UNITED NATIONS UNIVERSITY
UNU-LRT

UNU Land Restoration Training Programme
Árleynir 22, 112 Reykjavik, Iceland

Final project 2015

COMPARISON OF DIFFERENT VEGETATION RESTORATION PRACTICES: THE CASE OF GUNNARSHOLT, SOUTH ICELAND

Bulgan Andryei
Mongolian University of Life Sciences
Khan-Uul district, Zaisan, 17024 Ulaanbaatar, Mongolia
bulgan.msua@yahoo.com

Supervisors
Dr Bryndis Marteinsdottir
University of Iceland
bryndism@hi.is

Agusta Helgadottir
Soil Conservation Service of Iceland
agustah@land.is

ABSTRACT

Iceland is a fragile northern ecosystem where anthropogenic activities in conjunction with highly erodible volcanic soils and a cold, moist climate have caused severe land degradation. The degraded land and the slow natural recovery demand effective reclamation treatments. In this study the main purpose was to identify the most successful restoration treatment for degraded land at the study site and also to assess the effect of different restoration practices on soil organic matter and vegetation biomass. The study area consisted of reclamation sites in Gunnarsholt, South Iceland. In this study, I compared different restoration treatments. The different restoration treatments were: 1) control, 2) sown grass seeds and fertilizer applied in 2013, 3) sown grass seeds and fertilizer applied in 1962–1975, and 4) fertilizer applied in 1991. In each treatment I measured vegetation biomass, vegetation cover of each cover group (grasses, herbs, shrubs, dwarf shrubs, sedges, mosses, litter, lichens, fern, and bare ground) and counted the number of species. In addition, I measured soil organic matter and soil bulk density in each treatment. The results showed that the biomass and vegetation cover in fertilizer applied and sown seeds and fertilizer applied in 1962–1975 treatments were higher than on degraded land. Also, bulk density and soil organic matter were higher with fertilizer treatment than on degraded land. I concluded that the fertilization treatment was most effective for improving the degraded land.

Key words: Biomass, degradation, restoration treatment, soil organic matter.

This paper should be cited as:

Andryei B (2015) Comparison of different vegetation restoration practices: the case of Gunnarsholt, South Iceland. United Nations University Land Restoration Training Programme [final project] http://www.unulrt.is/static/fellows/document/andryei2015.pdf

TABLE OF CONTENTS

1. INTRODUCTION

Land is a unique asset, being both finite and irreplaceable, but human activities have played a significant role in land degradation. In order to achieve sustainability of land management we must reduce land degradation; this has been difficult for most countries (Crofts 2011).

In the beginning of the 20^{th} century, as a result of deforestation, Iceland had lost almost all of its forests and woodlands. The Icelandic Forestry and Protection Act from 1907 that combats soil erosion was a big effort in the battle against further soil erosion in Iceland (Arnalds et al. 2000; Arnalds 2004). The act helped to address major land related degradation, including soil erosion. Today, Icelanders are very knowledgeable and technologically skilled in the field of land restoration and the Soil Conservation Service of Iceland has over a 100 year long history (Crofts 2011). This experience of land restoration in Iceland can be taken as a lesson for a country like Mongolia.

In Mongolia, the main causes of land degradation are overgrazing, unsustainable land use systems, mining and climate change. Mineral law includes provisions for land rehabilitation after mining (Mongolian Government 2006). However, according to the Ministry of Nature and Environment of Mongolia, only 26% of the area mined for placer gold has been filled in and only 8% of the area has been restored with vegetation. It is therefore difficult for herders to use the pastureland again after mining (Suzuki 2013). Also, since the onset of economic changes in the early 1990s, increase in domestic animal numbers without any grassland use management measures led to increased grazing pressure, causing rangeland degradation (Jamsranjav 2009). In addition, intensive land cultivation began in 1950, and now 60% of the cultivated area has been eroded (Ministry of Food and Agriculture of Mongolia 2013). Therefore, I want to use the Icelandic experience of soil conservation and restoration to learn suitable restoration measures that I can adapt to Mongolia and use to contribute to available guidelines for sustainable land use management. To understand the effect of different rehabilitation measures, I studied one reclaimed site in South Iceland restored with different restoration treatments.

