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Research, part of a Special Feature on Ecological Restoration in Northern Regions

Drivers of Ecological Restoration: Lessons from a Century of Restoration in Iceland

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ABSTRACT. We analyzed the main drivers for ecological restoration in Iceland from 1907 to 2010 and assessed whether the drivers have changed over time and what factors might explain the changes, if any. Our study was based on a catalogue of 100 restoration projects, programs, and areas, representing 75% to 85% of all restoration activities in Iceland. Catastrophic erosion was an early driver for soil conservation and restoration efforts that still ranked high in the 2000s, reflecting the immense scale of soil erosion and desertification in Iceland. Socioeconomic drivers such as farming and the provision of wood products were strong motivators of ecological restoration over most of the 20th century, although their relative importance decreased with time as the number and diversity of drivers increased. In the 1960s and 1970s, the construction of hard infrastructure, and moral values such as improving the aesthetics of the countryside and "repaying the debt to the land" emerged as motivations for restoration actions. In the late 1990s, the United Nations Climate Change Convention became a driver for restoration, and the importance of nature conservation and recreation increased. Technological development and financial incentives did not show up as drivers of ecological restoration in our study, although there are some indications of their influence. Furthermore, policy was a minor driver, which might reflect weak policy instruments for ecological restoration and some counteractive policies.

Key Words: *birch woodlands; drivers; ecological restoration; heathlands; land degradation; revegetation; soil erosion; wetlands*

INTRODUCTION

Ecological restoration is driven by many interacting motivations and mechanisms. Increased ecosystem productivity is historically the main motivation of ecosystem restoration, but often does not consider other long-term ecological benefits or consequences (Hobbs and Norton 1996, Marais et al. 2007). The provision of a number of ecosystem services, such as clean water and climate amelioration, has also been a strong motivator of restoration (Clewell and Aronson 2006, Turpie et al. 2008, Suding 2011). Concerns about conservation values and biodiversity are important biotic rationales for restoration, including the preservation of rare and endangered species, biotic communities, and landscapes (Hobbs and Norton 1996, Clewell and Aronson 2006). The reversal of land degradation is another environmental motivation for ecological restoration (Hobbs and Norton 1996), often to compensate for ecosystem destruction by construction (Clewell and Aronson 2006, Suding 2011). Motivation for restoration can also be idealistic or moral, e.g., to atone for past or present environmental degradation, to reconnect with nature, or to seek spiritual renewal (see e.g., Clewell and Aronson 2006).

Mechanisms that stimulate ecological restoration can be financial or nonfinancial, or both. Financial mechanisms drive restoration projects by providing economic incentives such as private market arrangements, voluntary private nonmarket funding systems, governmentally run financial incentives, and government-supported market creation (de Groot et al. 2007). Nonfinancial mechanisms, on the other hand, involve indirect incentives, such as governmental intervention by laws and legislation, voluntary work of nongovernmental organizations (NGOs), other voluntary ecological restoration work resulting from local action, and restoration work based on aesthetic values, ethics, or faith (McGhee et al. 2007).

McGhee et al. (2007) suggested that a comprehensive inventory of restoration projects could be a valuable tool to inform decision makers and policy makers about the value of ecological restoration. We propose that such an inventory could also be used to analyze the factors driving ecological restoration. We compiled a review of ecological restoration in Iceland (Aradóttir and Halldórsson 2011) in relation to an analysis of the extent, status, methods, and results of restoration activities in the Nordic countries (Halldórsson et al. 2012). The history of organized soil conservation and restoration work in Iceland now spans more than a century (Crofts 2011). Thus, our review provided an opportunity to identify the factors driving restoration over a long period of time that involves profound changes in socioeconomic conditions and scientific understanding, as well as changes in national and international environmental policy. In this paper, we aim to analyze the history of ecological restoration in Iceland, with a focus on what has driven it. We also ask whether drivers for restoration have changed over time and, if so, what factors might explain the changes.

BACKGROUND: DISTURBANCES AND LAND DEGRADATION IN ICELAND

Iceland, one of the most active volcanic regions on Earth (Thordarson and Höskuldsson 2008), has undergone severe

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ecosystem degradation and desertification over the millennia since the Norse settlement (Amorosi et al. 1997, Arnalds et al. 2001, Dugmore et al. 2009). An important contributing factor is heavy utilization of its fragile subarctic to boreal ecosystems, primarily by extensive clear-cutting of natural woodlands and livestock grazing (Gísladóttir et al. 2010). This led to direct degradation and reduced resilience to natural disturbances such as volcanic ash deposition, long-lasting periods of unfavorable climatic conditions, and flooding (Aradottir and Arnalds 2001, Greipsson 2012).

About 42% of Iceland is a desert with limited vegetation cover (Table 1). The dominant soil type is Andosol, with organic Histosols occupying some wetland areas, but the deserts have sandy soils (Arnalds 2008). Severe erosion problems still exist, with considerable to very severe erosion occurring on about 50% of the country, and continuing land degradation problems (Arnalds et al. 2001). Extensive areas that still have vegetation cover are degraded and have reduced soil organic carbon and nutrient pools (Óskarsson et al. 2004). Not all desert surfaces of Iceland are anthropogenic; some are formed by volcanic eruptions and flooding, and many desert areas at high elevations are above the natural vegetation limits.

Table 1. Vegetation and other main surface types of Iceland, summarized by elevation belts. Based on the AUI Farmland Database (Nytjaland; http://groa.rala.is/Kortavefsja/default.aspx), simplified from Arnalds (2011). Areas are given in km².

Cover	m above sea level			Total	% of Iceland
	0-400	400-800	> 800		
Vegetated	31,194	14,509	470	46,173	44.8
Birch woodland/ shrubland	1194	11		1205	1.2
Grassland	2209	165	1	2375	2.3
Heathland	19,393	11,839	458	31,690	30.8
Wetland	4346	1449	2	5797	5.6
Other vegetated	4052	1045	9	5106	4.9
Poorly vegetated/ barren	10,284	24,576	8556	43,416	42.2
Glaciers	267	1147	9687	11,101	10.8
Rivers / Lakes	1513	648	69	2230	2.2
Total	43,258	40,880	18,782	102,920	100

Most of Iceland has been grazed by sheep since the Norse settlement. The grazing practices used to include winter and spring grazing, which had very damaging effects on ecosystems. Overgrazing has been a common problem and continues to be so in places, although winter and spring grazing have mostly been discontinued since the 1970s (Arnalds and Barkarson 2003).

From the 1940s until the late 1980s, extensive wetlands were drained for agricultural production, mostly for improving fields for haymaking and grazing, resulting in about 32,000 km of ditches, draining 50% to 75% of Icelandic wetlands (Óskarsson 1998). It has been estimated that this contributes to an immense release of greenhouse gases, equaling all the burning of fossil fuels in the country on a yearly basis (Hallsdóttir et al. 2010).

Other disturbances include road construction, with about 13,000 km of roads in rural Iceland, and over 3000 registered gravel mines (ICERA 2012). The construction of hydropower plants has disturbed many watersheds, with concomitant submersion of ecosystems by reservoirs. Likewise, geothermal power plants cause localized disturbances, e.g., in the form of drilling platforms and pipelines. More recently, urbanization of the Icelandic population (FAI 2009) is claiming increased land areas, and rapidly growing tourism is increasing pressure in vulnerable areas.

METHODS

Cataloging ecological restoration in Iceland

For the review of ecological restoration in Iceland, we asked public agencies, private companies, nongovernmental organizations (NGOs), municipalities, and other known or potential actors of restoration in the country (with the exception of private individuals) to provide information about their past and ongoing restoration projects. We contacted all directly, and held meetings with their representatives, as well as administrators and members of the scientific community. Not all of these parties were responsible for restoration projects, but those 10 actors who were responsible provided a short summary about their restoration activities, based on a standardized template. This included a short historical overview of their activities and their context, an overview table of restoration areas/projects, a self-assessment by agencies and actors of the outcome of restoration projects, and a list of published materials, where applicable.

The data provided information on when the restoration work started, the extent of the area, types of interventions, main objectives, and cooperative parties. We encouraged the actors to include photographs of the restoration activities, including "before" and "after" photos when available, and additional relevant information. An editorial group of restoration experts, representing a wide-ranging knowledge of restoration in Iceland, reviewed the contributions and selected which areas/projects to include. The Society for Ecological Restoration International Science & Policy Working Group (SER) definition of ecological restoration and its nine attributes of restored ecosystems, described in *The SER International Primer on Ecological Restoration* (SER 2004), were used as a guide for the selection. Ecological restoration is a long-term process and many areas and projects did not fulfill all the nine attributes. A minimum requirement was set that the interventions had to be based on approaches that were likely to result in a trajectory toward native ecosystems, such as heathlands, birch woodlands, or wetlands, based on past

Table 2. Main actors, number, and extent of ecological restoration areas in Iceland, 1907-2010. Two large-scale ecological restoration programs Hekluskógar and Farmers Heal the Land are not included in the table (see explanations in text).

Actors (main responsibility)		Habitat (no. of areas)			Total of areas	Size (km²)
		Heathland /grassland	Woodland	Wetland		
Public bodies	Soil Conservation Service of Iceland (SCSI)	26		1	27	1438.5†
	Forest Service (IFS)		26	1	27	186.3
	Iceland Road Administration			7‡	7	2.2
	Wetland Committee			10‡	10	2.5
	N-Iceland, Regional Afforestation Project		2		2	1.8
Energy companies	Landsvirkjun	7§	1		8	146.5
	Orkuveita Reykjavíkur	3	1		4	11.4
NGOs	Gróður fyrir fólk	11			11	1.3
Sum		47	30	19	96	
Area (km²)		1573.1	191.7	25.7		1790.5

† The SCSI only reported on restoration areas 10 km² or larger.
‡ Many of these projects were jointly implemented by the Iceland Road Administration and the Wetland Committee; in some cases involving local landowners and NGOs.
§ Most of Landsvirkjun's heathland/grassland restoration projects were carried out in close co-operation with SCSI.

research (e.g., Gunnlaugsdottir 1985, Gretarsdottir et al. 2004). This excluded areas that were dominated by, or were likely to become dominated by, exotic species, such as those seeded with Nootka Lupine (*Lupinus nootkatensis*) or planted with exotic tree species.

The review was published in Icelandic and contained 40 chapters, written by 35 authors (Aradóttir and Halldórsson 2011). In addition to the summary of restoration activities, it contained a catalogue of known current and past ecological restoration research projects in Iceland, giving information about their aims, project leaders, and institutions involved, together with a list of publications from each one. The review also included background information about land degradation and other disturbances, the history of ecological restoration, information about ecological restoration education and outreach activities, and a policy framework review. The policy review was based on a systematic search of all active laws and regulations that could potentially apply to ecological restoration and on relevant policy documents issued by governmental agencies and ministries.

Analyzing drivers of restoration

The motivation for most restoration areas and projects was described by the responsible actors in the review document (Aradóttir and Halldórsson 2011). In some cases, the motivation had already been described in original project descriptions of the Soil Conservation Service of Iceland (SCSI, *unpublished reports*) or other related documents. However, such information did not exist for many areas and projects established decades ago, and hence the responsible agencies were asked to give their evaluation of the main motivations for these areas and projects. Based on this information, the main drivers for each restoration area and project and their order of importance were determined for each of four periods: 1907 through the 1930s, 1940s through the 1960s, 1970s and 1980s, and the 1990s to the present. These periods were based on revegetation periods defined by Magnússon (1997), but with some adjustments. The drivers were broadly categorized into environmental drivers, socioeconomic drivers, law and policy drivers, and other drivers, and subcategories were added as needed. The most important driver was given the score 3, the second most important driver the score 2 and so on; totaling a maximum sum of 6 for each restoration area or project within each period. We categorized the ecological restoration areas by their prevalent habitat type and calculated the average score for each driver within habitat type and period. Because the scoring was value based, we did not analyze the data any further and we present the results without units.

RESULTS

Overview of ecological restoration in Iceland

The review of ecological restoration in Iceland included 96 restoration areas, covering nearly 1800 km² (Table 2). The review included two large-scale restoration programs not included in Table 2: Farmers Heal the Land (FHL) and Hekluskógar. FHL is a cost-share program, organized by the Soil Conservation Service of Iceland (SCSI), and covered about 150 km² of restoration areas in 2010 (Petursdóttir 2011). It involves around 600 farmers who carry out revegetation of severely degraded areas on their own land, but the SCSI provides fertilizer, extension services, and seed where needed. Hekluskógar is a recent program that aims to restore native woodlands and shrublands on more than 900 km² in the vicinity of the Mount Hekla volcano, but restoration actions have so far only been implemented on a part of this area (Óskarsson 2011*a*).

The SCSI was by far the largest actor of ecological restoration in Iceland, with 27 restoration areas covering 1438 km² (Halldórsson et al. 2011). The agency only reported on restoration areas larger than 10 km², which comprise nearly 80% of its restoration activities (SCSI *unpublished data*). Other actors were responsible for about 350 km² of restoration areas (Table 2). Our review did not include restoration by private landowners, except when it was related to restoration by agencies or to specific funding schemes, but we estimate this to be less than 100 km². Taking into account the 150 km² restored within FHL, the total extent of restored areas or areas undergoing restoration in Iceland was at least 2300 km², 2.5% of the country, excluding glaciers. Thus, we estimate that our review covered 75% to 85% of restored areas in Iceland.

Heathland and grassland were the most extensively restored habitats (Table 2), mostly restored by revegetation or reclamation of eroded or other severely degraded land. The difference between habitats was, however, not always clear-cut, as birch woodlands have later started to colonize some of the revegetated areas, and small wetlands may be formed in areas with a high water table. Most of the heathland/grassland projects were over 10 km² (Table 3). The SCSI was the main actor in heathland/grassland restoration (Table 2). Landsvirkjun, the largest energy company operating in the country, also contributed substantially toward ecological restoration of these habitats, but its restoration projects were often organized and carried out in cooperation with the SCSI (Gunnarsdóttir and Aðalsteinsson 2011). An NGO, Gróður fyrir fólk, reported on a number of small projects in these habitats that primarily used organic residues from horse stables in the capital region and from some other sources for revegetation of eroded or severely disturbed sites (Jónsson 2011).

The Icelandic Forest Service (IFS) was the largest actor in woodland restoration aimed at restoring native birch woodlands (Table 2; Eysteinsson 2011). This type of restoration was often passive, i.e., based on protection from livestock grazing, thus providing an opportunity for natural colonization of birch. In other cases, the restoration was assisted by revegetation or other actions to promote birch establishment. The majority of the woodland restoration areas were small, under 10 km² (Table 3). The energy companies were also active in small-scale woodland restoration (Table 2; Gunnarsdóttir and Aðalsteinsson 2011). Regional afforestation programs, which are currently the major actors in tree planting in Iceland, only reported on two small woodland restoration projects (Table 2; Thórsson 2011), but most of their operations are based on silviculture with nonnative tree species (Eysteinsson 2004).

Table 3. Size distribution of ecological restoration areas excluding two large-scale ecological restoration programs Hekluskógar and Farmers Heal the Land (see details in text).

Habitats	Actors	Number of areas in each size class† < 1 km²	1-10 km²	10-100 km²	> 100 km²
Birch woodland	Public	8	15	5	0
	Energy companies	0	2	0	0
Heathland/grassland	Public	0	0	25	1
	NGOs	11	0	0	0
	Energy companies	2	4	4	0
Wetland (incl. streams and lakes)	Public	18	0	1	0
Total no. of areas		39	21	35	1

† The SCSI only reported on ecological restoration areas 10 km² or larger.

A designated committee, formed by the Ministry of Agriculture in 1996, was responsible for initiating a number of wetland restoration projects between 1996 and 2003 (Garðarsson et al. 2006, Óskarsson 2011*b*), many of which were implemented jointly with the Icelandic Road Administration (Table 2). Wetland restoration most often involved the filling up of drainage ditches or installing small dams to restore mires, fens, or small lakes that were mostly less than 1 km² (Table 3). However, one large (> 10 km²) wetland area was formed after the revegetation of a floodplain area with a high water table, previously covered with entirely barren sand (Runólfsson et al. 2009).

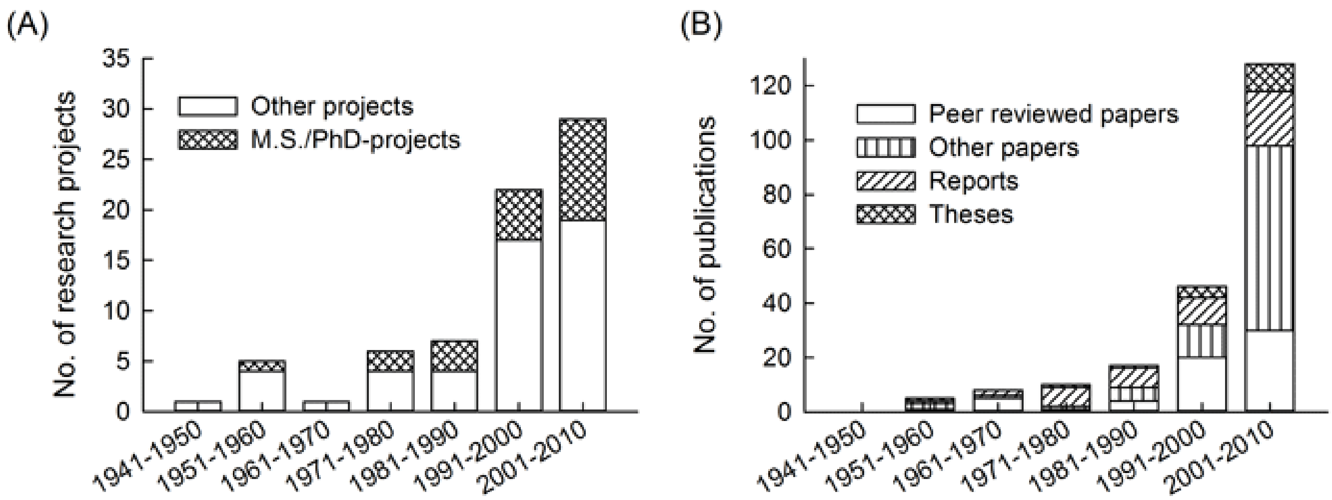
In addition to the restoration areas and programs detailed above, two projects dealing with restoration of animal populations or their habitat are included in the review: the Icelandic population of the White-tailed Eagle (*Haliaeetus albicilla*) population (Skarphéðinsson 2011) and the brown trout (*Salmo trutta*) population of Lake Thingvallavatn (Gunnarsdóttir and Aðalsteinsson 2011).

We also catalogued 70 research projects on restoration (Aradóttir et al. 2011). The oldest one started in 1946, but the number of projects increased sharply toward the end of the 20th century (Fig. 1A). The results of these research projects were presented in over 220 publications, of which nearly two-thirds were published in "gray literature," i.e., reports and other non-peer-reviewed publications (Fig. 1B).

Drivers of ecological restoration

The number of drivers increased with time in both birch woodland and heathland, from four in the first period (1907 to 1930s) to nine in the last one (after 1990), and some drivers remained important in all periods (Fig. 2). The drivers also differed among habitats. Halting of soil erosion and protection of vegetation and soils were the strongest environmental

Fig. 1. (A) Number of new research projects related to ecological restoration in Iceland, starting in each decade and (B) associated publications until 2010. No research projects related to restoration or revegetation are known before 1940.



drivers for heathland/grassland restoration throughout the 20th century. For woodland restoration, nature conservation and ecological restoration were the strongest environmental drivers. Those drivers also applied to the restoration of wetlands, lakes, and streams, once this commenced in the 1990s. The provision of wood and grazing land were important socioeconomic drivers for woodland and heathland/grassland restoration, respectively, although their relative importance decreased with time. In the 1970s, other socioeconomic drivers, such as mitigation associated with the construction of hard infrastructure (roads and power plants), came into play, and their importance increased after 1990, when there was a noticeable shift in the number and diversity of factors driving restoration (Fig. 2).

New drivers in the 1990s included mitigation of the effects of tephra deposition by volcanic eruptions and reduction of atmospheric greenhouse gases by carbon sequestration in vegetation and soils as a part of the governmental policy to comply with the United Nations Framework Convention in Climate Change (UNFCCC) commitments; the latter was categorized as both a policy and environmental driver. On the other hand, conservation of biodiversity, per se, was rarely included as an important driver. Furthermore, law and policy did not show up as strong drivers of ecological restoration in our analysis, although they were among the listed drivers of heathland restoration in the 1907 through 1930s and 1970s through the 1980s (Fig. 2). The first period coincides with the passage of the 1907 Act on Forestry and Protection against Soil Erosion, and the second period coincides with a parliamentary resolution allowing for increased funds for land reclamation and land conservation in 1974 (Table 4). Other recorded drivers include moral drivers such as romantic ideas about restoring past ecological riches ("paying the debt to the land") and preserving native birch woodlands, which were strong drivers in woodland restoration throughout the study period.

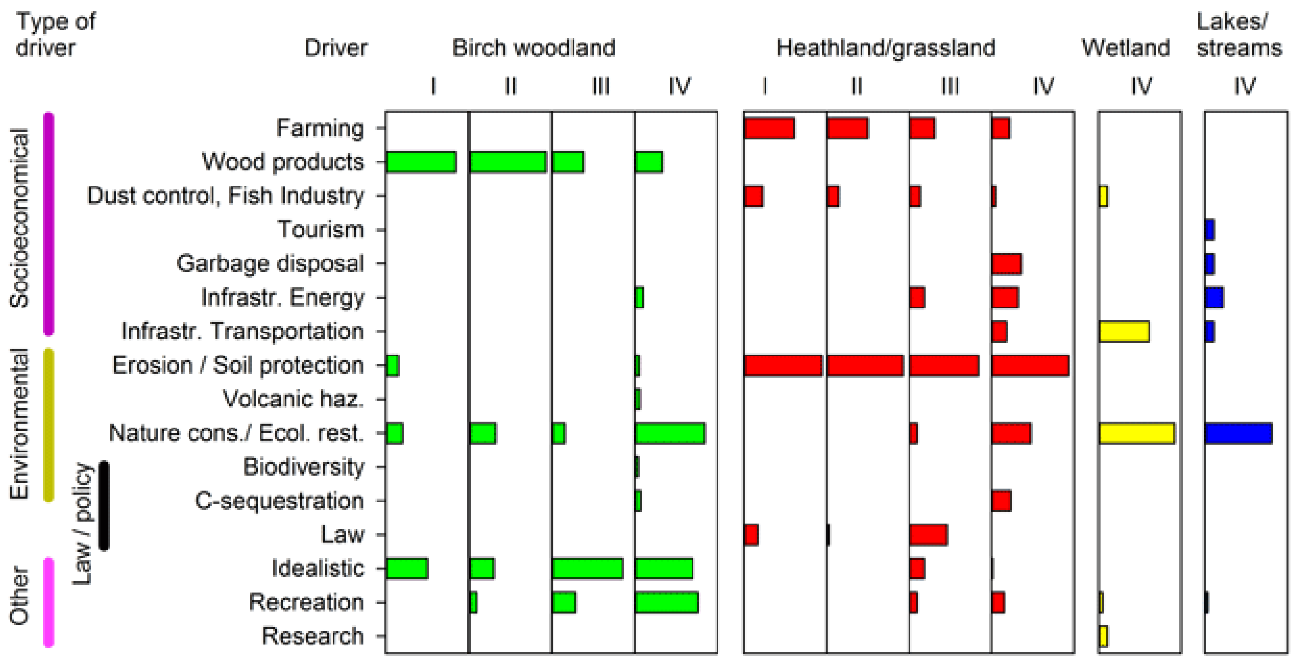
DISCUSSION

Changes in drivers of ecological restoration, 1907 to 2010

Deforestation, soil erosion, and declining agricultural production motivated conservation actions in different parts of the world in the late 19th and early 20th centuries (reviewed by Galatowitsch 2012). In Iceland, a law on vegetation and soil conservation that marked the beginning of organized work leading to ecological restoration and to the establishment of agencies that later became the Soil Conservation Service of Iceland (SCSI) and the Icelandic Forest Service (IFS), was passed in 1907 (Table 4; Runólfsson 1988).

From 1907 through the 1930s, the IFS emphasized the protection of the remaining birch woodlands from livestock grazing and attempted to establish trees by direct seeding (Eysteinsson 2011). The woodlands were an important source of firewood, which was initially a strong motivation for their restoration, although romantic ideas about preservation of the native woodlands also were influential (T. Eysteinsson, *personal communication*; Fig. 2). However, firewood extraction from the woodlands was limited after fossil fuels, hydropower, and geothermal energy became increasingly available. The catastrophic soil erosion was combated by protecting areas with advancing sand fronts from grazing, constructing sand fences, and seeding native *Leymus*

Fig. 2. Average score of main drivers of ecological restoration in Iceland by habitats and periods; I: 1907-1930s, II: 1940s-1960s, III: 1970s-1980s, IV: after 1990.



arenarius to stabilize moving sand (Kristmundsson 1958, Halldórsson et al. 2011). Although these actions were mainly motivated by the need to halt sand encroachment and preserve farmland and rangelands (Fig. 2; Runólfsson 1988), many led to ecological restoration of grassland or heathland (Halldórsson et al. 2011). The reduction of dust from soil erosion near some fishing villages was also an incentive for some early soil conservation measures (Kristmundsson 1958).

In the late 1940s and during the 1950s, emphasis in both forestry and soil conservation shifted from being predominantly protection oriented to more production orientation (Magnússon 1997, Eysteinsson 2011). Emphases on cultivation and utilization grew concurrently with agricultural intensification and new technology that allowed for larger scale operations than previously possible (Halldórsson et al. 2011). The IFS increasingly focused on silviculture for timber production, and it put less emphasis on the maintenance and restoration of the native birch woodlands than before (Eysteinsson 2011). Nevertheless, the protection of afforestation areas from livestock grazing promoted the expansion of birch woodlands through natural regeneration in many areas (Aradottir and Eysteinsson 2005).

In the 1950s, there was a rising concern over the growing number of sheep and increased grazing pressure (Sveinsson 1958), resulting in large-scale revegetation to improve land for grazing and hay making (Runólfsson 1988). This work was likely influenced by the large-scale revegetation of the Great Plains of the United States following the Dust Bowl, because there was considerable exchange between the U.S. Soil Conservation Service and the SCSI at this time (Sigurjónsson 1958). As on the Great Plains (Galatowitsch 2012), imported perennial grasses were used for revegetation, and the revegetated areas usually required continued fertilization to maintain productivity (Thorsteinsson 1991). However, a number of successional studies of old revegetation areas have shown that once management with seeding and fertilization was discontinued, their vegetation often developed toward native grassland, heathland, or birch woodland (e.g., Gunnlaugsdóttir 1985, Gretarsdottir et al. 2004). The initial inputs stabilized the soil surface, reduced frost-heaving, and enhanced levels of nutrients and organic matter in the ecosystem, thus accelerating soil formation and colonization by native species (e.g., Gunnlaugsdóttir 1985, Aradóttir 1991, Magnússon 1997).

In the late 1960s and early 1970s, there was a growing awareness in Iceland about the past and current treatment of the land and its poor condition compared to past ecological riches. The slogan “to pay the debt to the land” was widely used and Landvernd, an NGO dedicated to reclamation and environmental protection, was established. This stimulated

Table 4. A summary of potential legal and policy drivers of restoration in Iceland, 1907-2010 (based on Runólfsson 1988, Aradóttir and Pétursdóttir 2011, Crofts 2011).

Year	Title / description	Effects (potential or actual)
1907	Act on Forestry and Protection against Soil Erosion	Stimulated actions to halt sand encroachment and protection of birch woodland remnants, in some cases leading to woodland restoration and extension.
1914	Act on Land Reclamation	Government could fence off erosion areas to protect them from livestock grazing.
1923	Sand Reclamation Act	Formal appointment of a reclamation specialist by the government. Land with active erosion could be expropriated if owners could not or would not share land reclamation cost.
1941	Act Concerning Soil Reclamation and the Prevention of Drifting Sand	The Sand Reclamation Service became an independent governmental institution with increased control over soil reclamation work.
1965	Act on Land Reclamation (is still in force with minor changes)	A major revision of soil conservation law, more emphasis on protection of vegetation and soils, and sustainable land use than previous law. Formally established the Soil Conservation Service of Iceland.
1974	A resolution by Parliament regarding land reclamation and land conservation commemorating 1100 years of settlement in Iceland	A substantial increase in funds for vegetation restoration, soil conservation, forestry, and research over five years (extended twice but with reduced funds). Some of the resulting actions lead to restoration of native habitats, especially heathlands and birch woodlands, research and growing number of professionals in the field.
1998	Farming act	Land improvement should promote sustainable land use and take into account international commitments regarding conservation of biodiversity.
1999	Act on Nature Conservation	Among objectives is to secure as much as possible of the natural development of Icelandic nature.
1999	Act on Agricultural Education	Agricultural schools have a role in providing education in protection and restoration of land.
2000	Act on Environmental Impact Assessment (EIA)	Does not mention restoration explicitly, but EIAs are a part of the permission process for construction projects. In some cases, restoration as mitigation of environmental impacts has been a part of permission conditions. Large-scale projects, including restoration projects, have to undergo EIA.
2000	Changes of Act on production, pricing and trade of agricultural produce	Enabled ‘eco-friendly’ subsidies for sheep products, based on rangeland condition, among other things. Revegetation plans can be a part of cross-compliance for achieving governmental support.
2006	Act on Regional Afforestation Programs	Includes afforestation on degraded or eroded land with the aim of improving vegetation cover, soil quality, and hydrology, thus improving land-use opportunities. So far, only a few landowners have opted for restoration of birch woodlands within these programs.
1994 2008 2010-	Convention on Biodiversity (CBD) Implementation of CBD in Iceland 2008 Aichi targets	Governmental policy regarding the CBD includes goals of protecting and restoring biodiversity of Icelandic ecosystems, especially wetland ecosystems and native birch woodlands, and to limit distribution of alien, invasive species.
1994- 2002-	UNFCCC The Kyoto protocol	Governmental policy regarding the UNFCCC and the Kyoto protocol includes carbon sequestration in soils and biomass as one of several means to reduce CO_2 emissions. These include actions of revegetation, afforestation, and wetland restoration (that can lead to restoration).

public involvement in land reclamation projects, analogous to the growth in number of community groups focusing on restoration in many other countries from the 1960s to the 1980s (McDonald and Williams 2009, Stewart 2010, Galatowitsch 2012). Discussions in the Icelandic media about the state of the land were also instrumental and included scientists, governmental officials, and influential artists. This awareness was reflected at the governmental level, where a major revision of the soil conservation law was approved in 1965 (see Table 4), placing a new emphasis on soil and vegetation conservation and revegetation of eroded land. A special parliamentary resolution in 1974 to commemorate 1100 years of settlement in Iceland allowed for dramatic increases in funds for revegetation of eroded land and for research focused on land resources (Table 4). This targeted funding, commonly termed “the gift of the nation,” resulted in a new focus on vegetation and soil protection and a substantial increase in reclamation work, which involved seeding and fertilization of degraded land (Olgeirsson 2007).

Starting in the 1970s, energy companies became responsible for an increasing number of restoration projects. Revegetation of eroded areas was carried out in relation to the construction of power plants, with the primary aim to halt soil erosion in their vicinity, generate a better environment for their employees, and improve land for grazing (Gunnarsdóttir and Aðalsteinsson 2011). This work continued during the following decades with diverse aims such as to compensate for grazing pastures submerged by reservoirs, to reduce sedimentation from soil erosion into rivers and reservoirs, to enhance environmental quality near power plants, and to restore land damaged by construction and gravel mines (Friðriksdóttir and Hjartarson 2011, Gunnarsdóttir and Aðalsteinsson 2011). Some of these were mandatory compensation or mitigation actions (cf. Suding 2011); others were voluntary and/or a part of agreements between the power companies and local farmers and other land users. These restoration projects commonly addressed environmental problems that were not directly connected to the construction project in question, which might indicate efforts to demonstrate corporate goodwill or social responsibility (cf. McGhee et al. 2007).

The diversity of drivers for ecological restoration increased after 1990 (Fig. 2), as did the diversity of goals and approaches to restoration and soil conservation. Wetland restoration was predominantly motivated by nature conservation, but mitigation to offset damage to wetlands caused by road construction (cf. Mitsch et al. 1998) was also a driver (Stefánsdóttir 2011). Landowners were increasingly involved in revegetation, especially after the launch of the Farmers Heal the Land (FHL) program. SCSI's motivations for establishing FHL were to increase farmers' responsibility in taking care of the land, to increase their initiative and participation in the conservation process, and to build mutual trust between farmers and the agency (Arnalds 2005). A survey of FHL participants in 1999 (Schmidt 2000) showed that moral values such as improved aesthetics of the countryside and a wish to deliver the land in better condition to the next generation, together with environmental concerns, were important motivations for their participation in the project. Potential benefits of improved grazing management and direct financial benefits did not weigh as much, even though most of the participating FHL farmers used the reclaimed land for grazing (Schmidt 2000). Later studies have confirmed that idealistic or moral values are important drivers for farmers participating in FHL (Petursdottir et al. 2013).

International policy is increasingly becoming a driver for ecological restoration (see e.g., Bullock et al. 2011). Climate change strategies of the Icelandic government have included carbon sequestration in vegetation and soil (Icelandic Ministry for the Environment 2007), which has become one of the justifications for governmentally funded restoration and afforestation programs. Industry has increasingly supported restoration for the same purpose. Currently, there is a growing interest in curbing the immense release of greenhouse gases from drained wetlands through wetland restoration, as the rewetting of land with organic soil may become eligible as a mitigation action under the UNFCCC (2011).

The main motivation of the Hekluskógar project, initiated in 2007, was to increase the resilience of ecosystems near Mt. Hekla to impacts of volcanic ash from frequent eruptions in the volcano (Aradottir 2007, Óskarsson 2011*a*). This especially applies to secondary distribution of ash by wind and water, which can cause land degradation and soil erosion (Thorarinsdottir and Arnalds 2012). Thus, the Hekluskógar project exemplifies restoration to reduce adverse ecosystem degradation under likely disturbances (cf. Mori 2011, Suding 2011).

Socioeconomic and environmental motivations for ecological restoration

Motivations for restoration actions are often pragmatic and aim at restoring natural capital and ecosystem services (cf. Clewell and Aronson 2006, Suding 2011). This was often the case in Iceland, where the protection of woodland and soil resources, reversal of land degradation, increased forest or rangeland productivity and provision of other ecological services, especially amelioration of climate change, were common drivers for restoration. Restoration in relation to construction increased after 1970 and especially after 1990, coinciding with growth of the energy sector and road construction. On the other hand, the conservation of biodiversity, per se, hardly showed up as a driver for restoration in our analysis (Fig. 2) and our review yielded only two examples of preservation of rare or endangered populations. This separates Iceland from most other European countries, where biodiversity concerns are important motivators of ecological restoration (Madgwick and Jones 2002). A possible reason for this is the immense scale of the degradation in Iceland, and the importance of restoration actions as a response to the environmental threat of catastrophic soil erosion (Magnússon 1997). The importance of soil erosion as an environmental motivator for ecological restoration is more akin to emphasis in the Loess Plateau in China (Chen et al. 2007, Fu et al. 2010) and the drier parts of the USA and South America (e.g., Imeson 2012). As a consequence, restoration objectives in Iceland have often been rather vague and focus more on functionality, e.g., halting soil erosion or restoring soil fertility, and broad ecosystem structure such as birch woodland and heathland, rather than aiming at specific community types or historical fidelity.

Financial and policy mechanisms affecting ecological restoration

Financial incentives can be strong drivers for restoration (de Groot et al. 2007). In essence, the majority of ecological restoration projects and programs in Iceland have been funded by the government in one way or another (Arnalds 2005). In our study, funding was never identified as one of the three most important drivers for a restoration project (Fig. 2), but it is probably more important than our results indicate. For example, laws and policies were primarily identified as drivers when they resulted in special funding efforts, such as the "gift of the nation" or designated programs to stimulate carbon sequestration. The large scale Farmers Heal the Land program is an example of a project funded by the government, which would most likely not be active without this funding. The same applies to the Hekluskógar project, which did not commence until substantial governmental funding was secured.

In contrast to the EU, where policies such as the habitat directive, the bird directive, Natura 2000 networks, and the EU-LIFE Nature financial instrument provide strong mechanisms for ecological restoration (Madgwick and Jones 2002), Iceland has relatively weak policy instruments for restoration (Aradóttir and Pétursdóttir 2011). The current acts on forestry and soil conservation are from 1955 and 1965, respectively, and are in many ways outdated. These acts did not show up as influential in our analysis although they form the bases for the work of IFS and SCSI, the agencies responsible for most ecological restoration work in Iceland. Several other acts in Icelandic law touch upon subjects that can be interpreted as legal stimulus to restore degraded land (Table 4), but none of them explicitly mention ecological restoration (Aradóttir and Pétursdóttir 2011). This might be changing as recent governmental strategy papers relating to sustainable development and the implementation of the 2020 Aichi targets (http://www.cbd.int/doc/strategic-plan/2011-2020/Aichi-Targets-EN.pdf) include ecological restoration (e.g., Icelandic Ministry for the Environment 2008).

Iceland has some policy mechanisms that may hinder or compete with ecological restoration. For example, regional afforestation programs offer substantial financial incentives for afforestation that is mostly based on the planting of introduced tree species (Eysteinsson 2004). This practice is fortified by Icelandic tax authorities that in most cases do not recognize native forestry as a commercial enterprise qualifying for VAT refunds (Aradóttir and Petursdóttir 2011). Afforestation programs that encourage the establishment of alien over native forests are not unique to Iceland, but they can negatively affect the potential for ecosystem restoration and result in a net biodiversity loss (Marais et al. 2007, Lindenmayer et al. 2012). Governmental subsidies for sheep farming in Iceland pose another example of "perverse incentives" to ecological restoration (cf. Schuyt 2005). The poor state of communal rangelands in Iceland is mostly related to continuous grazing of sheep (Thorsteinsson et al. 1971). Nevertheless, subsidies of the sheep farming have had limited consideration of the state of the land, thus maintaining poor land condition in large areas (Arnalds and Barkarson 2003). In recent years, there have been some financial incentives to improve grazing land under the auspices of quality measures that have stimulated revegetation of private land and highland commons (Arnalds 2005, Crofts 2011).

Other potential drivers of ecological restoration

At the beginning of the 20th century, the Icelandic population was predominantly rural, and most people had limited means to provide for other than basic necessities (Karlsson 2000). Iceland was under Danish rule, but gained home rule in 1904. At that time there was a general wish for progress, and awakening of national values with an emphasis on the land (Kristmundsson 1958). For example, one mission of the Icelandic Youth Association, founded in 1907, was to "protect the country's natural environment and to heal the wounds which have been caused by the interaction of the land and the nation" (http://www.umfi.is/umfi09/veftre/umfi/um_umfi/). Like the slogan "to pay the debt to the land," this represents an example of both an idealistic and romantic motivation for restoration and is related to the "undertaking of restoration as atonement for environmental damage" (cf. Clewell and Aronson 2006). Such idealistic rationales for restoration may also relate to the love of the land or a wish to connect with nature (e.g., Jordan 2003, Clewell and Aronson 2006), as was seen in both the "romantic" notions in woodland restoration, and the wishes of the FHL farmers to improve the aesthetics of the countryside and deliver the land in better condition to the next generation.

Migration from rural to urban areas may offer opportunities for ecological restoration (McGhee et al. 2007, Wang et al. 2011). During the 20th century, the population of Iceland changed from being predominantly rural to predominantly urban, and the population of rural areas decreased from about 60,000 to about 20,000 (FAI 2009). A growing number of the rural inhabitants do not make their primary living from traditional agriculture. After the intensification of the sheep farming during most of the 20th century, sheep numbers decreased by nearly half in the 1980s (Jónsson and Magnússon 1997, FAI 2009). Hence, grazing pressure by sheep has been reduced in many areas, and some have been completely protected from grazing. These changes in demography and land use have created opportunities for both intended and unintended restoration, but their extent has not been documented. However, the free-roaming grazing systems used in Iceland (Arnalds and Barkarson 2003) limit the potential effects of this shift.

It has been argued that scientific advancements (technological drivers) and a strong conceptual basis are essential for progress in restoration (Hobbs and Harris 2001, Galatowitsch 2012); especially because restoration actions are often implemented before adequate field tests of methods (Palmer 2009). Toward the end of the 20th century, coinciding with the development of Restoration Ecology as a discipline, restoration research activity in Iceland increased markedly (Fig. 1), as did the number of scientists working in this field (Crofts 2011). Revegetation techniques and selection of grass species and varieties, mostly imported, were the main focus of early restoration research. Later on, the focus shifted to a greater variety of methods and native species, along with research on the trajectories and mechanisms of ecological succession and restoration of ecosystem services following restoration interventions. Although our analysis did not elucidate research or technological development as a major driver of restoration, they have at least influenced the objectives of restoration projects and have stimulated new approaches to restoration. For example, the inclusion of carbon sequestration in vegetation and soils in the climate change strategies of the Icelandic government was in part based on research showing significant carbon sequestration by afforestation (Snorrason et al. 2002) and by revegetation of eroded areas (Aradóttir et al. 2000, Arnalds et al. 2000).

CONCLUSIONS

Our results show that although the diversity of drivers for ecological restoration in Iceland increased markedly over time, some main drivers were important over most of the last century. In terms of area, halting of soil erosion and protection of soils and vegetation were the strongest drivers, which reflects the immense scale of the degradation and the importance of restoration actions as a response to the environmental threat of soil erosion. Idealistic or moral values were also important motivations of restoration interventions throughout the period.

Socioeconomic drivers such as farming and the provision of wood products motivated restoration over most of the 20th century. However, their relative importance decreased toward the end of the century. This coincided with changes in grazing pressure and land use associated with a demographic shift from rural to urban areas and a reduction in the number of sheep. Growth of the energy sector and the transportation infrastructure also contributed to the change in drivers, although the specified rationales for restoration were diverse, ranging from erosion control and mitigation actions to demonstrations of corporate goodwill. In the 1990s, climate change mitigation emerged as a driver and the importance of nature conservation and recreation increased, which reflects an increased emphasis on environmental issues in the post-Rio era as well as lifestyle changes of an increasingly urban population.

Our study did not reveal technological or scientific advancements, or financial incentives or policies as important drivers of ecological restoration in Iceland. Nevertheless, there are some indications that these factors can indirectly motivate ecological restoration and affect its objectives and approaches; however, different methods are needed to assess their importance. We propose that the main reason for the low importance of policy as a driver is the weak and outdated law and policy framework for ecological restoration in Iceland. It is urgent to strengthen and update the policy framework so that it is more in tune with current environmental paradigms, scientific knowledge, and international development. Such an update should also address "perverse incentives" that hinder restoration or pose a threat to biodiversity, including subsidies to farmers utilizing severely degraded land and subsidies for afforestation with exotic tree species.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5946

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LITERATURE CITED

Amorosi, T., P. Buckland, A. Dugmore, J. H. Ingimundarson, and T. H. McGovern. 1997. Raiding the landscape: human impact in the Scandinavian North Atlantic. *Human Ecology* 25:491-518. http://dx.doi.org/10.1023/A:1021879727837

Aradóttir, Á. L. 1991. *Population biology and stand development of birch (*Betula pubescens *Ehrh.) on disturbed sites in Iceland.* Dissertation. Department of Range Science, Texas A & M University, College Station, Texas, USA.

Aradottir, A. L. 2007. Restoration of birch and willow woodland on eroded areas. Pages 67-74 *in* G. Halldorsson, E. S. Oddsdottir, and O. Eggertsson, editors. *Effects of afforestation on ecosystems, landscape and rural development. Proceedings of the AFFORNORD conference.* TemaNord 2007:508, Reykholt, Iceland, June 18-22, 2005. [online] URL: http://www.norden.org/en/publications/publikationer/2007-508

Aradottir, A. L., and O. Arnalds. 2001. Ecosystem degradation and restoration of birch woodlands in Iceland. Pages 295-308 *in* F. E. Wielgolaski, editor. *Nordic mountain birch ecosystems*. UNESCO, Paris, France, and Parthenon, Carnforth, UK.

Aradottir, Á. L., and T. Eysteinsson. 2005. Restoration of birch woodlands in Iceland. Pages 195-209 *in* J. A. Stanturf and P. Madsen, editors. *Restoration of boreal and temperate forests*. CRC, Boca Raton, Florida, USA.

Aradóttir, Á. L., and G. Halldórsson, editors. 2011. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland. [online] URL: http://pdfvef.oddi.is/landgraedslan/vistheimt_a_islandi/

Aradóttir, Á. L., G. Halldórsson, K. Svavarsdóttir, and Ó. Arnalds. 2011. Vistheimtarrannsóknir – yfirlit [Ecological restoration research in Iceland – review]. Pages 112-127 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Aradóttir, Á. L., and Þ. Pétursdóttir. 2011. Opinber stefnumótun og stjórnsýsluhvatar er varða vistheimt á Íslandi [Policies and incentives for ecological restoration in Iceland]. Pages 24-30 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Aradóttir, Á. L., K. Svavarsdóttir, T. H. Jónsson, and G. Guðbergsson. 2000. Carbon accumulation in vegetation and soils by reclamation of degraded areas. *Icelandic Agricultural Sciences* 13:99-113.

Arnalds, A. 2005. Approaches to landcare – a century of soil conservation in Iceland. *Land Degradation & Development* 16:113-125. http://dx.doi.org/10.1002/ldr.665

Arnalds, O. 2008. Soils of Iceland. *Jökull* 58:409-421.

Arnalds, Ó. 2011. Náttúrufar [Physiography]. Pages 14-18 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [*Ecological restoration in Iceland*]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Arnalds, O., and B. H. Barkarson. 2003. Soil erosion and land use policy in Iceland in relation to sheep grazing and government subsidies. *Environmental Science & Policy* 6:105-113. http://dx.doi.org/10.1016/S1462-9011(02)00115-6

Arnalds, Ó., G. Guðbergsson, and J. Guðmundsson. 2000. Carbon sequestration and reclamation of severely degraded soils in Iceland. *Icelandic Agricultural Sciences* 13:87-97.

Arnalds, Ó., E. F. Þorarinsdóttir, S. Metusalemsson, A. Jonsson, E. Gretarsson, and A. Arnason. 2001. *Soil erosion in Iceland*. The Soil Conservation Service and the Agricultural Research Institute, Reykjavík, Iceland. [online] URL: http://www.rala.is/desert/Soil%20Erosion.pdf

Bullock, J. M., J. Aronson, A. C. Newton, R. F. Pywell, and J. M. Rey-Benayas. 2011. Restoration of ecosystem services and biodiversity: conflicts and opportunities. *Trends in Ecology & Evolution* 26:541-549. http://dx.doi.org/10.1016/j.tree.2011.06.011

Chen, L., W. Wei, B. Fu, and Y. Lu. 2007. Soil and water conservation on the Loess Plateau in China: review and perspective. *Progress in Physical Geography* 31:389-403. http://dx.doi.org/10.1177/0309133307081290

Clewell, A. F., and J. Aronson. 2006. Motivations for the restoration of ecosystems. *Conservation Biology* 20:420-428. http://dx.doi.org/10.1111/j.1523-1739.2006.00340.x

Crofts, R. 2011. *Healing the land: the story of land reclamation and soil conservation in Iceland*. Soil Conservation Service of Iceland, Gunnarsholt, Iceland.

de Groot, R., M. de Wit, E. J. Brown Gaddis, C. Kousky, W. McGhee, and M. D. Young. 2007. Making restoration work: financial mechanisms. Pages 286-293 *in* J. Aronson, S. J. Milton, and J. N. Blignaut, editors. *Restoring natural capital: science, business, and practice*. Island Press, Washington, D. C., USA.

Dugmore, A. J., G. Gísladóttir, I. A. Simpson, and A. Newton. 2009. Conceptual models of 1200 years of Icelandic soil erosion reconstructed using tephrochronology. *Journal of the North Atlantic* 2:1-18. http://dx.doi.org/10.3721/037.002.0103

Eysteinsson, T. 2004. Forestry in a treeless land. *Lustgården* 84:27-34.

Eysteinsson, T. 2011. Vistheimt á vegum Skógræktar ríkisins [Ecological restoration by the Icelandic Forest Service]. Pages 49-51 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Farmers Association of Iceland (FAI). 2009. Icelandic agricultural statistics 2009. The Farmers Association of Iceland, Reykjavík, Iceland. [online] URL: http://bondi.is/lisalib/getfile.aspx?itemid=2211

Friðriksdóttir, H., and G. Hjartarson. 2011. Vistheimt á vegum Orkuveitu Reykjavíkur [Ecological restoration by the Reykjavík Energy Company]. Pages 64-66 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Fu, B., D. Niu, Y. Lu, G. Liu, and W. Zhao. 2010. Land degradation and ecological restoration in China. Pages 140-174 *in* F. A. Comín, editor. *Ecological restoration: a global challenge*. Cambridge University Press, Cambridge, UK.

Galatowitsch, S. M. 2012. *Ecological restoration*. Sinauer Associates, Sunderland, Massachusetts, USA.

Garðarsson, A., B. Magnússon, E. Ó Thorleifsson, H. Óskarsson, J. Ó. Hilmarsson, N. Á. Lund, S. Thráinsson, and T. Baldursson. 2006. *Endurheimt votlendis 1996-2006. Skýrsla Votlendisnefndar* [Wetland restoration in Iceland 1996-2006]. Ritstjóri Daníel Bergmann. Landbúnaðarráðuneytið, Reykjavík, Iceland. [online] URL:http://www.sjavarutvegsraduneyti.is/media/Skyrslur/votlendisskyrsla.pdf

Gísladóttir, G., E. Erlendsson, R. Lal, and J. Bigham. 2010. Erosional effects on terrestrial resources over the last millennium in Reykjanes, southwest Iceland. *Quaternary Research* 73:20-32. http://dx.doi.org/10.1016/j.yqres.2009.09.007

Greipsson, S. 2012. Catastrophic soil erosion in Iceland: impact of long-term climate change, compounded natural disturbances and human driven land-use changes. *CATENA* 98:41-54. http://dx.doi.org/10.1016/j.catena.2012.05.015

Gretarsdottir, J., A. L. Aradottir, V. Vandvik, E. Heegaard, and H. J. B. Birks. 2004. Long-term effects of reclamation treatments on plant succession in Iceland. *Restoration Ecology* 12:268-278. http://dx.doi.org/10.1111/j.1061-2971.2004.00371.x

Gunnarsdóttir, H., and H. Aðalsteinsson. 2011. Vistheimt á vegum Landsvirkjunar [Ecological restoration by Landsvirkjun]. Pages 60-63 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Gunnlaugsdóttir, E. 1985. Composition and dynamical status of heathland communities in Iceland in relation to recovery measures. *Acta Phytogeographica Suecica* 75:1-84.

Halldórsson, G., Á. L. Aradóttir, A. M. Fosaa, D. Hagen, C. Nilsson, K. Raulund-Rasmussen, A. B. Skrindo, K. Svavarsdóttir, and A. Tolvanen. 2012. ReNo. Restoration of damaged ecosystems in the Nordic countries. *TemaNord 2012*:558. http://dx.doi.org/10.6027/TN2012-558

Halldórsson, G., K. Svavarsdóttir, E. F. Thorarinsdóttir, and S. Runólfsson. 2011. Vistheimt á vegum Landgræðslu ríkisins [Ecological restoration by the Soil Conservation Service of Iceland]. Pages 40-48 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Hallsdóttir, B. S., K. Harðardóttir, J. Guðmundsson, A. Snorrason, and J. Thórsson. 2010. *Emissions of greenhouse gases in Iceland from 1990 to 2008. National Inventory Report 2010.* Submitted under the United Nations Framework Convention on Climate Change and the Kyoto Protocol. Umhverfisstofnun, UST-2020:05. Environment Agency of Iceland, Reykjavík, Iceland. [online] URL: http://groa.rala.is/Kortavefsja/ICELAND_NIR_2010.pdf

Hobbs, R. J., and J. A. Harris. 2001. Restoration ecology: repairing the Earth's ecosystems in the new millennium. *Restoration Ecology* 9:239-246. http://dx.doi.org/10.1046/j.1526-100x.2001.009002239.x

Hobbs, R. J., and D. A. Norton. 1996. Towards a conceptual framework for restoration ecology. *Restoration Ecology* 4:93-110. http://dx.doi.org/10.1111/j.1526-100X.1996.tb00112.x

Icelandic Ministry for the Environment. 2007. *Iceland's climate change strategy*. Icelandic Ministry for the Environment, Reykjavík, Iceland. [online] URL: http://eng.umhverfisraduneyti.is/media/PDF_skrar/Stefnumorkun_i_loftslagsmalum_enlokagerd.pdf

Icelandic Ministry for the Environment. 2008. Líffræðileg fjölbreytni. Stefnumörkun Íslands um framkvæmd Samningsins um líffræðilega fjölbreytni [Biodiversity. Policy Strategy for Iceland in relation to the UN Convention on Biodiversity (CBD)]. Icelandic Ministry for the Environment, Reykjavík, Iceland. [online] URL: http://www.umhverfisraduneyti.is/media/PDF_skrar/liffjolbreytni.pdf

Iceland Road Administration (ICERA). 2012. *The road system 2012*. Icelandic Road Administration (ICERA), Reykjavík, Iceland. [online] URL: http://www.vegagerdin.is/vefur2.nsf/Files/RoadSystem2012/$file/RoadSystem2012.pdf

Imeson, A. 2012. *Desertification, land degradation and sustainability. Paradigms, processes, principles and policies*. Wiley-Blackwell, Chichester, UK. http://dx.doi.org/10.1002/9781119977759

Jónsson, B. G. 2011. Gróður fyrir fólk í Landnámi Ingólfs [Restoration by GFF, an NGO]. Pages 67-70 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Jónsson, G., and M. S. Magnússon, editors. 1997. *Hagskinna* [*Icelandic Historical Statistics*]. Statistics Iceland, Reykjavík, Iceland.

Jordan, R. 2003. *The Sunflower forest: ecological restoration and the new communion with nature*. University of California Press, Berkeley, California, USA.

Karlsson, G. 2000. *Iceland's 1100 years. The history of a marginal society*. Hurst & Company, London, UK.

Kristmundsson, G. 1958. Upphaf skipulagsbundinnar sandgræðslu [The beginning of organized soil conservation activities in Iceland]. Pages 187-249 *in* A. Sigurjónsson, editor. *Sandgræðslan* [Fifty years of soil conservation in Iceland]. Agricultural Society of Iceland and Soil Conservation Service of Iceland, Gunnarsholt, Iceland.

Lindenmayer, D. B., K. B. Hulvey, R. J. Hobbs, M. Colyvan, A. Felton, H. Possingham, W. Steffen, K. Wilson, K. Youngentob, and P. Gibbons. 2012. Avoiding bio-perversity from carbon sequestration solutions. *Conservation Letters* 5:28-36. http://dx.doi.org/10.1111/j.1755-263X.2011.00213.x

Madgwick, F. J., and A. T. Jones. 2002. Europe. Pages 32-56 *in* M. R. Perrow and A. J. Davy, editors. *Handbook of ecological restoration. Volume 2. Restoration in practice*. Cambridge University Press, Cambridge, UK.

Magnússon, S. H. 1997. Restoration of eroded areas in Iceland. Pages 188-211 *in* K. M. Urbanska, N. R. Webb, and P. J. Edwards, editors. *Restoration ecology and sustainable development*. Cambridge University Press, Cambridge, UK.

Marais, C., P. Woodworth, M. De Wit, J. Craig, K. D. Holl, and J. Gouza. 2007. Overcoming socioeconomic obstacles to restore natural capital. Pages 256-264 *in* J. Aronson, S. J. Milton, and J. N. Blignaut, editors. *Restoring natural capital: science, business, and practice*. Island Press, Washington, D. C., USA.

McDonald, T., and J. Williams. 2009. A perspective on the evolving science and practice of ecological restoration in Australia. *Ecological Management & Restoration* 10:113-125. http://dx.doi.org/10.1111/j.1442-8903.2009.00472.x

McGhee, W., J. Craig, R. de Groot, J. S. Miller, and K. Bowers. 2007. Making restoration work: nonmonetary mechanisms. Pages 294-302 *in* J. Aronson, S. J. Milton, and J. N. Blignaut, editors. *Restoring natural capital: science, business, and practice*. Island Press, Washington, D.C., USA.

Mitsch, W. J., X. Wu, R. W. Nairn, P. E. Weihe, N. Wang, R. Deal, and C. E. Boucher. 1998. Creating and restoring wetlands: a whole-ecosystem experiment in self-design. *BioScience* 48:1019-1030. http://dx.doi.org/10.2307/1313458

Mori, A. S. 2011. Ecosystem management based on natural disturbances: hierarchical context and non-equilibrium paradigm. *Journal of Applied Ecology* 48:280-292. http://dx.doi.org/10.1111/j.1365-2664.2010.01956.x

Olgeirsson, F. G. 2007. *Sáðmenn sandanna. Saga landgræðslu á Íslandi 1907-2007* [The story of ecological restoration in Iceland 1907-2007]. Soil Conservation Service of Iceland, Gunnarsholt, Iceland.

Óskarsson, H. 1998. Framræsla votlendis á Vesturlandi [Wetland drainage in West Iceland]. Pages 121-129 *in* J. S. Ólafsson, editor. *Íslensk votlendi, verndun og nýting* [Wetlands in Iceland, protection and utilization]. Háskólaútgáfan, Reykjavík, Iceland.

Óskarsson, H. 2011*a*. Hekluskógar. Pages 71-74 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Óskarsson, H. 2011*b*. Vistheimt á vegum Votlendisnefndar. Pages 54-55 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Óskarsson, H., Ó. Arnalds, J. Gudmundsson, and G. Gudbergsson. 2004. Organic carbon in Icelandic Andosols: geographical variation and impact of erosion. *CATENA* 56:225-238. http://dx.doi.org/10.1016/j.catena.2003.10.013

Palmer, M. A. 2009. Reforming watershed restoration: science in need of application and applications in need of science. *Estuaries and Coasts* 32:1-17. http://dx.doi.org/10.1007/s12237-008-9129-5

Pétursdóttir, T. 2011. Bændur græða landið – samstarf um uppgræðslu og endurheimt vistkerfa [Farmers Heal the Land – a cost share program on revegetaion and restoration of ecosystems]. Pages 84-85 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Petursdottir, T., O. Arnalds, S. Baker, L. Montanarella, and Á. Aradóttir. 2013. A social-ecological system approach to analyze stakeholders' interactions within a large-scale rangeland restoration program. *Ecology and Society* 18(2): 29. http://dx.doi.org/10.5751/ES-05399-180229

Runólfsson, S. 1988. Landgræðslan í 80 ár 1907-1987 [Eighty years of Soil Conservation Service of Iceland in 1907-1987]. *Græðum Ísland: Árbók Landgræðslunnar* I:99-124.

Runólfsson, S., E. F. Thórarinsdóttir, Á. L. Aradóttir, and K. Svavarsdóttir. 2009. Skógeyjarsvæðið - endurheimt votlendis úr sandi [Skógey – wetland restoration]. *Fræðaþing landbúnaðarins* 6:259-264.

Schmidt, G. 2000. Bændur græða landið – viðhorf bænda [Farmers Heal the Land – farmers perspectives]. *Ráðunautafundur* 2000:93-98.

Schuyt, K. 2005. Perverse policy incentives. Pages 78-83 *in* S. Mansourian, D. Vallauri, N. Dudley (with WWF International), editors. *Forest restoration in landscapes. Beyond planting trees*. Springer, New York, New York, USA.

Sigurjónsson, A., editor. 1958. *Sandgræðslan* [Fifty years of soil conservation in Iceland]. Agricultural Society of Iceland and Soil Conservation Service of Iceland, Gunnarsholt, Iceland.

Skarphéðinsson, K. H. 2011. Restoration of the Icelandic Sea Eagle population. Pages 18-21 *in* G. Halldórsson, editor. *Restoring the North – challenges and opportunities. International Restoration Conference, Selfoss, Iceland,* October 20-22, 2011. Book of abstracts. Soil Conservation Service of Iceland and Agricultural University of Iceland, Reykjavík, Iceland.

Snorrason, A., B. D. Sigurðsson, G. Guðbergsson, K. Svavarsdóttir, and T. H. Jónsson. 2002. Carbon sequestration in forest plantations in Iceland. *Icelandic Agricultural Sciences* 15:81-93.

Society for Ecological Restoration International Science & Policy Working Group (SER). 2004. *The SER international primer on ecological restoration*. SER, Washington, D.C., USA. [online] URL: http://www.ser.org/docs/default-document-library/english.pdf

Stefánsdóttir, M. B. 2011. Vistheimt á vegum Vegagerðarinnar [Ecological restoration by the Icelandic Road Administration]. Pages 56-59 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Stewart, M. J. 2010. Does the past matter in Scottish woodland restoration? Pages 63-73 *in* M. Hall, editor. *Restoration and history: the search for a usable environmental past*. Routledge, New York, New York, USA.

Suding, K. N. 2011. Toward an era of restoration in ecology: successes, failures, and opportunities ahead. *Annual Review of Ecology, Evolution, and Systematics* 42:465-487. http://dx.doi.org/10.1146/annurev-ecolsys-102710-145115

Sveinsson, P. 1958. Sandgræðslumálin á líðandi stund [Current issues on revegetation in Iceland]. Pages 291-311 *in* A. Sigurjónsson, editor. *Sandgræðslan* [Fifty years of soil conservation in Iceland]. Agricultural Society of Iceland and Soil Conservation Service of Iceland, Gunnarsholt, Iceland.

Thorarinsdottir, E. F., and O. Arnalds. 2012. Wind erosion of volcanic materials in the Hekla area, South Iceland. *Aeolian Research* 4:39-50. http://dx.doi.org/10.1016/j.aeolia.2011.12.006

Thordarson, T., and A. Höskuldsson. 2008. Postglacial volcanism in Iceland. *Jökull* 58:197-228.

Thórsson, B. 2011. Vistheimt á vegum Norðurlandsskóga [Ecological restoration by the North Iceland Afforestation Program]. Pages 52-53 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. Landbúnaðarháskóli Íslands og Landgræðsla ríkisins, Reykjavík, Iceland.

Thorsteinsson, I. 1991. *Uppgræðsla á Auðkúluheiði og Eyvindarstaðaheiði 1981-1989* [Revegetation on Auðkúluheiði and Eyvindarstaðaheiði heathlands in 1981-1989]. Agricultural Research Institute, Reykjavík, Iceland.

Thorsteinsson, I., G. Olafsson, and G. M. van Dyne. 1971. Range resources of Iceland. *Journal of Range Management* 24:86-93.

Turpie, J. K., C. Marais, and J. N. Blignaut. 2008. The working for water programme: evolution of a payments for ecosystem services mechanism that addresses both poverty and ecosystem service delivery in South Africa. *Ecological Economics* 65:788-798. http://dx.doi.org/10.1016/j.ecolecon.2007.12.024

United Nations Framework Convention on Climate Change (UNFCCC). 2011. Consideration of further commitments for Annex I parties under the Kyoto Protocol. UNFCC, Durban, South Africa. [online] URL: http://unfccc.int/resource/docs/2011/awg16/eng/l03a02.pdf

Wang, C., Y. Yang, and Y. Zhang. 2011. Economic development, rural livelihoods, and ecological restoration: evidence from China. *Ambio* 40:78-87. http://dx.doi.org/10.1007/s13280-010-0093-5

II

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Research, part of a Special Feature on Ecological Restoration in Northern Regions

A Social–Ecological System Approach to Analyze Stakeholders' Interactions within a Large-Scale Rangeland Restoration Program

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ABSTRACT. Large-scale restoration projects are normally part of a complex social–ecological system where restoration goals are shaped by governmental policies, managed by the surrounding governance system, and implemented by the related actors. The process of efficiently restoring degraded ecosystems is, therefore, not only based on restoring ecological structure and functions but also relies on the functionality of the related policies, the relevant stakeholder groups, and the surrounding socioeconomic and political settings. In this research, we investigated the SES of rangeland restoration in Iceland to estimate whether social factors, such as stakeholders' attitudes and behavior, can be used to evaluate the effectiveness of agri-environmental policies on rangeland restoration and improved land management. We used qualitative approaches, interviewing 15 stakeholders. Our results indicate that social factors such as attitude toward restoration and land management practices can be used as indicators to evaluate the effectiveness of restoration policies. They also strongly indicate that lack of functionality in the governance system of social–ecological systems can reduce the desired progress of policies related to large-scale natural resource management projects, such as rangeland restoration, and possibly halt the necessary paradigm shift among stakeholders regarding improved rangeland management.

Key Words: *agri-environmental policies; ecological restoration; evaluation; natural resource management; social–ecological systems*

INTRODUCTION

> *Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed.* – Society for Ecological Restoration Science and Policy Working Group (SER) (2004).

The desired outcome of restoration is a resilient and self-sustaining ecosystem with respect to structure, species composition, and function. The restored system should also be integrated into the larger landscape and support the sustainable livelihood of societies that rely on using land resources (SER and IUCN 2004). Such coupled human natural systems are defined as social–ecological systems (SESs), encompassing distinct but interacting subsystems and internal variables (Anderies et al. 2004). An SES defines the intricate links between an ecological and a social system and how they affect and shape each other (Ostrom 2009). Its sustainability relies on well-structured policies, as well as efficient institutional governance and cooperative resource users, all aiming to sustain and strengthen the functional capacity of the SES (Holling 2001).

An SES of ecological restoration builds on interventions aiming at repairing degraded ecosystems and seeks to support the related interactions between humans and nature (Bradshaw and Bekoff 2001, Hobbs et al. 2011). Even though the restoration of ecosystem structure and functions are given as the main objectives for restoration (SER 2004), the process of sustaining or restoring ecosystems is also highly related to the motivation of related stakeholder groups and the effectiveness of the correspondent socioeconomic and political settings (Ostrom 2009, Hobbs et al. 2011). These multiple approaches are emphasized in the design of restoration programs and, in recent years, they are also stretching into the evaluation of restoration outcomes (Clewell and Aronson 2006, Aronson et al. 2010).

The methods of economics are increasingly used to evaluate the achievements of ecological restoration, in addition to the standard measurements of ecological parameters such as soil and vegetation components (e.g., Herling et al. 2008, Weber and Stewart 2008). Economic approaches can capture some of the market value of restoration derived from the actual use of a restored ecosystem good or service but are vaguer concerning the nonmarket values that are not expressed in prices (Daly and Farley 2004). The most effective leverage points for successful restoration and improved land management practices may not even lie within the economic system, but instead in social factors like rules, information transfers, and paradigms constructed around the related SESs (Meadows 2008). Stakeholders' attitudes and/or behavior and the level of consistency within the governance system may, therefore, facilitate restoration activities and progress, or cause dysfunction within the SESs that can lead to reversal or even elimination of the desired ecological progress (Berkes and

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Folke 2000, Hobbs 2007, Hobbs et al. 2011). Achieving successful restoration outcomes requires the design of new approaches that can measure and link both ecological functions and human well-being (O'Farrell et al. 2011).

To investigate the possible effects of social factors on restoration outcomes we explored the SESs of large-scale rangeland restoration in Iceland, focusing on the system's main stakeholder groups and their interrelationships. We used Iceland as a case study because the country's government has supported and financed restoration of degraded rangeland and improved land management for over a century. The long-term effectiveness of restoration and sustainable land management policies have, however, never been evaluated. For this study, we interviewed selected stakeholders about their attitudes toward rangeland restoration and land management practices. We also asked about their views on related policies and the governance system to assess whether social factors, such as stakeholders' attitudes and behavior, could be used as indicators for evaluating restoration impacts and more generally in relation to sustainable land management practices.

METHODS

Background

Sheep farming, rangeland management, and restoration
Livestock farming has been practiced in Iceland ever since the country was settled in the late 9th century. From the 13th century, sheep farming has been one of the most important sources of subsistence in Iceland (Ingimundarson 2010), and since early 20th century, this farming has been mainly geared toward the meat production market. According to the Icelandic Agricultural Statistic (IAS) (2010), there were 1318 sheep farms and 138 mixed sheep/dairy farms operating in 2008, compared with 581 dairy farms. The average farm holds around 300 adult sheep, and the average farmer is 54 years old (IAS 2010). The majority of the farmsteads are located in lowland areas, with the lowest density near urban areas (Jóhannesson 2010).

Because of Iceland's northerly location and erodible volcanic soils, its pristine ecosystems were highly vulnerable to grazing and the wood harvesting practiced by the settlers. Frequent volcanic eruptions and a harsh climate made the ecosystems even more fragile and less resilient in the face of human intervention (McGovern et al. 2008). Severe loss of fertile soil and vegetation throughout the centuries created vast areas of degraded ecosystems that are, to this day, still dysfunctional to some extent (Arnalds and Barkarson 2003). Their natural succession is often hindered by instability of the soil surface, arising from factors like erosion, cryoturbation, lack of nutrients in the topsoil layer, and ongoing unsustainable land use (Arnalds 2008).

Icelandic sheep farming practices have changed over the past 50 years, even though a significant proportion of the country is still used as rangeland. Earlier, the sheep were commonly grazed all year round, but a strong focus on breeding and improved winter fodder has led to shorter grazing periods, down to approximately 6 months on average (June–November). Early spring and late autumn, the flocks are commonly grazed in fenced pastures next to the farm. However, rangeland management in the summer is generally still based on old traditions, rooted in centuries-old legislation that allows for communal grazing areas, or commons, provided by local communities for grazing animals (Barkarson and Johannesson 2009). In late June, the farmers release their sheep into summer rangelands in the lowlands (commonly held in private ownership but seldom entirely fenced off from the neighboring estates) or highland commons, where the sheep roam free until they are rounded up in September and brought back home again (Arnalds and Barkarson 2003). Sheep farmers still have very strong legal rights regarding land use and access to unenclosed land, which has caused conflicts in some regions over the changing land-use system resulting from changes in ownership of farmsteads, with a growing number of landowners who are not engaged in farming (Arnalds 2005).

In recent decades, many farmers have practiced restoration of natural or near-natural systems on their private lands, both on their own and in collaboration with the governments through public projects. In some regions of the country, farmers have also created local restoration nongovernmental organizations (NGOs) targeting collaborative restoration work in the commons (Crofts 2011). The most common restoration methods are spreading organic residue (e.g., manure or old hay) and/or spreading inorganic fertilizer, combined with restricted grazing while the area is undergoing a restoration process (Pétursdóttir 2011).

The governance system for sheep farming, rangeland management, and restoration
The Icelandic government approved the first environmental Act on soil conservation and afforestation at the beginning of the 20th century (Runólfsson and Agústsdóttir 2011). It was followed by the establishment of an environmental agency (known today as the Soil Conservation Service (SCSI)), under the auspices of the Ministry of Agriculture and the Agricultural Society (AS) (Crofts 2011). In the mid-20th century, the agency achieved self-autonomy, but links to the AS existed formally until 1996 (Alþingi 1996). A further division between the agricultural and environmental agencies took place in 2008, when the SCSI was transferred from the Ministry of Agriculture to the Ministry of Environment.

Agricultural policies in the 20th century focused primarily on marketing and pricing of agricultural produce (Stefánsson

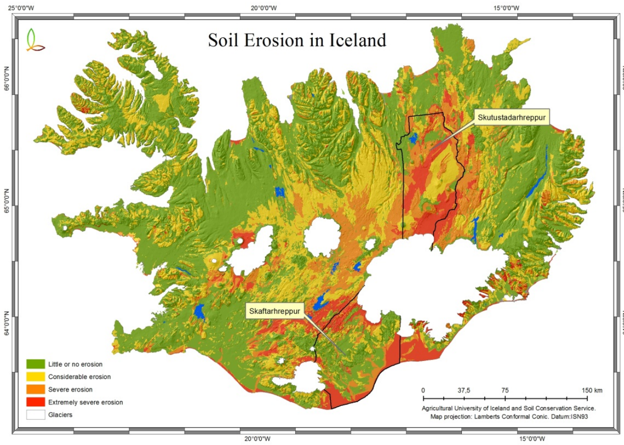
1998). The period between 1960 and 1980 was largely driven by production policies and a subsidy system that encouraged sheep farmers to increase production, regardless of domestic market needs. The excess meat production was exported to external markets and, in the late 1970s, the Icelandic market consumed only around 9800 tons of the 15,400 tons produced annually (Stefánsson 1998). Meat exportation was unprofitable, and in the early 1980s, the government finally removed the export subsidies and make drastic changes to subsidize the system through the use of quotas (Arnalds and Barkarson 2003). The importance of sustainable land use and environmental protection in sheep farming was stated for the first time in the Agricultural Act of 1993.

Another significant strategic change took place after 2000, when a new sheep farming subsidy system was approved by the government. As before, all farmers that had production quotas were entitled to get subsidies, but under the new agreement, a part of the total payment was directly linked to a quality management program. The agricultural Act of 1993 and the subsidy agreement in 2000 reshaped policies on rangeland restoration and sustainable land use and provided the first signs of an integrated agri-environmental policy on sheep farming and sustainable land management (Arnalds and Barkarson 2003).

The period between 1960 and 1980 was also, however, driven by conservation policies (Aradóttir and Petursdottir 2011). In 1971, one of the government's policy targets was the creation of a national strategy on restoration and sustainable use of resources (Croft 2011). In 1974, the Icelandic parliament followed this up by approving the establishment of a state-funded 5-year program to support restoration, afforestation, and improvement in land management (Arnalds 2005).

Throughout the 20th century, the AS provided consultation to sheep farmers, with a strong focus on breeding and improved winter fodder, but a limited number of advisors served the whole country (Jónsson 1985). In the early 1990s, the newly established Farmers Association (FA) started to develop regional advisory centers to provide more robust agricultural consultation (Bjarnason 1992). During the same period, the SCSI established district offices, parallel to the agricultural advisory centers, and strengthened its work in the field of agri-environmental research, which had previously mostly been served by an agricultural research institute (Crofts 2011). In 1990, the SCSI also established a cost-share restoration project, "Farmers Heal the Land" (FHL), which is based on collaboration between farmers and the SCSI but without direct participation of the FA (Arnalds 2005). The main reason behind its establishment was to use direct and indirect incentives to trigger rangeland restoration and improved land management; however, it also aimed to find new ways to build collaboration and mutual trust between farmers and the SCSI (Arnalds 2005).The FHL project and the following

Fig. 1. General overview of soil erosion in Iceland and the geographical location of Skaftarhreppur and Skutustadahreppur. (The map is based on results from a national survey on soil erosion, published in 1997 (Arnalds et al. 2001)).



participatory approaches started as an experimental project in only one region but soon developed into a nationwide project, based on voluntary participation. In 2010, around 600 landowners participated in the project (Petursdottir 2011).

Visiting and Interviewing Stakeholders

Our case study was based on two qualitative surveys, where semistructured interviews were used to interview preselected stakeholders. The first survey (A) was conducted in June 2009, when 10 sheep farmers were visited and interviewed by a team of two experts, a national expert (Petursdottir) and a visiting European expert (Montanarella). The farmers were asked about their attitudes toward land use, soil conservation, restoration, and agri-environmental policies. The second survey (B) consisted of interviews conducted by the lead author with five agricultural or environmental officials on the same discussion topics as in the previous survey.

(A) Sheep farmers

The survey was conducted within two rural municipalities (Skaftarhreppur in the southeast and Skutustadahreppur in northeast Iceland) that have in common a strong reliance on sheep farming (Table 1) and tourism (Júlíusdóttir et al. 2009). Both municipalities lie within the volcanic belt of Iceland and have severely degraded ecosystems that are, in part, still under the threat of soil erosion (Fig. 1). Sheep farming is the main agricultural activity in both municipalities (Table 1), but tourism is also an important economic activity (Júlíusdóttir et al. 2009). The municipalities are located far from urban areas but both contain a small village that serves the surrounding countryside (Table 1). Vatnajokull national park stretches into

Table 1. Background information for Skaftarhreppur and Skutustadahreppur

	Skaftarhreppur	Skutustadahreppur
Demographic (number)		
Total population	443	385
Villages/population	Kirkjubæjarklaustur/115	Reykjahlíð/160
Total farmsteads	34	26
BGL participants	27	15
Livestock (total number)		
Sheep	20,574	4799
Cattle	1824	392
Horses	632	111
Geographic		
Location	SE coast	NE inland
Elevation (m.a.s.l.)	<100–300	350–450
Mean annual temperature (°C)	4.5	1.4
Annual precipitation (mm)	1645	435
Area (km²)		
Total size	6946	6036
Size of lowland	1411	931
Size of highland	2761	3858
Restoration areas	208	137
Vegetation condition (%)		
Vegetated lowland	25	42
Poorly vegetated lowland	49	32
Barren lowland	26	25
Vegetated highland	5	0
Poorly vegetated highland	31	1
Barren highland	64	98
Vegetated restoration areas	6	20
Poorly vegetated restoration areas	25	23
Barren restoration areas	69	57

both of the municipalities, and both of them contain also other types of protected areas. The presence of a hydropower plant within the Skutustadahreppur region provides inhabitants with access to more varied job opportunities than those available to the inhabitants of Skaftarhreppur. However, Skaftarhreppur is one of several rural areas in Iceland that have officially been defined as highly dependent upon sheep farming, and therefore, farmers in Skaftarhreppur benefit from somewhat higher subsidies than those in Skutustadahreppur (Júlíusdóttir et al. 2009).

The main criteria used for selecting the participants were: (1) farms with more than 200 adult sheep, (2) farmers participating in the FHL restoration program, and (3) dissimilar attitudes toward land use and restoration. Local SCSI district officers were asked to identify and contact several farmers who they believed would fulfill these preset criteria. All the farmers who were contacted agreed to participate. Ten farmsteads were visited, and the farmers interviewed informally. The participants' ages ranged from 40–65 years, and all had practiced sheep farming for 20 years or more. Eight of the participants had additional sources of income apart from that gained through farming, such as through tourism or paid employment outside the farm. The farmers were informed beforehand about the research background, and matters of research ethics, such as participants' anonymity, were clearly stated.

The interviews were based on several key questions related to land management, soil conservation, and restoration, but the interviewees could also discuss other issues. In cases where the interviewee did not speak English, the national expert translated the conversation. Most of the visits took 3–4 hours. They started at the interviewee's home but were followed up by fieldtrips to explore each farmstead's restoration areas. The interviews were not recorded, but the main discussions points were documented by the interviewers after each visit.

(B) Agricultural and environmental officials

Five officials were defined as key informants, all with considerable experience in working in the public sector and in direct involvement in management and policy settings for agri-environmental topics. The officials were contacted by email and asked to participate. They were also informed about the research background, and again, matters related to research ethics were clearly stated. All the contacted people agreed to

Table 2. An overview of the participants' attitudes on land use/restoration, collaboration, and governance.

	Profession	Location	Land use/restoration	Collaboration	Governance
Farmers					
1	Sheep farmer	Skaftarhreppur	0	0	0/-
2	"	"	++	+	+/-
3	"	"	++	++	0
4	"	"	++	++	+/-
5	Sheep/Dairy farmer	"	++	++	++
6	"	Skutustadahreppur	++	+	0
7	Sheep farmer	"	++	+	+
8	"	"	++	+	+/-
9	"	"	++	+	+/-
10	"	"	++	++	++
Officials					
1	Director	Reykjavik	++	++	+/-
2	Parliamentarian	"	++	++	++
3	Director	"	++	++	+/-
4	Director	"	++	++	+/-
5	Director	"	++	+	+/-

participate. They were interviewed during the period from October to December 2009. Each participant was visited at his/her office and interviewed for about 1.5 hours. The interviews were semistructured, i.e., the interviewer followed a list of open questions based on the preselected topics used in the previous survey. This list of questions was followed through in each interview, but the participants could also discuss other related issues.

All the interviews were taped, and in two cases, the interviewer added additional information from her field notes. Afterward, each interview was typed up and treated by a coding method (Taylor and Bogdan 1998). The average length of each completed interview was about 30 pages. Due to the small size of the Icelandic agri-environmental public sector and in order to protect interviewees' anonymity, officials were coded based on the sector in which they were employed and not based on their profession.

The results from both surveys were divided into three categories: (a) Land use/Restoration, (b) Collaboration, and (c) Governance. These three categories were used as the setup for a table where each participant's attitude was roughly ranked, based on his/her view in comparison with the other participants' views on the same category. The symbols "+", "-", and "0" were used to distinguish among their attitudes, where "-" signified a negative view, "0" a neutral view, and "+" a positive view. Two symbols were used if the participant expressed a strong positive or strong negative view.

RESULTS

Land use/Restoration

The interviewed farmers usually agreed on the importance of soil conservation and restoration and claimed that rangeland management had improved during the last three decades (Table 2). They mentioned several reasons for this improvement, including improved technology for hay making leading to more quantity and quality of fodder for the sheep during the winter and in early spring, and less grazing pressure due to fewer sheep. They maintained that, due to improved information provided by the advisory services, farmers are now more aware than in the past about the degradation risk associated with following winter and early spring grazing, a customary practice until the 1970s. They particularly noted that the restoration support system offered by the SCSI had increased awareness among farmers about how rangeland restoration and rangeland management could be improved.

The farmers mentioned several reasons why they practice restoration. Those most commonly acknowledged were rooted in moral values, such as respect and care for the land. They stated that it was their responsibility to "heal" degraded land for its own sake and improve its condition for future generations. The majority of the farmers were also restoring to improve rangeland condition or the land's esthetic values as a tourist attraction, but only a few of them mentioned economic reasons, such as improved productivity, as the main rationale for their restoration activities.

The officials also usually agreed with the importance of soil conservation and viewed sustainable land management and restoration as important factors in maintaining healthy ecosystems and in improving the condition of degraded ecosystems (Table 2). However, their view on restoration was based on different perspectives. Those working in the agricultural sector claimed that restoration activities should primarily be aimed at optimizing land use. As one of them said: "...in my mind, restoration is a certain activity made to trigger vegetation growth... to change the color of sparsely vegetated or barren land to a green one." In contrast, the interviewees working in the environmental sector mentioned the importance of restoring ecosystem services and improved biological diversity as the main reasons for restoration. One of them stated: "...very important factors are of course to protect/maintain what still exists and restore lost vegetation and degraded ecosystems." They also noted the national obligations to fulfill commitments related to international conventions, such as the Convention on Biological Diversity (CBD) and the United Nations Convention to Combat Desertification (UNCCD).

Collaboration

Restoration activities appeared to have a strong social value among the farmers we interviewed in Skaftarhreppur. Some of them were volunteers in restoration projects and covered a substantial part of the projects' direct costs themselves. Most of the farmers were also members of the local restoration NGO (Landgræðslufélag Skaftarhrepps). This NGO was founded in 1994 by local stakeholders with the aim of supporting restoration of degraded land within Skaftarhreppur and strengthening the inhabitants' awareness of and education on the issue. All the work conducted by the NGO is undertaken on a voluntary basis, but the SCSI provides chemical fertilizer and grass seed when needed.

In Skutustadahreppur, restoration activities appeared to have less social value. The farmers worked individually on restoration on their own farmland, generally in collaboration with the SCSI, but did not seem particularly motivated to participate in voluntary work outside the farm. The restoration activities in Skutustadahreppur appeared to be more directly related to the availability of direct incentives, such as external funding, compared with Skaftarhreppur, and even though there was one large joint restoration project ongoing in Skutustadahreppur, it was managed through an NGO (Húsgull) from an adjacent area, and the work within the project was mainly carried out by contractors.

All the participants interviewed considered restoration projects to some extent to have societal as well as ecological importance. They commonly felt that the design of restoration projects and the corresponding action plans should be based on collaboration between stakeholders and that the majority of the annual costs of ecological restoration projects should be funded by the government, irrespective of the ownership of the degraded land in question.

The participants favored the use of participatory approaches regarding restoration activities, seeing them as leading to more efficient outcomes than activities where decisions and related management are organized in a top-down manner by the authorities. As one of the agricultural officials phrased it: "... the fact that when people work together; it increases trust and it shares knowledge...." The officials especially mentioned "bottom-up" methods, including working with stakeholders on a local scale, as examples of successful collaboration between farmers and the related governance system.

Governance

Some of the farmers felt that they lacked a stronger connection to agri-environmental agencies. They felt that officials often lacked a deeper insight into sheep farming and should visit the countryside more often to build up and strengthen mutual trust between farmers and the relevant authorities.

The participants generally stated that there was a lack of comprehensive government policy regarding land use and management. The officials argued that such a policy should not be based on the vision of individual ministries but should instead be developed jointly by the concerned ministries using multidisciplinary approaches. The following statement by an environmental official reflected this view: "...as the Icelandic governance is designed, we have put emphasis on, in contrast to many other countries, to have small ministries and strong agencies and actually put it into the hands of these agencies to formulate their own policies and prioritize projects and as it is built, it has mostly been in their [the agencies] hands."

According to some of the officials, this situation has given the agencies freedom to shape their own policies. Consequently, it seems to have given them more autonomy to focus on specific single issues. These types of single policy targets have, over the years, become informally accepted by the national governments (although they were never legally valid), as part of governmental laws or legislations. This development seems to have caused friction between governmental agencies and obscured who is the leading authority within different political or scientific fields. As one of the environmental officials phrased it: "...well, I say that some of the agencies are far too small... and they are individually given projects that should be handled by only one agency...."

Many of the officials felt that the optimal solution would be for the government to set a broad overall policy framework, within which the governmental agencies have the freedom to shape their policies. They considered this an efficient way because the professional knowledge needed for policy making is located within the agencies, and they themselves are, therefore, best suited to identify how best to use their resources. However, officials were somewhat pessimistic and mentioned that perhaps the governments lacked the will to create such a comprehensive policy framework. One of the agricultural officials said that: "...humans never want to give up the power they had, you see, although it serves the public interests to do so ... I think it's as simple as that." In addition, an environmental official stated that there was strong opposition to such a move among many stakeholder groups: "...there are such strong forces that don't want a comprehensive overview."

Some mentioned that parliamentarians might also lack the political strength needed to run such multidisciplinary actions. Local pressure from the electorate could also influence their decision making and possibly outweigh unpopular decisions. As one of the agricultural officials stated: "...if only it was, well just a strong political leadership here... we know always how the politicians are...."

The officials seemed to view the agricultural and the environmental sectors as distinct entities. They felt that the environmental and agricultural agencies and ministries often have a tendency to operate in a too institutionally "self-centered" manner, not being receptive to cooperation or transparent discussions on joint topics. They stated that this could increase the risk of overlapping or duplication of work and most likely decrease the institutional efficiency in the agri-environmental field. As one environmental official put it: "... we are a society with an enormous "silo-mentality" when it comes to institutions' structure....#8221; another environmental official said: "...just to talk straight out... this system is obviously a system of "chiefs' monarchy"...."

There seemed to be an underlying tension between the environmental and agricultural sectors, and the transfer of the SCSI from the Ministry of Agriculture to the Ministry of Environment in 2008 may have increased this friction. The agricultural officials felt the transfer had already weakened the ties between these two sectors and could probably lead to even further policy fragmentation. Nevertheless, environmental officials embraced these governance changes and felt they would lead to even more ecologically sound approaches to restoration.

DISCUSSION

The social–ecological system of rangeland restoration and rangeland management in Iceland is driven by agri-environmental policies, controlled by law, regulations, or other direct governmental decisions and supported and managed by related ministries and agencies. By interviewing selected sheep farmers and officials, we gathered information about their attitudes toward restoration and rangeland management and how they felt that agri-environmental policies, and the related SESs, were functioning.

For over a century, the importance of soil conservation and restoration has been emphasized in the political setting and scientific discussions in Iceland, and in recent decades, there has been increasing awareness among farmers of the need to adopt a solution-orientated approach to policy making (Barkarson and Johannesson 2009). In this research, sheep farmers showed, by and large, a positive attitude toward soil conservation and restoration, in line with results from other studies (Schmidt 2000; Berglund et al. 2013).

A national survey of soil erosion in Iceland completed in 1997 revealed severe soil erosion in 40% of the country (Arnalds et al. 2001). Current summer grazing on most of these highly eroded areas, especially in the highlands, is limiting the natural succession of degraded ecosystems (Magnusson and Svavarsdottir 2007). Despite this, the majority of sheep farmers still apply traditional methods and practices of land use (Arnalds and Barkarson 2003). Aside from shortening the grazing period over the past 50 years, from year-round to about 6 months with still shorter periods (2–3 months) in the highland commons, most of the farmers we interviewed continue to practice rangeland management in the traditional way of free-range grazing on commons. Only one of the interviewed farmers had entirely changed his grazing management, grazing only on fenced-off, private land instead of on the commons.

Even though sheep farming is highly subsidized by government, the annual income of a sheep farm is relatively low and, in many cases, not sufficient to make a living (Júlíusdóttir et al. 2009). The majority of the farmers we interviewed had to generate additional income outside their farm. Nevertheless, they seemed to have a strong cultural disposition toward protecting their land. The farmers emphasized moral values, such as respect and care for the land, as reasons for restoration and the duty "to pay the debt to the land" seemed to be deeply rooted in their mindset. Severe problems with drifting sand in the first half of the 20th century are still relatively close in time, and stories from that period continue to shape and influence the values that are held by current farmers (Crofts 2011). For several decades, the slogan "to pay the debt to the land" was used to raise awareness about soil conservation and land restoration (Aradóttir et al. 2013), which may also have influenced farmers' attitudes toward land restoration (Arnalds 2005).

Governments have a critical role in natural resource management. A well-structured governance system that brings well-designed regulations, policies, and incentives is essential to understanding and maintaining the sustainability of an SES (Liu et al. 2007). According to Basurto and Coleman (2010), strong institutions at higher levels can maintain trust and stability while also facilitating adaption to ecological conditions and social concerns at finer scales. Our results indicate that the SESs of rangeland restoration might be lacking such institutional strength. They point to key weaknesses, such as the lack of transparency within the governance system and the perceived lack of institutional cooperation and collaboration at higher levels. These problems have the potential to reduce the coherence of political decisions on rangeland restoration and sustainable land management.

The interviews with the farmers demonstrated noticeable differences in the farmers' willingness to cooperate in communal restoration activities between the two communities. The farmers living in Skaftarhreppur seemed to be collaborating more actively and taking more part in voluntary work, compared with the farmers in Skutustadahreppur. Before 1990, the SCSI commonly used top-down approaches to carry out soil conservation and restoration, mostly without any direct local cooperation and involvement (Arnalds 2005). This often led to tensions and disagreements between the agency and the farmers (Barkarson and Johannesson 2009). This was the case in Skutustadahreppur, where strong resistance to the SCSI eventually led to the establishment of the FHL project in 1990 (Arnalds 2005).

Using participatory approaches requires understanding of how participation can impact on project implementation, because the outcomes of participatory projects depend mostly on how process factors, such as project aims, power division, and interactions between participants, are attended to in the implementation process (Berglund et al. 2013). That the FHL project started in Skutustadahreppur, when participatory approaches were poorly developed, possibly led to fewer participatory practices between farmers and SCSI in that area. This factor and the previously mentioned resistance to the SCSI may help explain why the farmers in Skutustadahreppur seem to perceive the incentives provided by the SCSI as a direct subsidy, as opposed to the farmers in Skaftarhreppur, who may well see the incentives more as a stimulus for restoration and cooperation. The lower social importance of restoration activities in Skutustadahreppur than in Skaftarhreppur may, however, also be related to other issues, such as more employment opportunities in Skutustadahreppur or differences in the local advisory service.

Our results indicate high awareness among the farmers of the importance of restoration. Furthermore, bottom-up approaches seem to have successfully motivated all the farmers we interviewed to practice restoration. However, they have apparently not managed to trigger any general shifts toward improved rangeland management, even though that was the underlying policy target. The lack of change in behavior can possibly be ascribed to the traditions of land use, as cultural inertia can make it difficult to make necessary changes (cf. Liu et al. 2007). But it could also be related to the lack of strong institutional structure and strong regulations and/or to underlying institutional sluggishness and resistance to change (Barkarson and Johannsson 2009).

Management systems should be dynamic, but too often the internal inertia between and within institutions tends to dominate many aspects of natural resource management (e.g., Liu et al. 2007). The agencies involved may lack the administrative capacity to take a systematic approach to the design of restoration or land management programs and may fail to use policy instruments that are consistent with economic conditions, landholders' needs, and attitudes toward land management (Tarlock 1993). In our case, the current institutional structure splits the agri-environmental subjects into small administrative units managed by separate agencies, resulting in fragmentation and maintenance of the perceived institutional "silo mentality." These results agree with the findings of Niedziałkowski et al. (2012), who found that power relationships and vested interests can become the main drivers of a governance system without bringing gains in legitimacy or new policy options.

It can be complicated to reach a desired ecological outcome from restoration activities, especially in larger areas where inhabitants base their livelihood on using the degraded systems in question. The progress of a large-scale restoration, therefore, relies not only on ecological and environmental factors but also on the sustainability of the related SESs (Berkes and Folke 2000). These complications are clearly demonstrated by the outcome of the interviews in this research, e.g., how the farmers' positive attitudes toward restoration apparently fail to influence their rangeland management practices, or the perceived lack of cooperation between the agricultural and environmental sectors that may be preventing desired policy effectiveness.

Impacts of natural resource management projects are mainly evaluated by focusing on the attitude and behavior of those who are using the resources, but less emphasis is placed on analyzing the attitudes of other related stakeholder groups and relevant governmental and nongovernmental officials (Tuvendal and Elmqvist 2011). Our results strongly indicate that lack of effectiveness in the governance of the SESs can hamper the desired progress of policies related to large-scale natural resource management projects such as rangeland restoration. It can also block the necessary paradigm shift among stakeholders regarding rangeland management. We conclude that the sustainability of the SESs can be improved by the establishment of more comprehensive agri-environmental policies and by strengthening the interconnections between the different institutional agents and actors involved in the governance of this policy arena. But, as this study is based on results collected from a small sample, it only gives certain indications as to the existence of gaps and disconnectivities within the SESs.

We find an SES analysis useful for exploring the impact of restoration programs. But to achieve more robust results, we suggest a further development of the method to use on a larger scale, preferably a national one. Such analysis would be highly valuable for the development of stronger agri-environmental policies and for enhancing the sustainability of rangeland restoration and rangeland management within the SESs.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5399

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LITERATURE CITED

Alþingi [the National Assembly]. 1996. Parliamentary document 1108-389 case. [online] URL: http://www.althingi.is/altext/stjt/1996.073.html

Anderies, J. M., M. A. Janssen, and E. Ostrom. 2004. A framework to analyze the robustness of social–ecological systems from an institutional perspective. *Ecology and Society* 9: 18. [online] URL: http://www.ecologyandsociety.org/vol9/iss1/art18/

Aradóttir, Á. L., and þ. Pétursdóttir. 2011. Opinber stefnumótun og stjórnsýsluhvatar er varða vistheimt á Íslandi [Policies and incentives for ecological restoration in Iceland]. Pages 24–30 *in* Á. L. Aradóttir and G. Halldórsson, editors. Vistheimt á Íslandi [Ecological restoration in Iceland]. The Agricultural University of Iceland and the Soil Conservation Service, Reykjavik, Iceland.

Aradóttir, Á. L., þ. Pétursdóttir, G. Halldorsson, K. Svavarsdottir, and O. Arnalds. 2013. Drivers of ecological restoration - lessons from a century of restoration in Iceland. *Ecology and Society* 18 *in press*.

Arnalds, A. 2005. Approaches to landcare—a century of soil conservation in Iceland. *Land Degradation and Development* 16:1–13. http://dx.doi.org/10.1002/ldr.665

Arnalds, O. 2008. Soils of Iceland. *Jökull* 58:409–421.

Arnalds, O., and B. H. Barkarson. 2003. Soil erosion and land use policy in Iceland in relation to sheep grazing and government subsidies. *Environmental Science and Policy* 6:105–113. http://dx.doi.org/10.1016/S1462-9011(02)00115-6

Arnalds, O., E. F. Thorarinsdottir, S. Metusalemsson, A. Jonsson, E. Gretarsson, and A. Arnason. 2001. *Soil erosion in Iceland.* Soil Conservation Service and the Agricultural Research Institute, Reykjavik Iceland. (Translated from Icelandic Version.)

Aronson, J., J. N. Blignaut, S. J. Milton, D. Le Maitre, K. J. Esler, A. Limouzin, C. Fontaine, M. P. de Wit, W. Mugido, P. Prinsloo, L. van der Elst, and N. Lederer. 2010. Are socioeconomic benefits of restoration adequately quantified? A meta-analysis of recent papers (2000–2008) in *Restoration Ecology* and 12 other scientific journals. *Restoration Ecology* 18:143–154. http://dx.doi.org/10.1111/j.1526-100X.2009.00638.x

Barkarson, B. H., and M. H. Johannsson. 2009. Arctic landcare. Pages 55–63 *in* D. Catacutan, C. Neely, M. Johnson, H. Poussard, and R. Youl, editors. *Landcare: Local action—global progress.* World Agroforestry Centre, Nairobi, Kenya.

Basurto, X., and E. Coleman. 2010. Institutional and ecological interplay for successful self-governance of community-based fisheries. *Ecological Economics* 69:1094–1103. http://dx.doi.org/10.1016/j.ecolecon.2009.12.001

Berglund, B., L. Hallgren, and Á. L. Aradóttir. 2013. Cultivating communication: participatory approaches in land restoration in Iceland. *Ecology and Society* 18 *in press*.

Berkes, F., and C. Folke. 2000. Linking social and ecological systems for resilience and sustainability. Pages 1–25 *in* F. Berkes and C. Folke editors. *Linking social and ecological systems, management practices and social mechanisms for building resilience.* Cambridge University Press, Cambridge, UK.

Bjarnason, E. 1992. Leiðbeiningaþjónusta í landbúnaði [Advisory service in agriculture]. *In Ráðunautafundur.* BÍ, RALA: 211–222.

Bradshaw, G. A., and M. Bekoff. 2001. Ecology and social responsibility: the re-embodiment of science. *Trends in Ecology and Evolution* 16:460–465. http://dx.doi.org/10.1016/S0169-5347(01)02204-2

Clewell, A. F., and J. Aronson. 2006. Motivations for the restoration of ecosystems. *Conservation Biology* 20:420–428. http://dx.doi.org/10.1111/j.1523-1739.2006.00340.x

Crofts, R. 2011. *Healing the land, the story of land reclamation and soil conservation in Iceland.* Soil Conservation Service, Reykjavik, Iceland.

Daly, H. E., and J. Farley. 2004. *Ecological economics, principles and applications.* Island Press, Washington, D.C., USA.

Herling, M. C., C. F. Cupido, P. J. O'Farrell and L. Du Plessis. 2008. The financial costs of ecologically nonsustainable farming practices in a semiarid system. *Restoration Ecology* 17:827–836. http://dx.doi.org/10.1111/j.1526-100X.2008.00419.x

Hobbs, R. J. 2007. Setting effective and realistic restoration goals: key directions for research. *Restoration Ecology* 15:354–357. http://dx.doi.org/10.1111/j.1526-100X.2007.00225.x

Hobbs, R. J., L. M. Hallett, P. R. Ehrlich, and H. A. Mooney. 2011. Intervention ecology: applying ecological science in the twenty-first century. *Bioscience* 61:442–450. http://dx.doi.org/10.1525/bio.2011.61.6.6

Holling, C.S. 2001. Understanding the complexity of economic, ecological and social systems. *Ecosystems* 4:390–405. http://dx.doi.org/10.1007/s10021-001-0101-5

Icelandic Agricultural Statistic. 2010. *The Farmers Association of Iceland.*

Ingimundarson, J. H. 2010. Comparative-historical analysis of farming systems and agricultural intensification in medieval and early modern Iceland. Pages 319–337 *in* G. Winther and R. D. Rasmussen, editors. *Political economy of northern regional development.* Nordic Council of Ministries Publication, Copenhagen, Denmark.

Jóhannesson, T. 2010. *Agriculture in Iceland: condition and characteristics.* The Agricultural University of Iceland, Reykjavik, Iceland. [online] URL: http://www.lbhi.is/lisalib/getfile.aspx?itemid=4090

Jónsson, J. 1985. Staða og framtíðarhorfur í leiðbeiningaþjónustu [Current situation and future prospects of of advisory services]. *In Ráðunautafundur.* BÍ, RALA:8–19.

Júlíusdóttir, M., A. Karlsdóttir, K. Benediktsson, I. E. Vésteinsdóttir, and S. Steingrímsson. 2009: *Litróf búskapar og byggða: Fjölþættur landbúnaður á Íslandi* [The spectrum of farming and settlement: multifunctional agriculture in Iceland]. Háskóli Íslands, Reykjavik, Iceland.

Liu, J., T. Dietz, S. R. Carpenter, M. Alberti, C. Folke, E. Moran, A. N. Pell, P. Deadman, T. Kratz, J. Lubchenco, E. Ostrom, Z. Ouyang, W. Provencher, C. L. Redman, S. H. Schneider, and W. W. Taylor. 2007. Complexity of coupled human and natural systems. *Science* 317:1513–1516. http://dx.doi.org/10.1126/science.1144004

Magnússon, S. H., and K. Svavarsdóttir. 2007. *Áhrif beitarfriðunar á framvindu gróðurs og jarðvegs á lítt grónu landi* [Effects of sheep grazing protection on succession in sparsely vegetated areas in Iceland]. Fjölrit Náttúrufræðistofnunar No. 49.

McGovern, T. H., O. Vesteinsson, A. Fridriksson, M. Church, I. Lawson, I. A. Simpson, A. Einarsson, A. Dugmore, G. Cook, S. Perdikaris, K. J. Edwards, A. M. Thomson, W. P. Adderley, A. Newton, G. Lucas, R. Edvardsson, O. Aldred, and E. Dunbar. 2008. Landscapes of settlement in northern Iceland: historical ecology of human impact and climate fluctuation on the millennial scale. *American Anthropologist* 109:27–51. http://dx.doi.org/10.1525/aa.2007.109.1.27

Meadows, D. H. 2008. *Thinking in systems: a primer.* Chelsea Green. White River Junction, Vermont, USA.

Niedziałkowski, K., J. Paavola, and B. Jędrzejewska. 2012. Participation and protected areas governance: the impact of changing influence of local authorities on the conservation of the Białowieża Primeval forest, Poland. *Ecology and Society* 17(1): 2. http://dx.doi.org/10.5751/ES-04461-170102

O'Farrell, P. J., W. J. De Lange, D. C. Le Maitre, B. Reyers, J. N. Blignaut, S. J. Milton, D. Atkinson, B. Egoh, A. Maherry, C. Colvin, and R. M. Cowling. 2011. The possibilities and pitfalls presented by a pragmatic approach to ecosystem service valuation in an arid biodiversity hotspot. *Journal of Arid Environments* 75:612–623. http://dx.doi.org/10.1016/j.jaridenv.2011.01.005

Ostrom, E. 2009. A general framework for analyzing sustainability of social–ecological systems. *Science* 325:419–422. http://dx.doi.org/10.1126/science.1172133

Pétursdóttir, þ. 2011. Bændur græða landið – samstarf um uppgræðslu og endurheimt vistkerfa [Farmers heal the land —a cost share program on revegetation and ecological restoration of ecosystems]. Pages 84–85 *in* Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [Ecological restoration in Iceland]. The Agricultural University of Iceland and the Soil Conservation Service, Reykjavik, Iceland.

Runólfsson, S., and A. M. Ágústsdóttir. 2011. Restoration of degraded and desertified lands: experience from Iceland. Pages 153–161 *in* R. Lal, M. V. K. Shivakumar, S. M. A. Faiz, A. H. M. M. Rahman, and K. R. Islam, editors. *Climate change and food security in South Asia.* Springer, Dordrect, The Netherlands. http://dx.doi.org/10.1007/978-90-481-9516-9_11

Schmidt, G. 2000. Bændur græða landið – viðhorf bænda [Farmers reclamation project – the farmers' attitude]. *In Ráðunautafundur.* BÍ, LBH, RALA: 93–9.

Society for Ecological Restoration Science and Policy Working Group (SER). 2004. *The SER international primer on ecological restoration.* Society for Ecological Restoration International, Tucson, Arizona, USA. [online] http://www.ser.org/pdf/primer3.pdf

Society for Ecological Restoration International and IUCN Commission on Ecosystem Management. 2004. *Ecological restoration, a means of conserving biodiversity and sustaining livelyhood.* Society of Ecological Restoration International, Tucson, Arizona, USA and IUCN, Gland, Swizerland. [online] URL: https://www.ser.org/pdf/Global_Rationale.pdf

Stefánsson, G. 1998. Landbúnaðarstefnan og búvörusamningar [The agricultural policy and agricultural agreements]. *In Ráðunautafundur.* BÍ, LBH, RALA: 3–12.

Tarlock, A. D. 1993. Local government protection of biological diversity: what is its niche? *The University of Chicago Law Review* 60:555–613. http://dx.doi.org/10.2307/1600079

Taylor, S. J., and R. Bogdan. 1998. *Introduction to qualitative research methods.* Third edition. Wiley, New York, New York, USA.

Tuvendal, M., and T. Elmqvist. 2011. Ecosystem services linking social and ecological systems: river brownification and the response of downstream stakeholders. *Ecology and Society* 16(4): 21. http://dx.doi.org/10.5751/ES-04456-160421

Weber, M. A., and S. Stewart. 2008. Public values for river restoration options on the middle Rio Grande. *Restoration Ecology* 17:762–771. http://dx.doi.org/10.1111/j.1526-100X.2008.00407.x