5-1994

Discussion and Measurement of Soil Erosion in Iceland

Kimberly Jane Richardson
Utah State University

DISCUSSION AND MEASUREMENT OF SOIL EROSION IN ICELAND

by

Kimberly Jane Richardson

Thesis submitted in partial fulfillment of the requirements for the degree

of

UNIVERSITY HONORS

UTAH STATE UNIVERSITY
Logan, UT

1994

Discussion and Measurement of Soil Erosion in Iceland

Senior Thesis

By
Kimberly Jane Richardson
110672-2259
529-67-2031

December, 1992

University of Iceland
and
Utah State University

TABLE OF CONTENTS

Introduction

Soil erosion has occurred since the beginning of time. It is a natural process, but one that has been increasing at an alarming rate. Once soil is eroded--whether it is blown out to sea or washed down a river to sedimentize a lake--it is lost. It is almost impossible to reestablish similar soil components and characteristics in a given system. Since soil and vegetation reestablishment is expensive, the prevention of soil erosion by controlling its causes has become the most cost-effective reclamation effort.

After spending six months in Iceland, I wrote this paper on the unique erosion problems facing that country. It is based on my observations, conversations, experiences, and studies while working and studying with Icelandic people.

Objectives

The objectives of this paper are summarized as follows:

1. To give a general overview of Icelandic erosion as observed during summer work in Iceland.
2. To discuss grazing as a cause of erosion.
3. To measure the amount of vegetation loss at a specific site of significant erosion.

GEOGRAPHY AND HISTORY

Iceland is an island in the north Atlantic Ocean, located just south of the Arctic Circle between the latitudes of 63 23' and 66 32'. It covers an area of 103,000 km^2. The present population is around 260,000, half of which lives in Reykjavik, the capital city in the south-west. The remaining population resides in lowland (elevation less than 350 m) coastal villages and farms. The central Highlands, which constitute 65% of the

west. The remaining population resides in lowland (elevation less than 350 m) coastal villages and farms. The central Highlands, which constitute 65% of the country, are uninhabited and largely inaccessible except during the summer months.

Iceland was settled in 874 A.D., by Norse vikings and their Celtic slaves. Land shortages and political unrest in Norway coupled with good living conditions in Iceland contributed to a rapid population growth due to immigration. Since settlement, livestock rearing (mainly sheep and cattle) has been the basis for the domestic economy.

The principle industries of the country are fishing, agriculture, and other manufacturing and service industries. Before World War II, the society was basically agrarian and dependent on fishing and farming for subsistence. However, British and American military occupation during the war accelerated a conversion to the current industrial society. This change can be seen in a comparison of the percentages of the population in different sectors of the economy from 1940 to 1988 (Table 1).

NATURAL FACTORS INFLUENCING EROSION

There are many factors that contribute to the unique and rapid soil erosion in Iceland. Natural effects include cold climate, volcanic ashfall events and vulnerable soils, and vegetation type (Arnalds et al.,1987). It is important to note that when erosive climatic forces occur, exposed soil is usually removed down to the bedrock or glacial till. Since the removal of vegetation almost always results in increased soil erosion, the two can be considered together.

Climate

The location and name of Iceland suggest an ice-capped or frozen land. Although much of the water that surrounds the island is of cold, Arctic origin, the warm water brought by the Gulf Stream from the warm southern Atlantic Ocean maintains a relatively mild climate, characterized by cold temperate, moist, and oceanic weather with frequent and changing winds.

Mean annual temperatures in the lowlands range from 2°C to 5.7°C. The average temperature in July is around 10°C. The average yearly temperature is -1°C. Most of the south receives approximately 1,500 mm of annual precipitation, with 750 mm in the in north (Bergthorsson, 1987).

The main human perception of Icelandic weather is its apparent lack of consistency. Decisions and plans for activities are often postponed to the last minute, and are changed in accordance with the weather. It varies "from day to day, from season to season, from year to year. At times the fluctuations seem to be the only rule" (Sveinsson, 1953).

Climate, including short and cold summers and fluctuating precipitation, is a major limiting factor for plant growth in most parts of the country (Thorsteinsson, 1971).

Soil

Soil formed in volcanic tephra materials, like Icelandic soil, is classified in the taxonomic order Andisol. Andisols have physical and chemical properties that make them a unique order compared to other, older, more stable groups. The characteristics of Andisols include a low bulk density, low cohesion when wet, high organic content, and strong

aggregational factors (Wada, 1985).

Icelandic soils were created after the last glacial period, which ended 10,000 years ago. Since then, volcanic and eolian sediments have deposited relatively thick layers (0.2-3 m) above lava surfaces and basal till created by the receding glaciers that were remnants of the Ice Age. Icelandic Andisols are composed of eolian and tephra components and are termed "eolian-andic" (Arnalds et al., 1992).

There are two other common types of soils in Iceland. The first type, wetland soils (Histosols and Andisols), contain high amounts of organic matter, ranging from 10% to 50%. These soils are usually vegetated with nonvascular and low growing vascular plants. Approximately 25,000 km^2 of Iceland is classified eolian-andic and wetland soils.

The other type of soil is nonvegetated, barren soils that cover an estimated 65,000 km^2 of Iceland. These soils are mostly Entisols and Inceptisols, which have coarse grains and poorly developed soil profiles. Their physical characteristics are mostly dependent on the geology of the area (Arnalds, 1990).

The unique soil characteristics, especially of Andisols, make them very susceptible to erosion by any type of climatic disturbance, which are common with the ever-changing Icelandic weather. Although Andisols have a low cohesion factor, they are able to absorb water to over 100% of their dry weight base. This high water holding capacity, along with the fluctuations in Icelandic weather, intensifies processes of cryoturbation. For example, as water freezes and expands, it disrupts the soil stability, and erosion due to solifluction occurs (FitzPatrick, 1983). Although erosion does occur due to water, the main climatic erosion factor is wind. The Andisols form stable sand-size aggregates when dry, creating a large

surface area which contributes to wind erosion (Arnalds, 1992). The soil usually remains stable enough plant cover is able to aggregate the soil grains sufficiently. But if vegetation is removed, the sensitive soil is exposed to the various climatic forces.

Vegetation

The flora in Iceland developed 8,000-10,000 years ago, at the end of the last glacial period. Pollen analysis and remnants of former vegetation provide evidence that the island was covered with lush vegetation from glacial retreat until European settlement. Further evidence of this is given by historical records such as the Sagas (epic stories written in Iceland about their history, land, and people), annals, and farm surveys (Kristinsson, 1975).

From these accounts, it appears that more than 65% of Iceland was vegetated when the Norse arrived (Thorsteinsson, 1971). The climax community, dominated by mountain birch (*Betula pubescens*), is thought to have covered from 25%-40% of the island (Arnalds, 1987). Since then, the amount of vegetation has been reduced to the current estimate of 25%, with only 1% birch.

Since Iceland is an isolated and remote island, there were no opportunities for large vertebrates to migrate to the island after the Ice Age removed all such species. Therefore, the flora developed without the influence of any large herbivore, making it highly susceptible to the settlers' introduction of stock grazing. "A delicate balance between hostile environment and sensitive soils and vegetation was disrupted" (Arnalds, 1987).

The settlers also altered the fragile ecology by introducing new herbaceous species, increasing grassland for pastures, and cutting wood for building and fuel (Kristinsson, 1975).

GRAZING EFFECTS ON EROSION

The climate and soil types of Iceland cannot be changed. The increase in animal numbers have altered the grazing practices, vegetation, and the land, but cherished traditions play an important role in grazing systems. Of all the factors that contribute to the erosion problem in Iceland, the only one that can easily be regulated is the grazing pressure that is applied to sensitive areas.

Grazing System and Land Ownership

Dairy production with sheep raising and some horse breeding make up most of the Icelandic agriculture. Traditional grazing practices entail use of common grazing areas all around the country. The Highlands of Iceland are divided into grazing commons by either fences or natural barriers such as rivers, glaciers, and steep mountains. Each common is utilized and managed by neighboring farms in a community or "hreppur" (Thorsteinsson, 1971). Although the farmers' grazing rights in the Highlands are not disputed, the actual ownership of the land is. Farmers claim title to the land, but the High Court of Iceland has ruled in at least two separate cases that this land is public (Sigurthsson, 1991).

During the summer, animals graze freely. This means there are no herders and basically no control over where the sheep graze during this time. Depending on the weather and other environmental factors, farmers take their sheep up to the commons sometime in June, and collect them in September.

For centuries, natural rangelands were the primary source of forage, and animals were grazed during the snow free periods in the wintertime. Therefore, the amount of winterfeed

actually set the limit on the number of animals, which could be drastically reduced during a hard winter. As time went on, farmers began to cultivate pastures and fodder. Presently, winter grazing is almost obsolete, and hay growing has allowed farmers to increase their herds without relying so much on environmental conditions (Thorsteinsson, 1986).

