicil that the Minister of Agriculture establish a joint committee to supervise and monitor implementation. It comprised the Directors of Agricultural Research, Soil Conservation, Forestry and Agricultural Affairs. The additional resources allowed much greater effort. For example, prior to the Gift, 700-800 tons of fertiliser a year was distributed, but afterwards this figure rose to 3,000 tons and about 90,000 hectares of land in poor condition was protected against grazing. However, as time passed, inflation and the totally unrealistic expectations meant that the Gift did not have the anticipated impact.

By approving the National Endowment Gift, many MPs believed that the generously financed five year programme would be enough to halt all soil erosion, as well as repair the effects of 1100 years of human impact on the country's vegetation cover. Arguments about indexation of the funds went on for years and were only resolved in 1980 when index related increases were granted to the recipient agencies.

The programmes of restoration which followed were referred to as 'the nation paying its debt to the land after centuries of over exploitation'. These agreements were, without doubt, the most significant turning point in the debate about the effects of grazing, human habitation and economic development on Iceland's environment. It is an issue which has been prominent ever since and, unfortunately, the argument continues unresolved.

Evolving agricultural policy

Livestock numbers and controls on grazing had been an ever present issue for 60 years. A new statute, approved in 1969, provided for the setting of maximum livestock numbers in communal grazing areas, land owned by local councils, and on farms. Potentially, this could have changed the imbalance between grazing levels and land degradation. However, the procedures were time consuming and complex to implement and, in reality, the grazing pressure on the commons has never been reduced under this statute.

It had been evident for sometime that controlling the numbers of livestock, especially cattle and sheep, was crucial if land reclamation efforts were to be successful and the public money for conservation effectively applied. The answer lay in making changes to agricultural policy and the financial support regime for farmers. There had been a long term strategy of improving animal husbandry as a means of achieving agricultural self sufficiency. This policy resulted in enormous cultivation of hayfields, particularly after the influx of machinery in the 1950s. As a consequence, there was widespread overgrazing. During the 1970s, it became increasingly clear that the meat and milk industries were over producing, which led advocates of change in the agricultural system to become more vociferous.

Livestock quotas

In 1979, Parliament passed new statutes for managing agricultural production by reducing the production of milk and lamb. Farmers were set production limits, a quota based on their previous stocking levels. This plan rapidly led to reductions in sheep numbers. Farmers with unproductive land were given the opportunity of selling their production quotas, and the Farmers' Association of Iceland focused on reducing sheep production in these areas. However, reductions in sheep numbers varied according to region, as culling was not planned with vegetation conservation in mind, but simply for stemming over production of lamb. Overall, the 1979 reforms did not have a decisive effect on land conservation in those areas where the income of the farmers would have been significantly reduced.

It was not until the Agricultural Products Act of 1985 that it became possible to reduce livestock production to protect land from degradation. Agricultural production and individual production rights of farmers could now be structured in relation to land quality. A directive from the Minister of Agriculture in autumn 1987 implemented the new system. Another positive step was the Agricultural Productivity Fund, established in 1987, allowing farmers to be paid 15% more per sheep if they lived in areas where vegetation conservation required a reduction in livestock.

Production control soon had a significant impact on reducing the sheep population around Iceland, as Figure 4.1 illustrates, with sheep numbers declining by almost a half in the following two decades. Farmers in poorly vegetated areas were given the option of selling their production quotas. The Farmers' Association of Iceland actively participated in implementing the measures. In the first half of 1990, an agreement was concluded with the Association, the Soil Conservation

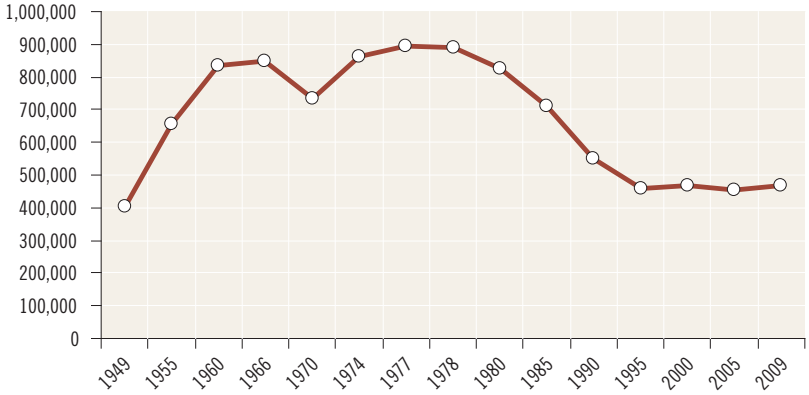


Figure 4.1 *Sheep numbers during the second half of 20th century showing the dramatic effect of changes in agricultural support in the 1980s*
Source: Farmers' Association of Iceland

Service and the Ministry of Agriculture to assess the land resources and farming capabilities of all farms in the country.

A new Agricultural Commodities Agreement between farmers and the government in 1992 sought to take land resources and the condition of vegetation into consideration before re-allocating additional production quotas to farmers. This inevitably called for further regionalisation of agricultural production. The Farmers' Association of Iceland proposed that farmers on land where reductions were planned should be given the option of receiving wages for land reclamation work provided they temporarily waivered production quota rights. This work would be supervised by the Soil Conservation Service. However, very few farmers took up this opportunity. The Farmers' Association proposed that the agreement should cover the development of agricultural production until the year 2000. The Minister of Agriculture voiced his agreement with this concept in the Soil Conservation Service's 1991 yearbook, revealing that the government intended to develop revegetation and afforestation projects for farmers to tap their knowledge and create diverse employment opportunities. This would, in effect, restructure land reclamation work in Iceland.

The goal was that by 2000 many of the most seriously degraded highland commons would be no longer open to grazing. There was reason for optimism as fewer sheep were grazed in the commons during the 1990s, in comparison to previous years. While the goal of no grazing on degraded commons has still not yet been achieved, with a few exceptions, the work to reclaim the commons has produced significant results in some locations.

Current agricultural law and policy

Although the land reclamation statute from 1965 marked a turning point, three decades later it was long outdated. It proved of little use, for example, when crises have developed from overgrazing. The Soil Conservation Service, with help from Australian experts on soil law, provided an analysis of best practice in soil conservation law from around the world. The report from a committee appointed by the Minister of Agriculture to formulate a land reclamation policy *In harmony with the land* formed the basis for a new Land Reclamation Bill introduced in the Parliament in 2002. Although the bill had considerable support and there was a great deal of debate, it was neither brought to a vote, nor reintroduced as there was significant opposi-

tion from the farming community. The issue was the power proposed to be given to the Soil Conservation Service to intervene in the case of severe overgrazing and abuse of the land; it proved a stumbling block which the Minister for Agriculture was not prepared to overcome!

In the spring of 2002, Parliament updated an Act of 1979 to provide grants for the construction of levees to defend the land along river banks. As there was little money allocated, only 50 projects could be supported annually.

Ensuring sustainable land use has been an objective of policy since the beginning of the new Millennium. An agreement between sheep farmers and the government in the spring of 2002 regulated production, pricing and sales of products. Significantly, it required farmers to follow sustainable land utilisation, verified by the Soil Conservation Service, or risk losing full government support. The definition of sustainable land use was, unfortunately, out of date. The Nytjaland Cooperative Project, the land resources database for all farms, was the prerequisite for developing the verification scheme. It was led by the Agricultural Research Institute. If the management of a farm failed the tests, farmers were expected to enter their land into a farm improvement scheme *Better Farms*, but there was no compulsion to do so. Moreover, horse farmers established a land use quality control programme, and the Soil Conservation Service drew up procedures for evaluating land use by horse breeders, and certified environmentally sound land use for about 50 participants.

A new Agricultural Commodities Agreement was signed in autumn 2006, but the linkage with environmental responsibilities of farmers was weak.

Despite all of the changes and the link between agricultural production and sustainable land use, the current system is outmoded. Payments are still largely in the form of support for production of lamb and milk, with barely any provisions for stimulating sustainable land use and no codes of practice, voluntary or mandatory. The system is, for example, at least a decade behind the European Union's Common Agriculture Policy which, despite its flaws, has clear cross compliance codes and positive payments for environmentally beneficial activity. The balance still needs to shift substantially in favour of the latter if the resources allocated to soil conservation and land reclamation are not to be undermined by those for agricultural production. New codes of practice on land reclamation, soil management and other elements of environmental stewardship, based on the best international experience, need to be introduced as a mandatory requirement before subsidy is paid. This point is developed in the final chapter.

Implementing new international Conventions

The international agreements made in Rio de Janeiro in 1992 focussed on sustainable development. They included two Conventions of particular relevance to Icelandic conditions: the Framework Convention on Climate Change ratified by Iceland in 1993 and the Convention to Combat Desertification ratified by Iceland in 1997. Iceland observes the World Day to Combat Desertification on 17 June which happens to coincide with its Independence Day, marking the significance which it attaches to this Convention.

The objectives of the Framework Convention on Climate Change of particular relevance to Iceland are to reduce the emission of greenhouse gases from human activity and to encourage the sequestration of carbon in reclaiming the land. Iceland is in a leading position globally in the implementation of key measures because of the production of electricity from renewable

energy sources, and the work on land reclamation and soil conservation. Article 3.4 of the Kyoto Protocol provides the basis for Iceland's other contribution by allowing for revegetation projects to be counted against a nation's action reduction of emissions. In 1997, the Icelandic government launched a campaign to increase carbon sequestration through revegetation. It proposed changes in approach to increase annual carbon sequestration from 78,000 tons to approximately 100,000 tons by the year 2000. Parliament passed a special appropriation for the project and selected 19 new areas covering 6,000 hectares for revegetation. The carbon sequestration campaign ended in 2000, but the work continued. In 2001, the Soil Conservation Service began a land reclamation project that will sequester an average of 6,000 tons of CO_2 annually through 62 projects in 32 areas with an estimated annual rate of sequestration of 0.6 tonnes carbon per hectare. These figures need to be put into the context of the estimates of the amount of carbon lost over the historic period. One estimate suggests a figure of between 120 and 500 million tonnes of which 50% was oxidised to the atmosphere[10].

The primary objectives of the desertification Convention are to combat desertification and promote revegetation, focussing on land use planning, research, education and cooperation between countries. Iceland is by no means unique as desertification and diminishing soil fertility threaten the ecosystems of about a quarter of the planet's dry land, and affects the lives of more than one billion people in over a hundred countries[11].

An agreement significant for Iceland was made by the parties to the Convention on Biological Diversity meeting in 2010. This set a target of restoring 15% of the world's damaged ecosystems by 2020. The work on ecological restoration, already begun, was given added stimulus.

Iceland has played a key role in the international fora seeking, for example, to influence thinking and to achieve the adoption of carbon sequestration in the protocols to implement the UN Framework Convention on Climate Change. It has also convened two international fora on soils to stimulate discussion and to influence thinking and practice at home and overseas[12]. The conference on *Strategies, science and law for the conservation of the world's soil resources*, held in Iceland in 2005, agreed *The Selfoss Statement* (see Appendix 1). The statement recognised the work undertaken in Iceland and how it could

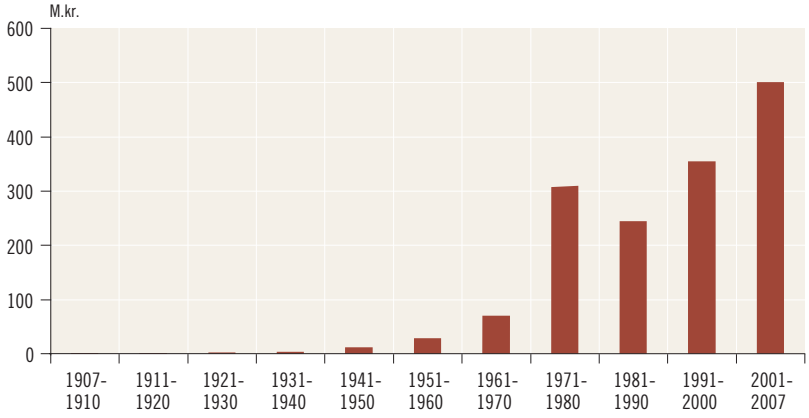


Figure 4.2 *Annual financial contributions to land reclamation each decade*

Source: *Law and Ministerial Gazette* for the respective years. Note: Amounts for each year are adjusted to 2006 price levels based on the consumer price index from Statistics Iceland. 76.50 ISK = 1 US$

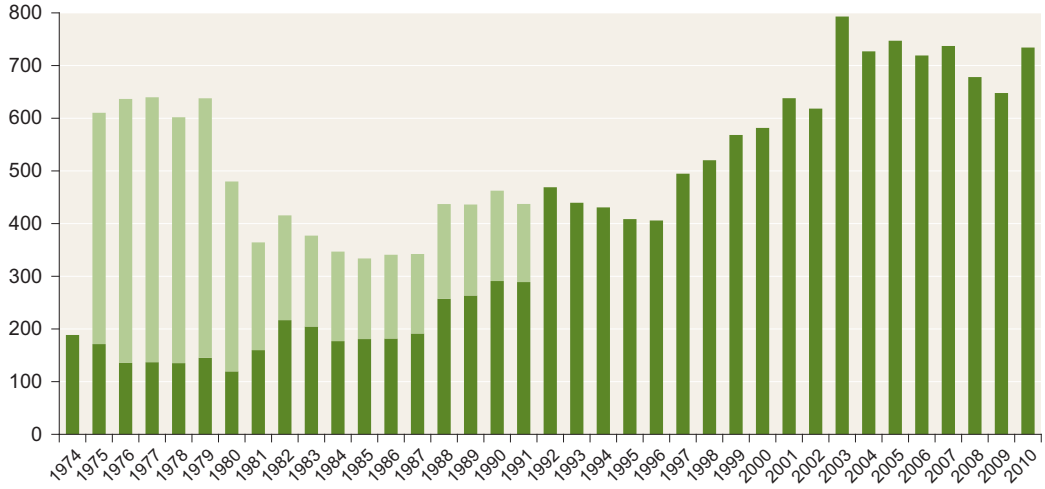


Figure 4.3 *Funding 1974–2010 showing additional resources from the National Endowment Gift (**light green**) later consolidated into the overall budget (**dark green**) of the Soil Conservation Service*

Source: *Law and Ministerial Gazette* for the respective years. Note: Amounts for each year are adjusted to 2006 price levels based on the consumer price index from Statistics Iceland. 76.50 ISK = 1 US$

help to improve practice around the world, and sought continuing support for the work, increased resources, new laws based on the best international experience, and restructuring of the organisations to improve effectiveness and reduce costs. Although the Statement helped to raise general awareness within government of the importance and value of soil conservation and land reclamation, the main recommendations went unheeded.

Resources for land reclamation

It might come as a surprise that Iceland has only spent 14,000 million Icelandic króna (ISK), US$ 116 million, on land reclamation during the past 100 years (adjusted to 2006 values). The average annual financial contribution for each decade during this period is depicted in Figure 4.2.

Funding for the first 50 years was only ISK 200 million (US$2.6m) and severely limited how much could be done and explains how difficult it was to retain seasonal staff. There was a significant increase following the formal establishment of the Sand Reclamation Service in 1941, but this was not guaranteed each year and there were many fluctuations. Following the significant increase in funding under the National Endowment Gift, funding decreased considerably during the 1980s due to the impact of inflation on the availability of government funds. Funding has risen over the past two decades. During the last five years it has been approximately ISK 600 million annually (US$ 14.6m).

Until 1974, funding came primarily from the Treasury, but after that time, the Soil Conservation Service earned income from its operations, mostly by selling seed at home and abroad. Funding for measures to defend against land loss along rivers has always been allocated as a special item in the national budget. The amount has been about ISK 30 million (US$ 0.26m), adjusted to today's price levels, and now risen to ISK 50-60 million a year (US$ 0.4-1.2m).

Three phases of government funding

can be identified from analysis of the figures and these reflect changing public and political attitudes. The trends were also significantly influenced by the greater knowledge of the extent of the problem, and the ever more sophisticated range of techniques adapted from other countries and devised in Iceland itself. The first 7 decades received a relatively low, but gradually increasing, level of resources. The 1970s marked a significant watershed with the establishment of the National Endowment Gift in 1974. The increases in the last decade arise partly from Iceland's recognition of its contribution to implementation of the UN Framework Convention on Climate Change through carbon sequestration, the policies of the 2002 national sustainable development plan and changes in agricultural support.

Numerous companies and associations have supported this effort, including the Pokasjóður (funds from the sale of shopping bags), Hagkaup, Íslandsbanki and Húsgull in Húsavík. Since its inception in 1995, for example, the Pokasjóður has donated about ISK 300 million (US$ 4m) to various revegetation projects.

Government organisation for land reclamation

Over the century, central government responsibility for land reclamation has remained largely unchanged with a Minister responsible for Agriculture. Responsibility lay within the Ministry for Employment until the Ministry of Agriculture was formed in 1970. This was a logical arrangement as the human causes of soil erosion, and the means of combating them, were directly related to farming and the role of farmers as livestock grazers and food producers. Without this arrangement, the fundamental changes in approach from the late 1960s would not have been possible.

There were long deliberations in the Parliament during the first half of 1990 concerning the establishment of a Ministry for the Environment. There were heated debates over responsibility for vegetation and land reclamation, activities previously within the Ministry for Agriculture's jurisdiction. Some wanted to transfer these to the new Ministry. A compromise was reached; the new law on nature conservation was added, with the Nature Conservation Council given responsibility, in consultation with the Soil Conservation Service and the Forestry Association, to work on vegetation assessments and conservation, but responsibility for land reclamation remained with the Ministry of Agriculture.

When a new government came into office in the spring of 2007, responsibilities for land reclamation and soil conservation and for forestry were transferred to the Ministry for the Environment, along with the two agencies responsible. At the same time, the Ministry of Agriculture was merged with the Ministry of Fisheries.

At the time of writing, consideration is being given to the establishment of a Ministry for the Environment and Natural Resources which, if achieved, should allow a more balanced policy approach to the use and management of Iceland's natural resources of land and water than has been the practice in recent decades. This change would be in tune with a good deal of international thinking that natural resources are not just a commodity to be exploited as quickly as economic circumstances allow, but their use should be in tune with their natural carrying capacity and be capable of being sustained indefinitely. Certainly Iceland's Nobel Laureate in Literature would ascribe to this as he led the arguments on the same theme over 40 years ago.

Arrangements for the administration of soil conservation have changed considerably over the century. The early emphasis was on afforestation with land reclamation

as a small component, and with the Iceland Forest Service as the lead agency. Three decades later the formal legal entity, the Icelandic Sand Reclamation Service, was established. Nevertheless, the earlier arrangements did not seem to impede the work on land reclamation and soil conservation. Much of this progress was the result of the close cooperation between the lead worker on land reclamation - Gunnlaugur Kristmundsson and the Agricultural Society of Iceland with the formal relationship enshrined in statute from 1914.

One issue which has not been resolved is the relationship between afforestation and soil conservation. The two separate agencies have entirely different cultures, both reporting to the same Minister. The fact that the Soil Conservation Service processes and plants many tree species and works effectively with the Regional Forestry Associations highlights the anomaly in the administrative structure. This is more serious in Iceland where the work of the Iceland Forest Service and the 6 regional forestry agencies has been more about the production of useable timber and less about the stabilisation of the land and conserving the remnants of the natural woodland. The situation is confused by the fact that Regional Forestry Associations operate throughout the country and allocate commercial forestry grants to farmers. These Associations involve at least six government agencies and report to the Ministry of Fisheries and Agriculture. From time to time, there has been talk of merging the Soil Conservation Service and the Iceland Forest Service. The Minister of Agriculture commissioned a review in 2005, but concluded that there was no political consensus for merging all of the forestry bodies with the Soil Conservation Service and abandoned the idea at the end of 2006. Fragmentation of administration is a recurring problem, especially in small countries.

Endnotes

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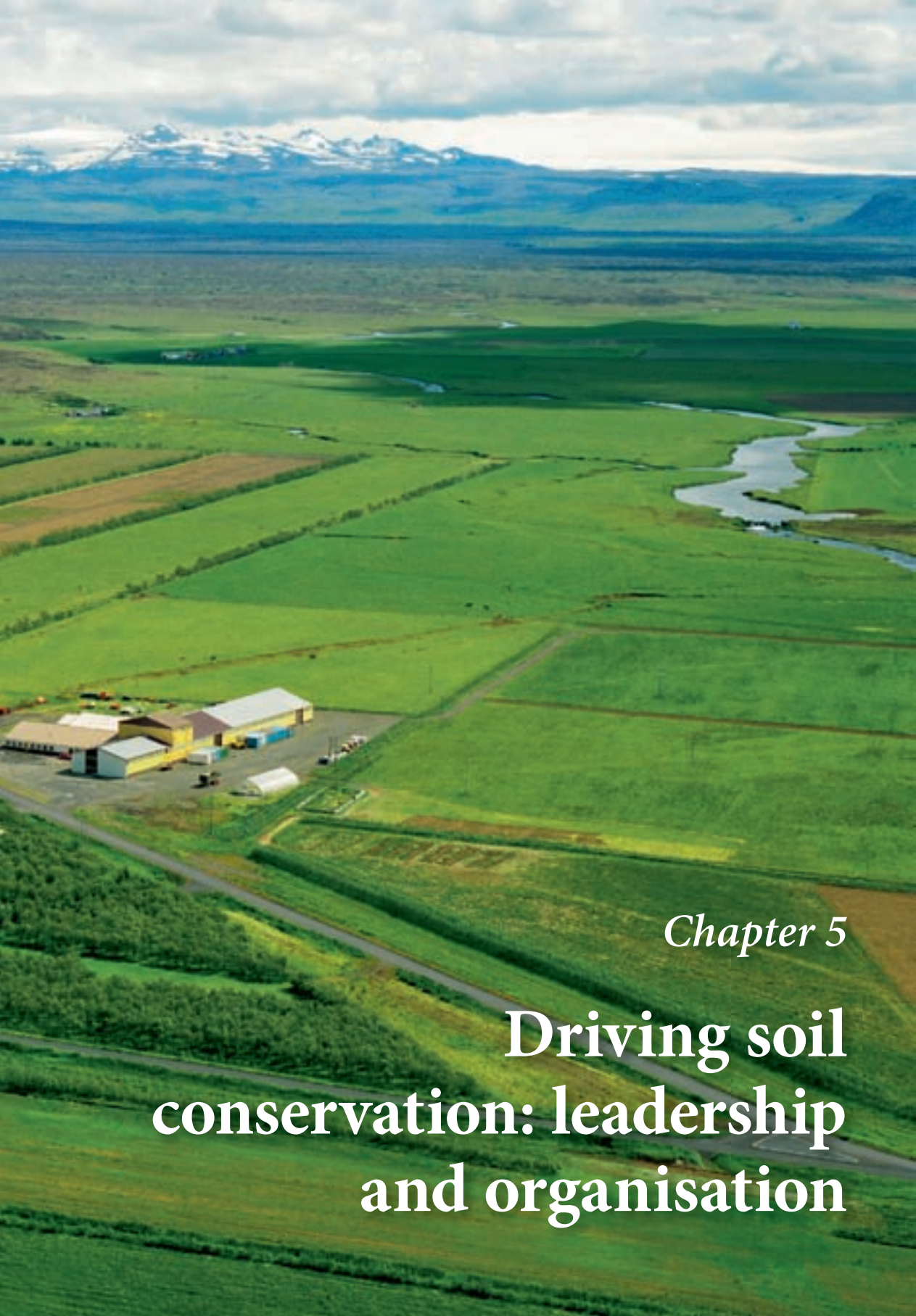

Chapter 5

Driving soil conservation: leadership and organisation

There are many competent organisations in the public sector, there are some very weak ones, but there are only a few exemplars for the best practice. The Sand Reclamation Service and its successor the Soil Conservation Service are certainly in the latter category because of the challenges they have successfully faced over a century of operation. Its success stems from a sound legal base, an appropriate level of resources, and political and public support. But delivery on the ground requires exemplary leadership, an effective organisation with evolving structures and approaches, and clear policies and programmes. These are the topics of this chapter. Sound science, an ability to work with others and continuing development of techniques are also critical components and are dealt with in the two succeeding chapters.

Exemplary leaders

There is some confusion about the early leadership of land reclamation in Iceland. Formally, A. F. Kofoed-Hansen, a Dane, was Director of Forestation and was the first leader of supervised soil reclamation in Iceland from 1907 to 1914. Kofoed-Hansen was much more interested in afforestation than soil reclamation, although he did recognise the value of the native woodlands in maintaining stability of the land, and he left his seasonal worker Gunnlaugur Kristmundsson largely independent in his work. On implementation of the 1914 Act, agricultural advisor Einar Helgason took over the supervisory role until 1923, as an employee of the Agricultural Society of Iceland. From 1923 to 1941, the Directors of the Agricultural Society must be considered the supervisors of soil reclamation work, but the new law in 1941 finally established the position of Director of the Icelandic Sand Reclamation Service. Throughout this period, 1907–1941, Gunnlaugur was the de facto leader and key worker until his formal appointment as Director in 1941. For all intents and purposes, therefore, the title Director can rightfully be said to have been his from 1907 to 1946.

Land reclamation and soil conservation in Iceland has been fortunate in having top quality leadership for over a century. Four leaders have been in post during that period: Gunnlaugur Kristmundsson, Runólfur Sveinsson 1947–1954, Páll Sveinsson 1954–1972, and Sveinn Runólfsson 1972 to the present.

The 4 leaders have a number of common characteristics, some of which are typically Icelandic, but others are common to effective organisations around the world operating in this field. All were sons of farmers and gathered from direct experience a deep knowledge of the land from their earliest memories. All were educated into the culture of Icelandic society: the natural and human history, the Sagas and the oral folklore, giving them a deep affinity with Icelandic people and places. As a result, they would have had a good understanding of a thousand years of history and the role played by their forefathers in changing the face of the land. All had further education devoted to agriculture and land use in Iceland. The later three directors were also formally educated abroad in

Photo 5.1 *A. F. Kofoed-Hansen first Director of Forestation and therefore responsible for sand reclamation from 1907 to 1914* NMI

agriculture and soil conservation, all in the USA, two in Denmark, and one in Scotland as well. And, all were directly in touch with those from overseas who had relevant experience.

The occupancy of the leadership role was for three of them long: Gunnlaugur 39 years, Páll 18 years and Sveinn so far 39 years. A strong organisational memory has been built up. At the same time, innovations have been introduced, stimulated from within, from the employment of new staff, and from external sources in Iceland and overseas. Their ability to take on new colleagues with new ideas and to create a learning environment around them has been critical for the evolution of the work and the increasing success of the effort to combat natural forces and human indiscretions. A final and most important attribute which they all shared was political 'nous': a common sense approach based on an ability to work with the politicians and political cultures of the time and to be influential in persuading Ministers and Members of Parliament to make improvements in policy and law, and to increase the resources available.

A pen picture of the 4 leaders will help to give some colour to the foregoing general points.

Gunnlaugur Kristmundsson

Gunnlaugur Kristmundsson (1880–1948), the son of a farmer, had two jobs until he was appointed as first Director of the Sand Reclamation Service in 1942, a post he held until 1946. He was a school teacher in winter, mainly in Hafnarfjörður, just south of Reykjavik, and a land reclaimer in the summer. His engagement on land reclamation was stimulated by his headmaster, a board member of the Agricultural Society of Iceland, who asked him to travel abroad

Photo 5.2 *Gunnlaugur Kristmundsson* SCSI

to familiarise himself with land reclamation. Gunnlaugur went to Denmark in the spring of 1906 and over the next year studied methods used to impede drifting sand and revegetate land. On the implementation of the 1907 Act, Gunnlaugur became the first state sand reclamation employee.

Gunnlaugur would depart each summer on horseback for the countryside with tools in hand to do battle with drifting sand. He worked predominantly in southern Iceland from his Gunnarsholt base, and concentrated on relatively small scale reclamation areas at the farm and on land permanently handed over from farmers as part of the statutory arrangements. During his 40 years of working in soil reclamation, Gunnlaugur hired many people to assist him during the summer season. The low wages offered and the long hours under very difficult conditions were a deterrent to continuity of summer employment, and freelancers were mostly hired on an *ad hoc* basis. However, a number did work with him for many decades and this continuity helped to build knowledge and make the work with limited resources more effective.

Photo 5.3 *Runólfur Sveinsson* SCSI

Runólfur Sveinsson

Runólfur Sveinsson (1909–1954) was the son of a farmer and trained in agriculture in Iceland and Copenhagen. He travelled in Scandinavia to further his knowledge of animal and agricultural science, as well as working on the family farm. He was appointed Head of the School of Agriculture and Manager of the large farm at the Agricultural Station at Hvanneyri, in west Iceland, in 1937. He built residences for teachers and housing for livestock. His ease of manner and warmth, as well as his optimism and determination, endeared him to his staff. In the spring of 1944, Runólfur was granted a year's leave to visit the USA, where he studied new trends and methodologies in agriculture at several universities, including Cornell at Ithaca, and travelled extensively throughout the country under the auspices of the United States Soil Conservation Service. He became familiar with new ways to impede drifting sand and revegetate sandy plains, as some parts of the USA had also experienced desertification. He returned to his position at Hvanneyri in the spring of 1945 and was appointed successor to Gunnlaugur Kristmundsson as Director of the Icelandic Sand Reclamation Service in 1947, when he moved to Gunnarsholt. He was well aware that Gunnlaugur had left behind a strong foundation on which to build, and invited him on a tour of the country to learn from his experience and knowledge. This enabled Runólfur to become well acquainted with the work and local conditions in a short span of time. Runólfur's time as Director was tragically cut short by a fatal accident at the electrical power station at Gunnarsholt.

Runólfur experimented with various types of imported grasses, particularly from the USA and from Alaska, some previously

unknown in Iceland, with very good results. More fundamentally, he established a major farming operation at Gunnarsholt. One of the motivating reasons was that the increasing scope of soil reclamation and subsequent cultivation had become so extensive that new measures were required for utilising the hay yield. Runólfur was an effective lobbyist who spoke eloquently and frequently on the radio and showed many guests around the Gunnarsholt facilities.

Páll Sveinsson

Páll Sveinsson (1919–1972) was the brother of Runólfur and 10 years younger. He trained in agricultural science in Iceland and began working with Gunnlaugur Kristmundsson in spring 1941, serving as his assistant until 1943 when he went to the USA to study. He first worked at the United States Soil Conservation Service for a year, and then spent two years studying at the Minnesota Agricultural College before completing a degree at Utah State Agricultural College in 1948 with a major in Range Management. He was the first Icelander to graduate from university with a degree directly related to land utilisation and range management. On returning home, Páll immediately began working as Runólfur's assistant at the Icelandic Sand Reclamation Service. Together they implemented numerous revegetation and agriculture innovations, including combining farming and revegetation by breeding beef cattle that fed on the new growth. He brought with him various types of grass from the USA. These grasses and various types of the native lyme grass were tested in revegetation work at Gunnarsholt in cooperation with the Agricultural Research Institute. With Runólfur's death in 1954, Páll was appointed Director.

Photo 5.4 *Páll Sveinsson* SCSI

Sveinn Runólfsson

Sveinn Runólfsson (born 1946) is the son of Runólfur Sveinsson. He spent most of his childhood at Gunnarsholt when his father was the Director. He studied agricultural science in Scotland and soil conservation at Cornell University in the USA. Sveinn began working for the Soil Conservation Service in 1959, just 13 years of age. He travelled around the country with agricultural scientist Ólafur Ásgeirsson evaluating soil reclamation areas and mapping soil reclamation fencing. This gave him an insight into how important it was to protect areas most affected by drifting sand from grazing. He was appointed farm manager of the biggest farm in Iceland at Gunnarsholt in 1963 at the age of 17, working in the summer and attending secondary school and, later, university in winter. In 1970 he was appointed assistant to the Director of the Soil Conservation Service. During this period, he travelled widely, giving him an overview of the erosion and reclamation situation throughout the country. In 1972, he was appointed Director of the Soil

Photo 5.5 *Sveinn Runólfsson* SCSI

Conservation Service at the age of 26, a position he still holds. He has implemented many innovations in the organisation's working procedures, stimulated new ideas and hired new staff to refresh the organisation. He has worked with land reclamation specialists from around the world, particularly in the USA and Australia, a great many articles about agriculture and land reclamation that have been published in journals and books at home and internationally. And he has received many awards in recognition of his services.

The evolving structure

Deputy Directors

The 1965 Act provided for the Director of the Soil Conservation Service of Iceland to appoint a deputy. Since then only 4 deputies have been in post, the current holder for 20 years: another measure of continuity, while maintaining momentum and stimulating innovation.

Páll Sveinsson hired range management specialist **Ingvi Þorsteinsson**. He had graduated with an M.Sc. from the University of Montana, USA. His responsibilities included supervising grazing land research and development of a vegetation map in association with the Agricultural Research Institute. Ingvi left in 1970.

Sveinn Runólfsson replaced Ingvi in 1970. In the autumn 1971, Sveinn was given leave to continue studies in soil conservation and on his return took over as Director from his uncle.

The third Deputy Director, **Stefán Hilmar Sigfússon**, was for two years part-time and full-time from 1973 to 1991. He trained as an agricultural scientist, first at the Agricultural School at Hólar in Hjaltadalur, north Iceland, and later at the Agricultural University of Copenhagen. From 1960 to 1973, Stefán worked as a specialist for the Settlement Agency, which helped young farmers to start farming on state land made available for these purposes. In 1962, he began working for the Feed & Seed Production Company, which was established at Gunnarsholt. He became its manager in 1969 until 1986 when the company ceased operations. His responsibilities included supervising seed and fertiliser flights and oversight of levees to protect against land loss caused by floods.

Andrés Arnalds is the current Deputy Director having been appointed to the position in 1991. He joined the Soil Conservation Service as a vegetation conservation representative in 1982. He trained in agricultural science at the Agricultural University of Iceland at Hvanneyri, and obtained post graduate degrees in plant and soil science and in range management in the USA. He was an assistant analyst at the Agricultural Research Institute in 1971–1972, and a specialist in land reclamation and vegetation conservation from 1974 to 1981 at the same institute. Andrés has placed special emphasis

Photo 5.6 *Andrés Arnalds* RC

on learning from the best experience in other countries, particularly Australia, New Zealand, and the USA and he has led their adaptation to Icelandic circumstances. As a result, topics such as land care and environmental literacy have been developed. He has worked on strategic planning and a structured approach to soil conservation, as well as developed projects involving farmers and the public in land improvements and land resource conservation. Andrés has written widely in international journals and chapters in books, and has presented at conferences around the world on Iceland's solutions.

Soil Conservation Service staff

The Soil Conservation Service operated with only seasonal staff for over 30 years until Gunnlaugur Kristmundsson was apointed to the full time post of Director in 1941. The position changed during the busy summer months when local people were hired to work on short-term projects. Some of them worked on this basis, as Sand Reclamation Wardens, for many decades. Páll Sveinsson worked on a part-time basis from 1941. Runólfur operated on the same basis with Páll as his only qualified assistant, a few permanent farm staff at Gunnarsholt and a few part-time wardens. Páll continued this approach.

The 1965 Act enabled Páll to hire two permanent staff and 15 part-time Soil Conservation Wardens. When Sveinn took over, he reduced the number of wardens but increased their responsibilities and converted them to full-time work. The wardens, in turn, hired people in the locality of reclamation projects.

From 1974 to 1994 the work force numbered between 120 and 250 during the spring peak, with only 20 to 30 employed in the winter. Later on, fewer staff were directly employed on reclamation as this was contracted out and a good deal of land returned to its owners. In recent years, around 65 staff have been employed: scientists, technicians, advisers, regional officers, and administrative staff. Additional staff have been taken on for specific tasks or as part of government employment programmes.

There has been very low turnover of either permanent or seasonal workers over the years. Nevertheless, the current Director estimates that well over 5,000 people have worked for the Soil Conservation Service over the century, albeit some for a very short time.

When Sveinn Runólfsson became the Director in 1972, he was the only staff member with a university degree in the field of soil conservation, although Stefán Sigfússon was educated in the field of agriculture. Today, there are more than 30 university educated staff members.

The gradual growth in staff numbers echoes that in many public sector agencies dealing with environmental and land issues. With the increase in staff numbers, the structure has also evolved. The most far reaching changes were introduced following strategic planning work in 2000 with the establishment of five divisions, including new activities in land information data, and research and development.

Locally based staff

Since the beginning of formal land reclamation activity, staff have been deployed around the country, primarily as summer season volunteers at the places where revegetation projects were underway. Supervisors were stationed in districts where revegetation enclosures were located. Under the 1941 Soil Reclamation Act, they were titled Soil Conservation Supervisors. The positions were part time. There were 21 supervisors in different parts of Iceland, especially in the south central, south west and north east, and a few in the north and north west.

The situation evolved after the passing of the 1965 Act. District advisors from the Icelandic Agricultural Society were required to monitor use of grazing land, and liaise with Soil Conservation Service staff. Assigning supervision responsibilities to locally based staff was a major step forward. The Vegetation Conservation Committees, first established in 1965, were later merged with district environmental groups, while at the same time classes were held on land literacy to increase awareness of the need for grazing management. The purpose was to help ensure that agricultural production would be increasingly governed in accordance with land quality. Soil Conservation Advisors were responsible for specific sectors and managed these operations. There were 16 Advisors in the second half of the 1980s. In 1986, the system was restructured and three of the supervisors were given responsibility over larger areas. This gave more flexibility by allowing the work to be carried out at the best time of the year. The Soil Conservation Supervisors were also responsible for hiring and supervising people to undertake the various tasks scheduled for their districts in spring and summer, as well as writing reports and paying wages.

Establishment of District Offices

A major change in the Soil Conservation Service's working procedures was the creation of District Offices in the 1990s (Figure 5.1). This was influenced by Andrés Arnalds' visits to the USA and interaction with Scottish Natural Heritage, which had established a series of Area Offices around Scotland to ensure improved interaction with local farmers and other key stakeholders. Andrés reported that

Figure 5.1
Soil Conservation Service districts and offices in 2007
Source: Soil Conservation Service

Photo 5.7
Soil Conservation Service District Officer working with a farmer SCSI

> "Based on the experience of other countries, in my opinion it would be preferable to change the structure of vegetation conservation and soil reclamation efforts in Iceland by dividing the country into vegetation and soil conservation districts, managed by the Soil Conservation Service of Iceland. District commissions, composed of local representatives, would have broad powers and responsibilities. Moreover, it would be advantageous for the Soil Conservation Service to have a professionally trained representative in each district. This move would transfer additional vegetation conservation efforts and responsibilities to the locals."[1]

Staff were often co-located with other bodies dealing with the land to facilitate improved cooperation. District Managers gradually took responsibility for supervising land reclamation work in their areas. Today, there are seven offices, each run by a District Manager. The Árnes office has been closed and the officer transferred to Gunnarsholt. Operations are diverse and the emphasis varies according to local conditions. The primary roles of all staff are to supervise and implement revegetation projects in their districts, as well as to strengthen affiliations with land users through cooperation, education, vegetation conservation and consultation. District Managers supervise the *Farmers Heal the Land* project (see Chapter 7 for more details). They appraise farms as part of quality control of sheep and horse farming, as well as evaluate projects in receipt of grants from the Land Restoration Fund. There is also considerable interaction with managers and staff at the headquarters at Gunnarsholt, who provide various support functions.

The Soil Conservation Service has had an office in Reykjavík for half a century, for a long time with the support of the Agricultural Bank, and for some years sharing a floor with the Icelandic Nature Conservation Service. It is now co-located with the Agricultural University of Iceland in the eastern suburbs of the city. The office has a staff of five, including the Deputy Director and the Public Relations Manager.

Successive leaders and senior staff have made it their business to be well acquainted with the issues and solutions in different parts of the country. What has become

known as 'management by walking about' in the management literature has been practised throughout the century of land reclamation in Iceland, and still continues. Gunnlaugur set the trend and all of the other subsequent leaders have followed in his steps. This is a vitally important lesson for all organisations: making sure the top management knows and understands what is going on locally around the territory so they can make more informed decisions to improve delivery of the service.

The Soil Conservation Service established a professional council to develop consensus among key bodies and lobby politically. However, it was not a success and after a four year life it was disbanded by its instigator, Sveinn Runólfsson. Now the organisation operates informally with other groups and the accountability lines are direct to the Ministry for the Environment.

Land ownership

As a result of legislation in 1914, 1923 and 1941, the Sand Reclamation Service owned a significant amount of land around Iceland. Under the 1965 Act, legal appropriation of land by the state was substantially modified. Nevertheless, the Soil Conservation Service has retained ownership of a considerable area (Figure 5.2) totalling 82,323 ha (although there is some legal dispute about ownership of some parcels of land). The holdings at Gunnarsholt and the associated highland commons inland are part of the original purchase in 1926 and have been retained to demonstrate new approaches and practices. The other holdings are more disparate and reflect a long legacy. The question arises to what extent does the Soil Conservation Service need to own land in different parts of Iceland to demonstrate

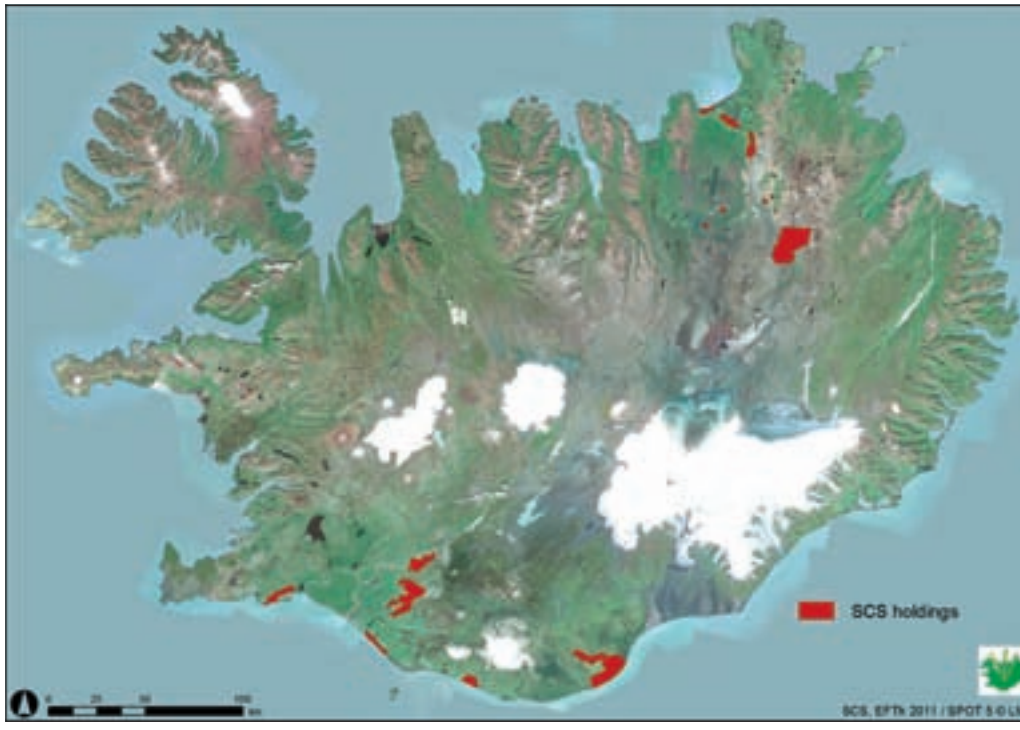

Figure 5.2 *Land owned by the Soil Conservation Service*
Source: Soil Conservation Service

land reclamation and soil conservation when it has so many private owners as partners undertaking similar work. This is moot point. It is perhaps a hangover from the past when identifying exemplary farmers who could demonstrate high levels of land stewardship was more difficult than it is now. It is a challenge for the current leadership to determine what land it should own, if any, in the future, in addition to the holdings at and around Gunnarsholt.

Systematic programme planning

Formal planning of work and use of resources became the norm after the parliamentary approval of substantial additional resources under the National Endowment Gift in 1974. Three Land Reclamation Programmes over the period 1974 to 1991 were established to ensure that the nation's will in voting additional resources was carried out in a transparent manner and the outcomes could be measured.

Land Reclamation Programme I 1974–1978

The majority of the first programme was earmarked for vegetation conservation and revegetation to be implemented by the Soil Conservation Service. The remainder was used for research on vegetation conservation, revegetation and vegetation utilisation, seed collection irrigation and forest protection.

A large amount of revegetation was accomplished, covering 843 km² with 146 km of fencing. One project enclosed 43,100 hectares with a 58 km long fence. The work was concentrated in south Iceland (see Figure 3.3). In addition, seed harvesting and processing technology was revolutionised and farmers and communities became more engaged in the conservation effort.

Land Reclamation Programme II 1982–86

There was a delay is drawing up the second programme, presumably because of lack of agreement on the continuation of the additional resources and pressures from other government priorities. The scope of the plan was narrower than the National Endowment Gift, but the main objectives were the same: to halt all rapidly advancing vegetation degradation and soil erosion. It was stressed that annual permanent funding for land reclamation and afforestation should not be reduced as a result of capital being allocated to the new plan, since it was conceived as a supplement to traditional revegetation efforts. Among the changes from the first plan was provision of funding for river levees and coastal protection. A new joint committee was established to monitor implementation of the plan, including political representatives from the Parliament's Appropriations Committee. The committee operated in cooperation with the managers of the respective institutes and made familiarisation visits. The presence of parliamentarians on the committee proved valuable when differences of opinion arose concerning inflation-indexed funding for the plan.

The most important results of the second programme were improved seed harvesting, greater engagement by farmers, improved methods for measuring vegetation and new approaches to grazing management.

Land Reclamation Programme III 1987–1991

The third programme was distinct from the others in several ways: projects were more precisely defined and work was concentrated in eight core areas around the country. Parliament resolved that, in addition to annual funding, a sum of ISK 266 million (US$ 6.5m), indexed at 1986 price levels, shall be

earmarked for land reclamation and land conservation issues. The Soil Conservation Service received 56.5% of the funding for land reclamation and vegetation conservation. Twenty one percent of the funds were assigned to the Soil Conservation Service specifically for protecting land being lost by river flooding and coastal erosion. The Icelandic Forestry Association received 12.9% to assess the condition of birch woodlands and to formulate proposals for their conservation and use, to strengthen afforestation in areas where forestry associations operated, for example by providing them with plants, and to develop a forestry cultivation programme. The Agricultural Research Institute was allocated 6.3% for funding seed research, use of grazing lands and to develop vegetation and geology maps. Finally, joint projects involving all three institutes received 3.3% of the funding, covering education, breeding of lyme grass, birch and nitrogen binding plants, for researching soil erosion and the condition of vegetation.

Overall, the plans achieved a greater level of land reclamation and increase in knowledge. A number of criticisms are evident. The funding for the first programme was not sustained into the later programmes. Objectives were widened to include levee construction and coastal protection which were not regarded as mainstream. And, there was a lack of systematic measurement of the effects of the programmes.

At the end of 1990, the Land Reclamation Commission, created in 1987, completed its work, and a new Commission was established comprising representatives from all parties in the Parliament. Its task was to develop a plan for the rest of the decade. In March 1991, the Commission submitted an implementation scheme for 1992 and 1993, and a year later, submitted a scheme for the remaining years. Parliamentary approval for the funding was never achieved due to a change in Minister and a lack of political will.

Soil Conservation Plan 2003–2014

After a considerable hiatus, and no doubt prompted by the conclusions of the seminal report on *Soil Erosion in Iceland*, a four-year implementation plan and cost estimates were developed and submitted to the Parliament. They were finally approved in 2002, and implemented as the Soil Conservation Plan 2003–2014. This plan, approved by the Minister of Agriculture, had clear objectives, areas of focus and key projects for the period, and placed high priority for the first time on revegetation to increase carbon sequestration. The overall plan contained a budget, with a more precise financial plan approved for the first four years. Unfortunately, Parliament never approved the funding of the 12 year plan and the resolution is no longer in effect. However, the Soil Conservation Service established a Land Improvement Fund within its overall budget to fund the activities of others in delivering the plan. This funding continues and is a more effective and efficient way of working through partners.

Contingency planning and building resilience

Snow avalanches have been a serious threat to many farms and villages near coastal cliffs from the beginning of The Settlement. The recurrence of eruptions with their effects on the land through tephra falls and flooding have also focussed the attention of the authorities. A prime example is the response of the government to avalanches. An avalanche catastrophe fund was established in 1994 and supervised by the Ministry for the Environment. It is funded from a small proportion of insurance premiums and currently amounts to about 8,000 m ISK (US $70 m). Some 15,000 m ISK (US$ 130 m) have been spent building avalanche control barriers and for research on avalanche behaviour.

The Ministry for the Environment has begun preparation of a similar fund for volcanic catastrophes. The aim is to take a holistic approach by minimising the effects of eruptions, developing greater understanding of volcanic activity, preparing communities to cope with the effects of eruptions, and clarifying responsibilities of all parts of government. Prior to the Eyjafjallajökull eruption in 2010, a contingency plan had been in action since 2003 in the south of Iceland aiming to prepare people for the expected eruption from Katla in Mýrdalsjökull. There is a law governing the Civil Emergency Service which is a part of the National Commissioner of the Icelandic Police, and the Department of Civil Protection and Emergency Management.

Practical action on the ground is also being undertaken to build resilience, such as the Hekla Forest project described in Chapter 3.

Endnotes

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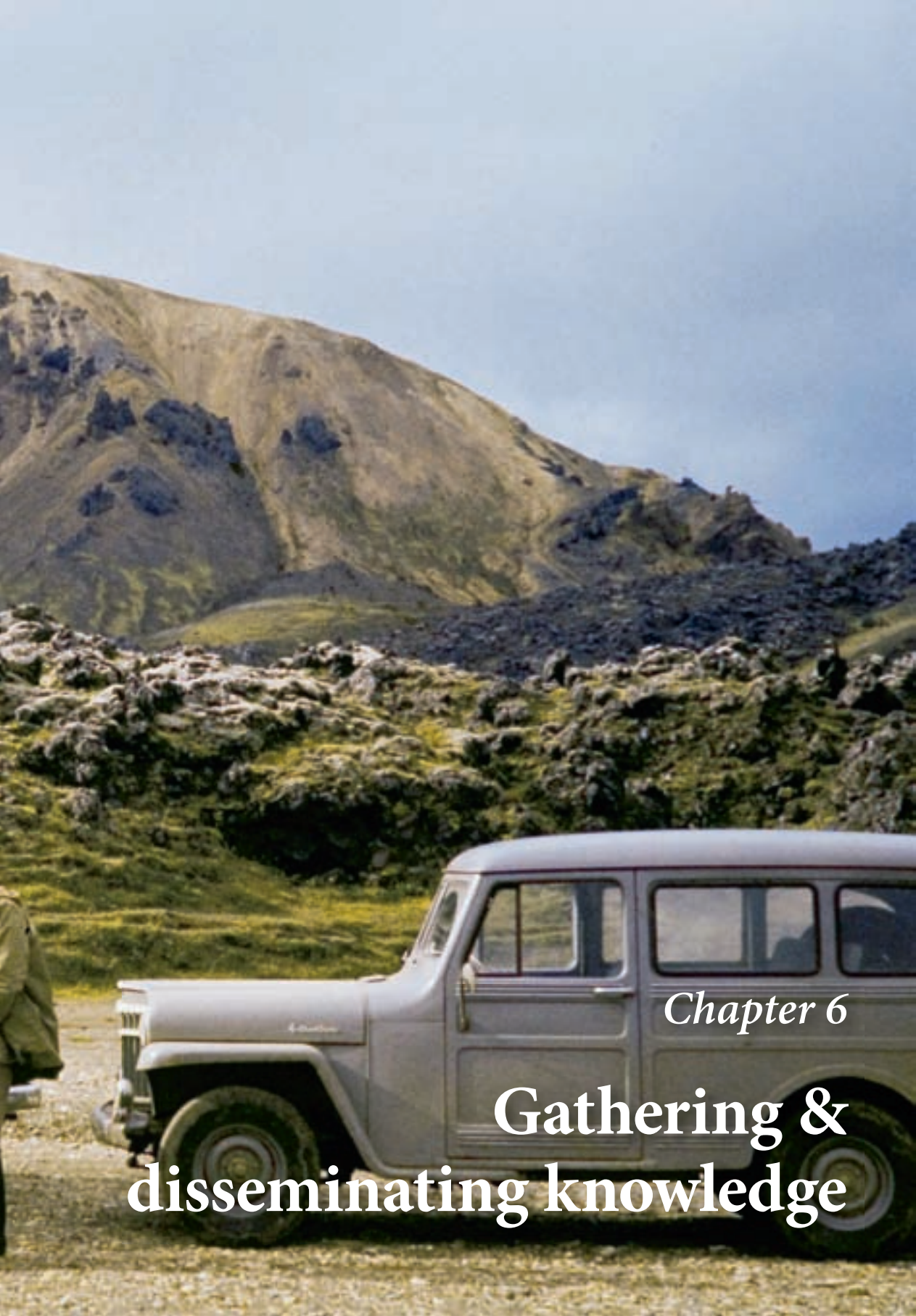

Chapter 6

Gathering & disseminating knowledge

It should be clear from the previous chapter that generating and gathering knowledge is a critical component in the evolution of land reclamation and soil conservation. Over the century, many approaches and techniques have been researched, devised and deployed to stabilise drifting sand and to revegetate the land surface. Complementary to the many types of plants assessed and used, have been a range of physical measures and development of specialised hardware. Some have been successful, others have failed, and yet others have passed their usefulness. However, it is important that the knowledge gained is disseminated to the relevant interests, especially practitioners on the land, farmers and their advisers, and Ministers, politicians and their advisers. These are the subjects of this chapter.

Gathering knowledge from others

Throughout the century, Iceland has benefited from visits to other countries by its own experts and by visits of other experts to Iceland. For example, knowledge and experience gained from visits to Denmark and other parts of Scandinavia, and to a lesser extent knowledge brought from Denmark by the first head of the Icelandic Forestation Service in the early decades of the 20th century, was used by Gunnlaugur Kristmundsson. But the most significant changes arose from the travels of Runólfur and Páll Sveinsson and their successors to the USA in particular, and by visits of external experts to Iceland.

Runólfur Sveinsson was quick to implement innovations. He imported varieties of grass from the USA, Canada and Sweden, and arranged for the Agricultural Research Institute to conduct research trials at Gunnarsholt. Páll had the same approach. When he returned from the USA, he brought a collection of grass varieties to use in revegetation experiments at Gunnarsholt, along with various types of native lyme grass. Results from these experiments were so positive that cultivation of unvegetated sand and gravel areas was begun on a large scale.

A very significant action came in 1953, when Runólfur Sveinsson requested that the United Nations Food and Agricultural Organization (FAO) send specialists to organise and implement research on the causes of soil erosion and land degradation, and to determine the grazing capacities of vegetation and the land. This request was sent through the Ministry of Agriculture, along with a report in English[1] stating that there was no agreement on the reasons for soil erosion and land degradation in Iceland, or on how much degradation had occurred since The Settlement. Most disagreement revolved around the role of livestock, particularly sheep. On the one hand, silviculturalists claimed that overgrazing destroyed the forests and allowed wind erosion to begin. On the other hand, sheep farmers contended that sheep had little or no impact and that vegetation grew and improved with increased grazing. Runólfur was quite clear that there were too many livestock; he argued that increased damage to vegetation arose from animals being kept out of doors in the winter

Photo 6.1 *John Baden Powell Campbell, FAO Adviser, in the field* BS

as a result of insufficient fodder production. The report is an extraordinarily penetrating analysis of the situation and worth reading even now, over 50 years after it was written. He stated that:

> "Many factors unite in causing erosion. These are the usual: severe climate, dry and long-lasting storms blowing from the same direction, cutting of bushes and tearing of heather, excessive grazing and even the volcanic eruptions themselves – and when volcanic soils begin to erode, in some places even up to 4 metres in thickness, the erosion is beyond control so long as rivers, lakes or bog soil do not hinder further spreading."[2]

This analysis and request for advice was used by FAO as a model for applications for technical assistance from other countries. This was a clear indication of Icelanders understanding of the problems of land degradation and their desire to learn from others: a very common and welcome Icelandic characteristic. Knowledge exchange was firmly underway.

The FAO sent a Canadian grazing science specialist, John Baden Powell Campbell. From his visits to Iceland in 1954 and 1956, he reported that the highland commons were generally in good or fair condition, noting that some grazing land in particular districts was over used, and considered that grazing by horses was largely to blame. He stated that:

> "Assessments indicated that horses were mostly responsible for the overgrazing in these areas. … The large, and substantially pointless, number of horses deprive Icelandic farmers those pastures that could otherwise be used to increase the number of sheep."[3]

Campbell proposed a limit of 750,000 sheep in Iceland, but surprisingly made no recommendations about the number of horses. He proposed appointment of a committee of Icelandic scientists to structure research on grazing and "… that a thorough set of

directives be established regarding the classification, treatment and utilisation of grazing commons that will be revegetated from barren lands"[4]. He also recommended that Gunnarsholt become the headquarters for land reclamation research. This did not happen for 30 years when the strictures of the 1965 Act, which made the Agricultural Research Institute the key scientific body, were removed.

The condition of the commons was much worse in reality and Campbell clearly failed to understand either the scale or extent of the problem. Perhaps the large reduction in the sheep population due to disease in the years prior to his visits played a role in safeguarding sensitive land. And, curiously, he also failed to understand the practical importance of horses for transport and work on farms, as well as their long standing cultural significance to Icelanders. Nevertheless, Campbell was instrumental in stimulating the first work to measure grazing capacity in Iceland: a theme which was to continue for many decades as one of the most fundamental issues in seeking to stabilise the land and ensure continuation of a prosperous farming sector based on sheep grazing.

Photo 6.2 *Ingvi Þorsteinsson* SCSI

Under Campbell's guidance, the Sand Reclamation Service worked with specialists from the Agricultural Research Institute, establishing systematic research on plants for revegetation, land reclamation strategies, the vegetation composition of grazing lands and commons, livestock grazing, and fertiliser requirements. Campbell recommended research on revegetation and surveys of plant succession in grazing areas, in part to determine the nutritional value of the vegetation. Work was concentrated on drifting sand areas north of Hekla and at Gunnarsholt. Naturalists Steindór Steindórsson and Ingvi Þorsteinsson pioneered this work. This was followed by vegetation mapping of Iceland's commons. Campbell also recommended arrangements for supervising the research work. Björn Sigurbjörnsson took over this role, working at Gunnarsholt and other sites around the country from 1957 to 1963, as a specialist for the Sand Reclamation Service and the Department of Agriculture University Research Institute. The Canadian's time in Iceland played a major role in creating the foundation for systematic and rigorous research work on revegetation and vegetation conservation.

A key figure in leading and supervising research for a long time was **Ingvi Þorsteinsson**. A specialist in vegetation mapping and vegetation research at the Agricultural Research Institute from 1955 to 1992, he acted as a land reclamation consultant at the Soil Conservation Service from 1965 to 1970 and was a founder and Chairman of an NGO *Vegetation for the People* in the 1990s. He led the work to produce the vegetation map of Iceland's highlands and lowlands from 1966 to 1989. He was awarded the Soil Conservation Service's Land Reclamation Award in 1997.

Grazing capacity research

In the 1950s, the Sand Reclamation Service began evaluating the grazing capacity of the highland commons to understand how to protect them and to revegetate them effectively. The foremost specialist in these issues, Páll Sveinsson, wrote the following in 1957:

> "Although in some ways this is a new direction in soil reclamation in this country, it is the general trend in agronomy, i.e. on the one hand vegetation protection and restoration, and on the other animal husbandry. These two activities must exist together, and it is therefore a dangerous doctrine that has been touted to farmers in recent years. You should and need to expand your fields, i.e. livestock must proliferate, but at the same time nothing is done to motivate them to meet feed needs of livestock during that time when they are free grazing.
>
> In recent years, there have been enormous advances in husbandry as hay fields have expanded, even multiplied in size. Livestock has therefore increased very rapidly, and will continue to increase. This trend has resulted in crowded conditions in pastures and commons. While this continues, and nothing is done for our valuable commons, perils await. There is a need for more than just words. Farmers need to learn to appreciate and understand their natural resources, which consist of pasture commons, and it is these (commons) that they can least of all be without."[5]

The next obvious step in understanding grazing capacity was to assess vegetation resilience and produce a vegetation map. This was a large undertaking by the Agricultural Research Institute and was not completed for all of the highlands until 1990. The research revealed that Icelandic vegetation and soil are highly sensitive and in greater danger of degradation than in other countries. The soil is drought prone and lacks binding materials. Vegetation cover plays an important role in protecting the soil and preventing it from blowing away. If this cover is weakened, water and wind erosion will occur. This is exactly what has happened in Iceland over the centuries, and the result is bare ground. The investigations showed that large areas of the country were highly degraded with little vegetation cover and low amounts of organic material. Much of the land was also arid. These conditions made it difficult to reclaim previously vegetated land. Natural rejuvenation of land is a slow process taking decades. Even revegetation efforts using seed and fertiliser can be difficult under such conditions.

The scientist Ingvi Þorsteinsson wrote the following in *Conservation of Vegetation*:

> "A result of overgrazing is the diminishing grazing value of vegetated areas, because the best plants disappear, the vegetation cover thins out and the plants' root system weakens. In turn, this leads to lower yields and lowering grazing tolerance, but also makes vegetation less capable of holding the soil together and thereby preventing wind erosion."[6]

Large grazing and land use experiments were undertaken from 1975 by the Soil Conservation Service and the Agricultural Research Institute, and involved many other partners, including farmers and their representative organisations. Dr. Ólafur Guðmundsson of the Agricultural Research Institute directed the project. Financial support and advice was provided by the United Nations Development Fund and FAO, and in particular from Dr. Robert Bement, a grazing specialist and farmer from Colorado, USA.

Photo 6.3
Sheep grazing and trampling undermining the root systems and causing further vegetation loss and soil erosion AA

The research concluded that overgrazing weakens the root system of plants, in turn reducing their tolerance to trampling, and therefore increasing vulnerability to water and wind erosion. Research indicated that the condition of vegetation is generally determined by the level of grazing stress. The consensus was that systematic grazing management was by far the best method to protect and strengthen vegetation, and was less expensive than vegetation restoration[7].

In the later 1970s, large grants from UN agencies enabled research, experimentation and training to be undertaken. Fencing material for large grazing areas at nine experimental sites around Iceland was purchased, as well as windmills and piping for pumping water for livestock in dry areas. The impact of livestock on different situations was assessed in detail. The objective of the grazing trials was to maximise product yield per hectare and per livestock unit, while at the same time maximising vegetation cover, plant mix and vegetation biomass. This was the first time that so many specialists from diverse disciplines had worked collectively on a project under one management team. The conclusions of the research were limited. Although numerous lectures were given, articles published in scientific journals and farming periodicals, and innumerable reports filed, many conclusions have never been assessed or published. A clear message from this failure is the need to ensure that research conclusions, and their translation into practical guidance on vegetation, soil and livestock management, are produced expeditiously.

More recent research has, for example, ascertained the critical link between palatability of species and grazing pressure. Grasses are able to resist grazing pressure to a greater extent than other species, with dwarf shrub heath less resistant and moss heath having the lowest resistance[8]. Detailed assessments of the type of plant cover are, therefore, an essential prerequisite to determining grazing capacity alongside other factors, such as surface cover.

Vegetation assessments over the past decade have focused primarily on horse pastures in the lowlands (horses do not generally graze the highland commons). Pasture land was evaluated to ascertain where horse grazing was not sustainable, followed by detailed surveys of the worst areas. Proposals for implementing improvements were then made in consultation with landowners. To facilitate the work, the Soil Conservation Service and the Agricultural Research Institute published

Horse Pastures[9] which divided horse grazing areas into 5 categories according to severity of grazing, from little to very serious. Soil Conservation Service staff visited numerous farmers annually to inspect vegetation and advise on land use.

Assessing seed types for revegetation

It is essential to stabilise the sand surface so that sand drifting is halted or, at least, substantially eliminated. The well tried and tested method, used from the earliest work on reclamation to the present day, has been to revegetate the surface by planting seeds, as revegetation does not happen naturally in most areas of Iceland. Assessing the most effective seeds to use has been a crucial element in the reclamation story. There are relatively few native seed varieties in Iceland suitable for reclamation and throughout the century trials of non-native species have been undertaken. However, one species, the native lyme grass *Leymus arenarius*, has been the most successful over the centuries.

Lyme grass

Any inspection of sand dune areas in Iceland quickly reveals that the native sand capturing lyme grass *Leymus arenarius* is by far the most effective, irrespective of location in the country. It is successful in the highlands, in the lowlands and on the coast. Lyme grass thrives on sand blow and is able to grow as the sand accumulates and its extensive root structure, growing at a considerable rate, is able to capture and stabilise the sand. It is the early pioneer species, with other species taking over when the sand has stabilised. Experiments in the 1950s demonstrated that of 5 ecotypes tested, the most effective for retarding drifting sand came from Háfstorfa, near Þykkvibær on the south coast[10]. Cultivating this ecotype in controlled situations, where the seeds could be harvested and processed each year for use in revegetation work elsewhere in Iceland, has been an important role of the land at Þykkvibær, combined with the seed processing unit established at Gunnarsholt. A number of operational and technical issues had to be overcome before lyme grass became the seed of choice for halting drifting sand. The seed is hairy, so it had to be hand sown until techniques for coating the seed were devised. It was difficult to collect

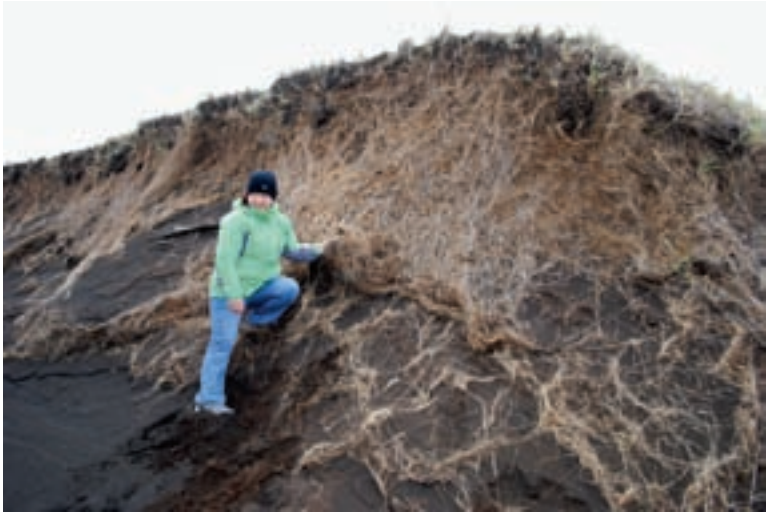

Photo 6.4
Lyme grass: the primary plant for sand stabilisation showing its very extensive root system JBJ

Photo 6.5
Björn Sigurbjörnsson photographing the trial plots at Gunnarsholt where he began research decades earlier RC

the seed in the quantities needed by using off the shelf machinery; hence specially adapted versions had to be devised in the workshops at Gunnarsholt.

More recent research on the characteristics of lyme grass conclude that, for best results, the plants should be cultivated in prepared plots as these will increase the ease of seed collection and the volume of seed collected, and that seed should be drilled to a depth of 5 cm at the reclamation sites[11]. For coastal sites, seed of local provenance should be used because it will have a greater salt tolerance.

Other grass and legume varieties

As an early coloniser, lyme grass cannot provide a totally stable and wholly revegetated surface. Other dune grass species, such as American dune grass *Leymus mollis*, have been trialled in Iceland, but they have been less successful than lyme grass on bare sand areas. Sand dune bluegrass *Poa macrantha* was collected and planted, but the trial failed because the seeds did not germinate.

Legumes are important as they fix nitrogen from the atmosphere. Between 1957 and 1963, Björn Sigurbjörnsson supervised nearly 50 experiments and studies on grass and legume varieties at Gunnarsholt and to the south on Geitasandur covering hundreds of plots, as well as at other sites around the country. The Icelandic variety of common meadow grass *Poa pratensis,* named *Katla,* proved to be a successful stabiliser, but lack of seed hampered its extensive use. Native legumes, such as the sea pea *Lathyrus japonicus* and vetch *Vicia cracca* and *V. sepium*, do very well when grown with other plants, but they are not effective colonisers of bare ground or low fertility soils. The sea pea seems to tolerate a wider range of conditions than the vetch, but its effectiveness is reduced probably because of lack of rhizobium bacteria for the roots. Seed production and machine harvesting is possible for the vetches, but seed from the sea pea has to be hand picked. Growth experiments were also

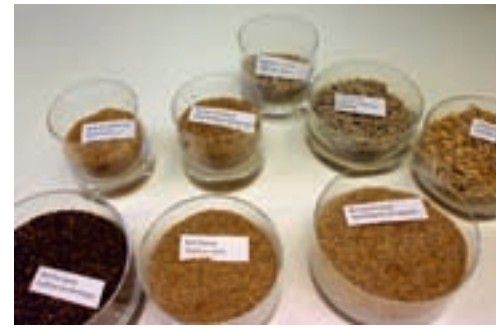

Photo 6.6 *Seed types used in revegetation* RC

undertaken using seeds of *Agrostis*, *Bromus*, *Phleum*, *Leymus, Poa*, *Agrophyron*, *Festuca* and *Phalaris*, along with legumes *Lathyrus*, *Medicago* and *Lupinus*. Results showed that many varieties, both native and imported, displayed excellent growth. No rhizobium bacteria were available for the legumes to be used on a large scale at the time. The legumes also were killed off in the winter.

Red fescue *Festuca rubra*, Bering's tufted hair grass *Deschampsia beringensis* and Kentucky bluegrass *Poa pratensis* have proved to be reasonably successful. They have been used for the reclamation of relatively stable areas, such as on the sandur planes of the south coast and in the relatively stable bare sand areas in the north, for example in the Lake Mývatn area. The grasses need fertiliser to become fully established and when the effects of fertiliser diminish in the rather poor soils, the plants are replaced by the native vegetation.

Overall, the most successful species were the native Lyme grass for the sandy areas and Red fescue *Festuca rubra* for revegetation of other types of soil.

Nootka lupin

One species that has been used intensively in certain locations is the Nootka lupin (sometimes called Alaska lupin in Iceland) *Lupinus nootkatensis*. Seeds first collected from Alaska in 1945 were not distributed widely until after 1990 when technical problems of seed harvesting were solved by adjustments to threshing machines. It has since become one of the main plants used in revegetation and, along with red fescue, second only to lyme grass. In recent years, it has only been used in large sandy areas where other methods are either too expensive or not feasible. It is useful because of its capacity to fix nitrogen through its root nodules and therefore reduce the use of expensive, imported fertilisers. It has been particularly successful on large sand and gravel areas and along main roads as it stops sand blowing onto and blocking the road and therefore helps to reduce sand storms which reduce the visibility on the road to a dangerously low level (see Chapter 3 example of Mýrdalssandur).

Photo 6.7 *Successful use of lupin to stabilise sand* ÞK

Use of lupin has been, and remains, an emotive subject in Iceland because it is a non-native species, it spreads rapidly and it has been sown by volunteers without thought in sensitive locations, such as in the Skaftafell National Park. In consequence, the Soil Conservation Service and the Icelandic Natural History Institute have mapped existing lupin in the highlands and on nature reserves and identified ways of eliminating it from selected sites. Experiments with the herbicide *glyphosate* show that dense mature lupins can be killed with a single application, but only limited tests have been carried out. Further rounds of application of other herbicides would be needed to halt germination of the large number of seeds in the soil, although how many and how often for complete success is not clear; applications are likely to halt seed germination in other species. Nevertheless, using herbicides in protected areas raises environmental concerns.

Birch and willow

Trees provide a middle, and eventually, an upper story in the vegetation and their growth habit lets light reach the woodland floor and allows ground cover species to grow. Research has shown that they are more resilient to tephra deposition[12]. Planting trees has been a major activity since the beginning of formal government action on land reclamation, particularly by the Iceland Forest Service, the Regional Forestry Associations, and the Soil Conservation Service.

The species used in the early decades was the native Downy birch *Betula pubescens*. Birch was superseded by other, non-native species for most of the second half of the century, but its use doubled to around 30% towards the end of the century. Birch has great potential for extensive use as a reclamation species[13]. It is estimated that between 100,000-200,00 ha (an additional 1-2% of the land area) has potential for birch woodlands

Photo 6.8 *Lupin in Morsárdalur, Skaftafell National Park* RC

Photo 6.9 *Birch woodland in Skaftafell National Park* RC

compared to the coverage of only 1.1% of the surface area in 1991, but land ownership, traditional attitudes and lack of public interest are obstacles. Willow *Salix species* (especially Tea-leaved willow *Salix phylicifolia* and Woolly willow *Salix lanata*) have been the other most common native species used.

With the reduction in grazing, it has been possible for birch and willow to become established, particularly in the lowlands. Obviously, seed production is less prolific than for grasses, but trees provide a more natural vegetation cover which also conforms to the past native vegetation mix in southern Iceland, as

Photo 6.10 *Birch and willow growth* SCSI

revealed by pollen analysis (see Figure 1.7). Seedlings are more effective than seeds and these are prepared in tree nurseries. Ground preparation is usually necessary by planting legumes and grasses and applying fertiliser, especially where freeze/thaw cycles are common.

The predominant non-native tree species used have been larch *Larix sibirica*, pine *Pinus contorta,* and spruce *Picea albies* and *Picea sitchensis*, collected originally from the boreal regions of the northern hemisphere. The trial areas at Hallormsstaður, near Egilsstaðir in the eastern fjords, have over the century formed what can truly be called a forest in Icelandic terms. Other more recent examples of tree planting occur, especially around some farms in south Iceland, to act as wind breaks, provide some timber and improve the landscape.

A few arboretums have been established in parts of Iceland, such as at Höfði near Dimmuborgir in north Iceland and at Múlakot in Fljótshlíð in south Iceland, by local groups or woodland specialists working for the Iceland Forest Service, as a demonstration of what can be achieved with the right species planted in the right location.

Barley

Farmers' interest in growing barley for animal feed lead to experiments in the early 1940s. Unfortunately, the weather was unfavourable for growing grain so the crops did not reach maturity. In 1964, the worst summer for grain growing for three decades, all of the breeding varieties of barley and oats were destroyed, taking with them years of breeding work and quality genetic material. Páll Sveinsson saw opportunities in seeding sand plains with barley for 2-3 years which was sufficient for vegetation succession to be established. Experience showed that he was absolutely right, with native willows and birch now colonising some of the barley fields of the 1960s.

Rhizobium bacteria for legumes

In the mid 1990s, attention turned to research at Gunnarsholt on plant colonisation, plant succession, grazing capacity, plant and bacteria symbiosis, carbon sequestration in vegetation and soil, coating seeds and sowing methods. The Icelandic Research Council and others supported research on the production of hardy bacteria stock for sowing lupin, for cultivating special bacterial strains for

Photo 6.11
The arboretum at Múlakot in Fljótshlíð
RC

Photo 6.12 *Laboratory preparation of bacteria stock for sowing lupin* RC

Photo 6.13 *Seed processing in the factory at Gunnarsholt* UB

Sea pea *Lathyrus japonicus*, and for research on the use of fungus root, i.e. mycorrhiza, when sowing lyme grass seed. The objective was to reduce significantly the amount of fertiliser used on newly sown lyme grass, since fungus root helps the root system to extract nutrients and moisture from barren sand.

Seed collection and processing

Once research had determined the most effective seed types, it was necessary to develop techniques for collecting and processing large quantities of quality seeds for use in land reclamation projects.

Seed processing plant

An important innovation was the establishment of the Fodder and Grass Seed Production Centre as a separate state company at Gunnarsholt in 1961. Björn Sigurbjörnsson supervised the experiments to cultivate grass and barley at Gunnarsholt to support this production. The challenge was to test the effects on the sand and soil of different row spacing, seed quantities and fertilisers, primarily nitrogen. Trials to determine the impact of the frequency and time of mowing were also undertaken to improve grass pellet production. Results from all of these experiments were made available to grass pellet companies, but were not published.

Photo 6.14 *Seed processing at Gunnarsholt* JRB

Distribution by aircraft from 1958 meant that the seeds needed to be made heavier in order to reach the ground at the same spot as the fertiliser granules when released from the plane's hopper. Coating the seeds with fertiliser was an obvious way forward, but there was no capability to undertake this task in Iceland and coated seed had to be imported. It was not until 1987, when the Soil Conservation Service acquired the technology and equipment for seed cleaning and processing, that the special adhesive to attach the coating materials to the seed was developed. The seed coating process requires diatomite, lime and fine sand. The diatomite company at Lake Mývatn in north Iceland and the state cement works donated these

Photo 6.15 *A novel hay making machine attached to the rear of a truck in 1958* SCSI

materials. This was a large-scale operation with the factory producing 7 tonnes of coated Bering's tufted hair grass and 4.3 tonnes of coated red fescue in 1988. The diatomite plant continued donating all the diatomite needed until it ceased operation in the early 2000s. Some businesses, such as Eimskip, the freight company of Iceland, donated equipment indispensable for seed processing.

The seed processing unit at Gunnarsholt has since played a key role in land reclamation work, making it possible for the Soil Conservation Service to provide volunteers with seed and plants, as well as supply seed for its own use and for selling to farmers, municipalities and institutes. In the past decade, supervision of seed production has been improved under the direction of Magnús Jóhannsson. A modern laboratory led by Ms Anna Bau, monitors quality, conducts research on bacteria strains for legumes, and performs extensive studies on mycorrhiza. Seed has been exported since 1990, mostly Bering's tufted hair grass, lupin and lyme grass to Alaska, Bering's tufted hair grass to Greenland, and some seed occasionally to Newfoundland.

The annual seed harvest in the 1990s at Gunnarsholt was gathered from around 1,000 hectares of land. Additionally, farmers produce lupin seed. The annual collection of lyme grass seed ranges from 20 to 30 tonnes, mostly from enclosed land reclamation areas along the south coast. In 1991, for example, 17 tonnes of Bering's tufted hair grass seed came from seed fields at Gunnarsholt. In addition, there was one tonne of red fescue, 10 tonnes of tufted hair grass, 3 tonnes of lupin and lesser quantities of other varieties from Gunnarsholt and other farms in south central Iceland. In 1997, the total harvest of domestic seed was over 31 tonnes and, when added to imported seed, the total production of seed for revegetation work reached 124 tonnes.

Innovations in machinery

Many innovations have been necessary to adapt off the shelf machinery to the special circumstances in Iceland. The workshops at Gunnarsholt were the design point, test bed and machinery production centre for devising new equipment and for remodelling existing equipment to suit the needs and circumstances of the different types and mixes of seeds and fertilisers used on the ground and from the aircraft. The photo sequence

Photo 6.16
A specially devised machine for sowing lyme grass SR

Photo 6.17
An adaptation for harvesting lyme grass SR

Photo 6.18 *Further development of a lyme grass cutter* RC

gives some idea of the type of adaptations required.

By far the most important innovation was the design of cutters for harvesting the heads of the lyme grass. Other innovations have included building of a new under carriage of hardened steel for the seed drill machines imported from New Zealand to withstand the stony surfaces. A new machine for sowing lupin seed was developed and resulted in improved germination, and another was designed for planting seedlings. A box with computerised timing and temperature control was built to test the germination conditions for all types of seed. A hydraulic

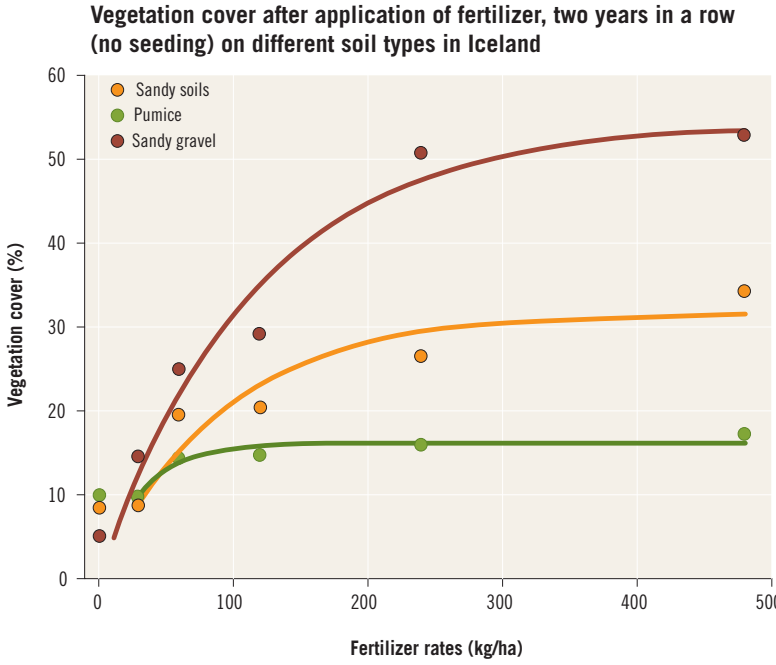

Figure 6.1
Graph showing the effects of fertiliser application
Source: Magnús H. Jóhannsson, Soil Conservation Service. With kind permission.

elevator was constructed to load fertiliser and grass seed in to the DC-3 aircraft. A portable wind tunnel was constructed fully equipped to record the movement of soil particles under different wind speeds. A tank was adapted and a sprayer fitted for distributing binding agents to stabilise sand. In addition, a number of specialised pieces of laboratory and field equipment have been designed and constructed, including a drying cupboard for soil samples, an instrument for sampling gravelly and stony soil, and field dust and sand samplers with data loggers to record sediment movement.

Use of fertiliser

Fertiliser experiments were begun in the later 1950s and their conclusions were published in the 1961 *Árbók landbúnaðarins* (*Agricultural Yearbook*), as well as in the monthly farming paper *Freyr* in 1963. They showed that the volcanic soils were poor in nitrogen, particularly the sand plains, phosphorus was often bound to the soil particles and not readily available to plants, there were no deficiencies of trace elements, but there was no need to apply potassium in revegetation.

A great deal of further investigation over a quarter of a century has been undertaken on the trial plots at Gunnarsholt. The key conclusions are as follows[14]. Fertiliser application stimulates greater plant germination and increases floristic diversity. Grasses planted as nurse crops are out competed quickly by native species, provided fertiliser has been applied at the appropriate times and in the appropriate quantities. As a result, there is an observable increase in nutrients, vegetation cover, organic litter and soil crust. However, there are no generic answers on the level or mix of fertilisers or the type and amount of plants and seeds; site and area specific decisions are needed. For example, on pumice the effect of fertilization is low. On sand, fertilisers are effective. On sandy gravel, the effect is quite good giving an increase from 5% to 25% vegetation cover in two years. Water holding capacity is probably the major reason for the differences[15]. It is also essential to use the

right amount of nitrogen and phosphate; too great a volume can impair the mycorrizhal function in the early years. Slow release and easily soluble fertilisers are most beneficial, but they tend to be extremely expensive. A very significant finding is that fertiliser application without seeding can stimulate revegetation by native species whose seeds are in the substrate or soil; as a result species diversity and soil organic carbon increase (Figure 6.1).

Developing physical measures, new techniques and machinery

Many techniques to aid land reclamation and soil conservation have been tried over the century, some very successful and some less so.

Stopping sand drift by constructing barriers

The most elementary, and yet the most successful mechanism for halting sand drift is the construction of barriers to transform a deflation plain into a dune field. Basically, the barriers reduce the saltation effect of small sand grains dislodging and setting in motion larger ones and allow sand to accumulate in one place. They also provide the opportunity for dune grasses, which thrive on drifting sand, to become established and gradually capture the sand on either side of the barrier, and so reduce the amount of drifting. The barriers are most effective when erected perpendicular to the prevailing wind direction: north east wind in south Iceland and south west wind in the north east.

Icelandic reclamation workers learned the crucial lesson of building barriers well up wind of the sand drift area and as near as possible to the source areas of the sand. Reducing the amount of sand drifting southwards from the Þjórsárdalur valley and the Hekla area, together with capturing the new ash and pumice from eruptions of the Hekla volcano down the Rangár river valley towards Gunnarsholt and what is now the town of Hella, are cases in point.

Photo 6.19 *New style of timber and wire fence tested for efficiency* JRB

The barriers were usually constructed of locally available basalt rock, were a few hundred metres long and always constructed in a straight line. If stone was not available locally, wooden fences were constructed with the same beneficial effect, especially as they required much less labour to construct. Given the general shortage of wood, this method was used less frequently, particularly from the 1960s. Icelanders saw the benefits of building walls up wind of their farmsteads to stop the buildings being overwhelmed. These methods were also applied at the coast where sand drift and sand storms were a frequent occurrence. Other materials were sometimes used as a substitute, such as old hay in the late 20th century which was no longer nutritious for animal feed.

Photo 6.20 *Using old hay to collect sand* AA

Keeping the surface wet: irrigation and water level manipulation

Iceland is often perceived as being very wet, but the climatic reality is that it is prone to desert conditions. Over much of the highlands and the north, and a crucial finger of land following the Þjórsádalur valley to the south coast, average annual precipitation is less than 600 mm per annum. At Hólsfjöll and Hólssandur in north east Iceland the precipitation is often less than 250 mm per annum. Only a few areas in the highest mountains in the north west fjords and in the south east have more than 2,000 mm per annum. The volcanic andosol soils have a low moisture retaining capacity, so the land dries quickly. Much of the surface is bare, consisting of generally fine grained sand or lesser size, with only gravel and larger materials remaining on the surface. Also katabatic winds from the ice caps have a drying effect. Putting all of these factors together means that the land surface is often dry and, therefore, the sandy surface material can easily be blown. Indeed, much of the interior is by definition a desert. Maintaining a damp surface reduces significantly the risk of wind blow and loss of topsoil, hence various approaches to wetting the surface have been tried over the decades.

Vegetated land has been irrigated to increase harvests since earliest times, but at the end of the 19th century irrigation was used to help reclaim unvegetated land by raising groundwater levels. The technique was quite simple: water was taken from rivers and transported in purpose-built canals to the site. The projects were reasonably successful with good vegetation growth. In some places, glacial sediments in the water caused the canals to become blocked, and farmers neglected to maintain the infrastructure. By the middle of the 20th century, many of the older canals were on the verge of collapse and were never repaired. Later in the century,

Photo 6.21
Dam on the Skaftá river at Kirkjubæjarklaustur. A unique private hydro power station for pumping water to keep the bare sand surface wet
Painting by Sigurður K. Jóhannsson EE

dams were constructed to maintain the level of water and allow canals to take water off to the reclamation areas. In a few instances, rivers were diverted to provide water supply to dry areas, but these diversions were not easily maintained as many of the rivers are subject to spate conditions. These methods were particularly successful if there was seeding and fertiliser application at the same time. But, overall, these techniques have not been very successful in Iceland.

At times, there was opposition from salmon fishing interests on rivers in south Iceland as they claimed that diversions of water and canalisation caused the rivers to cool. They often won the argument.

Photo 6.22 *Rapid and dense growth of vegetation on former bare sand inside an 11 year old fence demonstrates the effectiveness of fencing out livestock. Lyme grass as a primary coloniser* BS

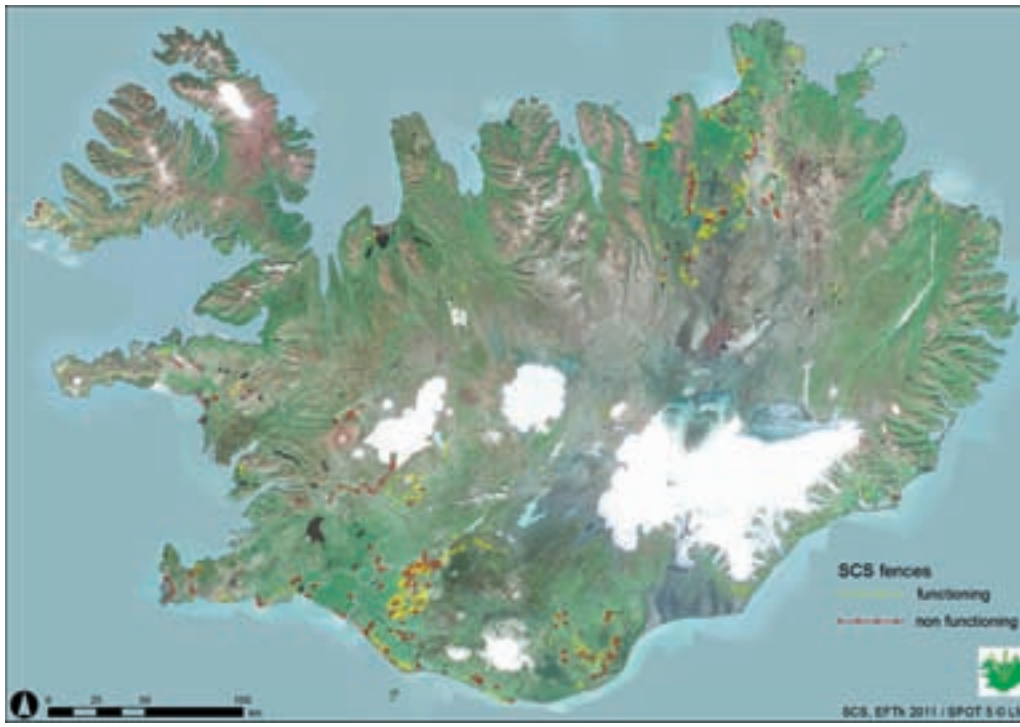

Figure 6.2 *Fences established around Iceland by the Soil Conservation Service*
Source: Soil Conservation Service

Fencing and livestock exclusion

Livestock exclosures using fences were one of Iceland's primary revegetation techniques during the 20th century. Their primary purpose is to restrain livestock, and especially sheep, from entering areas being reclaimed. This is particularly important at an early stage when the ground surface is still bare and unstable before the seeds germinate and the revegetation begins to take effect. By the end of the 20th century, there were about 170 fences around the country (Figure 6.2). The older fences were barbed wire attached to drift wood posts. In the 1960s, the technique changed with barbed wire at ground level, net fencing above and one or two wires at the top. All were zinc coated. Steel posts became more common in the mid 20th century. The posts were never set in concrete or similar material due to prohibitive cost. The first electric fences were introduced in 1981, and by 1990 there were 14. They require less maintenance than barbed wire, which by the 1990s had been largely replaced. Electric fences are most successful in desert conditions and least successful where the area is prone to wet weather and high vegetation growth.

Fence maintenance is a never-ending task, the amount of work required varying from year to year. Old, unnecessary enclosures must be removed, and others replaced. Soil Conservation Wardens usually supervise this work, often contracting out the work. Heavy snow is a particular problem, causing fence wire to break and fence posts to collapse.

The best evidence of the effectiveness of fencing to exclude livestock and stimulate revegation is that in recent years hundreds of kilometres have been removed as the ground is now stabilised.

Photo 6.23 *Wind erosion reduces a fence post to a small stick with small notches where the wire protected the post. Note the human fingers for scale* RC

Halting land loss by controlling rivers

The Soil Conservation Service has long been involved in preventing land loss caused by river bank erosion. Heavy rainfall and rapid snow melt lead to rivers rising rapidly and over topping their banks with the inevitable associated land loss, as well as damage to the transportation infrastructure. Following eruptions under ice caps, the floods are of even greater volume and velocity with corresponding increases in land loss. The most effective technique is to construct levees at the most vulnerable points where the river in flood would break its banks and spread onto farm land; this usually occurs where there is an abrupt change in the course of the river. These measures are also used to moderate water flow around bridges and other infrastructure to protect the roads from being washed away.

After eruptions under ice caps the tephra is carried downstream by rivers and deposited on the lower ground. It has proved necessary to remove the material deposited from the river bed by mechanical excavation to allow for more sediment to be deposited

Photo 6.24 *Gathering stone to construct a levee to stop flooding in 1940* HÓH

Photo 6.25
Levees to control river channels and to reduce flooding and consequent land loss
RC

and to stop the river over topping its banks and flooding the surrounding land. A recent example was in 2010 when, as a result of the Eyjafjallajökull eruptions, floods and sediment transfer to the rivers beyond their capacity caused flooding of farmland and filling of the stream beds. The material had to be dug about by large excavators and new, higher levees built to allow the channels to carry more sediment out to sea and lessen the risk of flooding of farmland. For those areas of farmland covered by ash from eruptions, the Soil Conservation Service has supplied fertiliser to stimulate the growth of the vegetation under the ash to reduce ash being blown into settled farming areas.

Photo 6.26 *Tephra from the Eyjafjallajökull eruption 2010 covering the vegetation on farmland* RC

Land reclamation from the air

In the 1950s, there were a number of forward looking people who began to realise that aircraft could be used to spread fertiliser and seed over areas difficult to reach by conventional methods. At that time, farmers only had small seed and fertiliser spreaders on equally small tractors. Agnar Kofoed-Hansen, Director General of Civil Aviation in Iceland (son of the first Director of Forestation), was one of these individuals. In 1953, he wrote an article in *Morgunblaðið* on revegetation work in New Zealand, describing how aircraft had been used over the past five years to spread fertiliser and seed on a large scale. He proposed that the Icelandic government look into the possibility of adopting the same method. A number of people were attracted to the idea, including Páll Sveinsson. A pilot, Björn Pálsson, wrote an article in the Sand Reclamation Service's 50th Anniversary Publication in 1958 stating:

> "It is easy for heavy farm machinery to navigate in lowland regions, and there it most certainly should be used. However, upon the heaths and commons, and other areas where the terrain is difficult to traverse, we must enlist aircraft into

Photo 6.27 *Small aircraft used for dispersing fertiliser* SCSI

> service as other countries that embrace the newest technologies have done. In New Zealand and the United States of America, aircraft fly hundreds of thousands of hours yearly spreading fertiliser, seed and insecticide. I am in no doubt that this is what we Icelanders should also do. We need to acquire aircraft to spread fertiliser and seed in the heaths and commons."[16]

A government appointed committee concluded that buying a plane was prohibitively expensive. Undeterred, Karl Eiríksson, the manager of a local flying school, applied for a licence to import a purpose built plane and, with his own money and financial support from Iceland's Consul in New York, a plane was bought from the USA and flew its first fertiliser run from Gunnarsholt in June 1958. Over the summer, 320 tonnes of fertiliser and seed were spread on 900 hectares of land: ⅓ Timothy grass, ⅔ red fescue combined with 100 kg of triple phosphate and 200 kg of nitrogen fertiliser per hectare. Such was the success of the airborne spreading, that in 1962 the Minister of Agriculture authorised the Sand Reclamation Service to buy 2 aircraft from the private operator. By 1967, one had crashed and the other was no longer airworthy. A larger capacity replacement was purchased and remained in service until 1982. A major step forward was the offer from the national airline, Icelandair, to supply a Douglas Dakota DC-3 plus parts and free maintenance. This aircraft had a much larger payload capacity and longer distance capability than previous aircraft. Following conversion, it was available in 1973 and was in use until 2006. Fittingly, the aircraft was named *Páll Sveinsson* and given new registration letters, TF-NPK, the chemical elements abbreviations of the principal fertilisers (nitrogen, phosphate and potash) used for land reclamation. It was initially based at Gunnarsholt and 3 other airstrips. The arrival of the new aircraft coincided with the additional resources from the National Endowment Gift enabling it to be used effectively. Other smaller aircraft were used until 1996.

With the voluntary help of around 100 pilots, over two thousand tons of fertiliser and seed were spread annually over the following years. The old and reliable DC-3 was used to cover areas up to 50-60 km from home

Photo 6.28 *The Soil Conservation Service Douglas Dakota DC-3 aircraft* SCSI

base, and a smaller plane was used for areas within 15 km. The revegetated area grew in size, and additional landing strips were constructed, for example one at Auðkúluheiði on the Kjölur route over the highlands in the north west funded by Landsvirkjun.

In the later 1980s and early 1990s, fertiliser flights were reduced. Budget cuts were one of the reasons, but more significant was the move to land based operations to encourage farmers to participate. Sowing seed and spreading fertiliser was outsourced to farmers and other contractors who used modern equipment. This was a fundamental shift, making the farmers more aware of land degradation and more engaged in combating it. Also, more emphasis was placed on halting land degradation in areas most sensitive to drifting sand. Harrowing of the lyme grass and lupin seeds was required to ensure successful germination. Since 2000, all the seeding work, whether from aircraft or tractors, has been very carefully recorded with GPS and mapped; the data are used specifically for monitoring of carbon sequestration and other purposes.

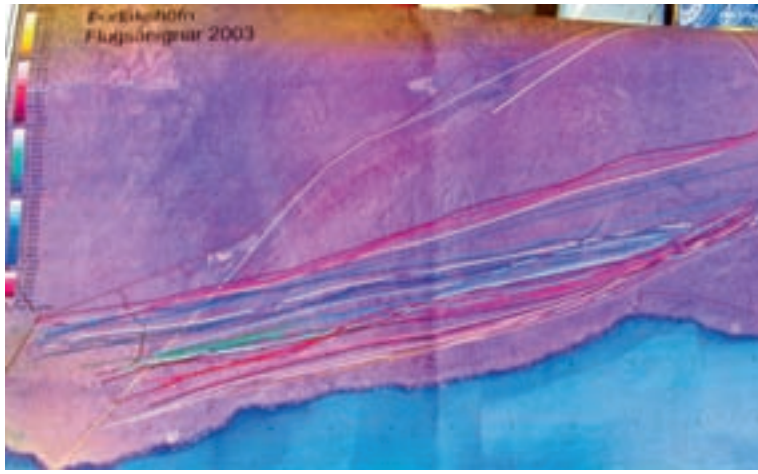

Photo 6.29
Log of fertiliser spreading using the Douglas DC-3 around Þorlákshöfn, south west Iceland
RC

Ecological restoration and ecosystem function

During the 1990s, research took a new and wider approach to develop a greater understanding of the functioning of the ecosystem as a way of encouraging natural plant succession and, therefore, more natural approaches to restoration than sometimes used in the past. If successful, this approach would reduce the amount of seeds and fertilisers used and, as a result, improve the effectiveness of land reclamation in the longer term. The research aimed to encourage natural vegetation succession and soil formation.

A number of research programmes have been undertaken with the aim of understanding the processes of succession and how different inputs may influence these processes. Studies comprise those covering primary succession sites (natural without any artificial inputs)[17], reclamation sites with known management history[18], an experimental site with treatments resembling those commonly used in reclamation[19], and reclamation sites where birch was sown or planted[20]. Most studies have focussed on vegetation, to a lesser extent on soils, and occasionally on soil fauna.

The research concluded that the type and intensity of reclamation input has a critical effect on the direction and rate of succession.

Photo 6.30 *Field investigations of soil fauna*
SCSI

Lack of safe, stable sites due to the instability of the surface from wind, water and frost action appear to be a more limiting factor than seed source for vegetation development in natural and in restored ecosystems. Restoration methods, including fertiliser applications, stimulate growth of soil biological crust on which native vascular plant species are more likely to establish. Establishment of birch can be relatively fast once the surface becomes stabilised and favourable conditions have developed.

Syntheses of results, both within and amongst the research programmes, currently being undertaken, are providing a better understanding of the processes involved in succession, and, therefore, assist in developing improved restoration methods. The recently published *Ecological Restoration in Iceland* (Vistheimt á Íslandi in Icelandic with a short English summary)[21] describes and reviews 85 selected ecosystem restoration projects covering 175,000 ha.

A notable element of recent research has been the assessment of carbon sequestration on land reclamation sites (Figure 6.3). Soil carbon data, bulk density, vegetation data (composition and cover) associated with reclamation methods are measured periodically to assess the rate of change. Sites are visited every five years, with 2011 being the last year of the first cycle, so results are still preliminary. They indicate the very positive effects of land reclamation in general. Species diversity tends to increase, with the exception of lyme grass and lupin sowings; this may have more to do with the extreme condition of the site. Carbon sequestration rates depend on the timescale and geographic location, but the rate of sequestration of soil organic carbon in andosols is twice that of other soils globally and therefore the potential is great in Iceland. The average sequestration rate is currently estimated to be 2.79 tonnes CO_2 /ha/y or 0.3 Mg C ha^{-1} y^{-1}; the maximum sequestration measured so far is 1.0 Mg C ha^{-1} y^{-1} [22].

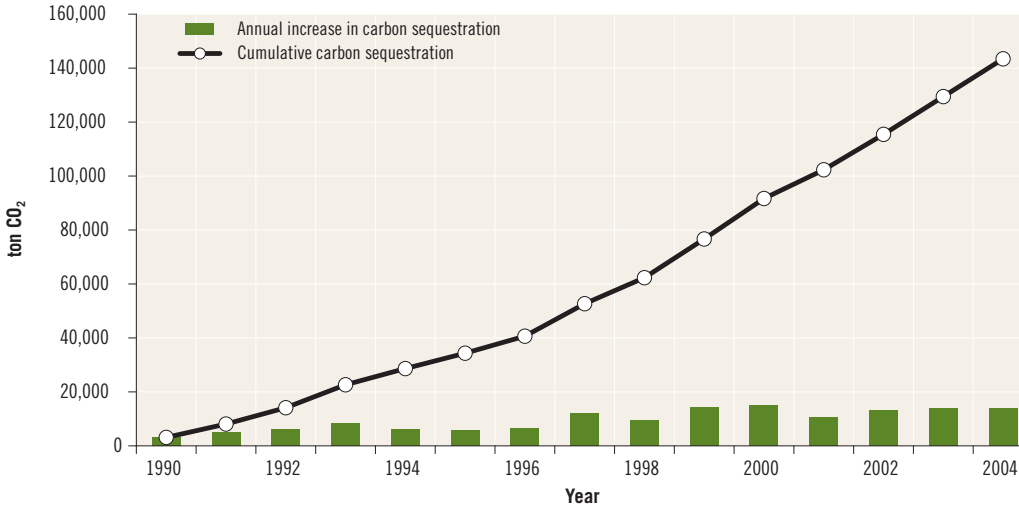

Figure 6.3 *Annual and cumulative carbon sequestration in soil and vegetation resulting from revegetation work in Iceland, 1990–2004.*

Source: Ágústsdóttir, A. M. 2002. Revegetation of eroded land and possibilities of carbon sequestration in Iceland. Conference NJF-seminar no. 342, Agricultural soils and greenhouse gasses in cool-temperate climate, held in Iceland, 31.7 – 3.8 2002
Ágústsdóttir, A. M. 2004. Revegetation of eroded land and possibilities of carbon sequestration in Iceland. *Nutrient Cycling in Agroecosystems,* 70(2), 241-247. With kind permission.

Assessing the extent of the problem

It is remarkable that the extent and severity of the erosion problem was not systematically assessed during the first 80 years of reclamation. One of the reasons was undoubtedly the lack of objective information across the whole country. When Andrés Arnalds returned from a visit to he USA in 1989, he argued the need for an assessment of land degradation and more emphasis on research:

> "In recent years, Icelanders have been opening their eyes to the enormity of soil erosion, and that the condition of vegetation is widely poor. The problems take various forms, and much needs to be done before a comprehensive overview of the degradation, and the necessary countermeasures, become available. This also applies to the condition of land, as vegetation today is largely determined by the activities of humans.
>
> In fact, there is not a reliable enough foundation on which to coordinate vegetation conservation and land use. It is, therefore, important to bolster soil erosion research, and begin mapping its scope as soon as possible with the aim of stopping the most serious instances of desertification by the turn of the century. Furthermore, it is necessary to define the kind of vegetation that should compete in the various areas. It can be expected that new attitudes and demands regarding the condition of vegetation relative to growing conditions will significantly influence land use in the coming years."[23]

Mapping soil erosion

Despite earlier efforts to use all of the information from aerial photographs, there was

Photo 6.31 *Ólafur Arnalds* RC

no overall assessment of the extent and severity of soil erosion, nor of the risks of erosion. Such information was essential if the resources for land reclamation and revegetation were to be effectively targeted and the best results achieved. During 1987 and 1988, discussions between the Soil Conservation Service, the Icelandic Forestry Association and the Ministry of Agriculture centred on the best method to categorise soil and land areas in relation to the risk of wind erosion. It also involved addressing how agriculture could be restructured to match with the land resources determined by these categorisations. The resulting report *Vegetation conservation, objectives and methods,* published in 1988, set out the objectives and methods for implementing a regional land use plan. It provided a detailed, joint strategy and priorities for the organisations.

Mapping soil erosion patterns and severity was a crucial task. This work took 7 years from 1990 under the direction of Ólafur Arnalds, a soil scientist at the Agricultural Research Institute. The Soil Conservation Service hired Ásgeir Jónsson and Elín Fjóla Þórarinsdóttir to work on the project.

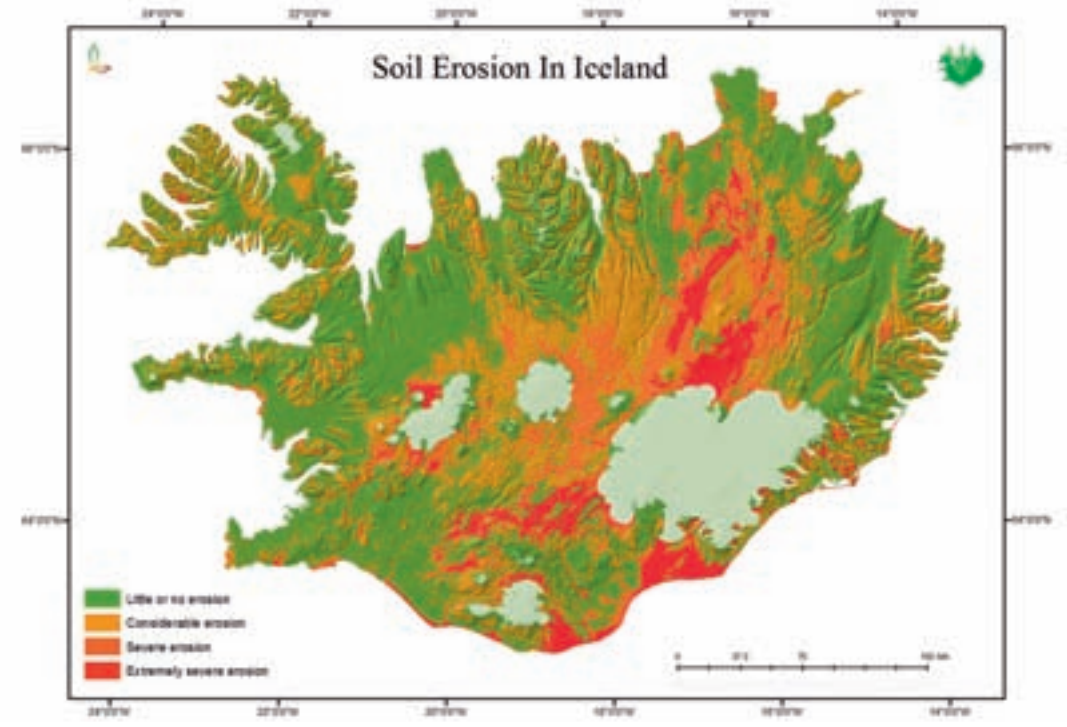

Figure 6.4 *Map depicting the distribution of erosion severity*

Source: Arnalds, Ó., Thorarinsdóttir, E.F., Metúsalemsson, S., Jónsson, A., Grétarsson, E. & Árnason, A. 2001. *Soil erosion in Iceland.* Soil Conservation Service and Agricultural Research Institute. With kind permission.

As part of this project, the National Land Survey provided satellite images of the entire country, originally purchased to create the Iceland Vegetation Map, which formed the initial platform for mapping erosion. The report used the best international practice in the classification of soil erosion adapted to the specific circumstances of Iceland. The basic parameters assessed were: surface form, surface material, erosion severity, and land condition.

The resultant material is summarised in Figure 6.4 and Table 6.1.

Table 6.1 Division of land by erosion class

Erosion class	Area km²	%
0 no erosion	4,148	5.2
1 little erosion	7,466	9.4
2 slight erosion	26,698	33.8
3 considerable erosion	23,106	29.2
4 severe erosion	11,322	14.3
5 extremely severe erosion	6,375	8.1
Total area	79,115	100.0

Source: Arnalds, Ó., Thorarinsdóttir, E.F., Metúsalemsson, S., Jónsson, A., Grétarsson, E. & Árnason, A. 2001. *Soil erosion in Iceland.* Soil Conservation Service and Agricultural Research Institute. With kind permission.
Note the area covered by mountains, ice caps and glaciers, lakes and rivers, and the unmapped area are excluded from the percentages.

The conclusions were presented at a conference in February 1997, and in the publication *Soil Erosion in Iceland* (published in English in 2001). The main conclusions were that 22% of Iceland was classified as being severely eroded, while 52% of the country was classified as being considerably, severely or extremely severely eroded when glaciers, lakes and mountainous areas were excluded (Table 6.1). Serious erosion degrading continuous vegetation totalled about 14,000 km². Areas with little erosion were in west Iceland, north west Iceland, the southern lowlands and some parts of east Iceland. Conditions were best in West Húnavatnssýsla district of north west Iceland. The key point was:

> "The conclusions clearly show that the general public has sufficient reason to view soil erosion as the most pressing environmental problem facing Iceland. Yet it must be kept in mind that soil erosion is not just linked to loss of vegetation. Nevertheless, land suffering severe erosion cannot be considered fit for grazing, whether it is vegetated land or wasteland (meaning desert)."[24]

Also of significance were the results relating to the severity of the different forms of erosion (Table 6.2). This data provides a quite different perspective to one derived from casual observation. *Rofabarðs* are not a dominant form in the severely eroded areas. But erosion spots (breaks in the vegetation cover exposing the soil) are a key form and need to be watched carefully for expansion; fortunately they largely occur in the most stable areas. Solifluction forms resulting from freeze/thaw cycles breaking the vegetation surface are also significant. The key finding from this analysis is that forms with sand at the surface are the most problematic and

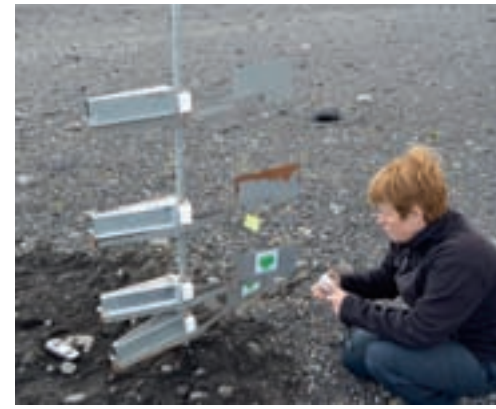

Photo 6.32 *Sampling wind erosion of sand erosion at different levels above the ground*
SCSI

Table 6.2 Erosion severity in relation to different erosion forms

Erosion form	Erosion severity %				
	1	2	3	4	5
Rofabarðs	7.6	7.5	7.0	10.3	5.5
Encroaching sand	0.0	0.0	0.0	0.3	0.4
Erosion spots	30.4	39.5	9.6	0.9	0.0
Solifluction	4.1	22.9	21.0	0.9	0.0
Landslide	1.7	0.4	0.3	0.1	0.0
Gullies	3.2	5.4	4.3	0.9	0.6
Gravel	43.6	18.3	23.1	0.0	0.0
Lava	8.0	0.5	0.1	0.0	0.0
Sand	0.9	0.7	1.1	9.1	42.9
Sandy gravel	0.0	1.6	19.0	51.9	19.5
Sandy lava	0.0	0.2	4.8	14.7	24.6
Soil	0.1	1.1	1.2	0.5	0.6
Scree	0.3	2.0	8.4	10.5	5.9
Totals	100	100	100	100	100

Source: Summarised from Arnalds, Ó., Thorarinsdóttir, E.F., Metúsalemsson, S., Jónsson, A., Grétarsson, E. & Árnason, A. 2001. *Soil erosion in Iceland.* Soil Conservation Service and Agricultural Research Institute, Table 4 with kind permission.

should be the focus of land reclamation and stabilisation effort, so that the loose material does not spread downwind onto stable, uneroded areas.

Soil Erosion in Iceland, which received the Nordic Nature and Environmental Award, became the basis for soil conservation planning and sustainable land use. The report opened a new chapter of knowledge and understanding about Iceland. It was used as the fundamental cornerstone for vegetation conservation, and in the following years modern conservation efforts have been built around the words *knowledge – support – supervision*. The report contained information about erosion throughout the country, and how to evaluate the grazing potential of pastures and other land areas, and clearly indicated where land use was not sustainable. It called for changes in attitudes towards land use and the conservation of land quality. The report concluded that large tracts of land were incapable of being used for grazing, while other areas had little erosion and were well suited for raising sheep. Nevertheless, there has been very little effort by the government to redistribute grants for sheep raising in the country on the basis of this excellent report.

The Soil Conservation Service responded by placing even more emphasis on encouraging land users to participate in revegetation work. The first step was to map local areas and restructure land use. The work began in Skagafjörður, north Iceland in partnership with the Agricultural Society of Skagafjörður and others, with 170 farms participating. The maps proved to be invaluable aids in helping farmers to put the use of their land on a sustainable basis. Comprehensive information about the quality of their land formed the basis for raising livestock in a purposeful and responsible manner. The latest technology in aerial imagery has generally replaced

the cartographic methods used in the Skagafjörður project. It has been deployed in the *Nytjaland Cooperative Project*, a collaboration to map the boundaries and vegetation coverage on all farms in Iceland between the Agricultural Research Institute, the Soil Conservation Service, the Farmers' Association and the Ministry of Agriculture, under the leadership of Ólafur Arnalds.

In 1997 the Soil Conservation Service also published *Revegetation strategy*: *the objectives, methods and main tasks up to the millennium.* It presented the results of expanding systematic research efforts and resulted in a large scale carbon sequestration project

Establishing a Geographical Information System

The Soil Conservation Service has from the outset endeavoured to utilise all available information about the country. This was a difficult undertaking since collecting information on land resources was not a priority in Iceland. Base maps made by Danish cartographers during the later 19th and early 20th centuries were the primary sources of information. During the first decades of the 20th century, work included collecting data about areas undergoing revegetation, in part to evaluate the results of various methods. The Sand Reclamation Service arranged for a number of areas to be mapped, and the work was carried out by Ásgeir L. Jónsson of the Agricultural Society of Iceland.

Aerial photographs of Iceland were first taken during the Second World War, and after 1950 the National Land Survey of Iceland arranged to photograph the country systematically. The Soil Conservation Service began using the aerial photographs in the 1960s to check on improvements to the vegetative cover. However, this work was organised according to need, rather than being methodical. Based on these aerial images, the Agricultural Research Institute, under the supervision of Ingvi Þorsteinsson, began mapping all vegetation in Iceland. This was an ambitious project. The maps were intended to determine livestock numbers on the commons, but it proved impossible to implement this idea to improve land use. There were so many other variables which the maps did not show - soil type, condition of vegetation and soil, and processes of erosion. As a result, attempts to determine the carrying capacity of land based on these maps always grossly overestimated the area where land use was considered to be sustainable.

Egill Jónsson, MP, was effective in convincing Parliament to allocate special funding in 1986 to purchase Landsat satellite images of the entire country, along with equipment for the National Land Survey of Iceland to make the data accessible to other institutes. This was a revolutionary change, as the data opened up many possibilities. Data was compiled on seven different spectral bands. In addition to being used to display standard composite imagery of the country, it was also possible for the individual bands to depict specific surface features, since image reflections vary according to the type of vegetation. The digital imagery could also be used to make a rough map of the country depicting vegetation categories and to assess the type and seriousness of soil erosion throughout the country. Most of this work was conducted at the National Land Survey in cooperation with the Agricultural Research Institute, and was the foundation for the report *Soil Erosion in Iceland*. This imagery was also valuable in demonstrating the land use challenges, and identifying drifting sand that threatened sensitive vegetated areas. When Soil Conservation Service staff took these images to farmers in devastated areas, there was recognition for the first time of the extent of the problems and a readiness to discuss solutions, instead of arguing whether there was a problem of land degradation.

Photo 6.33 *Soil Conservation Service staff using imagery for discussion with farmers*

SCSI

Shortly before the new millennium began, companies in the private sector began taking aerial photographs of the country, inserting geodetic coordinates and transferring them into digital format. These enabled recording of all land reclamation activities. The Soil Conservation Service contracted with a commercial supplier to purchase data of the largest lowland areas in Iceland.

The Soil Conservation Service's database has been restructured to make it easy for staff around the country to access geographic information. This has proved to be an excellent method for cataloguing land reclamation work. It is possible to view aerial images of revegetation sites and instantly access information about everything that has been done in each area over a long period. The images are also excellent for surveying and mapping, and for providing information on land use at particular farms and grazing areas.

Technology is forever advancing, and over recent years the Soil Conservation Service, along with numerous other parties, has purchased the next generation of satellite images, SPOT, which are much more precise than the Landsat data. Although they do not achieve the precision of aerial photos, these digital images offer a wide range of analytical capabilities, particularly with the infrared band suitable for all work on detecting vegetation.

Training Programmes

One of the consequences of exchange of experts and visits by experts is recognition of the need for training and how this can be most effectively undertaken on a cooperative basis. There are a number of recent examples of this cooperative approach which are benefitting Iceland and also the other institutions involved, as well as the participating students from around the world.

A new undergraduate programme, including a restoration ecology and management stream, as part of a three year degree programme in Forest Science, Restoration Ecology and Management was launched in 2007 by the Agricultural University of Iceland in Hvanneyri. Since then, an M.Sc. in restoration ecology has been established. Ása L. Aradóttir, then Director of Research and Development at the Soil Conservation Service and now Iceland's first Professor of Land Restoration Ecology at the Agricultural University of Iceland, participated in organising the programmes. This underlines the experience Iceland has accumulated, as only a few years have passed since universities – initially in the USA, Britain and Oceania – began offering such courses. Previously, students were selected from various fields of study as preparation for land reclamation work, such as land utilisation, soil science, ecology and various areas of biology and agriculture. This course is both wide ranging in its content and integrated in its approach towards land issues and therefore entirely in tune with the requirements of modern land restoration and soil conservation. The Agricultural University of Iceland is developing a unique position among universities and science institutes worldwide through the development of this course, recruitment of knowledgeable teaching staff and participation in the UN Land Restoration Programme.

Since the late 1990s it has been the ambition of leaders in soil conservation education

Photo 6.34 *Ása L. Aradóttir* RC

and research in the Soil Conservation Service and at the Agricultural University of Iceland to share with developing nations the Icelandic experience in dealing with land degradation and developing grass roots, participatory approaches. This has led to the establishment of a United Nations University - Land Restoration Training Programme as a new post-graduate training programme on Sustainable Land Management and Restoration of Degraded Land. Established in 2007, it aims to increase the capacity of individuals in developing countries to reduce land degradation and improve sustainable land management practices, and also increase networking between key organisations. The course accepts up to 10 Fellows a year from developing countries where there is severe land degradation and desertification, and a need for capacity building and training. African and Asian countries have provided the trainees to date. The programme is funded by the Icelandic Ministry for Foreign Affairs as a part of the government's development co-operation programme. It also helps the government fulfill broader obligations as a signatory to the United Nations Convention to Combat Desertification, the Convention on Biological Diversity and the Framework Convention on Climate Change. The programme is led by the Agricultural University of Iceland and delivered by staff from the university and the Soil Conservation Service; the management board is chaired by Sveinn Runólfsson. The importance which the Icelandic government attaches to this programme is emphasised by the funding being formally incorporated in the budget of the Ministry for Foreign Affairs and the course becoming a formal UN University training programme in 2010. A challenging strategy has been approved with one of the objectives being to increase the number of students by two each year until 2016.

Photo 6.35
Students attending the UN University Land Resources Training Programme in Iceland JBJ

Knowledge transfer and exchange

It is important for Icelanders to be aware of the successes achieved in revegetation, vegetation conservation and land stabilisation. But this aspect of the work was given little attention until the second half of the 20th century, and particularly in the last quarter-century. At first, information was presented to farmers, for example, at meetings and at lectures in agricultural schools and colleges. Students from agricultural colleges also visited Gunnarsholt, and Soil Conservation Service staff sometimes taught courses at these colleges. Reports were published. The media were often invited to visit Gunnarsholt and other reclamation sites to see at first hand what had been achieved, but did not always attend.

The first major publication on revegetation work in Iceland was *Sandgræðslan* (The Sand Reclamation) in 1958 written to celebrate the first 50 years of the Sand Reclamation Service. The 80th anniversary of land reclamation work was marked in 1988 with the publication of *Landgræðslan* (Healing Iceland. The Soil Conservation Service 1907–1987). This was followed by 'yearbooks' annually from 1987 until 1998 detailing the work of the organisation. These were replaced by annual reports, newsletters and information on the website. In addition, videos were released and meetings and conferences held.

In 1991, the Soil Conservation Service's newsletter, *Landgræðslufréttir,* (News from the Soil Conservation Service), was first published. Distributed throughout the country in a large print run, it regularly reported the latest news and information about operations. It ceased publication in 1999 when the web site took over that role. Also in 1991, the Soil Conservation Service participated in a cooperative project with the National Centre for Educational Materials to produce two films

Photo 6.36 *The Soil Conservation Service newsletter published in the early 1990s* SCSI

aimed at children about land reclamation and environmental protection titled *I Bet on Iceland* and *Healing Iceland – what can I do?* A year later, two other videos were released about land reclamation work: one covering Haukadalsheiði in the south highlands and the other on Dimmuborgir, the major natural site in the north east threatened with inundation by sand (see Chapter 3).

A new member of staff, Guðjón Magnússon, was hired in 1991 to teach volunteers land reclamation methods, as well as manage public relations. In the spring of 1992, responsibilities expanded to include supervising the work of volunteers, and being the contact person for various groups and organisations. That same year, the first *Soil Conservation Award* was presented. Its objective was to focus attention on the important role played by volunteers in land reclamation and vegetation conservation, as well as encourage others to participate.

Photo 6.37
Part of set of wooden carvings illustrating the history of soil conservation in Iceland by Alexander Robertson hung in the conference room at Gunnarsholt RC

In 1993, the Soil Conservation Service organised a conference *Revegetate Iceland – what can I do?* in cooperation with the Rotary movement in Iceland. Employees have also participated in many fora and held talks at conferences for various associations and clubs. These are examples of many meetings and conferences the Soil Conservation Service has held over the years to publicise operations and stimulate people to take action.

The Soil Conservation Service increased its publishing activities in the latter part of the 1990s. Some of the materials were aimed at specialists, others were for public consumption. Specialised publications included the 1997 booklet *Reading the Land* in cooperation with the Agricultural Research Institute, which was primarily conceived for the classroom. Another publication was *Horse Pastures*, which provided instruction on caring for land where horses grazed. *Soil Erosion in Iceland*, a major work intended for both the specialised and public sectors, was published in 1997 in partnership with the Agricultural Research Institute; in 2001 Danish, English and German translations were published. More recently, a booklet on sheep pastures helps farmers and field workers to identify good and bad practice and how to achieve improvements in management[25]. These works and other educational efforts were designed to convey the Soil Conservation Service's objectives and methodology, impart knowledge to help stop soil erosion and vegetation loss, explain the concept of sustainable land use, and discuss methods to reclaim degraded ecosystems.

In 1999, the Soil Conservation Service began publishing its research reports. The first was on *The use of domestic birch species in revegetation and land improvement, progress report 1997–1998*. Since then, a large number of reports have been released and can be accessed through the web site www.land.is.

In March 2002, the Soil Conservation Service signed an agreement to operate a communal website on Icelandic agriculture, www.landbunadur.is, based on cooperation between seven institutes and organisations. The objective was to create a venue for information relating to agriculture. The Soil Conservation Service followed this by opening a new website, www.land.is, with information about its operations. These websites have created new opportunities to disseminate educational and other information that previously had been released as hardcopy.

This is only part of work by the Soil Conservation Service to convey information about its operations. In addition, up to 2,000 people visit the headquarters at Gunnarsholt

annually to acquaint themselves first hand with operations. Moreover, a great many people visit the district offices for consultation and information about land reclamation and vegetation conservation.

An excellent visitor and education centre was opened in April 2011 at Gunnarsholt. It tells the story of soil conservation and land reclamation, it provides information for visitors on the work done and being done, and has office, reading and training rooms for study and education.

Overview

The research themes have inevitably evolved over the century and the methods and techniques have become more sophisticated. But a number of common themes run throughout the period, as might be expected given the scale of the erosion and degradation problems and the singular influence of the type and level of grazing by domestic herbivores. Amongst the most important themes have been: techniques of reclamation, assessments of the effects of grazing, calculations of grazing capacity of different land types and different levels of grazing, the most effective types of seeds and plants for revegetation, the most effective ways of sowing them to ensure germination and productivity, and last, but by no means least, the assessment of the extent and severity of erosion and the relative risk of erosion throughout the country and the application of this knowledge to reclamation efforts on the ground.

What is clear from the last two decades is a very significant increase in scientific activity and the development of a cadre of internationally recognised research scientists. The key component was the establishment of a research team at the Soil Conservation

Photo 6.38 *The new centre 'Telling the story of land reclamation' at Gunnarsholt* SCSI

Service comprising Dr. Ása L. Aradóttir as its head, Dr. Magnús Jóhannsson, Dr. Anna María Ágústsdóttir and Dr. Kristín Svavarsdóttir, and later Dr. Guðmundur Halldórsson. Important was work undertaken at the Agricultural Research Institute (now part of the Agricultural University of Iceland) led by Professor Ólafur Arnalds and at the University of Iceland involving among others Professors Guðrún Gísladóttir and Þóra Ellen Þórhallsdóttir. As a result, the level of knowledge has been transformed through ground breaking studies particularly relating to ecological succession and restoration ecology, assessing seed types for revegetation, improving seed collection and processing, estimating carbon sequestration and land restoration in the laboratory and on the ground, as well as overseeing the longer field investigations of the soil plots.

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Chapter 7

Working in partnership

The Soil Conservation Service has been involved in a growing number of cooperative projects and partnerships throughout its existence, especially over the past two decades. It has good relationships with most of the farmers and various regional conservation associations, has long enjoyed a partnership with the two electric power companies, collaborates with the Icelandic Road Administration and interacts with other public bodies nationally and regionally, and has been a contractor for state agencies like the Icelandic Maritime Administration, many municipalities and towns. All are important, but given the task of reclaiming land the most important is working with farmers, especially as they own or have the grazing rights to almost all of the entire land area. Not all of these relationships have been easy, due to different perspectives and expectations, but what this chapter describes is an evolution of working in partnership as an essential and necessary component of the soil conservation story.

Working with farmers

Most of lowland Iceland is owned by farmers or rented by them from the state. The rearing and finishing of livestock, especially sheep, and the provision of feed for them has been the main occupation of farmers. The highland commons, although their ownership is contested by the state, are places of traditional summer grazing, especially for sheep. The grazing rights of farms and the farming community have now been consolidated in High Court. The annual pattern of taking sheep to the commons in June and gathering them up in September is an important part of the cultural calendar for many Icelandic farmers and rural communities; it is now also becoming a tourist attraction.

The reviews of history and analysis of the causes of land degradation presented earlier indicate that over stocking and over grazing have been a perennial problem. Many find it difficult to believe that for the first 1050 years of settlement almost all livestock relied on grazing the land throughout the year, with hardly any hay or other winter feed. The major reforms of agricultural support in the early 1990s were in recognition of the need to reduce livestock, and especially sheep, numbers, so that the meat produced was in balance with market demand and the numbers were in balance with the grazing capacity. It was therefore inevitable that, whilst, farmers in the past have been correctly seen as part of the erosion problem, they have in recent decades been seen as a fundamental part of the solution in their role as long term stewards of the land. This was recognised by the Sveinsson brothers Runólfur and Páll, both sons of a farmer, and is a major component of the work by the current leadership of the Soil Conservation Service. The role of farmers has changed over the past century, alongside changes in approach to livestock numbers and grazing management.

Over stocking and over grazing by livestock

Livestock numbers have fluctuated significantly over time (see Figures 1.8 and Table

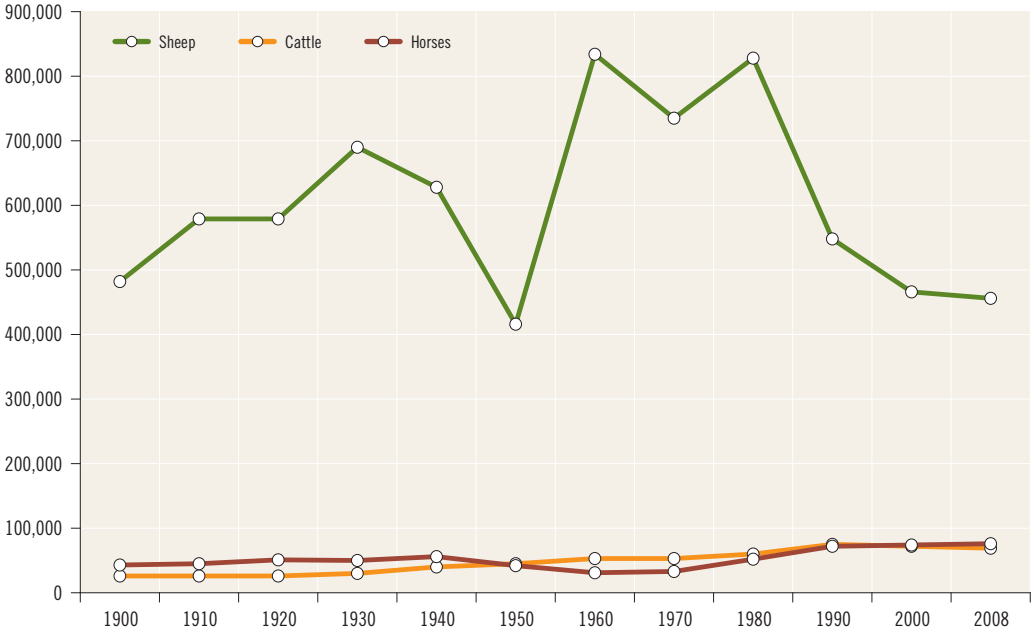

Figure 7.1 *Livestock numbers in Iceland during the 20th century*

Source: Icelandic Agricultural Statistics, various dates, The Farmers Association of Iceland. Note figures are rounded to the nearest 1,000.

7.1). There are good explanations for the variation: disease, changes in policy and in agricultural support, but it should be born in mind that farmers consider their primary role as food producers and therefore their attitudes towards and reluctance to change is a significant factor.

Cattle

Livestock proliferated in Iceland in the first half of the 20th century. Numbers increased from the 1920s until the 1950s. The increases reflected the development of other milk products, such as cheese. Cows were given hay from cultivated fields, while in summer they grazed on uncultivated

Photo 7.1
Poor animal husbandry and land degradation RC

land. This began changing by the mid 20th century when farmers in ever increasing numbers grazed cows on cultivated pastures to increase productivity. This resulted in over production of milk and triggered the introduction of milk quotas and resulted in a small decrease in cattle from the peak of around 75,000 in 1990.

Sheep

Sheep numbers have always fluctuated. There were about 300,000 winter-fed sheep at the turn of the 19th century, but fifty years later the number had more than doubled to over 600,000 (see Figures 1.8). Disease reduced this number to 357,000 in 1869, but by the end of the century they had increased to about 480,000. Bearing in mind that every year farmers put all their sheep out to pasture and onto the commons for as long as possible throughout the year, it is easy to imagine that something had to give – the land simply could not bear so much grazing, and especially not in the most sensitive areas. The quality of grazing land deteriorated as grazing increased, and substantial wind erosion during the 'hard times' of 1860–1900 had devastating effects on the amount and quality of land available. Despite this, sheep numbers continued to increase substantially from the late 19th century to the early decades of the 20th century, before a temporary decline in mid century due to high levels of disease in some parts of the country. The peak number was reached in 1978 with a total of 896,000 and is now around half of that total. The subsidy system was a key upwards driver of the numbers rising from 2,000 ISK (US$ 20) per head in 1960, to a peak of 5,000 ISK (US$ 62) per head in 2000[1].

Sheep farming had long been the mainstay of animal husbandry in Iceland as the land was considered suitable for this activity, especially for wool production and later for lamb as well. Nevertheless, it became increasingly evident to some Icelanders in the middle of the last century that farmers had often overgrazed the land by not managing it in accordance with its grazing capacity. Virtually no thought had been given to this concept. The problem was that farmers throughout the country had to sustain their livelihoods, often facing extremely difficult conditions and hardships. To achieve this, they grazed their sheep on heaths and commons, regardless of whether there was continuous vegetation or widespread erosion. The situation in rural Iceland was exacerbated by the use of willow and birch as fuel for cooking and heating houses. Interestingly, records kept by the Farmers Associa-

Photo 7.2
Just too many sheep in ecologically fragile areas RC

Photo 7.3
Horse riding and exercising horses is an important pastime RC

tion in late 19th and early 20th recorded the number of horse loads of wood as well as horse loads of hay.

Horses

While sheep numbers diminished and large tracts of land were declared protected against grazing by the Soil Conservation Service, another problem appeared: the horse population was on the increase. In 1901, there were 43,000 horses. Since then numbers have increased almost each year, with a few exceptions to reach a peak of over 80,000 in 1997. There are more horses per capita in Iceland than anywhere else in the world, and these numbers are probably an under estimate. The majority of horses are grazed on uncultivated land all year round, and in some cases horses are taken to the commons in the summer. About a quarter of the stock is fed indoors.

From the time of The Settlement, Icelanders have had a special relationship with their horses, not surprising considering the important role they have played in daily life down the centuries. Interestingly, Runólfur Sveinsson said in 1953 "Horses are kept for many kinds of work on the farm, pulling and carrying, for their meat, and for no purpose at all"[2], the latter point referring to the cultural tradition. As prosperity grew in the second half of the 20th century and people had more time to enjoy outdoor activities, horse riding became extremely popular, but sensitive vegetation, especially on the commons, was ill prepared to withstand this increased strain. In some areas, this lead to horse numbers reaching beyond the land's grazing capacity, especially in cold years. The Soil Conservation Service instituted a check on all horse grazing areas and identified many problem locations. As a result, discussions with horse farmers were initiated and gradually brought results. In addition, discussions were held with the Icelandic Horse Clubs Federation and companies offering horse tours aimed at rerouting riding trips.

Controlling livestock numbers and stocking levels

The 1941 parliamentary Bill on sand reclamation included a report containing what was probably the first public admission that overgrazing was a problem. It stated the following:

> "There may not be more sheep in the country than considered suitable for both the land and the sheep… . There must be a change of course; land preservation and cultivation instead of exploitation, overgrazing, soil erosion and drifting sand. Farmers must learn to live on small, planted fields and have few well fed sheep, instead of many that yield low profitability and graze on uncultivated land that turn into deserts."[3]

Livestock were dependent on vegetation, and well into the 20th century they were primarily raised on uncultivated land, often all year round. Runólfur Sveinsson called this 'exploitation' in a 1947 radio broadcast. He added that in recent decades fields were being increasingly cultivated, and exploitation was correspondingly declining. Nevertheless, restoration of land remained insufficient. Misuse was still a reality in the mid 20th century: grazing capacities were ignored, resulting in continuing soil erosion and land degradation.

After the Sand Reclamation Service had proved it was possible to cultivate sand and gravel at Gunnarsholt, farmers expressed an interest in doing the same to enlarge their pastureland to secure food supplies for the increasing number of sheep and dairy cattle. With the assistance of the Sand Reclamation Service, farmers especially in the south of Iceland began to cultivate the sandur plains along the coast. This practice was extended over the next decades, but with a significant difference as sheep farmers decided to subsidise this work along with support from

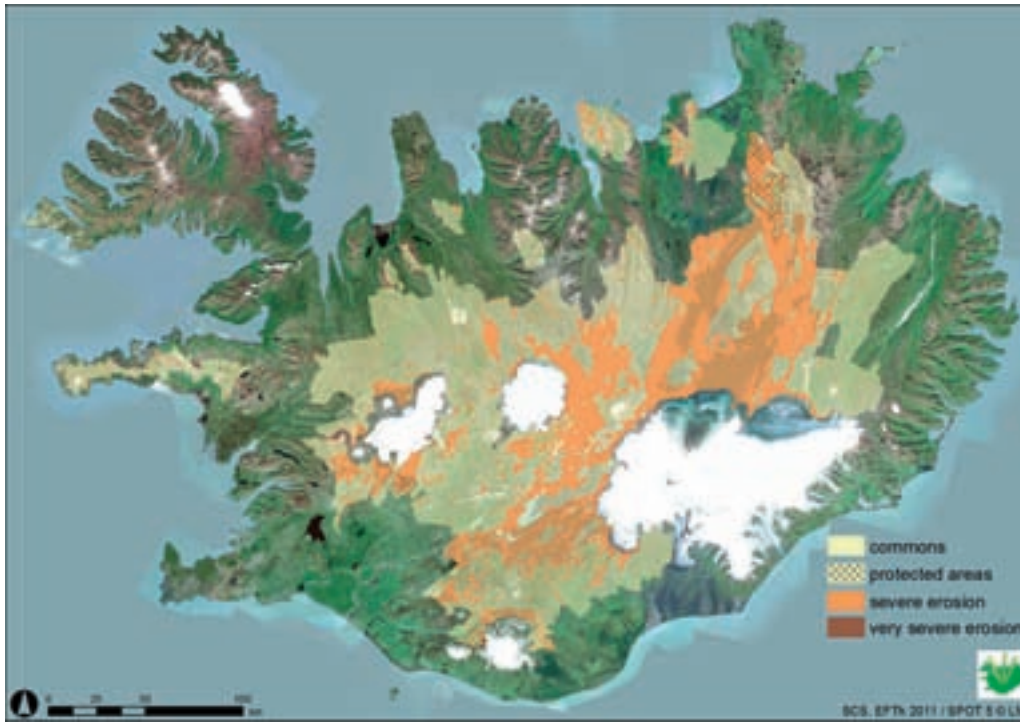

Figure 7.2 *A classic failure of policy and practice: only a few areas of 'very severely' and 'severely' eroded commons determined from the survey published in Soil Erosion in Iceland are protected from grazing*

Source: Soil Conservation Service

municipal authorities and the Soil Conservation Service.

Despite increasing numbers and the weight of evidence linking over grazing with soil erosion, nothing significant was done to stem the numbers, with no changes in statute or in livestock subsidies. Sveinn Runólfsson forced some movement by persuading several vegetation conservation committees to demand that municipalities delay the opening of their highland commons for grazing, and in some instances moving the round up to an earlier date. In several areas, municipal authorities took the initiative in setting maximum livestock numbers in communal grazing areas to reduce grazing pressure. In addition, the Soil Conservation Service had at its disposal an aircraft to spread seed and fertiliser, and arranged with various municipalities to protect and revegetate specific sectors of commons.

Local grazing committees and grazing of the commons

A significant change was brought about by the 1965 Act which contained clauses enabling the Soil Conservation Service to work on preventing degradation of vegetation and soil erosion through vegetation conservation and monitoring its condition. The statute permitted the establishment of Vegetation Conservation Committees in all administrative districts around Iceland. These Committees were seen as an important link between the Soil Conservation Service and local authorities. One of their responsibilities was to determine common grazing seasons. This cooperation worked well in most cases, but, of course, there were differences in commitment. The parties worked to delay putting sheep out to the highland commons when spring arrived late and pushed round ups to an earlier date to reduce grazing pressure. These measures turned out to be one of the most significant steps taken for vegetation conservation on the commons. In addition, systematic efforts were made to convince farmers not to graze on those commons where conditions were poor. This also proved successful. But, as their role was entirely non statutory with no power to enforce their advice, their efforts were most often fruitless.

Sveinn Runólfsson was appointed Director of the Soil Conservation Service when the work of Vegetation Conservation Committees was still being framed. He remembers this time well and refers often to 'the battle of the commons':

> "When I took this position, vegetation conservation on the commons and highland grazing issues became an increasingly important part of my activities, and I developed good working relationships with the Vegetation Conservation Committees in the reclamation priority areas of Iceland. I travelled widely holding meetings with municipalities and farmers, and mobilising Vegetation Conservation Committees to work with us in monitoring land use on the commons. I was appalled at the widespread practice of sheep grazing very early in the year on communal grasslands, and that horses were grazing on many vulnerable rangelands. In many instances, I felt this practice was indefensible, especially in the highlands of south Iceland where there was wind erosion and desertification. These situations were quite unsuitable for grazing horses. This created a good deal of conflict during the years 1974–1980. There were many meetings, and they weren't always calm."[4]

There were some successes in reducing grazing levels in the 1990s. For example, successful negotiations were concluded with farmers and local authorities to declare Hólsfjöll, in the north east highlands, off-limits to all

Photo 7.4
Farmers gathering seed SR

livestock. This was the worst example of land degradation in Iceland and fencing it would have been financially and technically prohibitive, so the agreement was ground breaking. But some negotiations took much longer. For example, in the 1980s, government agencies established the goal of limiting livestock grazing throughout the Reykjanes Peninsula in south west Iceland by 1990. Despite early reductions in sheep numbers, it took until 2005 to achieve the goal.

The Soil Conservation Service was interested in improving the structure of vegetation conservation, and, in partnership with the Agricultural Society of Iceland and the Agricultural Research Institute, introduced a large scale educational programme *To read the land*. There were a growing number of people who understood that grazing reductions and use of fencing to achieve grazing levels in balance with the carrying capacity needed to go hand in hand. It was hoped that revegetation and land use plans for individual farms could be the prerequisite for official support for agriculture, focussed on utilising sensitive land, as was done in other countries. Unfortunately, this has never materialised.

Around 1990, the Soil Conservation Service and local farmers launched a cooperative land reclamation project in north Iceland around Lake Mývatn and this was followed by similar schemes in other areas. Farmers spread fertiliser and seed on their land, and split the cost with the Soil Conservation Service. The objective was to reduce grazing pressure on sensitive pastures in the respective districts. For years, the Soil Conservation Service had to some extent carried out this work, but farmers were handling this in growing numbers over the coming years. The programme evolved into the Land Restoration Fund.

Also around 1990, free range grazing of horses was restricted, yet land use management in Iceland was still primitive compared with other countries. The Soil Conservation Service hired a veteran horseman and range specialist to inspect horse pastures around the country, as well as provide horse owners with information and instruction about grazing. These efforts proved successful. In addition, the Soil Conservation Service assisted farmers in managing and improving their land resources. The objective was to achieve vegetation and soil conservation, while increasing efficiency in husbandry.

Farmers Heal the Land

Cooperation between farmers and the Soil Conservation Service, therefore, has a long history, but formal collaboration did not begin until 1990 with the so-called *Neighbourhood Project*, a partnership of farmers and the Soil Conservation Service to revegetate individual localities around the country. After a few years, this programme was renamed *Farmers Heal the Land* to reflect better the critical role of farmers and the need to heal the wounds of the past. There were 370 farmers involved in the scheme in 1994, between 400 and 500 in 1997 and over 600 in 1999. Since then the numbers have gradually increased to 650, most of them being sheep farmers and representing about one third of all sheep farmers in Iceland. Participants are evenly distributed around the country (Figure 7.3): 18% in west Iceland and the West Fjords, 19% in the north west Iceland, 24% in north east Iceland, 16% in east Iceland and 23% in south Iceland. Farmers in South Þingeyjarsýsla in the north of Iceland are the largest single group of participants.

The objectives of the programme are to stop erosion and revegetate the land and, in most cases, to enable it to be grazed again. The intended land reclamation site must be barren or near barren, and local grazing lands used only in moderation. The Soil Conservation Service pays about 85% of fertiliser costs and provides seed. Staff visit farmers regularly to survey the revegetated areas and discuss progress as well as other relevant issue, such as land use and grazing pressure by horses. The project has proved extremely important in building up trust between farmers and the Soil Conservation Service.

At the same time, a new development

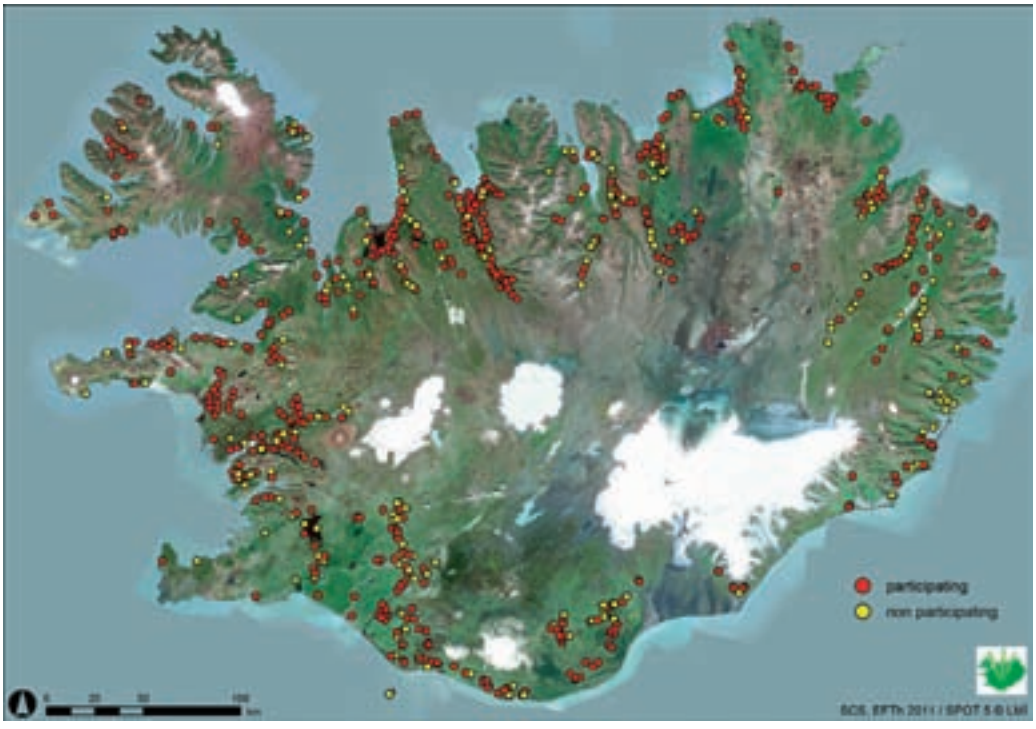

Figure 7.3 *Locations of farmers in Farmers Heal the Land programme*
Source: Soil Conservation Service

Photo 7.5
Farmers take over fertiliser spreading
GS

project was launched called *Better Farms*. It involved developing a procedure, and devising a grazing and revegetation plan in collaboration with 10 farmers living under dissimilar conditions. The farmers tested and re-evaluated their scheme in the summer of 2001. At the close of the project, a new procedure was available for all farmers interested in a grazing and revegetation strategy for their farms.

Having won the argument about excessive livestock grazing and offering technical support and financial help for reclamation in return for farmers meeting good standards of husbandry, the tables have turned and a collaborative approach has succeeded. There remain some farmers who do not participate and who overgraze their land with sheep and especially with horses, despite the incentives and despite the benefits they would attain if they changed their practices.

More recent trends towards cultivating arable crops, whilst potentially beneficial to farmer incomes in the short term, risk stimulating soil erosion on previously stable areas as the ground surface is bare for much longer periods, especially at the most vulnerable times of the year, particularly in winter and early spring. For example, wind erosion from barley fields in becoming an increasingly serious problem in the spring.

Land Care and Land Restoration groups

Inspired by experience in Australia, the first Land Care group was established in Öræfi in south east of Iceland in 1992 in collaboration with the Soil Conservation Service. Since then 14 other groups have been established around Iceland. They concentrate on land restoration and are helped by grants and contributions from the Soil Conservation Service's Land Restoration Fund, the Shopping Bag Fund and other sources. Information leaflets and DVDs have been produced, and conferences and workshops held to stimulate

Photo 7.6 *Farmers Landcare group meeting in south Iceland in 2011 where one third of the population are members of group* SR

Photo 7.7 *A long standing tradition of community involvement in reclamation activity* SCSI

involvement. Disappointingly, many groups have not devoted much effort to promoting sustainable land use, as it is too controversial among members.

As noted in Chapter 4, although the advent of quotas for livestock in the 1990s resulted in substantial reductions in stocking, the policy was founded on reducing meat production and not on land reclamation and conservation. Hence the task of stimulating famers to operate on sustainable land use principles is all the more difficult.

Engaging the Public

It will be clear from earlier chapters that the public have had a considerable influence on politicians in making new laws and voting resources for land reclamation. This has been especially pertinent at key points in the recent history of Iceland, such as Independence in 1944, the major legislative change in the 1965 Act, and the National Endowment Gift in 1974. Another element of public involvement is through stimulating voluntary groups, communities and individuals to participate in land reclamation activities irrespective of their knowledge and expertise.

After the passing of the 1965 Act, emphasis was placed on engaging the public in vegetation conservation, and demonstrating that moderate utilisation of vegetation was one of the pillars of revegetation efforts. Public interest in vegetation conservation was aroused, and people from all walks of life were now interested in improving the quality and appearance of their environment. Associations such as the Iceland Environment Association were founded, companies actively helped, a soil conservation plan was formulated and a vegetation conservation committee was established in every district around Iceland.

This widespread public awakening about land reclamation was among the factors leading to the founding of the NGO *Landvernd*, for Land Restoration and Nature Conservation, in 1969. The association united individuals, companies, organisations and institutes around Iceland to protect and revegetate the

Photo 7.8
Old hay being spread by volunteers to provide ground cover
JRB

country, to disseminate information about soil erosion and to battle against activities harmful to nature. In 1987, the State Fertiliser Plant began manufacturing convenient land reclamation bags filled with grass seed and fertiliser which were sold by the Baldur Lions Club at petrol stations. The public used these as their contribution to revegetating and restoring their country. At the founding meeting of Landvernd, directors of the Lions Club presented it with the proceeds of the sales, which were then used in a major campaign to educate the public.

Initially, youth associations were most active in forestry and revegetation projects. The first to help in reducing the extent of the sand desert was a 30-person group from Héraðssambandið Skarphéðinn in the summer of 1967. In cooperation with the Soil Conservation Service, they attracted media attention working at the Biskupstungur Commons in south central Iceland spreading one ton of seed and eight tons of fertiliser. This was a call to action, and over the following years, youth associations, such as the Icelandic Youth Federation, and adult groups, such as Rotary Clubs and Lions Clubs, took on revegetation projects throughout Iceland. Soil erosion affected everyone, and the nation took notice of the work being accomplished by these volunteers in partnership with the Soil Conservation Service.

The following are a few examples of the revegetation work undertaken by volunteer groups. In 1967, members of the Baldur Lions Club in Reykjavik, in collaboration with the Soil Conservation Service, put up a 7 km fence in Hvítárnes at Hvítárvatn lake in south central Iceland. For two summers, the club had tried to sow grass seed to no avail because of grazing sheep. This suddenly changed after conservation of grazing land was introduced. The Freyr Lions Club, also from Reykjavik, followed this example and set up another fence to extend Baldur's, alongside Hvítárvatn lake, and in subsequent years both clubs cared for their areas. The latter fence is no longer in use, but Baldur still tends to revegetation tasks in Hvítárnes every year. Club members have made these trips into family outings, and for almost 40 years have been teaching their children and grandchildren how to understand and take care of the land.

The Rangárvellir Rotary Club was one of the most active and effective. It established its first restoration plot near Gunnarsholt in 1966 and succeeded in revegetating a bar-

ren hill. The club was so successful that it was assigned land in the sacred valley of the Trolls at Þórsmörk. The club sowed it with grass, spread fertiliser, and planted trees, continuing until the area was fully vegetated. For almost four decades, club members and their families have made an annual trip to sow grass seed and plant birch trees. Lions Club members healed erosion escarpments in the area focussing on two large erosion escarpments. Some older citizens remembered vegetated fields with beautiful shrubs at the turn of the 20th century. Agreements were made with landowners and the area fenced. In 1974, Lions Club members turned to the eastern erosion escarpment by levelling it and sowing the open sore with hardy varieties of grass. The western escarpment was steep, so it was covered with a herring net to give the grass seed a better chance of germinating and growing. This proved successful. Sveinn Runólfsson worked with them and later described their efforts as follows:

> "These evenings with the Lions were such memorable moments. Everyone worked like maniacs levelling escarpments – a very hard task indeed – all through the night. One time a colleague of mine from America was with us, Robert Bement, and I remember how simply amazed he was over how enthusiastic Icelanders were for land reclamation work."[5]

The interest of these Lions club members was so passionate that when their work was finished on the escarpments, they began sowing lyme grass seed in dunes that were encroaching onto and becoming a threat to a large birch woodland at the foot of Hekla. After several years, the dune was fully vegetated.

As the 1990s approached, public interest was greater than it had been for decades. People were becoming more interested in outdoor life and wanted to improve and restore the environment. This led to increasing cooperation with the Soil Conservation Service. It was very popular to "adopt a piece of land" – associations and groups were assigned land by the Soil Conservation Service, which in turn provided them with seed and fertiliser for revegetation. It was common for about 200 individuals and groups to be given seed, fertiliser and plants annually. Companies and institutes celebrated their anniversaries by taking part in planting.

Schoolchildren were also involved. Stu-

Photo 7.9
Learning to be land reclaimers under the expert guidance of Guðjón Magnússon of the Soil Conservation Service GLP

Photo 7.10 *Youngsters planting a tree for the future health of the land* SCSI

dent Land Reclamation Days were held in the spring of 1988. Schools in south and south west Iceland took part in revegetation work: sowing, planting and spreading fertiliser, as well as cleaning up the environment. Over the following years, schools throughout the country followed their example.

The annual general meeting of the Federation of Icelandic Trade on 25 January 1988 approved a proposal by Árni Gestsson, CEO of Glóbus hf., that they celebrate their 60th anniversary by assisting the Soil Conservation Service with a *Land Reclamation Campaign*. The Federation enlisted the help of many parties, and hired a campaign manager who was based at the offices of the Soil Conservation Service. The project focussed on drawing attention to land reclamation work and raising funds for revegetation. An advertising agency designed the campaign logo with the slogan *Heal Iceland – Everyone Profits*. The first donation was presented to the Soil Conservation Service on 14 June. Many companies contributed and a successful lottery was arranged. Land Reclamation Days were held on 23 and 24 July at Gunnarsholt and about 3,000 guests attended. The media carried stories about land reclamation throughout the year, most centring on soil erosion around Iceland. The campaign ran for three years with excellent results.

Photo 7.11 *A cheque from the petrol supply company Olís for conservation work* SCSI

In 1990, the Icelandic Forestry Association celebrated its 60th anniversary. To mark the occasion, it decided, along with the Iceland Forest Service, the Soil Conservation Service and the Ministry of Agriculture, to create a land reclamation project for restoring woodlands and enriching outdoor life. The concept was to establish woodlands on barren or slightly vegetated land areas. They held a preliminary meeting in spring 1988, after which a management board was selected and several expert groups formed to implement the work. Suitable areas around Iceland were selected, sites where developing woodlands would be relatively easy, as well as places along the coast that would be more difficult. Since 1990, one million trees have been planted annually on areas covering between 400 and 500 hectares. There are currently about 140 woodlands covering 12,000 hectares.

One notable contribution was by around 100 qualified pilots who flew the DC-3 aircraft for free over the period 1973 to 2006. Many participated because they had seen the problems of erosion from the air and wanted to make a contribution to improving the land. The pilots were so proud of their efforts that they often explained what they had been doing to passengers on domestic flights. The pilots took countless reporters from the media on flights and so raised the profile of the reclamation effort to the general public. The pilots union was given the Soil Conservation Award in 2002 in recognition of their members' efforts.

Interest by influential people is also a crucial ingredient of success. The former President of Iceland, Vigdís Finnbogadóttir, has always been a great supporter of land reclamation, nature conservation and afforestation. With customary passion and ardour, intelligence and eloquence, she encouraged young and old during her presidency to help revegetate the land. She played a major role in sparking the interest of her fellow citizens in land reclamation and afforestation during the latter part of the 20th century. She was instrumental in the conception of the Friendship Forest in Þingvellir National Park where Heads of State and many other guests visiting Iceland were invited to plant a tree (including the author). She founded the Yrkja Fund, which is used to purchase plants for elementary school children. And, she tirelessly encouraged Icelanders in her writings and speeches to take part in restoring the country's vegetation. In the foreword to the Soil Conservation Service's publication *Healing Iceland* released in 1988, Vigdís said the following:

> "And although we have long since learned to understand beauty and rural prosperity, learned to value naked mountains and craggy lava – there is, nevertheless, something in each of us that protests calling wasteland, that man has himself created through his activities, beautiful. There is something disagreeable about such landscapes, something that is downright morally wrong… nature does not need to be improved upon; rather it is sufficient that she be given friendly backing."[6]

Partnerships in government

The Soil Conservation Service has been working with other government agencies engaged in conservation and reclamation,

Photo 7.12
Former President Vigdís Finnbogadóttir a great environmental champion GV

notably the Nature Conservation Council and its successor bodies and the Iceland Forest Service. These bodies jointly decided to hold tripartite meetings in late 1985 to discuss land use issues, evolving into a consulting committee called NASL, an acronym for nature conservation, afforestation and land reclamation. Meetings were held over the winter months and committee members travelled together in spring and summer throughout the country. Discussion topics at meetings were diverse, for example, preserving grazing lands, environmental assessments and local authority planning, but the underlying issue was always land use. In May 1992, NASL's operations were reviewed and a resolution passed stating that its principal strategy would be to ensure that land use must always be in harmony with the natural environment and its capacity. This cooperation has prevented misunderstandings and conflicts from developing, created trust and opened avenues for joint working, even though the remits and cultures of the organisations are substantially different. The 100th meeting was held in 2005. Meetings are now less frequent, perhaps because of electronic communications and that from January 2007 the agencies all reported to the Ministry for the Environment.

The Soil Conservation Service has placed great emphasis on developing good working relations with local authorities from the outset. Cooperation has covered many issues, such as the levels of grazing in the highlands, setting grazing capacities for pastureland and undertaking vegetation assessments. Cooperation in conducting assessments increased significantly in the last quarter of the 20th century. Until then, landowners were required to contribute financially to the cost of fencing land earmarked for revegetation, with local municipalities sometimes guaranteeing the farmer's obligation. Such cooperation created trust between the parties.

The Soil Conservation Service has worked effectively with the urban municipalities in Greater Reykjavík and the Reykjanes Peninsula. A joint effort by the Soil Conservation Service, the City of Reykjavík, the adjoining town of Kópavogur and local sheep owner associations to reclaim barren land at Sandskeið was successful and, within a few years, the area had become fully vegetated. Reykjanes had suffered badly from wind erosion over the centuries, as well as from removal of trees for firewood when the fishing communities were established in the 18th and 19th centuries and from over grazing in the 20th century. This was to change when the Soil Conservation Service set up a 22 km fence traversing the peninsula from Vogar to Grindavík, and free-ranging livestock were banned on the west side where grass seed and fertiliser have since been spread in massive quantities.

Collaboration with the roads authority

There has been very good collaboration with Vegagerðin, the roads authority, for a very long time. The roads authority was responsible for protecting land from flooding until a 1979 Act assigned the responsibility for protecting agricultural land, buildings and other property from erosion by rivers to the Soil Conservation Service; the roads authority retained responsibility for roads and bridges. The law on protecting the land was again amended in 2002 to clarify priorities and the participation of landowners.

The collaboration has been particularly successful around settlements, such as Þorlákshöfn in south Iceland, by halting sand drift and revegetating areas adjacent to the roads. The largest cooperation project started in 1986 on Mýrdalssandur in south Iceland, as described and illustrated in Chapter 3. The most extensive collaboration is on the Markarfljót river in south Iceland where 42 levees extending over 40 km in length

have been installed (see Photo 6.25), with Vegagerðin responsible for levees protecting the traffic system and the Soil Conservation Service taking care of those which protect land. After the eruption in April 2010 in Eyjafjallajökull, there has been close cooperation between the two agencies in preventing floods in the glacial rivers from damaging farmland, roads and bridges. The work is expected to last for the next two years at least. In other instances, the Soil Conservation Service acts as an expert adviser and contractor to the roads authority in preventing sand drift onto roads in various parts of Iceland.

Collaboration with Landsvirkjun and Orkuveita Reykjavíkur

The state and city owned company Landsvirkjun has responsibility for developing electricity to meet commercial and domestic needs in Iceland. Its primary activity is the development and operation of hydro electric schemes throughout the country. The Soil Conservation Service has been advising Landsvirkjun on various reclamation projects and has served as a contractor in some of the most difficult conditions. A significant practical issue is the exposure of bare sediment around the reservoir shores, especially during dry weather in summer when the water level is at its lowest.

An example of the collaboration begun in 1967 when the Soil Conservation Service took on the task of revegetating land in the vicinity of the Búrfellsvirkjun Hydropower Station then under construction in south central Iceland. The areas east of Búrfell to the Þjórsá river and west to the Sandá river were barren and unvegetated, and high winds caused large quantities of sand to become airborne creating problems for those working and living on-site and for the land down wind which had been successfully stabilised after many years of work. Around 300 hectares of land was revegetated around Búrfell. Although the new grassland was covered with pumice from the 1970 Hekla eruption, it recovered with remarkable speed after being top dressed with fertiliser. Land adjacent to the planted area began revegetating on its own, and birch spread from nearby areas.

The greatest challenge for the revegetation partnership between the Soil Conservation Service and Landsvirkjun is at the Kárahnjúkavirkjun dam and Hálslón reservoir project in the eastern highlands. The government permission for the reservoir required a formal plan to be implemented to stop sand blow. A great deal of sand drift from the reservoir shores in early summer was forecast. An FAO expert was commissioned and produced a report in 2005 recommending irrigating around 350ha of the exposed shoreline sediments during the summer months[7]. Soil Conservation Service scientists set up an extensive research programme to tackle the problem, including testing binding agents in a purpose-built wind tunnel at Gunnarsholt, various trials with soil binding agents, wind barriers, and establishing lyme grass at 700m above sea level with a short growing season.

The development of the power scheme was not without controversy as many Icelanders, including the Soil Conservation Service, and experts from overseas objected, unsuccessfully, to the construction of the power plant and the reservoir in an area of the eastern highlands internationally important and exceptional for its wildlife and wildland values[8]. It is worth noting that the land was grazed by sheep and non-native reindeer. Nevertheless, and despite its own earlier objections internally within government to the project, if the expertise of the Soil Conservation Service had not been applied then the sand drift problems would have been a serious problem.

An innovative approach was also devised to compensate communities for the loss of grazing land through Landsvirkjun paying all of the costs for revegetating barren and

Photo 7.13 *Development of new techniques to reduce sand blow around the shores of the Hálslón reservoir* SR

partly vegetated land to replace what was now under water. Landsvirkjun participated in land reclamation at Hafið to compensate for vegetation lost when the Sultartangalón reservoir was constructed on the Þjórsá river in south central Iceland. When the reservoir for the Blönduvirkjun Hydropower Station in northern Iceland was filled, a large area of land became submerged. To compensate, the Blöndusamningur Agreement was made between local people and RARIK, later Landsvirkjun, around 1980, which required the latter to pay for revegetating barren and partly vegetated land to replace what was now under water. Significantly, a compensation scheme paid by Landsvirkjun to revegetate an area equivalent to the Hálslón reservoir has been implemented; the task is about 85% complete.

There has also been a good deal of collaboration with Orkuveita Reykjavíkur, the Reykjavík power company. It specialises in harnessing geothermal energy and has worked closely with the Soil Conservation Service in land restoration in the vicinity of their power plants and has provided grants for research on land reclamation.

International partnerships

A number of international partnerships have developed over the past two decades, either on an institutional basis, or more often on an individual basis.

A major Collaboration Agreement was signed in 2007 with Ohio State University, USA, involving exchange of scientists and students, research on carbon sequestration to mitigate climate change, and projects to foster participatory approaches in research and soil conservation. A new agreement for 5 years, with a possible extension for a

further 5 years, was signed in 2011. A Collaboration Agreement with the University of New England was signed in 2010 and work is evolving on several aspects of environmental governance, such as development of strategies and natural resource management law, education for sustainability, and means to stimulate awareness and local participation in the work.

A most beneficial Collaboration Agreement was signed in 2008 with the European Community, by the Institute for Environment and Sustainability of Joint Research Centre in Ispra, Italy. It involves exchange of scientific staff, study visits and participation in workshops and conferences. Þórunn Pétursdóttir, an employee of the Soil Conservation Service, is undertaking a Ph. D. there as a part of the agreement. Dr. Luca Montanarella is their representative and he has visited Iceland several times and assisted soil conservation in various ways in Iceland.

Three foreign experts, in particular, have contributed to the development of approaches to soil conservation in Iceland in recent years. Andrew Campbell was the first National Landcare Facilitator in Australia. He first visited Iceland in 1993 and assisted in forming strategies for bringing about more participatory oriented approaches in the tasks of the Soil Conservation Service. Ian Hannam, originally with the Soil Conservation of New South Wales in Australia, has visited Iceland a number of times and provided advice regarding strategies and law for soil conservation and natural resource management. He submitted a consultancy report to the government of Iceland in 1996 on reform of soil conservation policy and legislation for sustainable management. The author has visited Iceland about 20 times first as Chief Executive of Scottish Natural Heritage and later in a private advisory capacity. He has focussed on organisational leadership, culture and management, government policy and organisation, and public outreach[9].

Endnotes

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[9] See www.rogercrofts.net/articles/Iceland

Progress and Prospect

Chapter 8

Looking back and looking forward

Iceland is ecologically the most heavily damaged country in Europe. Jared Diamond[1]

It is not an exaggeration to state that many of the currently inhabited and cultivated areas around Iceland would have been an uninhabited desert of drifting sand without the work and leadership of the Soil Conservation Service and its partners over the century.

But, greater progress would have been made with more modern legislation and policy instruments providing incentives and restraints on farmers to manage livestock in an ecologically sustainable manner, especially on the highland commons. The author's assessment

The story of a century of soil conservation and land reclamation in Iceland has been set out in the foregoing chapters. What has been achieved? What is the overall assessment of progress made? What were the key ingredients of success? What were the obstacles to progress? What are the remaining obstacles? This chapter provides an overview of all of these issues and identifies the lessons learned of relevance to Iceland and those of relevance to other countries which equally face the struggle to stabilise the soil and make the land more productive. The starting point is the extent of reclamation achieved, the evolution of approaches and a catalogue of events.

Cumulative extent of reclamation

For a century, the Soil Conservation Service has worked at protecting and reclaiming land in accordance with existing laws and regulations at about 170 revegetation sites throughout Iceland (Table 8.1; Figures 8.1. 8.2 and 8.3). Their combined size is about 571,000 ha, 7.35% of the reclaimable land area, i.e. excluding mountains, glaciers, rivers and lakes. More than 100 areas have been returned to their owners fully or almost fully vegetated. In addition, there has been the work undertaken by farmers, individuals and municipalities.

The amount of land reclaimed has varied significantly over the 104 years (Table 8.1 and Figure 8.2), with the highest coinciding with the significant increase in resources under

Table 8.1 Extent of reclamation 1907 to 2010

Period	Amount reclaimed ha	Average reclamation per year	Percent of total reclamation
1907–1946	55,000	1,375	9.6
1947–1973	97,000	3,730	17.0
1974–1995	289,000	13,136	50.6
1996–2010	130,000	8,667	22.8
Total	571.000	5,490	100.0

Source: Soil Conservation Service

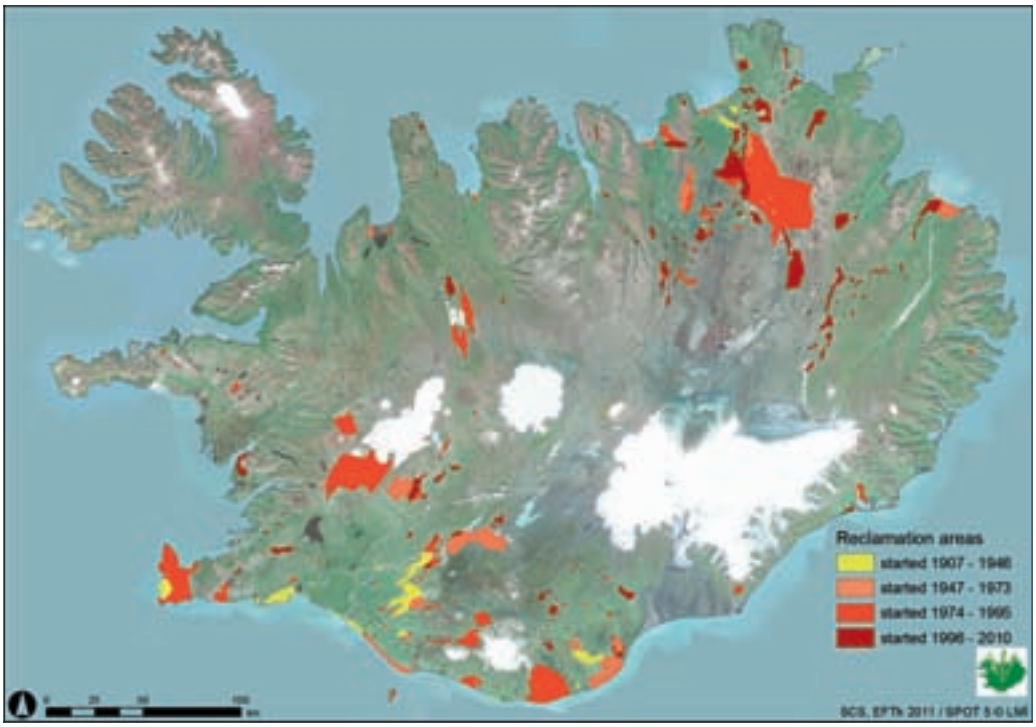

Figure 8.1 *Cumulative extent of reclamation activity around Iceland 1907–2010*
Source: Soil Conservation Service

the National Endowment Gift with a considerable fall in the annual rate and the total reclaimed since those resources were reduced by inflation and by reductions in government funding in the 1980s.

The distribution of effort has been concentrated in those areas where the problems were greatest arising from the deposition of volcanic material, the effects of river flooding and poor management of livestock. Some revegetation sites will probably never be utilised for agricultural production and require

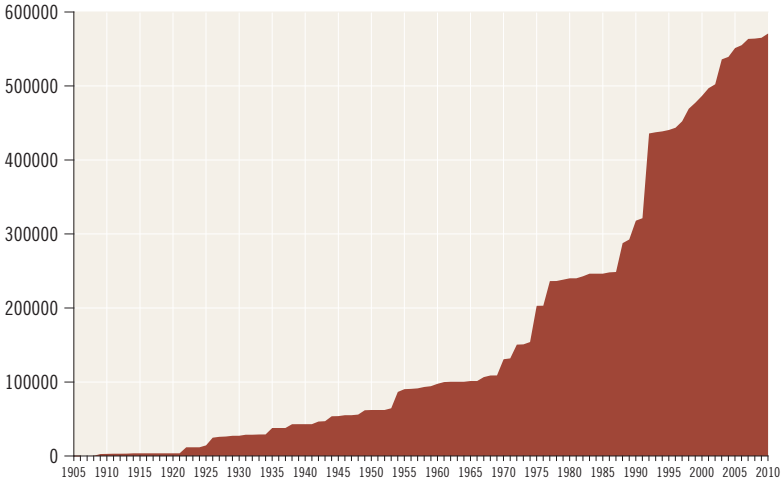

Figure 8.2
Cumulative extent of land reclamation by the Soil Conservation Service
Source: Soil Conservation Service

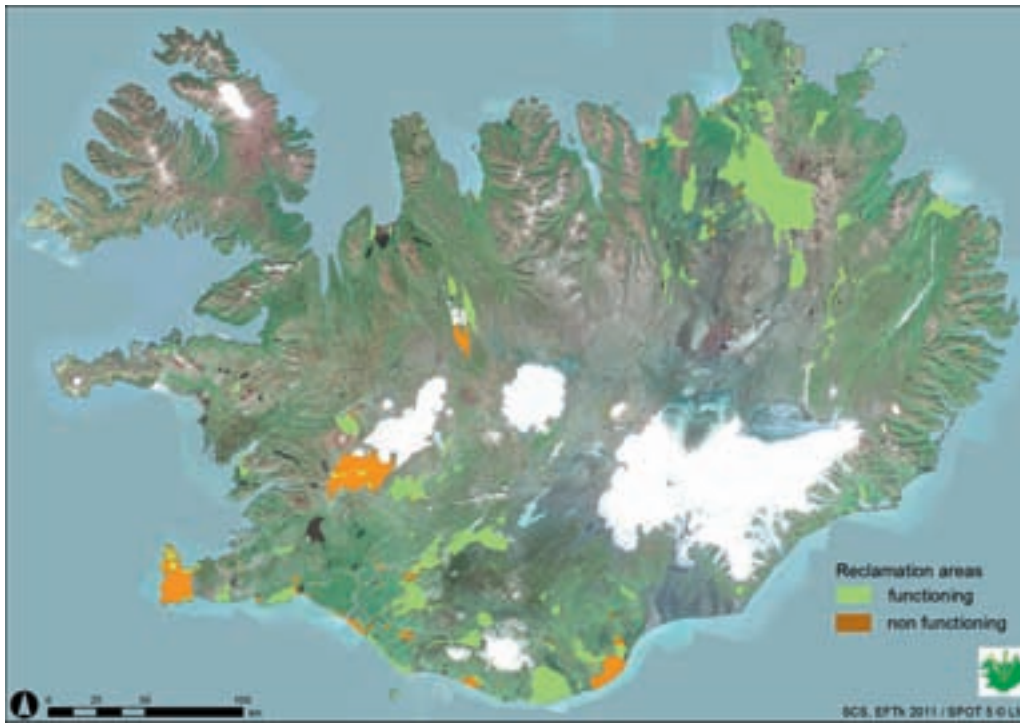

Figure 8.3 *Reclamation activity over the century: currently operating and previous areas of reclamation*

Source: Soil Conservation Service

continuous care. These include sandy coastal areas where new sand is constantly being washed ashore, for example in south Iceland, and along bays in the east and north east where glacial rivers flow into the sea.

The amount reclaimed is equivalent to about a third of the area classified as subject to severe erosion and clearly indicates the scale of the task still required. Nevertheless, the extent of reclamation is an excellent result, particularly considering the limited resources available for most of the time, that revegetation is not carried out unless the need is urgent, and even then the most difficult, sand blown areas are given priority.

Evolving approaches

Nothing is ever static and that has certainly been the case for soil conservation and land reclamation over the century. Learning from experience, from the work of leading farmers, from visits abroad, from the visits of experts from elsewhere, the staff experimented and trialled many different approaches. Some worked well, some did not work at all, and some worked when modified to suit the particular circumstances. As with any effective organisation, there has been a steady evolution of ideas and practises and, on occasions, totally new approaches were rapidly introduced, especially when new leaders were appointed or when senior staff returned from fact finding visits overseas. As a result, new objectives have been defined, new approaches developed, new information utilised, new leaders have been appointed and new people with fresh ideas employed. It is possible to identify a number of phases of evolution over the period. Sigurður Magnússon developed

a valuable schema[2]. This has been modified and extended by the author with the help of Sveinn Runólfsson and forms the basis of the analysis of evolving approaches which follows.

The seven phases identified are not always separated in time as, especially in more recent decades, new objectives have been introduced and retained, and others added to them.

Stabilising the sand: 1907–1947

This phase focussed on stabilising as many areas of drifting sand as possible recognising the continuing problems caused by sand blow. It is a period when basic statutes were enacted focussing on curtailing sand drift. These formed the basis for operation under the aegis of the Agricultural Association of Iceland for most of the period, and under the Director of Forestation only for a short initial period, and towards the end under the newly established Sand Reclamation Service. The latter name itself, following over 3 decades of activity, underlines the importance of stabilisation. This activity was largely undertaken by the state with resources from central and local government, with the significant legislative provision of the expropriation of land as the farmers could not be trusted to have the resources to undertake the job effectively. Land was fenced and seeded, and grazing animals removed. Much was achieved with the limited resources available, basically a few part-time workers each summer under the determined leadership of Gunnlaugur Kristmundsson, and with no mechanical help to assist their labours.

Photo 8.1
Gunnlaugur Kristmundsson: leader of the work during the first phase SCSI

Photo 8.2 *Beef cattle at Gunnarsholt in 1955* NMI

Reclamation and agriculture compatible: 1947–1970

With the appointment of Runólfur Sveinsson as Director and his brother Páll as his assistant the work took another turn, which continued when Páll became Director. Both recognised that engaging with farmers was essential if the sand drift problem and land degradation was ever going to be tackled successfully over extensive areas of the Icelandic lowlands. State control of the land was beginning to lessen and hence persuading farmers to be better stewards of their own land was a crucial ingredient in the new approach. They embarked on a new phase, therefore, where the principle objective was to demonstrate to farmers that land reclamation and agricultural production were not mutually exclusive and could work hand in hand. They brought in beef cattle and sheep to Gunnarsholt, and showed how they could graze on newly reclaimed land providing that they were properly managed and the grazing pressure did not exceed the carrying capacity of the land. This was a very fundamental point to them and a lesson which has taken time to be accepted by many Icelandic farmers.

They had a vision for the transformation of the desert, especially the sandur plains reaching from the glacier fronts to the coasts in the south, into valuable arable land and demonstrated this on the largest farm in Iceland at Gunnarsholt. They experimented with many varieties of seed, including native seed and strains brought from the USA and other parts of the Northern Hemisphere, and gradually increased the use of fertiliser as a vital growth stimulant. Páll was instrumental in the introduction of aircraft to undertake seed and fertiliser spreading over extensive and more remote areas. Many farmers

did recognise the benefits of reclamation and agriculture, but ensuring that these lessons were fully accepted and continued in practice proved to be a daunting task which was only taken up again from the later 1980s.

The battle of the commons 1970–1990

The extensive poorly vegetated highlands commons have been used for summer grazing of sheep for centuries (Figure 8.4). There is no doubt that farmers in Iceland made very little winter feed for their livestock, except for some of their milking cows. Sheep, goats, horses and pigs were grazed on the land throughout the year. Indeed, taking the sheep to the commons in the spring and gathering them back in September became important events in the farmers' calendar culminating the annual gathering festival - the 'réttir'. However, many of the commons were so sparsely vegetated that they should not have had any animals grazing there.