Reclamation success was estimated by measuring vegetation biomass, cover, species richness and soil organic matter (SOM). Soil is fundamental to our life and soil organic matter is the second largest carbon pool on the planet, after the oceans. Soil organic carbon (SOC) is a continuously changing component of the terrestrial systems. The change happens both internally and externally in the atmosphere and the biosphere. Restoring soil carbon is thus essential to enhancing soil quality, sustaining and improving food production, maintaining clean water, and reducing increases in atmospheric CO_2 (Wang et al. 2011). Carbon sequestration in the soil involves the process of transferring CO_2 from the atmosphere to the soil. This happens through crop residues and other organic materials in the soil system. The process of transferring CO_2 to the soil helps to absorb emissions from the burning of fossil fuels and other carbon emitting human activities. At the same time this enhances soil fertility and can support long-term productivity. Soil carbon transfer can be facilitated by soil fertility management systems that can add a huge amount of biomass to the soil system and reduced soil disturbance (Sundermeier et al. 2005). SOC is related to atmospheric CO_2 levels with soils having the potential for C release or sequestration, depending on vegetation cover, land management and climate (Wang et al. 2011).

1.1 Goal

In this research project, different restoration treatments, using various plant species and fertilization regimes, were selected. The goal was to identify the most successful combination of restoration treatment for the area under study.

1.2 Objectives

The objective of this study was to assess the effect of different restoration practices on soil organic matter and biomass (vegetation).

1.3 Research questions

- Is there a significant difference in plant groups (vascular plants, mosses, herbs) cover among the different restoration treatments?
- Is there a significant difference in species richness among different restoration treatments?
- Is there a significant difference in moss and vascular plant biomass among different restoration treatments?
- Is there a significant difference in soil organic matter among different restoration treatments?
- Is there any effect of vegetation biomass on soil organic matter (SOM)?
- Which restoration method is most effective for improving the degraded land?

2. METHODS

2.1 Study area

The study area was reclamation sites close to Gunnarsholt, which is located in the south of Iceland (63º510 N, 20º180 W, elevation 50–60 m). After the settlement of Iceland, deforestation and draining of wetlands become a common phenomenon. Gunnarsholt was no different from other areas of the country. As a result the birch woodland cover decreased from 25% to less than 1%. From the barren land, dust and sand storms were the major problems destroying grazing lands and settlement areas. To reduce this problem and reverse the problem of land degradation, a formal land reclamation arrangement was established in 1907. Throughout the 100 years of land reclamation history of the area, sand drifting protection, revegetation of barren lands, stabilization of coastal areas and reclamation of drained wetlands have been carried out. This land reclamation was accomplished through human labour, machines and airplanes that spread fertilizer (Crofts 2011). Currently a total of 160.8 hectares of land have been rehabilitated in the study area.

This study compared different restoration treatments: 1) control, 2) seeding and fertilization (new), 3) seeding and fertilization (old), 4) fertilization (Table 1). The location of different treatments were: control site at 63º54’740N latitude and 20º02’663W longitude, fertilizer applied site at 63º53’270N latitude and 20º07’071W longitude, sown seeds and fertilizer applied in 2013 on site at 63º55’386N latitude and 20º01’448W longitude, and sown seeds and fertilizer applied in 1962–1975 on site at 63º53'186N latitude and 20º05'636W longitude in Iceland (Fig. 1).