Traditions

"That's just the way it is," said one young Icelandic farmer. "Things have always been that way and they will always be that way. We just don't question why." Traditional farming practices, especially the free ranging and gathering of the sheep and horses, are tightly integrated into the Icelandic society and culture.

One Icelandic tradition that helps maintain the current sheep raising practices is the "rettir." This is the process of gathering the sheep and horses each autumn from the common grazing areas and then separating the animals to their proper owner.

I had the opportunity to observe both sheep and horse rettir. This is a time when the history and pride of Iceland is exemplified in everyone. Farmers as well as citizens of Reykjavik attend the festivities. Men, women, and children, clad in the traditional "lopapeysur" (traditional Icelandic sweaters), mill through the sheep, looking for their specific marking on the sheep's ear. Separating the horses is a bit more complicated, because of the size of the animal. Following the day of separation, there was traditionally dancing, singing, and drinking all night.

Although Icelanders are still practicing traditions such as these festivals, they are not as big or well attended as they once were. The decrease in sheep numbers and the alteration

of grazing practices have changed the makeup of the rettir. Now only the largest rettir have these "sveitaball" parties. The event of sheep and horse separation that once took one full day now takes a few hours.

Animal Numbers

Domestic animal populations have changed in recent years. Pressure on rangelands from sheep grazing increased from 1947 to 1980; sheep numbers rose from 450,000 to almost 820,000 in these 33 years (IAIS, 1990). This jump can be partially attributed to subsidies provided by the government, which were part of an effort to increase the export of sheep products to bring foreign currency into the country. Since 1980, economic constraints at home and abroad have forced the government to change its stance on financial support of farmers. Now, herd reduction is promoted via quotas and reduced subsidies. Realistically, there were never large enough markets to support the production induced by the government subsidies. In 1990, sheep population was down to 561,000, almost a 68% reduction since 1980 (IAIS, 1990).

These same economic effects have not put restraints on the amount of horses raised and grazed on common and private land. Horses and horse products are not widely sold or exported, so only private economic constraints control horse production. In fact, in contrast with the sheep, the number of horses have increased by 48% from 1970 to 1989 (IAIS, 1990).

This change in animal counts has effected the grazing pressure throughout the country. Because of their weight, the size and action of their hoofs, and their activity, horses cause

significantly more soil and vegetation disturbance than an equal number of sheep in a given area (Rittenshouse, 1983).

Regulation

Although Iceland is fairly small, there are several diverse habitats with different types and levels of vegetation and soil. Therefore, not all parts of the country can support the same amount of grazing pressure and react to similar fluctuations in animal numbers. For example, significant rainfall in most areas in the Northwest supports lush vegetation and maintains an ecosystem that can support many herbivores. But in the windy, barren Northeast around Mývatnssveit, grazing should be reduced or even completely stopped--the severe erosion that has already taken place is the most striking indication of the impact of grazing on this land.

However, reduction laws and quota restrictions have been structured in a political, not ecological, way. Each farmer is given a quota, and is subsidized only for the allotted amount of sheep. No consideration is given to the area where his sheep graze or the status of the land. Another of the problems with this regulation is that it does not account for the variation in range condition from one district to the next.

Farmers have a disproportionate amount of votes in the parliament compared to their population. These votes, coupled with their powerful lobbying influence makes initiating reforms in land use practices very difficult for politicians, scientists, and the general public. "Farmers carry a lot of political weight, especially in sparsely populated areas, ... The politicians need their votes" (Eysteinsson, 1992).

The current grazing system has changed little from settlement times. Some farmers have formed alliances with representatives from the Soil Conservation Service and are trying to preserve what is left of their grazing area. But a complete change in grazing systems and areas would be culturally unacceptable. "How do you tell a farmer whose grandfather was born on this land and has always been doing things this way that he must take his sheep 500 km away to graze for the summer? Things just don't work that way" (Magnússon, 1992).

ICELANDIC EROSION

Although the term "wind erosion" is used to classify many erosive processes where wind is considered the main agent, there has been a more concise classification system proposed for the specific Icelandic wind erosion forms. The terms of the major forms include advancing fronts, escarpments, isolated spots, channels, landslides, creep and solifluction, and barren landforms (Arnalds, 1990).

Of this list, the most striking features are the escarpments (Figure 1), which are so numerous that the Icelandic word, "rofabard," specifically describes them. Rofabards are formed because plant roots near the surface of the eolian-andic soils provide strong cohesion for soil, while the materials under the root mat are less cohesive. Exposure to the wind causes abrasion and removal of the less cohesive soil, which removes the soil underlying the root mass. After rofabards have been undermined to a certain degree, the root mat collapses, the remaining viable soil is blown away, and the glacial till is all that remains.

Rofabards are common along the volcanic rift zone, where the European and American continents meet (Figure 2). This area, stretching southwest to northeast,

encompasses over half of the country (Arnalds, 1992).

The magnitude of effects on the landscape can be enormous (10-20 km/km^2) (Arnalds, 1990). Measuring lengths of rofabards from aerial photographs yields a great deal of information. For example, by taking two or more photographs from different years and measuring the lengths of the vegetated and nonvegetated land, the retreat rate can be calculated. Loss of vegetative cover and soil loss can then be estimated. The commonly used response value for length measurements is km of rofabards per square km of vegetated land. Such lengths can exceed 50 km/km^2 of vegetated land (Arnalds and Metusalemsson, 1992).

The method used to assess the retreat rate of rofabards involves measurements in the field and use of aerial photographs from different time intervals. There are two techniques used with aerial photographs. One way is scanning and image analysis. The other is digitizing. The use of aerial photographs involves a certain margin of error. The aim of this project was to find out the margin of error associated with digitizing and to measure the retreating rate of a few selected rofabards.

Materials and Methods

Two black and white aerial photographs in a scale of 1:4000 were used for the project. The photographs were taken in the area of Húsavíkfjall, just north of the town of Húsavík, in north Iceland. The photographs, obtained from the Icelandic Land Survey Institute (LMI), were: number 13301, class AMS, date April 24, 1960 and number 0472, class H, date September 4, 1983. The site is a typical rofabard area, with rofabards

measuring 1.5 m high. Soil type on the vegetated area is Andisol with totally barren, rocky soil between rofabards. Vegetation is mostly grass with some heath and low growing shrubs.

The photographs were given 6 control points for reference and correspondence. They were digitized with an ILWIS-GIS (ITC, 1992). Each photograph has a physical size of about 280 cm^2, and portrays an area of about 0.5 km^2. Each photograph was measured twice to estimate the margin of error.

Results and Discussion

The amount of vegetation cover in the study area changed from 0.3400 km^2 in 1960 to 0.3375 km^2 in 1983. This calculates to a 0.0025 km^2 or 0.25 ha of vegetation cover that was lost in the 23 year period, which converts to 109 m^2 of vegetation lost per year (Table 3 and Table 6).

The perimeter of all rofabards is equal to approximately 11.8 km, or 11,800 m (Table 5). Total vegetation loss was 0.0025 km^2 or 2500 m^2 (Table 3). Vegetation retreat is computed by dividing the amount of vegetation loss by the perimeter of the rofabards, or 2500/11,800. This equals 0.21 m or 21 cm of vegetation loss for the entire perimeter of the rofabards. This translates to less than 1 cm of perimeter retreat per year (Table 6).

Next, percentages of total vegetated land were developed. 0.5465 km^2 or, 62.60% of the land was vegetated in 1960. In 1983, that number dropped to 61.45%, making a difference of 1.15% total vegetation lost in the 23 year period (Table 2).

Tables 4 and 5 summarize the actual number concluded from the digitizing project. They give the margin of error, in percent, for the two digitized maps for each photograph.

The margin of error for calculating total area is between 0.49 and 1.9%. The margin of error for the length of rofabards is between 0.2 and 8.0%.

Conclusions

The margin of error in calculating area was figured to be between 0.49 and 1.9%. This represents a very small difference in overall results for this type of analysis. Therefore, it can be concluded that this method of measuring the rate of retreat of rofabards is valid.

There was a larger, more pronounced difference (0.2 and 8.0%) in measuring lengths. More digitizing on both photographs would provide sufficient information on the validity of this method for measuring lengths. Since the length of the rofabards is so long within the boundary, only a few centimeters of retreat can result in enormous vegetation, and consequently soil, loss. The loss rate was measured as 109 m^2 of vegetation per annum in this half square kilometer of land.

The pencil line that was digitized into the ILWIS-GIS software is 0.5 mm wide. This corresponds to a 2 m wide line on the photograph in the scale of 1:4000. The results of this study indicate that the rofabards have retreated an average of 21 cm along the entire length of the rofabards. Considering the width of the line, these results are not significant. In other words, this method is not valid for recording the vegetation loss of this magnitude over time.

Digitizing pencil lines on aerial photographs seems to be a valid method to calculate lengths and areas of rofabards and vegetation, but not for accurate comparisons of areas between years. Enhanced image methods are better procedures for that purpose (Arnalds and Metusalemsson, 1992).

Since it is not known exactly how high the rofabards are, the total amount of soil loss cannot be calculated. But it can be concluded that there was significant soil loss during these 23 years. It can be assumed, since no alteration has been done to this land since the last photograph in 1983, that this rate of erosion is continuing.

CONCLUSION

It is hardly disputed that erosion has occurred, and is continuing to occur in Iceland. The direct measurements of erosion are only one indication of the problem . There are several causes of this erosion, including: climate, soil type, delicate vegetation, and the effects of grazing. There have been many efforts to control the erosion and to reclaim the land. However, the only change that can easily be made to improve the situation is regulation of the grazing pressures. Stricter regulations and use of better practices must be enforced by the government, and an emphasis should be placed on practical research.

The effects of grazing on the land in Iceland is the result of what Garrett Hardin termed "The Tragedy of the Commons." Although Hardin's discussion focused mainly on human populations, his arguments can be considered for all population problems. In fact, his example used to symbolize and describe overpopulation and over-use of a common resource is almost the perfect depiction of the Icelandic grazing process. Hardin said that a system like this will be over-used until it collapses.

Hardin said that there are no technical solutions to the problem of overpopulation and over-use of any common resource. He argued that a change in human values or ideas is the only way any kind of solution could be enforced.

The traditional perspectives and values that Icelanders have toward their land have resulted in an almost obliteration of soil capable of sustaining life. The view of the general population is summarized by the idea that since the human population is so small that there will never be a land-use problem. This mindset must be changed and a new set of values molded. Values are difficult to change, and the effort must start with education and an understanding of the problems and potential solutions. This social change will be difficult and could take generations.

Cooperation is also necessary for an integrated reclamation and regulation process. Farmers are beginning to work with the Soil Conservation Service and research groups in order to maintain their livelihood. Continued cooperation by all interest groups, including conservation-minded individuals, and as much understanding and information transfer as possible is a change that can only improve the situation. Although cultures and traditions are difficult to modify, change will be necessary at some point in order to reduce the current high rate of degradation of soil and vegetation in Iceland.

Table 1. Occupational distribution in Iceland. IAIS, 1990.

	1940	1960	1980	1988
	%			
Agriculture	32	17	8	4
Fishing	14	8	5	5
Construction and Industry	21	36	34	29
Trades and Services	32	40	52	60

Table 2. Average percent of vegetated and nonvegetated areas

	1960	1983	Total Difference
	%		
Vegetated	62.6	61.45	-1.15
Nonvegetated	37.4	38.55	1.15

Table 3. Average difference in vegetated and nonvegetated land from 1960 and 1983.

	1960	1983	Difference
	km^2		
Vegetated	.3400	.3375	-.0025
Nonvegetated	.2040	.2120	.0080

Table 4. Area computed from digitized photographs.

1960	A	B	Difference	% Difference
	km^2			
Total Area	0.545	0.542	0.003	0.55
Vegetated	0.342	0.338	0.004	1.10
Nonvegetated	0.203	0.204	0.001	0.49

1983	A	B	Difference	% Difference
	km^2			
Total Area	0.545	0.554	0.009	1.7
Vegetated	0.342	0.338	0.005	1.5
Nonvegetated	0.210	0.214	0.004	1.9

Table 5. Perimeters of boundary and rofabard length.

1960	A	B	% Difference
	km		
Boundary	3.016	3.049	1.0
Rofabard	11.885	11.778	0.9
1983	A	B	
	km		
Boundary	2.996	3.004	0.2
Rofabard	11.429	10.508	8.0

Table 6. Summary

Total loss of vegetation cover . . . . 2500 m^2
Amount of soil lost per year . . . . 109 m^2/year
Perimeter of vegetation loss per total area . . . . 21.85 km/km^2
Perimeter of vegetation loss per area of vegetated land . . . .37.60 km/km^2
Retreat of vegetation per year . . . . .91 cm/year
Loss of vegetation cover per year . . . . .02 (ha/km^2)/year

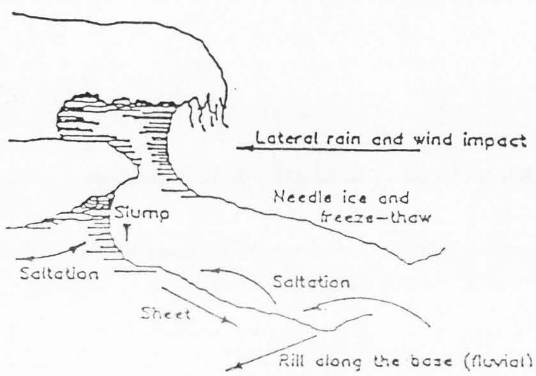

Figure 1. Some of the processes active at rofabards (Arnalds 1992).

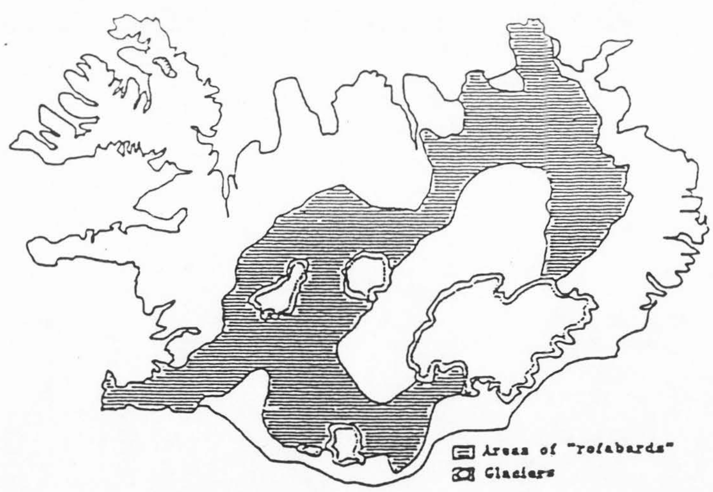

Figure 2. Rough draft showing approximate extend of common erosion features in Iceland. Main areas of rofabards follow the volcanic belt (Arnalds 1992).

WORKS CITED

Arnalds, A., 1987. Ecosystem disturbance in Iceland. Alpine and Arctic Research. 19(4):508-513.

Arnalds, O., A.L. Aradottir and I. Thorsteinsson, 1987. The nature and restoration of denuded areas in Iceland. Arctic and Alpine Res. 19(4):518-525.

Arnalds, O., 1990. Ph. D. Dissertation, Texas A&M University, College Station, Texas, U.S.A.

Arnalds, O., 1992. Erosion caused by climatic change and anthropogenic disturbance in Iceland, in *Disturbance Related Dynamics of Birch and Birch Dominated Ecosystems*, pp. 16-17.

Arnalds, O., and S. Meusalemsson, 1992. Erosion in the Myvatn area. Reproduced from RALA to the Land Use Planning Committee for the area.

Bergthosson, P. , 1987. Introduction to The Impact of Climatic Variations on Agriculture. Reidel: Dordrecht, The Netherlands, 1:1-20.

Eysteinsson, T., 1992. Personal Communication, July 15, Husavik, Iceland.

FitzPatrick, 1983. Soils, their formation, classification, and distribution. Longman: New York.

Hardin, G., 1968 The Tragedy of the Commons. Science 162:1243-1248.

Iceland Agricultural Information Service, 1990. Agricultural Statistics.

ITC: International Institute for Aerospace Survey and Earth Sciences, 1992. Enschede: The Netherlands.

Kristinsson, H., 1975. The vegetation and flora of Iceland. American Rock Garden Society Bulletin. 33(3):105-111.

Magnusson, G., 1992. Personal communication, July 10. Myvatnssveit, Iceland.

Rittenhouse, L., 1983. Range management and livestock grazing in Iceland, Submitted to the Ministry of Agriculture, Iceland.

Sigurthsson, P., 1991. Eignar og afnotarettur yfir Hallendi Islands. In: Hregguidur Northdahl, ed., Framidarnyting Halendis Islandis. Landverd, Reykjavik.

Sveinsson, R., 1953. A memorandum on soil erosion and reclamation problems in Iceland.

Thorsteinsson, I., 1986. The effect of grazing on stability and development of northern rangelands: A case study in Iceland, in *Grazing Research in Northern Latitudes*. O. Gudmundsson, ed. Plenum Press, New York.