Photo 8.3 *The sheep gathering, 'réttir' at Árnes* RC

Sveinn Runólfsson took this issue up in the 1970s in the hope of being able to persuade the grazing committees and the municipal authorities to reduce the levels of use on

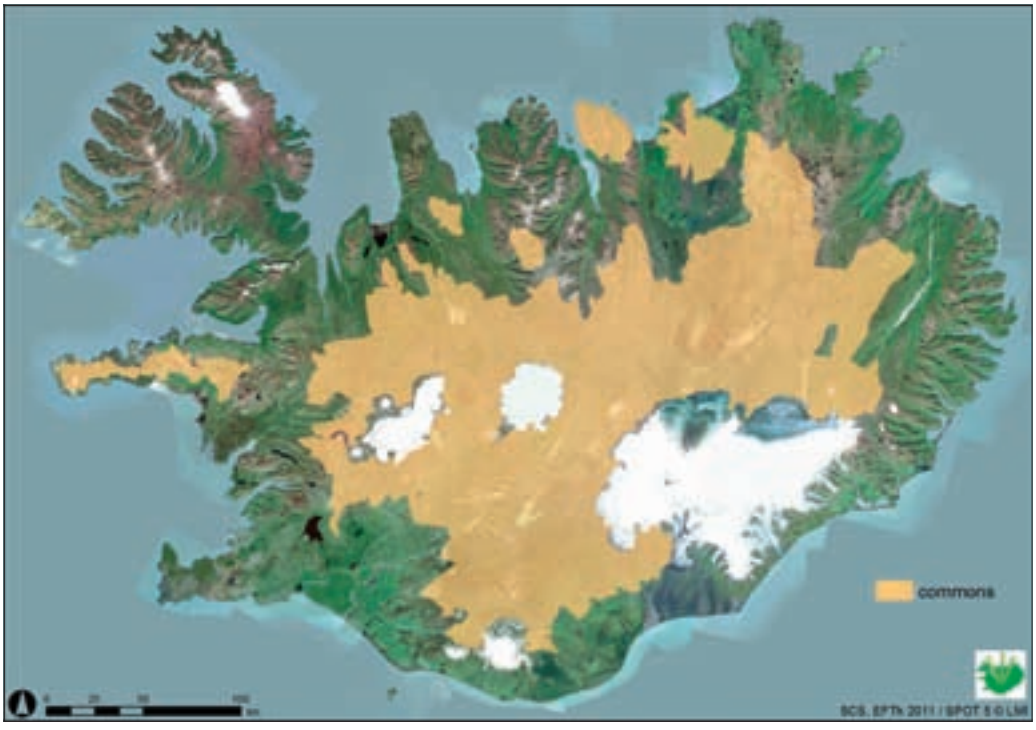

Figure 8.4 *The extent of the commons*
Source: Soil Conservation Service

grounds that the grazing was well beyond the limits of the vegetation capacity. The experiments and observations on grazing capacity begun by his predecessors were brought to bear in the long drawn out arguments with the graziers. Some of the commons committees were persuaded to fence off the most fragile areas and allow them to be seeded by aircraft. But many were not capable of persuasion, so that it is fair to call this phase 'the battle of the commons'.

Work was regularly carried out to determine the best methods to reclaim barren land, sand and gravel, and thereby increase arable land for both grazing and mowing. These areas were considered incapable of being cultivated, as a thick layer of soil had been blown away, leaving behind barren and rocky land that was unworkable. Natural conditions did not help in the recovery of eroded areas: low temperatures, the frequency of the freeze/thaw cycle, drying and abrasion of the surface by the wind, low biological activity in the surface layers, and lack of seed sources being the most significant.

The net outcome of the battle was that dates of taking the sheep to the commons were delayed in most instances, and the dates of the autumn gathering were brought forward. Also, agreements were made to stop taking horses to the commons.

Despite the best efforts of Sveinn and his staff, the argument was rarely won as graziers saw these areas as expendable and the annual tradition as part of their native rights. Suffice to say 'the battle of the commons' was not successful in this phase and, unfortunately, is still going on with the arguments still not won in many parts of Iceland. Although sheep numbers on the highland commons have been significantly reduced, this is more to do with changes in agricultural policy than the advice from the Soil Conservation Service and scientific experts on grazing. Those knowledgeable about grazing of the highland commons still say "we cannot yet look into the eyes of our descendants and state unequivocally that land utilisation of the highland commons is sustainable"[3]. Survey evidence from the turn of the millennium

Photo 8.4 *Aircraft spreading fertiliser* PPJ

shows that about 80% of the highland commons were in poor condition and most of it was desert, with only a tenth having any vegetation, and, yet there were still over 31,000 ewes grazing there[4].

The big leap forward on reclamation: 1974–1992

The National Endowment Gift approved by the Icelandic Parliament in 1974 more than trebled the resources for land reclamation and soil conservation for the following 5 years. The increases were consolidated into the budget in the 1980s. These allowed a substantially increased level of reclamation activity. Extensive areas throughout the lowlands were seeded and fertilised, primarily using a range of aircraft suited to different conditions. Also volunteer effort began through local groups and the formation of a new non-government organisation, Landvernd, focussed attention on land reclamation. The additional area reclaimed under the first 4 years after the National Endowment Gift was 843 km².

A systematic and prioritised approach: 1989-present

The work begun at the beginning of this phase fundamentally changed the way that land reclamation was understood and the way it was undertaken. A more systematic and programmed approach than ever previously used was informed by the findings of research and assessment exercises and using key tools, such as remote sensing imagery.

Surprisingly, perhaps, there had been no major assessment of the extent or severity of soil erosion and land degradation. Led by the Agricultural Research Institute under Ólafur Arnalds, and involving key staff in the Institute and the Soil Conservation Service, a radically new approach was begun which is still in use today. The assessment of the severity of erosion and the risks associated with it was undertaken for the whole of Iceland and detailed estimates were made for each region. The resulting publication *Soil Erosion in Iceland* ranks as probably the most important ever produced.

Photo 8.5 *The seminal study;* SOIL EROSION IN ICELAND SCSI

The availability of remote sensing imagery became a key tool by enabling progress to be measured and allowing plans for reclamation projects to be widely shared by staff with farmers and others involved in the reclamation work.

Another significant change came about in the 1990s when the Soil Conservation Service became a research and consulting institute. The work, conducted alone or in collaboration, covered all facets of soil and vegetation conservation and has led to increasingly effective and productive results. New and more robust revegetation plants are now being used, innovative revegetation

methodologies have been implemented and, in recent years, the research has increased knowledge on the use of fertiliser, seeding, utilising legumes and using birch and willow in land reclamation after the soil has been stabilised.

Farmers given a key role: 1990-present

The role of farmers in land reclamation had been a difficult issue from the outset of formal soil conservation due to their unwillingness to contribute financially to the activity and, more fundamentally, their lack of recognition of the need for action to become better stewards of the land. By the late 1980s, farmers were rethinking their attitudes towards land utilisation, were willing to decrease the number of sheep on sensitive land, and were prepared to revegetate those areas and undertake other activities while the land was healing. Farmers also had the knowledge, experience, and the equipment to carry out land reclamation work and were significantly influenced by the new quota systems for stocking levels.

Returning from a study visit to the USA, Andrés Arnalds, the Deputy Director of the Soil Conservation Service, reported that instead of soil conservation staff undertaking revegetation activities themselves, efforts should be focussed on persuading those who utilised the land, farmers in most cases, to change their approach to land management by balancing land utilisation with land capacity, and by becoming involved in revegetation efforts. In his report, Andrés states the following:

> "Icelandic farmers, as well as other landowners and residents, must strive

Photo 8.6 *Farmers at work preparing to spread seed and fertiliser* SCSI

to be at the forefront of soil conservation efforts in a manner similar to what their counterparts in other countries are attempting to implement."[5]

These views were reflected in *Land Reclamation and Conservation Policy,* published in autumn 1991 by the Soil Conservation Service in association with the Ministry of Agriculture, describing changes in working procedures to coincide with changing times, changing attitudes and new knowledge. The establishment of the District Officers and appointing expert advisers to each of them was a core part of this phase. The new land reclamation policy was founded on three pillars: the Soil Conservation Service's work and experience, core issues that had been discussed in the 1989 booklet *Vegetation Conservation – Objectives and Methods*, and lessons learned from other countries that had achieved effective results.

This heralded a significant change in approach which has continued to today. It was instrumental in developing perhaps the most salient programme of action on land reclamation in Iceland *Farmers Heal the Land*.

Delivering multiple objectives 2000-present

The final phase brings together the inherited objectives of the all of the previous phases into a combined and integrated approach. Increasingly, organisations are recognising the need for programmes and activities which deliver a range of objectives. In the case of soil conservation and land reclamation in Iceland, these are soil development, ecological restoration, use of predominantly native species of all types, encouraging natural vegetation succession, improved biological and agricultural productivity of the land, greater resilience to natural forces, increased carbon sequestration, biodiversity enhancement, improved water management, and greater access by the public to attractive and stable areas for informal recreation. If these objectives can be achieved, there are many benefits, not least lowering of the cost of reclamation and reducing the need to undertake it repeatedly at key locations, using smaller amounts of fertiliser to the same effect over a longer period of time, and increasing the resilience of the ground surface and the vegetation to both natural and human activity.

Photo 8.7 *The work programme of the Soil Conservation Service 2008–2020* SCSI

The key factors needed to implement the new approach successfully are clear objectives and outcomes, a planned approach to implementation with monitoring and review, increased research focussed on the key questions of the moment and addressing the longer term issues, active engagement with stakeholders who take a lead in delivery on the ground, learning from international experience, and raising awareness among the public and decision makers. The early 1990s represents a fundamental shift in the operation of the Soil Conservation Service from undertaking all of the work itself to playing a greater enabling role and building the capacity of others to undertake reclamation activity.

The timeline of a century

Table 8.2 Key events in the reclamation story 1907–2010

	Phase 1 Stabilising the sand 1907–1947
1907	In June Gunnlaugur Kristmundsson begins working to halt sand drift on behalf of the government.
1907	The first law on soil conservation, *Act on Forestry and Protection against Soil Erosion*, passed by Icelandic Parliament 22nd November 1907: established formal sand reclamation.
1908	The first soil conservation fence erected for grazing control, to protect unstable areas from sheep grazing.
1914	Law amended. The first unique laws on soil conservation are passed and the involvement of the Director of Forestation and forestry officers in matters of land reclamation and soil erosion repealed.
1923	New law passed permitting for government expropriation of degraded land for soil conservation.
1926	Gunnarsholt farm purchased and restoration projects begin.
1930s	Enclosures for reclamation established around Iceland.
1941	Position of Director of Sand Reclamation Service established by law. Gunnlaugur Kristmundsson appointed.
	Phase 2 Reclamation and agriculture compatible 1947–1970
1947	Runólfur Sveinsson appointed Director of the Sand Reclamation Service and permanent base established at Gunnarsholt.
1947	New technology introduced: motorised vehicles (tractor) and importation and experimental use of new plant species from Alaska.
1954	Páll Sveinsson appointed Director of the Sand Reclamation Service.
1958	Aerial distribution of grass seeds and manufactured fertiliser using aircraft, revolutionizing the work and revegetating large areas in short time. Publication of assessment of first 50 years.
1965	Major change in soil conservation law and change of name to Soil Conservation Service.
1969	Landvernd, land reclamation and nature conservation association, a significant non-governmental organisation, established.
	Phase 3 The battle of the commons 1970–1990
1972	Sveinn Runólfsson appointed Director of the SCS.
1972	Air Iceland donates a DC-3 aircraft for soil conservation and revegetation work.
1980s	Battle of the commons some progress but no overall agreement on the solution.
	Phase 4 The big leap forward on reclamation 1974–1992
1974	The National Endowment Gift from the nation, celebrating 1100 years of settlement on the island, provides additional resources for soil conservation and reclamation.
1974	First plan for additional activities 1974–1978 by Soil Conservation Service approved by Parliament.
1979	The SCS becomes supervising authority for controlling river flooding onto farmland.
1980	Operational Plan for 1980–1984 approved.
1987	Operational Plan for 1986–1990 approved.
1988	SCS seed processing plant begins operation, managing the whole seed production process.
	Phase 5 Systematic and prioritised approach 1989-present
1990	Assessment of erosion distribution and severity initiated.
1997	National Assessment of Soil Erosion and Land Degradation completed and report "Soil Erosion in Iceland" published.
1997	"Revegetation strategy: the objectives, methods and main tasks up to the millennium" published.
1998	SCS establishes department of research and development.
	Phase 6 Farmers given a key role 1990-present
1990	New programme "Farmers Heal the Land" initiated with work jointly funded by SCS and farmers, and undertaken by farmers.
1991	Booklet published on ethics in environmental protection and how to obtain long-term goals in land restoration.
1992	The first regional office of SCS is established in Húsavík, north Iceland.
1992	The first local soil conservation group was established in south east Iceland.
	Phase 7 Delivering multiple objectives 2000-present
2000	Action programme on quality management of land for horse breeders initiated.
2000	New controls on sheep numbers agreed by Ministry of Agriculture and farmers.
2003	Parliament approves new operational plan for SCS "A soil conservation plan 2003–2014" and additional resources.
2003	Land improvement fund established by SCS to support soil conservation locally.
2003	SCS supervises certification of sustainable land use on "quality management in sheep farming" as a part of requirements on governmental agricultural subsidies.
2007	Celebration of the Soil Conservation Service Centennial including international conference on 'Soils, Society and Global Change'.
2008	Responsibility for SCS moved from the Ministry of Agriculture to the Ministry for the Environment.

Source: Sveinn Runólfsson, Anna María Ágústsdóttir and the author

Assessment of success

In celebrating a century of soil conservation in Iceland, many achievements can be identified. Moving sand dunes have been stabilised safeguarding the land down wind and keeping the roads open. A number of settlements have been rescued from being overwhelmed by advancing sand dunes. The colonisation of recent lava flows has been accelerated by planting a combination of native and non-native species to stimulate the formation of soil. Nitrogen has been fixed through the use of legumes. New farmland has been established where once the land had little or no carrying capacity. And soil erosion has been moderated and its spatial effects reduced. None of these would have happened without increasing the knowledge and understanding of the public and gaining their support; in turn ensuring that more resources were made available and new and improved legislation enacted; farmers providing the local solutions on the ground; and government administering changes in support to reduce the size of the sheep flock.

Has land reclamation and soil conservation worked?

The area of land stabilised is greater than at the beginning of the 20th century, despite the many natural destructive events occurring during the century and despite the poor management practices on some of the farmland and on the highland commons. Measures to increase the resilience of the ground surface to disturbance have been undertaken: plants now forming ground cover, shrub layer and tree cover have been established; soil has formed; root systems have been established to increase the binding capacity; and nitrogen has been fixed. Contingency planning to help combat the effects and lessen the consequences of natural events now exists, and has been trialled and tested in both simulated situations and in real events.

But, the situation is far from favourable according to the OECD:

> "The share of the total land area subject to a medium to severe risk of soil erosion remains high (this is measured in terms

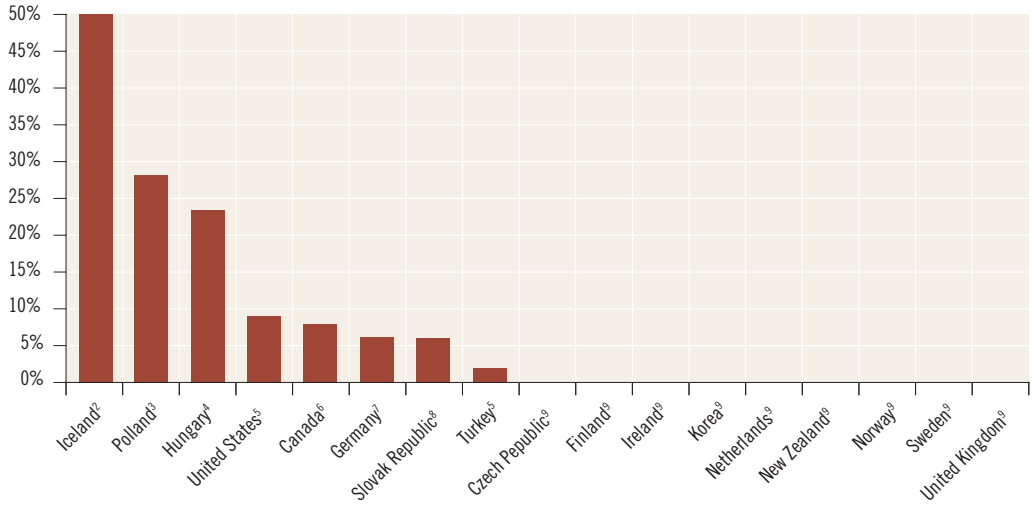

Figure 8.5 *Countries with agricultural land area classified as having moderate to severe risk of wind erosion*

Source: OECD, 2008. *Environmental Performance of Agriculture since 1990: Main Report*, Paris, France, ISBN 978-92-64-04092-2. See chapter on soil, http://www.oecd.org/dataoecd/25/52/40678565.pdf

> of landforms and in tonnes of soil loss). Severe and very severe erosion occurs on about 17% of the country, and medium erosion on an additional 22%. When glaciers, water bodies and high mountains are excluded, about 50% of the land is subject to substantial erosion. Concerning agricultural land 5% of permanent grasslands (i.e. 95% of agricultural land) are affected by moderate to severe water erosion and 50% by wind erosion."[6]

Put in an international comparative context, Iceland has the greatest proportion of its agricultural land classified as having moderate to severe risk of wind erosion (Figure 8.5).

These figures demonstrate the scale of the effort still required, but in no way diminish the work that has been done over the century and the successes achieved. Without this work the situation would have been much worse. The conclusion drawn by Icelandic ecological scientists recently is that "degradation of ecosystems is very extensive. In spite of a century of restoration efforts, much remains to be done"[7] is an accurate assessment of the situation.

It is fair to ask the questions why restore the land, and why not let nature take its course. This has never been a credible approach over the century, due as much to the Icelanders' consciousness of what their forebears had done in, perhaps unconsciously, damaging the land, vegetation and ecological functions, and their continuing desire to halt sand drifting and restore their land. Despite the gloomy statistics and the views from external assessors, such as the OECD, the critical question is what would Iceland be like now without a century of effort. The author's assessment is simple:

It is not an exaggeration to state that many of the currently inhabited and cultivated areas around Iceland would have been an uninhabited desert of drifting sand without the work and leadership of the Soil Conservation Service and its partners over the century.

So the key message is that it is possible to reclaim the land from drifting sand and to make it productive economically, ecologically and aesthetically.

What were the ingredients of success?

In a paper from the Soil Conservation Service in preparation for the Government of Iceland's submission for membership of the EU the following statement puts the position succinctly

> "Overall the pressure from agriculture on the environment has decreased. With the dominance of pastoral farming in the agricultural sector, the decline in livestock numbers since 1990, especially the national sheep flock, but little change in the area farmed, the intensity of agriculture has diminished. Despite these improvements, agriculture remains a major contributor to soil erosion, and as a consequence, a continued threat to biodiversity."[8]

Given that contextual comment, what have been the ingredients which have resulted in progress over a century? As will be obvious from the analysis presented in earlier chapters, there is no one answer to this question as the situation is complex and the solution requires many components.

Public recognition of the problem and the need to act

The formation of the Icelandic Environment Association, Landvernd, and the causes fostered by such major Icelandic figures as Vigdís Finnbogadóttir and Halldór Laxness have been instrumental in stimulating public

interest in the problems of soil erosion and sand drift. They have also led to campaigns seeking political action to provide legislation and resources. The role of civil society has been a pervasive one in a country which values comment and listens to both criticism and proposals for improvements, even though these are not always acted upon, or at least not immediately.

One measure of recognition of the work of the Soil Conservation Service was the Exemplary Institute Award given by the Ministry of Finance in 2000. It is awarded every two years to the government agency that distinguishes itself for excellence in its work. The selection committee considered that the main objectives and priorities of the Soil Conservation Service's projects were highly intelligible, that the organisation was a model for operational and managerial excellence, and for the utilisation of public funding. The committee concluded that the organisation had succeeded in utilising opportunities, and rallying widespread support from the public and business community.

More recent independent opinion polls also provide some valuable insights. In May 2004, Capacent Gallup conducted an opinion poll of the Soil Conservation Service and its work[9]. Most respondents, 93.4%, had a positive opinion of the organisation, 1.0% were negative and 5.6% had no opinion. Most respondents, 76.1%, considered that land reclamation work produced significant results. When asked if its operations were advantageous or disadvantageous for the country, 91.5% answered in the affirmative. Finally, 75.5% believed that the organisation provided benefits for the entire nation.

It is also interesting to examine the conclusions of a national opinion poll on deserts in 2006[10]. Defining a desert as land with very little or no vegetation, when asked if they existed in Iceland, 88.4% of respondents answered yes and 11.6% said no. For the lowlands, 48.2% of respondents wanted them to be revegetated, 38.9% wanted to revegetate as well as plant woodlands, while 12.9% preferred to do nothing. Icelanders had different views about the highlands: 49.4% said they should be left alone, while 37.5% wanted to revegetate, and 13.1% wanted to revegetate and plant woodlands. Finally, respondents were asked their opinion of using public funds to revegetate barren areas. The majority, 77.9%, supported the approach and 11.9% were opposed, while 10.2% did not have a firm opinion.

Photo 8.8 *The Soil Conservation Service is given the Exemplary Institute Award in 2000 by the Minister of Finance* PS

Politicians and political leaders willing to act

Throughout the century there has been a willingness by government ministers and by Members of the Icelandic Parliament to provide new laws and regulations and to vote additional resources. This has not always been straightforward, with the usual vested interests protecting them, such as the farming representatives seeking to protect land from expropriation and from contributing their own resources, causing long delays in the agreement of progressive measures. Nevertheless, at significant points in the nation's history, such as establishment of the Republic in 1944, support has been galvanised. The

leaders of soil conservation have, throughout the century, shown a willingness to address political leaders with their concerns and to lobby effectively for support for new laws and resources. Indeed, all four leaders have displayed great political nous in working with the political grain and, in turn, seeking to turn matters in favour of land reclamation. Spending time in Reykjavik, as well as taking politicians to see the problems and the solutions on the ground, have been key elements of this process. This approach has also been taken with local political representatives. As a result, most politicians, nationally and locally, are fully aware of the issues and support the solutions and the longer-term costs of restoration, and are aware of the even greater costs of ignoring the situation. Policy makers have ensured that new policies and programmes have been implemented and have brought about a noticeable reduction in sheep numbers through the quota system.

Choosing the right moment for changes in national psyche

Icelanders have a great sense of their history. Choosing those key moments in history or in the celebratory events to promote forward looking approaches to redress the negative inheritance from previous generations have been a key part of the agenda.

Organisational leadership and development

As in any field of endeavour, ensuring that the right people are in the right jobs at the right time is critical. The Soil Conservation Service has been immensely fortunate in having stability and continuity of leadership and, at the same time, maintained a dynamic approach. One family has lead soil conservation in Iceland for over 60 years. During this time, many lessons have been learned from its own activities and from other parts of the world, and new approaches taken and new people hired. The current Director and his Deputy have made sure that the organisation has a relevant strategy, have changed its approach when appropriate, particularly to implement a collaborative approach with farmers, have sought the best advice, have hired top rate staff, and have spread the message of Icelandic soil conservation to many parts of the world.

Keeping the organisation up to date and ensuring that its approaches and activities are progressive is an essential ingredient. The Soil Conservation Service, and its forerunner the Sand Reclamation Service, has periodically refreshed its policies and practices, has employed and trained expertise so that it is a leader in the scientific and technical fields. It has learned from others through visits and inviting experts to advice and work with them. It has hired new expertise to develop and implement new thinking, and to challenge old ideas and practices. And, it has made sure that those working at the headquarters are well acquainted with what is happening around the country, both in the organisation and with key stakeholders, such as farmers.

Leadership in science and practice: inventory and assessment

Policy, law and resources alone cannot solve the problems of soil erosion and land degradation. The development and appliance of science is equally important. The work of the two brothers Páll and Runólfur Sveinsson set the tone by using scientific techniques to test new seeds and plants in the revegetation effort, as well as introducing the idea of grazing and revegetation as mutually compatible.

Decades later another family has contributed significantly. Andrés Arnalds has through his prescient approach ensured that new thinking from other parts of the world

has been applied as appropriate in Iceland. For example, he was instrumental in the 'land care' ethic from Australia being adopted as the Farmers Heal the Land programme in Iceland. He has also campaigned for greater environmental literacy, and for resolution of specific issues, such as the campaign against illegal off-road driving. Ólafur Arnalds, Andrés brother, lead the seminal work on assessing the state and extent of soil erosion in Iceland and has contributed much innovative thinking on the classification and characteristics of volcanic soils and arguing the need for changes in policy. Ása L. Aradóttir, his wife, has creatively led the development of new research techniques, particularly relating to ecological succession, carbon sequestration and land restoration in the laboratory and on the ground, as well as overseeing the longer field investigations of the soil plots near the headquarters and developing restoration ecology as a key plank of the work.

The importance of soil restoration to store and sequester carbon has been high on the agenda for a long time with key provisions under the Framework Convention on Climate Change used to stimulate action. It has more recently been aided by eminent soil scientists at Ohio State University in the USA.

Scientists in Iceland have brought their knowledge and expertise to bear with many innovative solutions that are at the cutting edge of applied science in the world. And, many scientists from around the world have lent their support to Iceland's endeavours and provide beneficial advice and guidance.

Participatory approaches

There has been a long standing debate about the balance between leadership and action by the Soil Conservation Service itself and its role as a facilitator and enabler of land reclamation. Some criticise the action orientated approach as too hands on and argue that it fails to address the role of other stakeholders. In doing so, they fail to recognise the lack of trust by successive politicians in farmers undertaking the work; increases in resources only being guaranteed through direct delivery by the Soil Conservation Service. Nevertheless, the position did change fundamentally in the early 1990s. Recognition by Sveinn Runólfsson and Andrés Arnalds of the role of farmers led ultimately to one of the most important changes in practice in soil conservation: giving farmers a leading role in land reclamation and soil conservation. Local farmers are now, for the most part, engaged actively in the conservation work and lessening the effects of their activities through improved husbandry and reduction in stock numbers. The role played by the Icelandic Agricultural Association has been a major positive factor throughout the century, despite the inherent conservatism of the farmers themselves and their failure to recognise that their actions were part of the degradation problem. Such mental blockages take a long time to turn round and require persistence by those seeking change and the active support of the progressive members of farmers' organisations. This has occurred, but it has not been easy and results took many decades to materialise and many issues remain, particularly in relation to agricultural support policy.

In addition, local communities are engaged in restoration work and young children have a high level of understanding and play an active part in restoration. These collaboration activities take a good deal of effort to establish, require a positive cooperative ethic in the organisation and an ability to respond to the ideas and deeds of collaborators. The inherent problem of some organisations having what is known as the 'not invented here' syndrome is anathema to collaborative working. Increasingly, the Soil Conservation Service has demonstrated that it both understands the problems of such an ethic and seeks to avoid it.

Following a decade and a half of involvement in Iceland, the author can see a great transformation in approach with all of the different facets required for successful soil conservation, land restoration and renewal in place in an integrated whole. Significantly, all of the staff of the Soil Conservation Service and those in related supporting institutions appreciate the contribution which they make to the whole effort. Tractor drivers in the fields harvest seeds from native and introduced species for the conservation effort. Mechanics in the workshops adapt machinery to cope with specific situations. Scientists in the laboratory and on the experimental plots, for example, and use mycorrhiza to stimulate growth of seed, have an increasingly important role. Spatial imagery specialists make an important contribution as they analyse the extent and severity of erosion, and plan and monitor reclamation activities. Communication specialists have become an intrinsic part of the work by interacting with the media and communities to get the message over to politicians and public in Iceland and beyond. In addition, farmers' sons and daughters and other technical experts, employed around the country, work effectively with active farmers to support them in the restoration effort.

A number of conclusions can be drawn from the six ingredients identified. There is greater public knowledge of the soil erosion and land degradation problems and support for the provision of public resources. Reasonably effective policy and legislation is in place. A dedicated organisation is maintained to lead the work. Improved policy has partly reduced the effect of perverse incentives, particularly in relation to production subsidies for sheep and allowed greater focus on land reclamation and soil conservation outcomes. Improved legislation to stimulate land reclamation and to provide organisational leadership was put in place. Some decades ago, a higher level of resources, including specific funds dedicated to new initiatives arising from significant moments in the nation's history, have been approved. The close engagement of farmers in collaborative working to provide local solutions to erosion and increase the stability and productivity of the land has been a major benefit, despite the length of time to achieve even limited progress. And, finally, there is that rare outcome in public life: an agency widely known and respected nationally and internationally.

What have been the barriers to progress?

It would be quite wrong for the reader to think that the efforts of a century have all been positive and readily supported by decision makers, farmers and the interested public. Far from it! There are always barriers to progress. The trick is to know what they are, who are the principal actors who need to be persuaded to remove them, and to develop arguments that turn barriers into opportunities and in turn into successes.

Agricultural policy

As in many countries, agricultural policy in Iceland has for a long time been too production orientated and farmers have taken their cue from this orientation in what they do and how they do it. And, unfortunately, that is still the case. A substantial change in the mind-set of the farmers' representative bodies and in the ministry responsible for the regime is still required. There has been a long standing natural alliance between the Ministry of Fisheries and Agriculture (and its predecessors) and the farmers and their representative bodies which has dictated the agenda and the pace of change. This was further aggravated by the low incomes and the continuing necessity of support for livestock

farmers. All of these have been barriers to progress. Ironically, it was the recognition that livestock production was greater than market demand which caused the shift towards a livestock quota system and lower levels of production support leading to a significant reduction in sheep numbers. It took much longer for the recognition by the farming community that livestock numbers were greater than the carrying capacity of the land. Although this had been clear from the farming activity at Gunnarsholt from the 1950s, it took until the early 1990s for the farming community to accept fully this point and be prepared for the Minister of Agriculture to make changes in support to give farmers a role in land management to help the reclamation effort. There are still some who do not support this approach, as can be seen from pastures over grazed by sheep and/or by horses, but fortunately they are in a minority. More fundamentally, Icelandic agricultural policy is still out of tune with government policy on land reclamation and soil stabilisation. With 89% of the agricultural budget for production support demonstrates that the policy fails to connect farmers work to soil conservation and to stewardship of the land.

Attitudes of farmers

It should be clear from the preceding paragraph that the attitude of farmers towards the land and their grazing activities has been another barrier. The lack of any recognition, never mind acceptance, that grazing damaged vegetated land proved to be a long standing problem. Attitudes such as these take a long, long time to break down and reverse, and need the active encouragement of leading farmers, the involvement of conservation experts who have a farming and agricultural background and are known to the farming community, and sound science with a practical output. Throughout the centenary, the Icelandic Agricultural Society, now called the Farmers' Association, has played a key role. Until recently, it administered the agricultural support scheme on behalf of the ministry, is the key advisory service for farmers, and is mainly government funded. Its attitudes and approach played the fundamental role in shaping policy and legislation. To have the farmers lobby running the extension services remains a gross mistake and does not reflect the best practice in other countries. It is one of the failures of the government's approach and reflects the political power of the farming lobby compared with what is clearly an overriding national imperative to stabilise the land and make it productive ecologically and agriculturally. The Soil Conservation Service was fortunate in having staff who were sons of farmers, who had received formal agricultural training, and were also willing to engage with farmers on their land, as well as demonstrate at Gunnarsholt what could be achieved. But the frustration which they have felt about the slow pace of change, despite their efforts, has been and remains an enduring feature.

Lack of financial resources

There is never sufficient money for revegation and all of the associated activities. At times, additional resources voted by the Icelandic Parliament have appeared to be generous, when in reality they were only additional for a short time. At other times, the funding levels have been reduced in real terms. This is not surprising as funding will be partly dependent on the state of the nations' finances and the political impetus for funding other calls on public money. Lobbying and, most important, demonstrating that the resources were well spent and the results were of inestimable benefit to the nation and its people were crucial factors throughout the period and remain so. The clear conclusions

are that resources for soil conservation are totally inadequate given the scale and intensity of the remaining problem and compare unfavourably with other areas of government expenditure. Put into the wider context of overall government expenditure, the budget of the Soil Conservation Service is, for example, only 4% of the agricultural support budget, 6.3% of the expenditure on environmental protection, and only 0.09% of general government total expenditure[11].

Government organisation

The organisation of government and its agencies for land reclamation and soil conservation has been another barrier and remains so. From the outset, the failure to establish a formal statutory body with primary responsibility for land reclamation and soil conservation was a mistake. To give the duties as a very subsidiary objective to the newly established forestry service exacerbated the problem. If it had not been for the persistence of Gunnlaugur Kristmundsson for 40 years, there would have been little or no reclamation work and advancement in reclamation techniques. Even the belated establishment of the statutory body, the Sand Reclamation Service, in 1941, eventually to be named the Soil Conservation Service, was not ideal as the Forest Service remained a separate agency of government. The problem remains, despite the fact that much of the scientific effort is mutually supportive and the objective of afforestation should primarily be to stabilise the land and make it more productive and environmentally beneficial, rather than to produce timber.

There has been a persistent lack of natural resource coordination at ministerial level. Agricultural policy and soil conservation policy, although being the responsibility of the same Ministry (Agriculture for many decades until changed to Environment in January 2008) was not seen as part of the same overall issue of the better stewardship of natural resources. Even in the widely acclaimed Icelandic government sustainable development strategy, published in 2002[12], the section on soils was not connected to the rest of the strategy. Although with the change in ministerial responsibility it is to be hoped that this situation will not re-occur, it remains essential that the other departments with responsibility for natural resources, particularly the Finance, and the Fisheries and Agriculture Ministries, play their role positively.

Legislation

At times, it has taken an age to obtain parliamentary approval for new legislation and the resourcing of its implementation. The age old problem of protecting vested interests has been a recurrent theme throughout the century. The 1965 Act has stood the test of time, but its up-dating is long overdue as it is essential that the statutory provisions are fundamentally reviewed in the light of changing circumstances, new international obligations and the inherent failures of the current agricultural policy. A new statute on land restoration, ecological restoration and carbon sequestration is sorely needed, along side fundamental changes to agricultural policy.

Reclamation techniques

Some of the reclamation techniques used, such as the range of non-native plant species and the use of aircraft, have created tensions between different interests. The environmental movement, in particular the highly respected NGO Landvernd has questioned and continues to question the use of non-native species, especially in visually prominent and environmentally sensitive locations. The lack of dialogue on this issue has been a problem until relatively recently when,

maybe through the engagement of environmentally committed staff in the Soil Conservation Service, has begun to change.

The use of aircraft over a long period for seed and fertiliser spreading could be questioned. When this activity began in 1958 there were only small horse power tractors and most of them could not be used outside the hayfields. To improve grazing land and restore vegetation on a large scale required different means and Páll Sveinsson introduced aircraft following positive evidence of their use in other countries. It was only after 1980 that farmers started to acquire four wheel drive tractors with mounted distributors that they were contracted to undertake seeding and fertiliser spreading. The largest aircraft was kept in service because it was tackling some areas with extremely difficult terrain. It is fair to say that without the use of aircraft the amount of reclamation activity, especially over large unstable areas and in locations inaccessible to land based machinery, would have been substantially less. It is significant that the phasing out of the use of aircraft coincided with the formal introduction of programmes for land reclamation directly involving farmers.

Scientific expertise

The lack of formal scientific expertise in the Soil Conservation Service has, arguably, also been a barrier in the early decades. The 1965 Act specifically stated that the Agricultural Research Institute should provide all of the research. So the organisation did not neglect scientific activity, but used the output from the Institute, now part of the Agricultural University of Iceland, for many decades. The establishment of a formal research and development department in the Soil Conservation Service in the early 1990s changed the perspective and meant that scientific thinking and action was an intrinsic part of the organisation. This remains the case.

What are the unresolved issues?

By no means have all of the issues been resolved. Some are intractable, others have emerged relatively recently and some just take a long time to resolve.

Agricultural support regime

The most fundamental problem is that the agricultural support regime is out of date, does not reflect the requirements on farmers to cultivate the land in an environmentally sustainable manner, and does not support the resources and effort devoted to soil conservation and land reclamation. Related to this, is the ongoing issue in Iceland, as in other countries, is what is meant by sustainable farming or land use. The lack of codes of practice on good environmental management, such as the codes that have been an intrinsic part of the EU Common Agricultural Policy for the last 8 years, is lamentable. Also, the agricultural support system has a built in perversity as two thirds of the support is for the meat produced and only one third is for the sustainable management. Even then, the requirements for the latter are very low, they are not defined in a way that is necessary for the farmer to know what is required, or for the advisers to advise the farmer or the assessors to judge whether it is being done. Indeed, the lack of compliance monitoring on environmentally sustainable agriculture is a major failure of an already weak and outmoded system.

Battle of the commons

The battle of the commons is unfinished business. There is a reasonable argument that there should be no grazing on the highland commons and on other grazing land, such as the sandur plains, where there is no vegetation

to support livestock and where further grazing will merely disturb the surface, remove the pioneer plants seeking to become established, and provide more sand and dust to be spread downwind onto stabilised land. To achieve this will take a sea change in attitudes in the communities who have the traditional rights and regard it as part of their cultural calendar. There are some commons with sufficient vegetation to allow grazing over the summer. At the very least, the system of support for sheep should have a cross compliance rule which forbids grazing on those commons which are regarded, from objective assessment by the Soil Conservations Service and its expert advisers, as having no carrying capacity and where grazing will only make a bad situation worse.

Non native species

The debate about the use of native or non native species continues unabated**.** Most attention is focussed on the nootka lupin *Lupinus nootkatensis* as it is highly invasive, has been used by land reclamation enthusiasts indiscriminately in some places, and with its blue flowers stands out in the landscape in areas degraded by poor management in the past. It has positive properties for land stabilisation: it fixes nitrogen readily, it forms a dense ground cover during the growing season, the dying vegetation provides ground cover, it is a prolific seed producer and the seeds can be readily harvested and processed for later use elsewhere. When used on degraded land, it is said to significantly increase biodiversity, particularly in the soil, but there remains debate on this aspect. It has been used most effectively along the side of roads, but it has been spread indiscriminately in the highlands by individuals. The current views within the Soil Conservation Service differ with the pragmatists stating that the lupin has its place alongside other species, and those more concerned with conservation values considering that its use should be stopped. It is unlikely the position will be resolved in the near future. A recent development has been agreement between the Soil Conservation Service and the Icelandic Institute of Natural History that lupin should not be used above 400m altitude, but this is awaiting implementation through new nature conservation legislation. The previous altitudinal limit was 500m. The case about the use of other non-native species is now generally accepted in public, although there are differences of view among the specialists. This is, perhaps, partly because only grass experts can tell the difference between native and non-native grasses and the latter are not prominent in the landscape and have less invasive characteristics.

Off road driving

A recent problem has arisen out of the desire of Icelanders to drive off road, even though this is strictly forbidden by law, except on the snow. It is born out of the traditional freedoms felt by Icelanders and the availability of 4x4 vehicles and track bikes. The amount of ground disturbance and soil erosion being caused is increasing as the tracks do not easily disappear and the vegetation, if it exists, is readily damaged. The position is exacerbated by the use of global positioning systems which many Icelanders have fitted to their 4x4 vehicles and which produce a trace of where any vehicle has been. This is currently accepted by the Government's land mapping authority as representing a route and is reproduced on the computer based maps which many vehicles have displayed on the computer screens in the vehicle cabs. This is clearly a case of bad practice by users, acerbated by a lack of clarity of the roles of national agencies, and absence of proper planning procedures in defining the future network of vehicle tracks. New regulations are needed and they need to be enforced.

But the blockage is the intransigence of the 4x4 lobby and the lack of consensus within government agencies on whether anything needs to be done. The hard work of reclaiming land and making the surface stable is being undermined by those who consider it their personal right and freedom to act outside the law.

Recognition of carbon sequestration

Iceland has been lobbying internationally as a signatory of the UN Framework Convention on Climate Change to have soil conservation and land reclamation recognised as a legitimate means of reducing green house gas emissions. The country is a global leader on the carbon agenda through its land reclamation activity and the research and monitoring undertaken to assess the sequestration achieved, as well as on renewable electricity development. But natural energy exploitation is seen by many political and industrial leaders as paramount in providing jobs and giving a boost to the economy. Too often hydro-electric schemes, and more recently geothermal energy schemes, have been approved without taking sufficient account of the consequences for the stability of the land surface and the costs of the mitigation efforts to restore damaged areas. The damage being caused to the vegetation around the newest and largest geothermal plant at Hellisheiði in south west Iceland and the erosion caused by the construction of the Hálslón reservoir in eastern Iceland and the exposure of the unvegetated sediments around it when the water level fluctuates due to water off take, are cases in point. The so-called national economic imperative is used as a blunt, rather than a subtle, instrument of policy. The position needs to change to avoid greater damage to natural processes and higher costs of mitigation. Without such a change in approach, the environmental reputation of the nation will be called into question, as it has been in recent years.

Urban attitudes

With the migration of the rural population to the greater Reykjavik area in south west Iceland and the increasingly urban attitudes of the population, there is an inherent danger in the people living in urban Iceland not getting the message. Despite frequent visits to the family home in the country and the high level of ownership of the 'summer house', an increasingly sophisticated urban style dwelling in rural areas used throughout the year, the mentality of many Icelanders seems to be changing to more urban and materialistic values. As a result, there may be emerging a loss of empathy with and interest in the long term agenda for devoting public resources to land reclamation and soil conservation. Continuation of educational programmes through the schools, volunteer participation in planting and similar events in the area of residence and around the summer houses, together with continuation of the active programme of information provision and volunteering activities run by the Soil Conservation Service is called for.

Merging organisations

An outstanding issue for many of those closely involved in soil conservation politics in Iceland, including the author, is the need for the merger of relevant organisations. For a small country with limited resources Iceland has far too many governmental organisations; many are small with no economies of scale and no sharing of facilities. For example, in the administration of environment and natural resources nationally under the Ministry for the Environment there are 12 separate agencies, over 20 committees and over 20 statutory reporting mechanisms. This is a highly centralised and very fragmented approach. A

formal government review has been undertaken, but no changes have yet emerged. What is required is improved conservation of natural resources, natural resources management, and ecosystem services; increased administrative efficiency and effectiveness; greater contribution to Iceland's economy; and improved engagement of local constituents. One obvious step is to bring together the key organisations dealing with the land and its resources. At the very least, this should mean the merger of the Iceland Forest Service and the Regional Forestry Agencies with the Soil Conservation Service; more radically it should mean bringing together this new organisation with the nature functions of the Icelandic Environment Agency and the functions of the Natural History Institute. This would bring great benefits for the delivery of an integrated natural resource management and restoration agency.

And, finally, a plea is that more of the research and experience is published in English, so that international audiences can understand, share, learn from and engage in the Icelandic endeavour.

What lessons have been learned?

The key lesson is that ***it is possible.*** It is possible to reclaim the land, form soil, grow crops, revegetate, store carbon, and restore the ecology and ecosystem functions.

Many lessons have been learned in Iceland and better practice implemented. The lessons from Iceland and for Iceland are, first and foremost, that political support only continues while the problem is being addressed effectively and is of such magnitude that it cannot be solved quickly. Top down approaches which ignore the role of farmers and other land managers do not to work as effectively as active engagement of these stakeholders. Scientifically informed approaches allied to clear advice through locally based staff are likely to be more effective than the more traditional 'government knows best top/down approaches'. It is essential that the national consciousness is stimulated and maintained to activate political leadership to provide modern legislation, policy, incentives and resource allocation.

A flexibility of approach which allows new objectives to be defined and appropriate changes to be made to programmes is another lesson. No strategy can last forever as circumstances change. Soil conservation serves many purposes, but these do change over time in the light of new knowledge, new political imperatives and changes in societal values. For example, the importance of soil conservation and land reclamation for mitigating the effects of climate change through carbon sequestration, its importance in recovering the loss of biodiversity, and its importance in regulating water flows, are all new reasons which have been taken on board and influenced the scope and nature of the work.

At the organisational level, a number of lessons are obvious from the foregoing. It is essential that the top management knows and understands what is going on locally around the territory and therefore makes more informed decisions to improve delivery of the service. New staff need to be hired to bring new ideas and approaches and to fill gaps in the competencies of the organisation. Openness to new thinking at home and overseas through a variety of formal and informal arrangements works wonders to give the organisation vibrancy and creativity.

Other more specific lessons have been learned. The following are highlighted as being of great practical significance for land reclamation and soil conservation. Stabilisation work should start at the source of the problem – the supply of new bare sand and other material, for example from overgrazed and poorly managed land, from ice melt and

glacier recession, from rivers emanating from the ice, from glacial lakes and reservoirs with oscillating water levels, and where rivers meet the sea. Unless the numbers of domestic livestock are in balance with the grazing capacity of the land, erosion will occur. Therefore, controlling livestock numbers and influencing grazing patterns are both essential. Many practical approaches to achieve these results have been used successfully, such as fencing out livestock from reclamation areas until the land has a strong vegetative cover, changes to agricultural support regimes to stimulate better stewardship, and persuading farmers to change their practices through demonstrations on government controlled farms. Reclamation work is most effectively focussed on the areas of greatest vulnerability and greatest restoration potential, so it is necessary to know the scale and distribution of the erosion problem and develop strategies and priorities for action accordingly. An enduring lesson is to ensure that people on the ground see themselves as part of the solution: farmers and livestock owners, and also local authorities, businesses and community groups. There are always potential solutions. The trick is to make sure that, through experiment and trial, all ideas are tested to success or destruction.

Finally, division of effort and lack of coherence can make achievement of solutions exceedingly difficult. It is essential to make sure that all of the elements come together and integration occurs between science and practice, between science and policy, between statute, policy and practice, and between and within organisations.

What are the issues for the future?

No centenary should just be an exercise in self congratulation or looking back. It provides an excellent opportunity to look forward: to identify emerging challenges and the knowledge and skills required to bring about a beneficial outcome. For the future, six issues are paramount for soil conservation and land restoration in Iceland.

Capturing carbon

There needs to be greater recognition internationally that the capture and storage of carbon is a legitimate activity. This issue shows some signs of making progress following the meetings of the Conference of Parties to the Framework Convention on Climate Change in Copenhagen in 2009 and Cancún in 2010. At these Conferences there was an acceptance in principle of the role of forests in carbon storage through the Reducing Emissions from Deforestation and Forest Degradation (REDD) mechanism. But the role of soil is similar and, arguably, more important. It will take a great deal of international lobbying to obtain agreement and to have the relevant mechanisms in place to stimulate greater effort, such as placing a realistic economic value on carbon storage and providing incentives for reclamation work. These changes in approach would benefit other vital ecosystem services, such as water and biodiversity, and would benefit not only Iceland, but many other countries given the global problems of poor land stewardship and degradation of the soil.

Building resilience

The land surface of Iceland is still very vulnerable to natural forces and to human mismanagement. Building greater resilience in the land to withstand these forces will be critical if the gains already made are to be maintained. This will require continuing experimentation and trials of different techniques and application of new management practices, some of which are currently not known, as well as designing and delivering

woodland ecosystems with their greater in-built resilience. Scientific creativity and excellence will be required. Of particular importance will be improved understanding of the components of reclamation. Whole landscape approaches and focussing on ecological restoration will need to be at the heart of future activity. It will also require exemplary contingency planning involving all relevant local and national authorities to build greater resilience in the land and to ensure that actions taken in emergency situations do not undermine the longer term activities of land restoration and soil conservation.

Educating the younger generations

Maintaining the culture of land restoration and understanding why it is essential is fundamental component of the education of Iceland's young people. Training programmes in the classroom, activities on the ground in local communities throughout the country, with incentives and awards for the best efforts are among the ingredients for achieving this. Undergraduate and post graduate training programmes need to be maintained and their content continually up dated. And both basic and applied research in Iceland, and in collaboration with international scholars and practitioners, needs to be maintained.

Integrating approaches

Ensuring that there is a coherent and integrated approach to the use and management of natural resources, of which land reclamation and soil conservation are critical elements, is the fourth challenge for the future. Too often the economic drivers for the exploitation of natural resources have predominated at the expense of long term stewardship of the land. New strategies for sustainable development and the use of natural resources must recognise the overwhelming need, as seen from outside Iceland and many in the country, to have land reclamation as a critical element in any strategy and resourcing package.

Influencing the agenda

Bearing in mind the dramatic and unfortunate effects of the global credit crunch on the Icelandic economy at the start of the second century of soil conservation, it will be vitally important to keep environmentally sustainable land management and land restoration as high as possible up the public and political agendas on the grounds of the benefits which continuing action will bring to the land and people of this wonderful country.

Multiple objectives

And, finally, it is essential to ensure that soil conservation and land reclamation is a multifacetted activity, meeting many objectives. Single issue approaches are no longer tenable. There is good progress, but it is essential that the new strategies and policies, the proposed changes to the legal framework, potential changes to the institutional structures, and the allocation of resources have, at their core, the meeting of multiple objectives. These objectives must include production of food and fibre, species and habitat conservation and restoration, improved ecosystem functionality, landscape scale ecological restoration, surface stabilisation, increased resilience to natural and human impacts, and mitigation of and adaptation to climate change. This is very challenging and will require leadership at political, policy, administrative, operational and scientific levels.

An ethical approach

The author has written elsewhere and spoken about the need for a new ethical approach

to Iceland's natural resources including its land[13]. He suggested that a vision could be:

> ***Iceland should care for, value and use its natural resources sustainably to benefit this and many future generations.***

In this vision, the key words have the following meaning:
Care: is an active pursuit, generally meaning to conserve, restore and reclaim, but to preserve where necessary;
Value: is the ethical, cultural and economic value placed on a nation's resources;
Use: for jobs, for enjoyment, for exports, for food etc, but within the natural carrying capacity;
Benefit: socially, economically, culturally, and educationally, and long lasting: that is they are sustainable in the true and strict sense originally defined over 20 years ago.

If this approach were accepted and implemented the outcome should be an aspiration for Iceland to be the laboratory and the best exemplar of real sustainable development of natural resources in the world.

What are the lessons for other countries?

Iceland is not unique in experiencing substantial loss of soil due to the effects of wind and water erosion, exacerbated by the introduction and poor management of domesticated herbivores and misuse of nature. The stories of land degradation in many countries in earlier millennia and in Africa, parts of Asia, Australia, New Zealand and the USA at the present day are similar in many respects to those told in this book. Again, it is clear that poor stewardship of the land has been a major factor in its degradation.

World soil erosion statistics are alarming[14]. In 2007, for example there was 30% less usable soil in the world per person than in 1980. Three tons of soil erodes annually per capita, and it is expected that several hundred million people will have to abandon their homes in the coming years due to desertification. Over the next 40 years, world food production needs to be tripled. Food shortages will increase and growing numbers of people will have difficulty finding water. Something must be done. Land degradation must be stopped.

At least a quarter of the excess CO_2 in the atmosphere has come from land use change in the last century. The challenge is to put it back into the soils. To achieve this, a better understanding of the processes, practices, measurement and monitoring of carbon sequestration in terrestrial ecosystems is needed. The global potential of 1 to 2 billion tons of carbon sequestration by restoration of degraded ecosystems is valued at US$30 billion/year at present market values.

The international soil and land restoration community has gathered twice in recent years in Iceland to recognise the strides made, to salute the innovative work undertaken, to celebrate the successes, and to take messages back to the international community. Particularly important have been the messages to the major Conventions on Climate Change, Combating Desertification and Biological Diversity to ensure that there is a soil focussed approach and greater coherence between the three Conventions. A wide variety of tools and approaches are needed linking pure and applied science, with practical application and engagement with all of the international, national and local constituencies of interest.

The outcome from the 2007 international forum on *Soils, Society and Global Change*, hosted by the Icelandic Soil Conservation Service, is quite instructive. The headline was *Soils for the Sustainable Health of Our World - achieving acceptance of healthy soil as a fundamental component of human life: an ethical, value-driven and practical approach*

at the core of a new Global Covenant[15]. To achieve this, the participants concluded that a new paradigm was needed. Any solution has to recognise the complex interrelationship between the drivers of soil erosion and land degradation. Whole ecosystem approaches are needed, recognising that humans are a constituent part. Restoration and improved stewardship of the soil is the most sustainable route and will achieve many benefits, including climate change amelioration, poverty reduction, water retention, and reduction in biodiversity loss. Any solution must recognise that land degradation and the poverty trap are interlinked in complex ways, and the solution lies in breaking this negative cycle and replacing it with a more positive one. Training of leaders through schemes like the innovative UNU Land Restoration programme will be an essential component. The results from scientific studies should be made accessible to local communities, key actors, and other members of the public. Options for sustainable land use, including a new future for farmers, will need to be developed. And, finally, improved interactive approaches with a greater focus on local solutions with effective knowledge management and transfer are required.

End point

There is no single solution to land reclamation and soil conservation in Iceland or elsewhere. An integrated and coherent package of policy, mechanisms and action is needed. The key words are resilience and stewardship. The main components should be as follows.

Perceptions of the importance of soil have to be changed to achieve common recognition that soil is a critical element in human survival, essential natural capital, part of healthy ecosystem function and essential for biodiversity conservation. Educational programmes and active participation by individuals are necessary elements.

Methods for placing a monetary value on soil conservation and land restoration are needed in order for it to be included in economic accounting systems and investment decision making. More work by environmental economists, similar to the Stern report on climate change and the Suskdev report on The Economics of Ecosystems and Biodiversity (TEEB), are needed[16].

Knowledge needs to be improved, including soil sensitivity to erosion, soil carrying capacity, rates and causes of soil erosion, and practical soil conservation measures.

Improved means of knowledge transfer and exchange should be provided linking the laboratory to the farmer and the field, and back again. Codes of Practice, demonstration farms, Extension Services, and making technical advice readily understandable and available to all, are part of this element.

Incentives to stimulate soil stewardship are required**.** These should include developing and implementing a basic soil stewardship code, providing incentives for soil conservation and, crucially, involving farmers in developing and delivering conservation solutions.

A national legal framework should encapsulate a package of measures. The components of the legislative package will depend on national needs and circumstances. It can include a legal definition of the soil as critical natural and social capital; a requirement on owners and tenants of land for achieving soil stewardship with a statutory Code of Practice; soil research, development and demonstration projects; financial incentives; and a specific authority or agency to promote soil conservation

Any strategy for combating soil erosion and land degradation and stimulating the ethic and practice of conservation should encompass all of the above elements recognising that natural, social and political circumstances will vary from country to country. They should be developed with active

input from all relevant stakeholders and should be developed and implemented in an integrated manner.

Iceland has made great progress on many of these elements, and so a century of achievement deserves celebration. In the second century, a great deal needs to be done. The Soil Conservation Service is best placed to continue its leadership and innovation on land reclamation and soil conservation and to convince the people of Iceland of the need for continuing effort. It is also best placed to show the world, beyond its national shores what can be achieved in the face of the greatest natural forces anywhere in the world and how to persuade sometimes reluctant partners to join actively in the effort.

A fitting end point is the statement made in 1995 by Guðmundur Páll Ólafsson in *Iceland: The Enchanted*

> "The land of the future is a land of growth - growth of mind, culture, and society. Only growth of this kind can give the Icelanders back their pure land clad in green and 'its flourishing valley communities'. We can still hope that, one fine day, the land will be shown the respect and warmth that, as our tender and elderly mother, it deserves."[17]

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Appendices / Index

APPENDIX 1: The Selfoss statement on soil conservation in Iceland

We, the scientific and technical experts on soil conservation from 30 countries attending the International Workshop on Strategies, Science and the Law for the Conservation of the World's Soils meeting at Selfoss in southern Iceland in September 2005:

1. Recognise the power and scale of the natural processes which cause soil erosion in Iceland. In particular, we note the effects of deposits of volcanic ash and tephra which destroy the vegetation, the floods and jökulhlaups which wash away the soil and vegetation, and the wind from the ice caps which erodes the bare soil.
2. Note the views of Icelandic experts that since The Settlement of Iceland in the Ninth Century human activity has added to the natural soil erosion problems through removal of trees for fuel, through excessive grazing and trampling particularly by sheep and horses, and leaving the soil bare at the most vulnerable times of the year.
3. Congratulate the Government of Iceland on its longstanding commitment to combating soil conservation. In particular, we welcome the interest shown and the financial and other support for The Icelandic Soil Conservation Service especially by the Ministers of Agriculture, Finance, and Environment.
4. Congratulate the Icelandic Soil Conservation Service for its work over almost a century to combat soil erosion and to educate the owners and users of the land in conservation practices.
5. Congratulate the Icelandic Soil Conservation Service on its integrated programme of activity, embracing the fundamental science of soil stabilisation and vegetation growth, the quantitative assessment of the extent and severity of soil erosion, the use of this data to inform soil conservation priorities, the use of technical expertise to devise new seed mixes and stimulants for growth, its work with local farmers to increase their knowledge and capacity as soil conservers, and its contingency planning to combat the consequences of future volcanic induced soil erosion.

In praising the progress made, we also note the remaining large areas of unstable soil and the potential for significant natural events and human activity to cause more soil erosion. We call, therefore, on the Government of Iceland and the Parliament of Iceland to:

1. renew its commitment to soil conservation for the next century as it has done for the last century;
2. provide the resources needed for working with farmers and other land holders to intensify the efforts for soil conservation in all parts of the country;
3. develop a new law on soil conservation modelled on the best international practice as discussed and agreed at this

Workshop and adjusted to suit the particular circumstances of Iceland;

4. change the organisational structure by bringing together all national and regional bodies responsible for soil stabilisation and conservation into one new organisation in order to improve delivery of conservation effort and to achieve savings and removal of duplication;
5. provide resources for increased regional and local delivery of soil conservation around Iceland in recognition of the importance of working with local farmers and other land holders; and
6. recognise the high international standing of Icelandic soil conservation work and support the promotion of Icelandic knowledge and experience in soil conservation to other parts of the world.

Source: Conference on *Strategies, Science and Law for the Conservation of the World's Soil Resources* http://eusoils.jrc.ec.europa.eu/projects/scape/TheSelfoss-Statement.pdf

APPENDIX 2: Further reading

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APPENDIX 3:

Photograph credits

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BS	Björn Sigurbjörnsson
EE	Einar Erlendsson
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GM	Guðjón Magnússon
GS	Guðrún Schmidt
GV	Gunnar Vigfússon
HÓH	Hálfdan Ómar Hálfdanarsson
HO	Haraldur Oddsson
IFS	Iceland Forest Service
IINH	Icelandic Institute of Natural History
IAT	Institute of Archaeology, Iceland
JE	Jónas Erlendsson
JKS	Jón Karl Snorrason
JRB	Jón Ragnar Björnsson
JBJ	Jóna Björk Jónsdóttir
JT	Jóhann Thorarensen
KM	Kristján Magnússon
MT	Marinó Thorlacius
MWL	Mats Wibe Lund
NMI	National Museum of Iceland
OS	Oddur Sigurðsson
PPJ	Pétur P. Johnson
PS	Pjetur Sigurðsson
RTH	Ragnar Th. Sigurðsson
RMP	Reykjavik Museum of Photography
RC	Roger Crofts
SCSI	Soil Conservation Service of Iceland
SR	Sveinn Runólfsson
ÚB	Úlfur Björnsson
ÞK	Þórir Kjartansson

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Iceland's unique approach to the reclamation of its degraded land and the conservation of its soil is the theme of this book. It tells the story of natural and human history of the land and the century of effort to improve its stability, as a prelude to analysing the ingredients of formal soil conservation. The politics, law, policies, resources, and organisation for soil conservation are examined, along with the science and practice of gathering and disseminating information, developing land reclamation techniques and working with others. A critique of successes and obstacles, and identification of outstanding issues and lessons learned for Iceland and the wider world concludes the work. This book is aimed at all interested and engaged in the fundamental global issue of improved stewardship of the soil and land resources, and those wishing to know more of Iceland's approach to reclaiming the birthright which was lost by earlier generations in the struggle for survival.

100 years of land reclamation

SOIL CONSERVATION
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