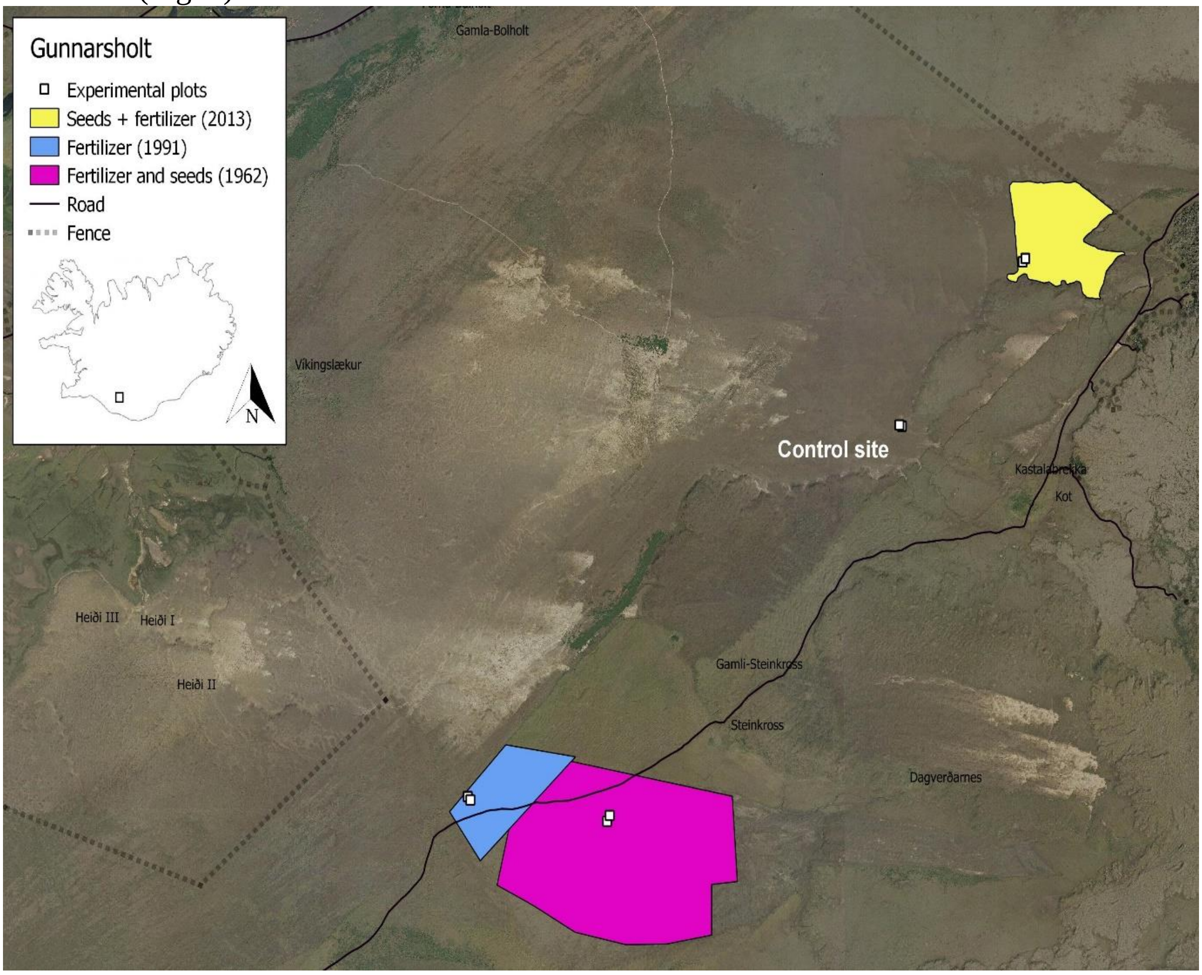

Figure 1. Map of the study area with the sampling points. There were four different restoration treatments: yellow site – seeds and fertilizer applied in 2013; control site – untreated area; pink site – seeds and fertilizer applied in 1962–1975; and blue site – fertilizer applied in 1991. (Source: Agusta Helgadottir, Soil Conservation Service of Iceland, 2015)

The mean temperatures close to Gunnarsholt from 1970 to 2011 were -1.4ºC in January and 11.0ºC in July, with a mean annual precipitation of 1122 mm (The Icelandic Meteorological Office).

According to Arnalds (2015), Iceland is dominated by Andosol soils but other common soils are Vitrisol and Histosol. Icelandic Andosols are further grouped into three classes, i.e. Brown Andosols, Gleyic Andosols and Histic Andosols. In my study area, the dominant soil type was Brown Andosols in vegetated environments. They are usually well drained, have light soils (bulk density of less than 0.8 g cm^{-3}) and less than 12% carbon in dry areas (Arnalds 2015).

Reclamation activities around Gunnarsholt started more than 100 years ago (Crofts 2011). Reclamation treatments included the seeding of several grass species (*Festuca rubra* and *Poa pratensis*) and the addition of fertilizer. The long-term effects (20–45 years) of reclamation treatments on plant succession in the area have previously been studied, including by

Gretarsdottir et al. (2004). The study site is generally flat and far from good natural vegetation.

Table 1. Description of the four reclamation treatments at the study sites near Gunnarsholt.

Treatment	Treatment year	Total used fertilizers weight, kg	Treatment area, ha	Fertilizer type	Seeding and fertilization machinery	Sown species	Total used seeds species weight, kg	GPS coordination
Control	-	-	-	-	-	-	-	N63º54'740 W20º02'663
Fertilizer	1991	12000	39.9	Chemical	Airplane	-	-	N63º53'270 W20º07'071
Seeds.fert.new	2013	86800	54	Meat meal	Tractor seeding	*Festuca richardsonii*	1500	N63º55'386 W20º01'448
						Lolium multiflorum	800	
						Deschampsia beringensis	140	
Seeds.fert.old	1962 – 1975	2500	8.3	Chemical	Airplane	*Festuca richardsonii*	NA	N63º53'186 W20º05'636

2.2 Data Collection

2.2.1 Vegetation

This study compared different restoration treatments: 1) control, 2) seeding and fertilization (new), 3) seeding and fertilization (old), and 4) fertilization. In each treatment two plots (each plot 10 x 10 m) were randomly established. In each plot five quadrats 0.5 x 0.5 m were laid out randomly (Fig. 2).

Determination of vegetation cover and species richness: In each quadrat I measured the vegetation cover of each cover group (grasses, herbs, shrubs, dwarf shrubs, sedges, mosses, litter, lichens, fern, and bare ground) and counted the number of species. Also, I determined vascular plant species richness in each of the different reclamation plots. Species names followed Kristinsson (2005) and Flora of Iceland (n.d.). The vegetation cover was estimated based on eight cover categories: 1: <1%; 2: 1–5%; 3: 5–10%; 4: 10–15%; 5: 15–25%; 6: 25–50%; 7: 50–75%; 8: 75–100% (Braun-Blanquet 1932).

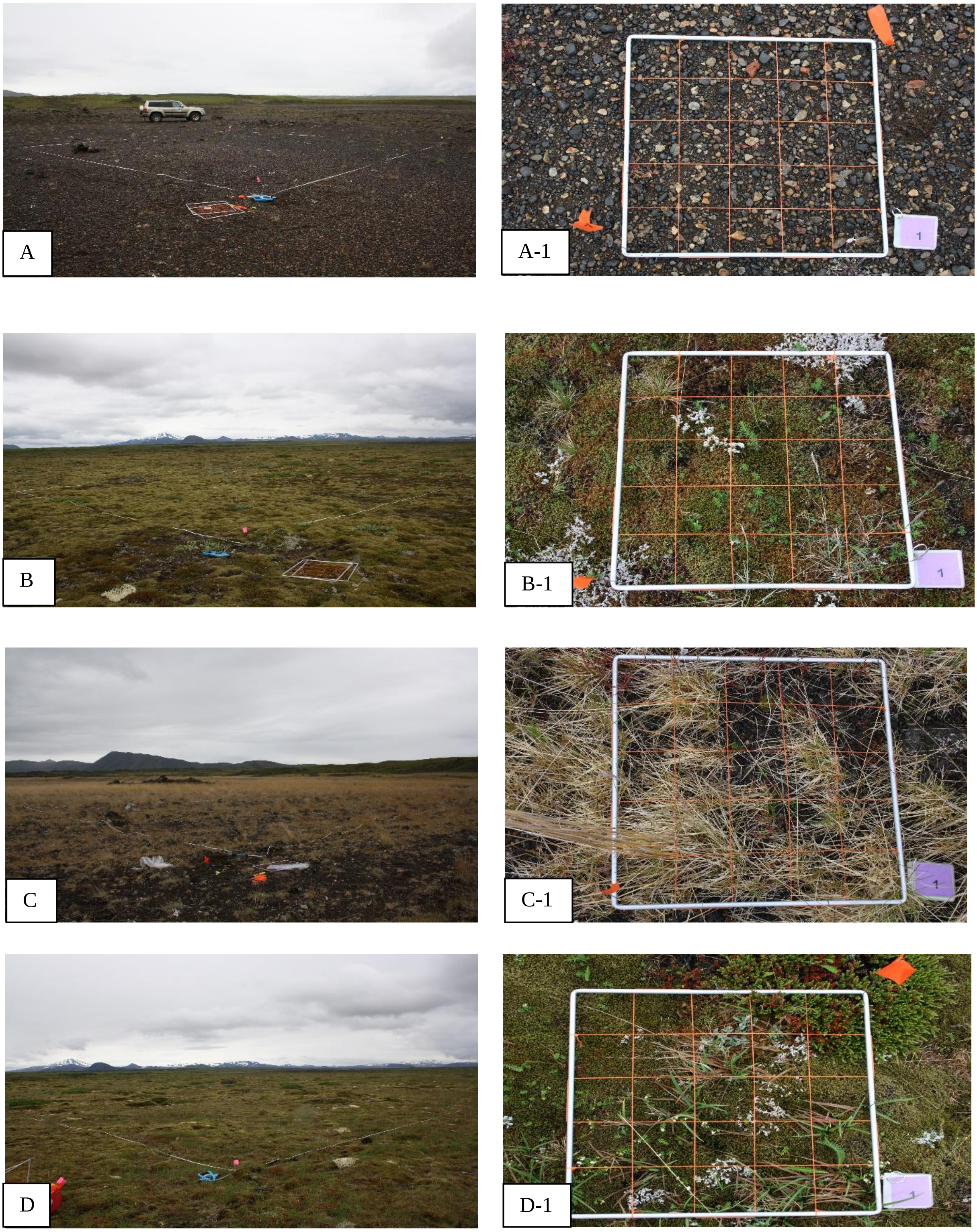

Figure 2**.** Different restoration treatment plots and quadrats: A; A-1) control, B; B-1) fertilizer, C; C-1) seeding and fertilizer (new), D; D-1) seeding and fertilizer (old).

Determination of vegetation biomass: Vegetation biomass (vascular plants and cryptograms) in each quadrat was harvested by cutting first the vascular plants (grasses and herbs) that grow above the cryptogram layer (mosses and lichens) and then the cryptogram layer was harvested at the soil surface. The layers were collected in separate paper bags. The samples were dried at 70°C and then weighed (Fig. 3).

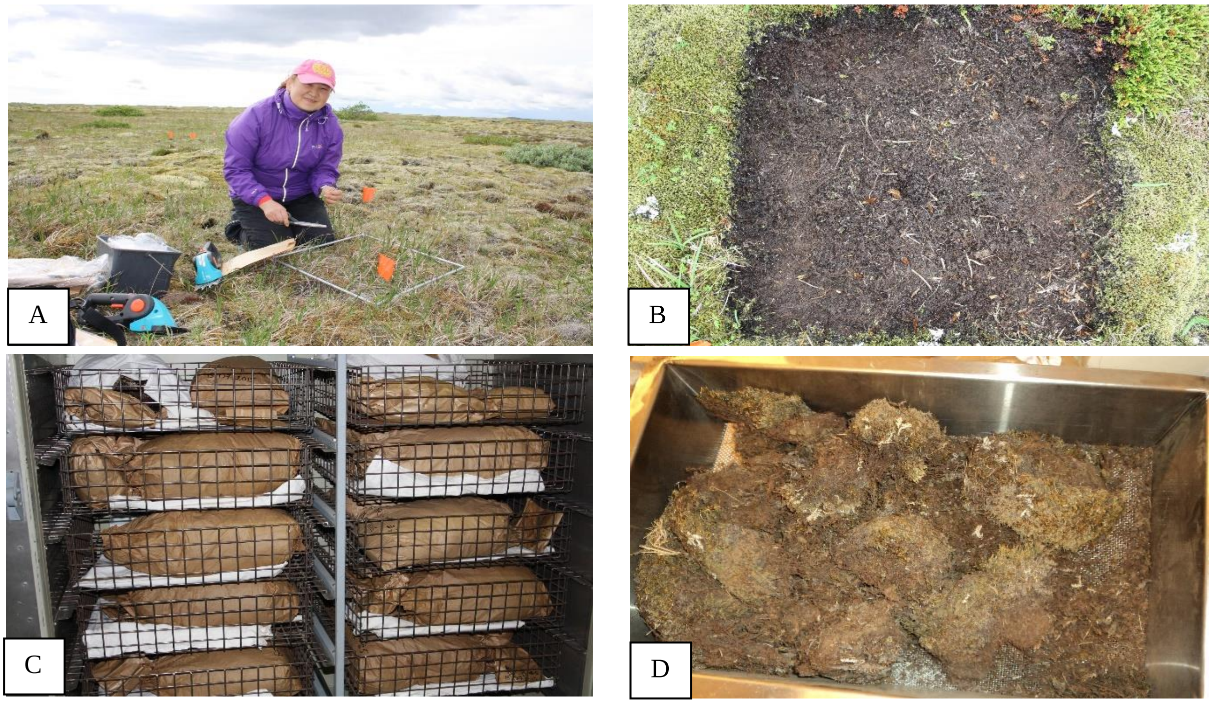

Figure 3**.** Vegetation sample collection from each treatment. A, B) Sampling in each quadrat within plot, C) samples dried in the oven at 70ºC and D) weighed biomass.

2.2.2 Soil

Soil sampling: The samples for soil organic matter measurements were collected from all four different restoration treatments. A soil auger was used to collect the samples at a depth of 0–10 cm. In each treatment, within each plot, samples from five quadrats were collected and then combined (Fig. 4).

In addition, samples for bulk density were collected by using a 4.8 cm diameter, 25 cm long conical soil auger, down to a 10 cm depth. For bulk density samples, three replications were randomly collected near the plots in each treatment.

Sample preparation: Soil samples for soil organic matter analysis and bulk density measurements were air-dried in a room with proper ventilation. The individual soil samples were then sieved in a 2 mm sieve to remove materials >2 mm (Fig. 4).

Determination of soil bulk density: Bulk density was used to determine the mass of the soil in the field which was used to calculate the amount of carbon per ha in each treatment. Each sample was measured before drying to determine the weight of wet soil. The samples were then heated in an oven for 24 hours at 105°C. Then the samples were sieved to determine soil fractions of <2 mm. The weight of <2 mm fraction was measured. Density, weight of rock fragments and core volume were also determined. The bulk density was calculated using the procedures of Burt (2004) given by:

Db = (ODW – RF) / [CV - (RF / PD)]

where
Db represents bulk density of <2 mm soil particles at sampled, field water state (g cm^3),
ODW represents oven dry weight,
RF represents weight of rock fragments,
CV represents core volume,
PD represents density of rock fragments.

Determination of soil organic matter and carbon: Determination of soil organic matter by means of the loss on ignition (LOI) method, which is based on sequential heating of the samples in a muffle furnace, was applied. After oven-drying of the sediment to a constant weight (24 h. at ca. 105°C) organic matter was combusted to ash and carbon dioxide by heating the sediments at a temperature 550ºC for 4 h in a muffle furnace. The samples were then re-measured and LOI calculated by the following equation:

$LOI_{550} = ((DW_{105} – DW_{550}) / DW_{105}) * 100$

where
LOI_{550} represents LOI at 550°C (as a percentage),
DW_{105} represents the dry weight of the sample before combustion (g),
DW_{550} the dry weight of the sample after heating to 550°C (g).

The weight loss is proportional to the amount of organic carbon contained in the sample (Salehi et al. 2011). Carbon content (C%) and carbon density (Dc) were calculated by the following equations:

$C\% = 0.499 * LOI_{550} - 0.509$

where
C% represents soil carbon content (%),
LOI_{550} represents loss on ignition (%) (Askelsdottir & Gudmundsson 2009).

Dc = C% * Db * Sd

where
Dc represents carbon density (t/ha),
C% represents carbon content (%),
Db represents bulk density (g cm^3),
Sd represents soil depth (m).

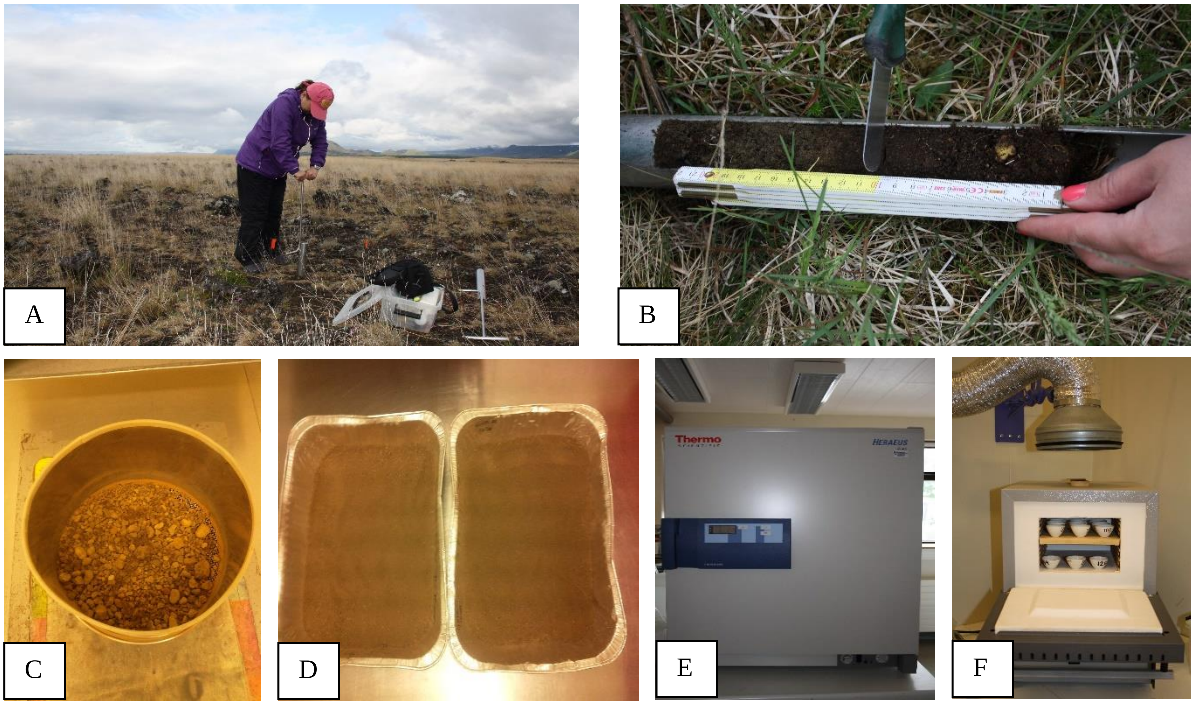

Figure 4. Soil sample collection from each treatment. A) Sampling using auger, B) sampling to 10 cm depth, C) sieving 2 mm sieve, D) preparing for analysis and E) heating for bulk density (105ºC) determination and F) LOI (550ºC) in muffle furnace.

Sampling point mapping: A Global Positioning System (GPS) reading was taken for each sampling point and mapped by using QGIS 2.8.2 software. This helped to assess the uniformity of the distribution of the different land rehabilitation treatments in the study area. The meta data were from Landmaelingar Islands (LMI), aerial photos were from Loftmyndir ehf, and the reclamation data were received from the Soil Conservation Service of Iceland (Fig. 1).

2.3 Statistical analysis

I used R statistical analyses program (R Development Core Team 2008). To assess the effect of restoration treatment on biomass, plant species, species richness and soil organic matter, I used the Kruskal-Wallis rank sum test and a Tukey and Kramer (Nemenyi) post hoc test to test for differences among treatments. I tested for significant correlation between biomass, vegetation cover and soil organic matter by using a correlation test.

3. RESULTS

3.1 Reclamation treatments

Biomass differed among reclamation treatments. No moss was found at the control site and the sown seeds and fertilizer applied (new) site. However, moss biomass was affected by treatment, with the highest moss biomass in the sown seeds and fertilizer applied (old) site ($\chi^2 = 34.75$, $p < 0.001$) (Table 2). The mean value of vascular plant biomass in fertilizer, sown seeds and fertilizer applied (new) and sown seeds and fertilizer applied (old) treatment were found to be significantly higher than the control ($\chi^2 = 23.07$, $p < 0.001$) (Table 2). In addition, fertilizer and sown seeds and fertilizer applied old had a significantly higher total biomass than sown seeds and fertilizer applied new ($p < 0.01$). However, there was statistically no difference between the sown seeds and fertilizer applied new and the control ($p>0.05$).

Table 2. Moss and vascular plant biomass (t/ha) of different reclamation treatments near Gunnarsholt, Iceland. Control: untreated site; Fertilizer: only inorganic fertilizer applied in 1991; Seeds.fert.new: grass seeds and fertilizer applied in 2013; Seeds.fert.old: grass seeds and fertilizer applied in 1962–1975. Mean moss and vascular plant biomass, total biomass mean, standard deviation (Sd) and standard error (SE) are given.

Treatment	**Mean**		**Total biomass, t/ha**		
	Moss, t/ha	**Vascular plant, t/ha**	**Mean**	**SE**	**Sd**
Control	0.0	0.05	0.05	0.01	0.04
Fertilizer	22.5	0.5	23.07	3.26	10.32
Seeds.fert.new	0.0	1.2	1.22	0.21	0.68
Seeds.fert.old	32.2	0.6	32.81	2.64	8.35

The total vegetation cover of the control was significantly lower than other treatments ($\chi^2 = 33.28$, $p < 0.001$). In addition, the total vegetation cover of sown seeds and fertilizer applied (old) treatment was significantly higher than the fertilizer and sown seeds and fertilizer applied (new) treatments (Fig. 5).

Mean values of herb ($\chi^2 = 11.66$, $p < 0.01$) and grass vegetation cover ($\chi^2 = 26.16$, $p < 0.001$) of the fertilizer and sown seeds and fertilizer applied (new) treatments were significantly higher than control and sown seeds and fertilizer applied (old) treatments. But mean values of moss vegetation cover of the sown seeds and fertilizer applied (old) and fertilizer treatments were found to be higher than the control and sown seeds and fertilizer applied (new) treatments ($\chi^2 = 35.81$, $p < 0.001$) (Fig. 6).

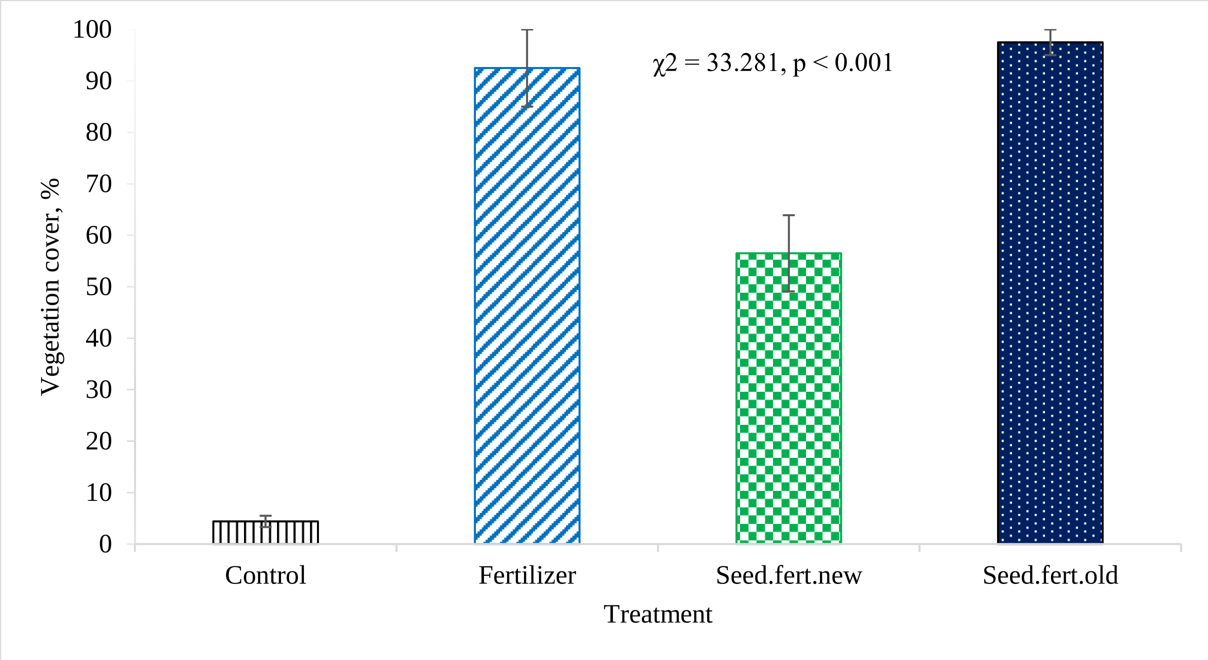

Figure 5. Mean total vegetation cover and standard error of different reclamation treatments in Gunnarsholt, Iceland. