A MEMORANDUM

ON

SOIL EROSION AND RECLAMATION

PROBLEMS IN ICELAND

by

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Handrit þetta er prentað eftir frumútgáfu skýrslunnar sem Runólfur Sveinsson sandgræðslustjóri sendi sem fylgiskjal með beiðni íslensku ríkisstjórnarinnar um tæknilega aðstoð frá Matvæla- og landbúnaðarstofnun Sameinuðu þjóðanna, FAO.

Stafsetning og annar frágangur er að mestu óbreytt.

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Position, geology and vegetation changes

Iceland is an island in the North Atlantic Ocean, close to the Arctic Circle, situated between 13½° and 24½° western longitude and between 64½° and 66½° northern latitude. The size of the country is a little more than 100,000 square kilometres (approximately 40,000 square miles). The country is very mountainous, the lowlands, constituting altogether about 1/15 of the entire country, are chiefly located along the coast, cutting only in valleys into the central highlands. The country is created during the Tertiary and Quaternary periods in basalt eruptions. Later the substrata have tilted towards the middle of the country, forming a central depression which has been filled by tuff formations. During the later periods subsequent volcanic eruptions have piled upon the tuff numerous layers of lava, pumice, volcanic ashes, and sand, which mixed with earth constitutes the prevalent soil forming material in these areas. In other parts of the country where the foundation is made of basalt layers, the soil has higher moisture holding capacity than the pumice and sand soils. The latter types are therefore much more susceptible to wind erosion, as will be further discussed on the following pages.

Two thirds of Iceland's surface are entirely devoid of vegetation. Glaciers constitute 13,000 sq. kilometres; lava 12,000 sq. kilometres; deserts (rock and sands) 25,000 sq. kilometres; naked mountains (devoid of vegetation) 30,000 sq. kilometres. The rest, about 30,000 sq. kilometres, have some kind of vegetation, of which about one half is estimated to be of agricultural value.

The settlement of Iceland took place during the years 875-930 AD. According to written accounts, vegetation is supposed to have been considerably greater at the time of colonization; among other things the records speak of fairly extensive forests of birch and willow. It may, however, be considered certain that grass has then as well as now, been the predominant factor in the flora of Iceland. Nevertheless it is very probable that a change took place in the country's vegetation already at the time of settlements, caused by the impact of the livestock, rapidly increasing in numbers. These changes in the vegetation have been constantly taking place during the eleven centuries of inhabitation. These changes have been more and more noticeable in the period of the past few decades, effected mainly by the import of new crops and artificial fertilizers. Changes in vegetation caused by inhabitation, are therefore by no means synonymous with destruction of vegetation.

The destruction of soils and deterioration in vegetation which have appeared since the colonization of Iceland may be attributed to the following factors, which will be discussed separately below: Volcanic eruptions; floods caused by sub-glacial eruptions (jökulhlaup); ordinary floods and water erosion; wind erosion (also originating on sandy seashores); severe winters; excessive exploitation of forests and tearing of heather; inhabitation of man and overgrazing by livestock.

Volcanoes and Eruptions

Iceland is a country of volcanoes. Of about 100 volcanoes 70 are now considered extinct, whereas 30 have been active since the settlement of the country. Of these some have erupted repeatedly. The volcanoes with their lava floods, pumice and ashes which are often scattered far and wide, have played a very influential part in the formation of present soils in Iceland.

The southern part of Iceland and a sector extending through the central interior highlands to the northern and western districts constitute the main areas of volcanic activity. Later in this paper a further reference will be made to the division of the country into volcanic areas, and mention will be made at the same time of those parts which are without volcanoes.

Volcanic eruptions are events of great interest and news value both within and outside the country concerned. In this country a considerable number of historical sources deal with volcanic eruptions, and their effect on the vegetation, livestock, and on the lives of the population in general. Some of these sources relate in detail special cases of destruction of soil thus wrought by the forces of nature. Many such eruptions have occurred in recent times, and not a few even at present.

The most famous volcanoes of those still active, are Katla in the Mýrdal Glacier and Hekla in the Rangá-District. But many others have in former times caused a great deal of damage. We know for certain that the Katla eruptions have destroyed great areas of grassland, together with densely populated parishes, which are now covered by thick layers of lava or by sandy deserts.

About the Katla eruptions 1311 AD we read the following description: There was a great fire in the Mýrdal Glacier, causing a glacierflood which laid waste a great district called Lágeyjarhverfi. It is related that in this parish every inhabitant perished with the exception of one man and a child. This great district was located where the extensive Mýrdal desert is now.

On the Katla eruption of 1721 AD the sources state among other things this: The floodwave rose as high as the Höfðabrekka mountain, i.e. 800 feet, whereby all grasslands up to that height were swept away. On May 13th (i.e. in bright spring) the ashes eruption reached the greatest intensity and force causing such darkness in the adjoining district that the people had to use lights in the middle of the day. This darkness lasted about six hours. The ashes reached a thickness of several inches at a hundred miles distance (more than hoof deep in places). A light had also to be lit in such distant places as Saurbæ on the north coast of Hvalfjordur (more than 200 miles away), and fishermen had a difficult time finding their course back home from the nearest fishing grounds in Garður (Reykjanespeninsula). On May 16th the cloud of volcanic ashes was carried to the northern part of the country, causing pitch darkness there with a downpour of ashes as far west as Svarfaðardalur, and footprints could easily be traced on the ground in Eyjafjörður.

In the Katla eruption 1918 a great quantity of ashes and sand were scattered over Skaftafell county, killing all vegetation both in mountain pastures and home regions. Numerous other Katla eruptions, which will not be discussed here, have had disastrous effects on vegetation and spoiled great tracts of land.

The famous volcano Mount Hekla is believed to have erupted at least about 20 times. Many of these eruptions have been very sizeable, piling up great quantities of pumice, ashes and sand, which have been spread over many remote parts of the country, although the greater part has fallen in the vicinity of the volcano and in the southern district in general.

After the Hekla eruption in 1294 AD the Rangá (a sizeable river) could be crossed on foot on the pumice stranded in it's basin. In many places Thjórsá (Iceland's biggest river) was quite covered by thick layers of floating pumice. This gives an idea of the great mass of pumice from that particular eruption.

In the year 1300 AD the Hekla eruption lasted about one year. Then great rocks of lava were cast to and fro like small pieces of cinder in a forge, and the downpour of hot pumice burnt the roofs from the farm Naefurholt (in several miles distance).

Another Hekla eruption occurred in the year 1341, causing such darkness that people had to keep the lamps burning days on end, and the ashes fell ankle deep on the ground in the Eyjafjallaregion. The ashes were carried as far west as Borgarfjordur, poisoning the grass and killing livestock in the affected districts. The ashes destroyed the soil in five parishes in the immediate vicinity of Hekla (Rangárvalla county). In Skálholt (the southern Episcopal seat) 80 head of cattle died of ash poisoning. This eruption was followed by a great famine and an almost complete failure of crops.

A great Hekla eruption took place in the year 1510, with such a violent outburst of pumice and ashes that people in the open some 20-30 miles away were unable to reach their homes and perished on the spot.

In the year 1693 another great Hekla eruption occurred spoiling great tracts of mountain pastures and farms in the southern part of Iceland, especially in the highland regions of Árnes- and Rangárvalla counties.

A description of the Hekla eruption 1766 contains the following: The beginning of the eruption was particularly vehement. Rocks of pumice up to six feet in circumference were thrown as far as eight miles from the mountain. An eight pound stone fell so deep in the frozen ground near Naefurholt that a crowbar was needed in order to pull it out. Five farms had to be abandoned altogether, while a number of others were subject to great damage. The vegetation in Árnes county was to a great extent spoilt in this eruption, including remote woods and moorlands. The Western Rangá was dammed up by pumice causing floods in the vicinity when this dam broke. The rivers carried great floats of pumice out to sea where they were run into by ships far from the shore. During the precipitation of ashes such darkness followed that people could not even discern their own hands. Pastures and meadows were spoilt in many places, causing the death of livestock. And the volcano kept on erupting ashes and lava rocks without cessation from the 5th to the 9th of April. Then the flow of lava commenced. It continued through April 21, when the column of ashes reached the height of almost 18000 feet, and lasted the whole summer and fall, followed as usual by disease, famine and loss of livestock.

When the 1845 eruption started, on September 2, the ashes and pumice were -mostly spread over Síða and Skaftártunga, and also to a certain extent over the mountain pastures of Rangá and Skaftafell counties.

And in the most recent Hekla eruption, in the year 1947-1948, a great quantity of pumice fell over Rangárvalla mountain pastures, completely destroying all vegetation in extensive areas.

One of the greatest falls of pumice and ashes recorded in Iceland occurred during the

Laki eruption in the year 1783 AD. Then the pumice and ashes were scattered over most parts of the country, both inhabited localities and moorlands and mountain pastures. The sky was black days on end and the air was thick with pumice and volcanic dust. This dust and pumice covered the ground spoiling or destroying vegetation, poisoning the livestock, inflicting famine and death upon the population all over the country. The lavafields flowing from the Laki devastated a considerable area of prosperous farmland.

Turning now to Iceland's highest mountain, the Öræfajökull, which is also one of it's most famous volcanoes, it has brought devastation to many flourishing rural communities in the south. In the year 1362 three simultaneous eruptions took place in the south, the greatest being the one in Öræfajökull. It lasted from June to late in the fall with such a force and destructive power that a whole community was completely wiped out (the Litlahérað) and great parts of Hornafjörður and Lón districts sustained severe damage. The Hnappafellsjökull burst into the sea, where it had been 30 fathoms deep previously, carrying with it such piles of rock and mud that a level sand desert was created. Two parishes were completely laid waste, those of Hof and Rauðalæk, which together has embraced 70 separate farms. The sanddust on the ground was about one foot deep, and the highest drifts almost concealed the dwellings. The ashes also fell in the north so thick that footprints could be traced on the ground. These eruptions also carried such great quantities of pumice into the sea around Iceland that navigation of vessels encountered severe difficulties both in the West and North.

There are many volcanic centers in the North, especially to the south of the Thingeyjar counties. In 1717 the Kverkfjöll, at the northern edge of Vatnajökull, erupted. On September 17 of that year, the ashes caused complete darkness in the Thingeyjar counties and the volcanic dust covered the whole area from Svarfaðardalur to Fljótsdalshérað. This enormous mass originated in the glacier where the Jökulsá in Axarfjörður has its headwaters. The glacier melted and caused great swelling of the river and devastation in Kelduhverfi. After this eruption the ground was covered by a two inches thick layer of volcanic dust.

The famous Mývatn eruptions started on May 17, 1724, with the great cloud of ashes originating in the crater west of Krafla now called Víti (Hell). The fall of ashes was followed by a veritable storms of glowing lava. People to the south and east of Mývatn fled and abandoned their farms. The cover of pumice, sand and sulphuric ashes which buried the ground reached a thickness of three feet in places.

On the 11th of January 1725 the eruptions started again, this time on the western slopes of the ridge called Leirhnjúkur. This hill exploded, leaving only an irregular system of rifts and holes which spouted sulphuric mud for a long time afterwards. On April 19, of the same year, an eruption occurred in Bjarnarflag east of Reykjahlíð. These eruptions caused, as usual, a great damage to pastures and crops.

In 1728 a number of eruptions took place in the Mývatn region, accompanied by great earthquakes. A stream of lava covered tracts of land close to the inhabited area. A crater opened in a small valley, called Hrossadalur, and from there a stream of lava flowed almost to the farm Reykjahlíð. Two days later there was a lava eruption in Dalfjall at Reykjahlíðarsel.

On January 30, 1729, there began in the Leirhnjúkur crater a still greater eruption than before. This eruption lasted until late in the summer. On July 6, the lava flow reached the rural district. Three farms, Stöng, Fagranes and Grjót were laid waste, while the farmers escaped. The same day the people fled from Reykjahlíð although the lava spared the farm until August

The desert from Theisareykjabunga to Trölladyngja is the site of many craters which have erupted a number of times. In later years the greatest eruptions have occurred in Askja, Dyngjufjöll in Ódáðahraun and Sveinagjá in the Mývatn desert, both in 1875. The first eruption in Askja took place on January 3rd. It was visible from the Thingeyjar counties; and on February 18th the eruption in Sveinagjá began. Then the craters in the direction of Skógarmannafjöll opened. From there flowed a great current of rough lava. This rift erupted again on March 10th; and 15 new craters opened, yielding great quantities of lava. On March 29th there was another eruption in Askja still more colossal than the first, causing complete darkness over the whole of North-Eastern Iceland with a great fall of ashes. This situation lasted almost the whole day. At a great distance the size of the pieces of pumice from this eruption were equal to a doubled fist. Volcanic dust was found on a varying scale in the area from Smjörvatnsheiði to Berufjarðarskarð. The layer of ashes reached a thickness of about eleven inches in Jökuldalur. In the Upper-Jökuldalur 17 farms were abandoned for a year. This eruption brought about great changes both in soil and vegetation. Bogsoil turned into dry land, and drifts of sand and pumice on hills and mountain slopes caused wind erosion in many places.

The examples which have been mentioned above, and enumerated in some detail, as to volcanic activity in Iceland, together with the detrimental and often fatal consequences, in lava, pumice and glacial floods, only serve to illustrate the direct impact of these natural forces on the vegetation in Iceland. This enumeration is by no means exhaustive, a multitude of eruptions, old and new, have not been mentioned. The indirect effect of the eruptions on the vegetation in most parts of the country is also great. That matter will be discussed separately below.

Volcanic areas and soil formation

The main volcanic area, where craters are most frequently found, and where lavafields are most extensive, tuff mountains most numerous and the greatest multitude of moraines and sand deserts, is situated on the sector from NE to SW all the way between the two oceans. The eastern limit is from Finnafjörður south to Hornafjörður, and the westernmost part of this end can be reckoned approximately from the mouth of Skjálfandafljót. From these starting points the area can be traced west of Bárðardalur over Mjóadalur in a south-westerly direction through Kalmanstunga in Borgarfjörður, west of the mountains Botnsúlur to Kópavogur close to Reykjavík. The greater part of this area and also a part of the Snæfells-mountain range owes its formation to lava, tuff, piles of pumice, erosive sands and volcanic dust. Strata of humus are observed between the layers of pumice and volcanic ashes.

Of course pumice and volcanic dust has been carried outside the volcanic area proper, although thick strata of pumice and coarse volcanic gravel are very rarely found deep inside areas where no eruptions have taken place. The soil outside volcanic areas in Iceland is therefore quite different. There the basalt foundation is dominant. The soil is a mixture of humus and silt with layers of peat in many places. The moisture holding capacity here is far greater than in the volcanic soils. Therefore the danger of erosion is always far less outside the volcanic area. In the volcanic area, on the other hand, where the soil is only a thin layer on the top of tuff and lava, and in addition mixed with pumice and volcanic dust and consequently spongy, the rain pours through the soil and lave, and emerges later on as fountains along the edges of the lavafields. In some places these fountains form great lakes such as Kleifarvatn, Thingvallavatn, Mývatn, Veiðivötn in the Rangárvalla mountain pastures, etc. Many rivers in the volcanic area have the same kind of origin.

On the lowest part of the southern lowlands, where the soil water has become stationary and without outlet, bogsoil and morass is quite extensive. As examples may be mentioned the following districts: Ölves, Flói, Safamýri, Landeyjar, Mýrdalur, Meðalland. These bogs will remain completely resistant to wind erosion until they have been filled and dried up by drift sand, as in Meðalland and Landeyjar.

The Effects of "glacierbursts" (jökulhlaup)

We have mentioned above how the glacial floods which accompany some of the volcanic eruptions have laid waste and turned into black desert great tracts of fertile land. These glacial bursts are most frequent in Mýrdalsjökull and Vatnajökull, north and south, including Öræfajökull. In addition to the devastation caused by these floods, the glaciers themselves have submerged the vegetation in considerable areas, especially in the Skaftafell counties. The Breiðamerkur glacier has caused the greatest damage, but on a lesser scale all the glaciers have had the same effect, covering pastures and meadows with rocks and silt, piling up moraines and killing all vegetation. As the glaciers thaw these high moraines and sand hills are left in their wake, liable to wind erosion, causing damage to vegetation far and wide from the source.

Flooding by Rivers

There are many great rivers in Iceland; some of them comparatively long and deep, although their volume is quite different. Most of them have their headwaters in the glaciers. They carry with them great quantities of mud, silt and pumice from the inland deserts down to the sea. During the spring thaw and other occasional swellings these rivers inundate their banks and flood the vicinity, tearing up the soil and choking the vegetation with layers of sand and gravel. These gravel and sand banks in and along the rivers will then in turn provide a fresh source of material for the wind erosion.

The Effect of Climate on Soil Erosion

Iceland is situated at the northernmost latitude at which agriculture can be maintained as a profitable industry. Considering only the latitude and the average temperature one should think that conditions for farming were not particularly favourable. But the warmth which the Gulf Stream carries along creates fair possibilities of growing in Iceland some useful plants of importance in agriculture, especially various types of grass. In general the climate of Iceland is cold temperate and oceanic; the summers being rather chilly and the winters comparatively mild and warm.

The precipitation varies a great deal according to the different parts of the country. In the North the annual precipitation is about 500 mm; in the South-west 1000 mm; while it amounts to about 2000 mm on the southern slopes of the central highlands.

The climate from year to year and through decades and centuries is the dominant factor as to vegetation in Iceland. This is especially true of the country's wild flora. Of course the cultivation in field crops and vegetables is at least as dependent on climate condition as the growth of the native flora of the open range.

The chief feature of the Icelandic climate is its lack of constancy, its unsteadiness from day to day, from season to season, from year to year. At times the fluctuations seem to be the only rule. On the whole the weather is quite unpredictable. Still when we study the 1000 years old climate history of the country and read the conclusions of the 100 years of meteorological observations some facts and even laws seem to emerge, especially as regards the difference in weather and climate conditions when long periods, such as decades and even centuries, are compared. There seems to be some systems in these changes, and a certain regularity can be discovered.

These factors will be the subject of the following discussion, as well as the general effects of climate on the destruction of vegetation and soil erosion in Iceland.

A great deal of information on climate in Iceland can be found in the book "Climate in Iceland" by Thorvaldur Thoroddsen. This book covers the period from 900 to 1900 AD. If the historical sources on which this book is based are interpreted literally, the climate must have been a great deal milder during the first centuries of this period than later.

Some contemporary meteorologists and geologists, especially in Scandinavia, are of the opinion that during the three centuries - 1600 to 1900 - the climate in the Northern Hemisphere has grown colder than during the preceding centuries. In this book Thoroddsen reaches the same conclusion, and in addition that the climate has gradually grown colder within that period (i.e. 1600-1900). Accordingly a higher number of severe winters is recorded in the 19th than in the 18th or 17th centuries. The climate was exceptionally and extremely cold in Iceland during the one hundred years period 1740-1840; at least the number of severe winters is far greater than that of mild winters in that period. The years 1840-1860 are comparatively mild; the mild winters being a few more than the severe ones. From 1860 the cold increases steadily, culminating in a decade of extremely severe climate from 1880 to 1890; probably the coldest period since the colonization of Iceland.

Meteorological observations have been carried on in Iceland during the last 100 years, in Stykkishólmur, S.W. Iceland, most of the time daily records of temperature have been kept during this period. Small changes in the mean temperature, f.i. 1 degree centigrade, may have fatal effects on vegetation in general and on the cultivation of food crops in particular.

In the years 1860-1890 the mean temperature in Stykkishólmur was 2.8 degrees Celsius, whereas it has increased to 4.0°C. during the period 1920-1940.

At the experimental farm Sámstaðir in Fljótshlíð temperature has been taken constantly since 1928. In this 25 year period the lowest annual mean temperature was + 4.4°C. in 1949, but highest the year 1939, + 6.1°C. In most years the annual mean temperature in this place was above + 5°C., and in several years close to + 6.0°C.

The flora of the central highlands is of course very much dependent on temperature and climate conditions in general. The borderline of desert and vegetation in the highlands and in places also in the vicinity of inhabited areas has no doubt been swayed back and forth by the influence of climate alone. Erosion and other destructive forces affecting vegetation are at times caused by a drop in the annual mean temperature, especially in the highlands, if the weather remains severe during some considerable time. The written sources dealing with soil erosion and destruction of vegetation caused specifically by wind erosion (drift sand) are neither many nor complete. Much less can we speak of research in this field before the 19th century. One is, however, tempted to conclude on the basis of the scanty material and likelihoods at our disposal, that soil erosion (including wind denudation) has been greatest after the year 1600 AD. As already implied, we have good sources regarding wind erosion (drift sand) covering the 19th century and the period since. Those sources will be discussed later in this paper.

During the years 1702-1712 Árni Magnússon and Páll Vidalín compiled their famous farm register, containing a clear description of every farm and estate in Iceland, with their emoluments and deficiencies. Very often they mention how soil erosion and sand drift damage the land on a number of farms, especially in the volcanic area. Since the beginning of the 18th century it is therefore much easier for us to evaluate the extent of soil erosion, and with a lesser degree of certainty the maintenance and fate of the flora during the same period (i.e. the last 250 years).

We are not in a position to undertake a complete evaluation of the flora in Iceland through the years, or make a survey of the balance, whether there is an economy or deficit or profit in the country's vegetation. In order to make such a survey an extensive project of research would be needed, and such a project would both require a great deal of time and quite considerable expenditure. Nevertheless we consider it vital to know, whether the vegetation of the country is still being destroyed, and if so, to what extent. If the increase in cultivation does not outweigh the destruction by erosion, a great calamity has befallen the country. And now, when the leaders of agriculture are planning a considerable increase in livestock, there is a great necessity to know as soon as possible how the scales stand as to the vegetation of the country. And in this connection it is necessary to remember, as mentioned before, that the climate is of the greatest importance to all vegetation and cultivation, and is one of the determining factors of soil erosion.

We have discussed above the erosion in the volcanic areas around the year 1600. But the erosion in the Reykjanesskagi has also been great during the latter part of the 17th century. It is f.i. recorded that the great farm Strönd in Selvogur was completely destroyed in the year 1690, the famous church alone standing.

Great tracts of land were completely stripped by erosion in the Rangárvallasýsla during the years 1860-1890. The devastation was greatest around the year 1880. The year 1882 was called in the South the "Year of the drift sand". The climate that year has been described in the following way: "A severe northerly storm lasted for a long while and literally ground the dry land which was already exhausted by excessive grazing, tore the roofs off the farmhouses which were thatched with green turf, and demolished the walls which were at the time mostly made of sod. The force and fury of the devastation was so great that it is quite incredible to other than eye witnesses or people familiar with such phenomena. Many persons fled, some to America, some to other districts in Iceland, and a few resettled on the small patches of land left on their farms". A number of good farms were thus laid waste in Rangárvallasýsla during these years. This is written about the destruction of one of them: "For two days not even the bravest men had the courage to leave their homes; such was the force of the sandstorm and stone shots. When the people broke out of their houses on the third day, the livestock was either dead or on the verge of dying in the stables, which were buried under heaps of sand. On some of the houses even the congealed roofs were swept off windward". It should be clear to everyone what destructive force is let loose by such storms, especially when they occur in a period of severe climate such as 1860-1890. The impact on the vegetation is beyond discussion. In large districts the erosion destroyed all plant life during this period, especially in the volcanic areas of the south. When the dry northern and north-easterly winds are dominating the weather for a long time, often accompanied by cold or even severe storms, it will prove difficult to maintain vegetation or prevent further erosion in the southern districts most threatened by drift sand.

In the Skaftafell counties the damage to vegetation has mostly been caused by eruptions, glacial floods, flooding by rivers and by drift sand from the coast, which is entirely made of sand and gravel.

Another famous and extensive drift sand area is in the Hólsfjalla district. The erosion there is considered to have begun close to the mountain and "far from the pastures of excessive grazing". People in that region seem to think that the erosion has been abating during the last decade, although its strength has been greatest as a whole during this century. This is probably

mostly due to the mild weather in the 20th century, especially the period 1920-1950. The erosion in the Hólsfjalla area has a direction on the Axarfjörður, which incidentally is one of the very best sheep raising districts in Iceland. Therefore it is a very urgent task to stop the erosion in this area. The experience of the past few years has shown that the erosion can be put under control and even stopped altogether in the inhabited areas, if there are enough means available in order to take the necessary precautions. These methods will be discussed further below.

The cutting of woods and forest fires

As has already been mentioned, it may be assumed that there have been some birchwoods in Iceland at the time of colonization; together with willow, heather and grass, etc. These woods are not supposed to have been tall. The settlers have no doubt made wide use of these woods for the erection of houses, for making charcoal and for fuel. We have many records of forest fires in connection with the making of charcoal. It has proved difficult to heal these scars, because of unfavourable weather and bad conditions for the growing of trees in general. The making of charcoal was quite extensive for centuries, and the cutting of woods has been mostly for that purpose. The shrubs and heather have been torn recklessly for fuel even almost up to the present time. This misuse of the forest flora has proven very detrimental to all vegetation, as can be clearly seen all over the country. The traces are, however, most evident in the volcanic areas, where the damage caused by excessive cutting and tearing is greatest. In some places the woods have been replaced by grass, willow and other vegetation. The scars are still too numerous and in all too many places.

The Effect of Grazing

The settlers carried with them livestock from abroad, especially sheep, cattle and horses. But as winters are quite mild in Iceland and the ground therefore not so often covered with snow as might be expected, the livestock was kept grazing in the wintertime. The number of cattle and sheep increased rapidly, and in the course of two centuries the former had reached 150,000 while the latter is considered to have amounted to 300,000-400,000; besides there were several tens of thousands of horses. It is certain that this livestock has left its imprint on the vegetation of the country, especially when the winters were severe and the growth of grass little in the proceeding summer; and through many centuries many farmers intended or collected little or no fodder for their livestock and depended almost entirely on the winter grazing. Excessive grazing is of course liable to cause complete destruction of the vegetation and therefore also erosion. And since farming in Iceland has almost exclusively been confined to raising of livestock, with very little agriculture in the literal sense, and the livestock having 2/3 of its fodder from grazing, there is a great need to be on the alert; and try to avoid excessive grazing, and most especially where the soil is susceptible to wind erosion, as in the volcanic area. In this connection of methods available one can mention a better and more careful planning of grazing, and a more widespread cultivation of pastures.

Wind Erosion

Wind erosion in the form of drift sand has by far been greatest in the volcanic areas. These counties have suffered the greatest damage: the Skaftafellssýslur, Rangárvallasýsla, Árnessýsla, Gullbringusýsla and Thingeyjarsýslur. The wind erosion has very often started in the interior deserts, and in the wake has then gradually and successively followed erosion in the moorlands and the inhabited areas. Very often the erosion has begun in the inhabited districts thereby causing great and widespread destruction. Then many factors unite in the beginning erosion. These are the usual: Severe climate, dry and long-lasting storms blowing from the same direction, cutting of bushes and tearing of heather, excessive grazing and even the volcanic eruptions themselves (i.e. the pumice eruptions) - and when the volcanic soils begin to erode, in some places even up to four meters in thickness, the erosion is beyond control so long as rivers, lakes or bog soil do not hinder further spreading.

As we have seen above many of the great rivers carry with them considerable quantities of sand, mud, silt and gravel all the way down to the sea, where it has been heaped up into great rolling hills along the coast. The whole coastline from Thorlákshöfn to Hornafjörður is such a sandy formation; in places the sand reefs along the coast extend up to several kilometres inland, where they meet grown land. From these coastal sandbanks the erosion has often started, destroying great tracts of fertile soil in (f.i.) Meðalland, Vík in Mýrdal, Landeyjar, Thykkvabæ, Eyrarbakki, Aðaldalur and a number of other places. In some of the western firths the shellsand has drifted into the valleys, destroying vegetation. The damage has been greatest in the following places: Bolungarvík, Sauðlauksdalur, Dýrafjörður, Kollavík and Breiðavík.

Protective Measures - Historical Survey

Exactly 200 years ago, i.e. in the year 1753, definite measures were taken in Iceland with the purpose of stopping driftsand and wind erosion. This is the attempt of the Rev. Björn Halldórsson in Sauðlauksdalur to stop wind erosion and protect his homefield from drift sand by erecting a great stonewall around it. The remnants of this wall can be clearly seen still. Since then the records are silent about further attempts to stop the drift sand and wind erosion, until at the end of the century.

At the close of the cold period 1860-1890 a good deal was written and a lively discussion maintained on the problem of wind erosion in the South, and the great damage it had caused during the preceding decades, which seemed bound to continue if protective measures were not undertaken. Some of the best farms in Rangárvallasýsla had already been laid waste and many more were in immediate danger by the wind erosion. The drift sand was also closing in on many farms in the Vestur-Skaftafellssýsla, Selvogur etc.

About the beginning of the 20th century the Agricultural Society of Iceland showed a growing concern for the problems of erosion in general and of the drift sand in particular. On its initiative a number of specialists, including Danish, were sent to undertake a field study of the problem and to put forward their proposals for improvement. The Althing granted a small

sum of money designated to fight or stop erosion. The farmers also undertook protective measures, which consisted mainly of erecting walls of stone or timber right across the direction of erosion on the limits of affected areas and grown land. The results of these individual and public attempts to stop the erosion were of course by no means encouraging or satisfactory.

In the year 1906 the Althing passed a law on desert reclamation. A special director of sand and desert reclamation for the whole country was appointed, and he took office in 1907. Since then the desert reclamation has been continued, in spite of too small allocation of funds during the first years, and on the whole limited means considering the importance and magnitude of the task. The desert reclamation began its activities by importing barbed wire, which was used to fence in and preserve small affected plots and protect them from the grazing of livestock. The farmers living in the neighbourhood of the eroded areas did not have much faith in these experiments in the beginning and considered their usefulness of limited value. But soon it became evident as a first results of the protection, that vegetation started within the fence, even if the plants grew up slowly to begin with; of these the Icelandic *Elymus arenarius* was first to take root and grow in the drift sand. More plants were experimented with such as *Poa*, *Festuca*, *Agrostis*, *Salix* etc. Then a systematic gathering of the *Elymus arenarius* seed was undertaken for the spring sowing. The plant grew wild in many places; but later on the seed was also collected within the reclamation fences.

Simultaneously with the sowing an erection of windward fences was undertaken. Sometimes these fences were made of lumber; and sometimes stonewalling was used to shelter the young plants. Such were the main features of the organization of the desert reclamation until 1920. With that year a considerable number of small desert reclamation fences had been erected in many places of the country. People were beginning to believe that wind erosion and drift sand could be stopped by protecting the land from all too much intrusion of livestock, and by sowing the *Elymus* seed in the worst drifts.

Elymus does not thrive well except in drift sand and then only when there is a fresh annual addition of loose sand. In general *Elymus* does not form a continuos vegetative cover, but collects the sand around its roots in small heaps which gradually grow into hills, the so-called craters. If no other growth than *Elymus* has succeeded in taking root in the affected areas the sides of these *Elymus* tufts begin to erode when the craters have reached a certain height. Of course new heaps are subsequently formed and later craters. The danger of complete erosion is therefore lessened as the sand is not carried so far as before. In case of severe climate as during the years 1860-1890 the danger of erosion is imminent. The *Elymus arenarius* does not withstand much use, neither grazing nor harvesting (mowing). In order to turn the eroded areas into useful land other measures than the sowing of *Elymus arenarius* must be undertaken.

After the year 1920 the desert reclamation service began to expand. More money was allocated in the budget for the purpose, and a number of big soil conservation fences were erected in the following counties: Rangárvellir, Skaftafellssýslur, Árnessýsla, Thingeyjarsýslur etc. The greatest effort was made in Gunnarsholt, Rangárvallasýsla, which is now the main seat of the Icelandic Soil Conservation Service. The farm Gunnarsholt was finally evacuated in 1923, when the farmhouses had been moved four times with the advance of the erosion front. Its land had never recovered from the severe erosion year 1882. In 1926 the Soil Conservation Service bought the farm together with the adjoining deserted farms. During the next years the fencing and erection of new houses was completed. The recultivation of the home-fields was

undertaken and farming started again. For the homefields where the growth was continuous artificial manure was used. In 1947 Gunnarsholt was made the head seat of Soil Conservation and its main experimental farm.

At the end of 1952 the size of the various desert reclamation fences was this:

Skaftafellssýslur	96,766	kilometres	13,599.3	hectares
Rangárvallasýsla	288,940	"	25,620.6	"
Árnessýsla	63,876	"	9,862.8	"
Gullbringusýsla	23,138	"	5,994.3	"
Barðarstrandarsýsla	7,500	"	400.0	"
Ísafjarðarsýslur	12,916	"	255.5	"
Thingeyjarsýslur	107,243	"	14,582.8	"
Total:	600,379	kilometres	70,315.3	"

This survey shows that little has been done with regard to soil conservation outside the volcanic and tuff areas. The erosion in other places is almost exclusively caused by drift sand originating along the coast. This kind of erosion is most extensive in Barðastrandarsýsla and the Ísafjarðarsýslur, as may be concluded from the table above. But the biggest reclamation fences have been made in the volcanic area, which fact does testify to the overwhelming necessity of fighting erosion there.

The most obvious result of the soil conservation activities during the past 45 years is the erection of the desert reclamation fences listed above. The main importance of this task is, however, the reclamation, recultivation of the land within the fences and turning it into useful farmland for harvesting and grazing. The success so far can be measured by the fact that in Rangárvallasýsla alone five farms have already been reoccupied, and there is still enough cultivated land for five in addition. Of course the vegetation is sparse in places and some of the land is grown by *Elymus arenarius*, and therefore of limited use. Some of this land is still without vegetation. But is has become evident that wind erosion and sandstorms have been halted where the reclamation fences have been erected. In the main it can be stated that the protection against grazing has been sufficient help for the self-cultivation in order to stop the wind erosion. In this connection one has to bear in mind the favourable climate which has been dominant since 1900, and even more especially since 1920. It goes without saying that it has been one of the main causes of the good results of self-cultivation within the reclamation fences. We have therefore reason to fear that a period of severe climate, such as 1860-1890, should it arrive in the near future, might cause an erosion on a much larger scale than we have witnessed the first half of the 20th century. There is also the possibility, if the weather conditions deteriorated a great deal, that the growth within the desert reclamation fences would become exposed to the danger of erosion, at least if protection from grazing were relied upon as the only measure. In such a case a liberal use of artificial manure is advisable and the sowing of grass, even on a large scale. That matter will be discussed further presently.

The Sowing of Grass in eroded Areas

In the year 1946 experiment were begun in Gunnarsholt with the sowing of various seeds, mostly grass-seed, imported from the U.S.A., in sand soils which were completely stripped of the last remnants of humus. The following varieties have been tested:

Ammaphila	*arenaria*
"	*breuiligulata*
Poa	*macrantha*
"	*confinis*
"	*ampla*
"	*compressa*
"	*pratensis*
"	*secunda*
"	*nevadensis*
"	*paluctris*
Festuca	*rubra*
"	*elatior*
"	*elatior var. arundinacea*
"	*ovina*
Bromus	*inermis (eight varieties)*
"	*erectus*
"	*catharticus*
"	*polyarthus*
Agropyron	*cristatum*
"	*inerme*
"	*dasystachyum*
"	*elongatum*
"	*sibiricum*
"	*intermedium*
"	*desertorum*
"	*silaris*
"	*smithir*
Elymus	*canadensis*
"	*glaucas*
"	*junceus*
"	*giganteus*
"	*triticoides*

"	*mollis*
Phleum	*pratense*
Phalaris	*arundinacea*
Dactylis	*glomerate*
Alopecurus	*pratensis*
Arrhentatherum	*elatius*
Panicum	*virgatum*
Eragrostis	*trichodes*
Agrostis	*alba*
Andropogon	*zurcaters (3)*
"	*intermedius*
"	*ischaemum*

In addition to these kinds of grasses and a number of varieties of some of them, the seed of various pulses has also been tested. None of the pulses have, however, gained foothold in the sands so far.

Of the grasses tested *Poa macranthe*, *Bromus inermis* (varieties from Canada, Minnesota and Alaska), *Phleum pratense* and varieties of *Festuca* have given best results. Varieties of *Dactylis glomerata* and *Phalaris arundinacea* are high-yielding but comparatively short-lived. Probably *Poa macranthe* is the hardiest and best suited sand grass of the varieties tested so far, but its use is unpracticable because its seed is impossible to procure.

In the year 1948 a cultivation of grasses for agricultural use was started on the sands of Gunnarsholt, especially of those varieties tested which seemed to be most suitable as a commercial crop. This cultivation has been kept on and expanded on a growing scale, depending on the allocation of funds and other circumstances, and now there are 80 hectares of fully grown land where previously had been practically bare sands. The grass has been both for grazing and for harvesting. For this cultivation the following varieties have been used: *Bromus inermis*, *Phleum pratense*, *Festuca rubra* and *Festuca elatior*. Judging from the experience of the past five years in cultivating the sands of Gunnarsholt, one is entitled to conclude that the recultivation of bare sand deserts in Iceland is comparatively easy, safe and inexpensive.

Livestock and Grazing Capacity

Farming in Iceland is mainly animal husbandry. Regular agriculture in the sense of producing seed crops in open (plowed) fields has scarcely existed in Iceland. The cultivation of the past as well as the activities of the present has almost exclusively been growing of grass (cultivation of home fields). The cultivation of grass is the basis of farming in Iceland. The geographical position of the country as well as the climate conditions will jointly make the growing of grass and the breeding of livestock the main pillars of farming in Iceland in the future, as they have been in the past.

Three kinds of livestock have been of the greatest importance for the animal husbandry in Iceland, these are cattle, sheep and horses. The cattle are practically only kept for the sake of milk. The by-product of the cattle industry are hides and a rather low category of meat. The sheep are the main source of the meat industry, also producing wool, skins, including fleece. Horses are kept for many kinds of work on the farm, pulling and carrying, for the meat, and for no purpose at all!

As we have seen above the livestock was in former centuries quite numerous and often more numerous than now, especially the cattle. The annals of past centuries and the statistics regarding possession of livestock in Iceland from 1703-1900 show that the number has increased and decreased alternating according to the swinging of the climate and the seasons, good or bad, including eruptions. During the severe periods a number of the livestock was killed, but with improving conditions the number increased again. This tends to show, among other things, that the existence of livestock depends on the growth of grass more than anything else, the cultivation of grass on homefields and in the pastures, both for harvesting and grazing.

The latest figures about the possession of livestock, from the end of 1951, are as follows: cattle 43,842; sheep 410,894; horses 41,411. The number of farms (farmhouseholds) is 6,221. According to this the size of average farm in Iceland (possession of livestock) is thus; 7 head of cattle, 66 sheep, 6.7 horses. These households are too small to ensure a decent standard of living for the people concerned. From this fact one arrives logically at the conclusion that one of the most immediate and important tasks of Icelandic farming is to enlarge the households. In addition measures are taken to increase the number of farms, both by instituting new homesteads and restoring to habitation deserted farms.

Agricultural produce in Iceland is at present about enough for the home market. The market of dairy products is already full, and the same is fast becoming true of the mutton market. The increase of households will therefore have to rely on foreign markets. The only exports would have to be mutton or beef (of beef producing cattle). Therefore the number of sheep has to be increased and beef producing kinds of cattle introduced. It will prove comparatively easy to increase the number of sheep when the fight against the sheepdiseases, which have raged in Iceland since 1936, is brought to a successful conclusion. By 1960 the number of sheep ought to have reached the one million mark. If a determined action was started now in order to breed a stock of beef producing cattle the number would easily be around 50,000 by the year 1960,

Some people contend, especially the foresters, that because of impending erosion the number of livestock must not be increased, least of all sheep. These statements are not based

on any research as yet, nor on how large the number of livestock ought to be all over the country, i.e. the grazing capacity of the present pastures.

Shortly after 1930 the number of sheep was over 700,000, and a decade later that of horses about 70,000. We have no proof to the effect that the pastures were at that time subject to excessive grazing, or that this number of livestock did cause or threaten dangerous erosion. It is quite clear, however, that with regard to the planned increase in livestock, an investigation must be undertaken as to the grazing capacity of the pastures vegetation in different parts of the country. It must be clear, for what has been said above about the vegetation in the volcanic areas, that pastures there do not possess the same capacity as the pastures in other regions of Iceland.

Of course, we know for sure that we are in a position to increase considerably the area of pasture land simply by applying artificial manure. Then there is also the possibility of reclaiming and cultivating the eroded areas, which are now either completely stripped of vegetation cover or do not nourish growth of any use. Another important measure to take is to place and distribute the livestock according to the quality and grazing capacity of the pastures in question, even more carefully than has been done before. These are all matters which deserve careful research and investigation. The same is true of a number of other factors which influence the grazing capacity of the land as well as the danger of erosion.

Gunnarsholt, May 1, 1953

Runólfur Sveinsson

APPENDIX

Some facts concerning the Soil Conservation Service

The Service is now operated according to the law No. 18, May 28, 1941, "about desert reclamation and the hindering of sandstorms". The Ministry of Agriculture has the supervision of these matters.

The central station and main seat of the Soil Conservation Service is now at Gunnarsholt in Rangárvallasýsla. Gunnarsholt is also the residence of the Soil Conservation Director, who is a graduate of the Agricultural University in Copenhagen, Denmark. Mr. P. Sveinsson, a specialist employed by the Service at Gunnarsholt, had his education in U.S.A. He was with the U.S. Soil Conservation Service for a year and a half, and studied later for two years at the University of Minnesota and graduated from the University of Utah, majoring in Range Management.

In the six main reclamation areas the staff under the direction of the Service is charged with the task of supervising, protection, fencing, cultivation etc.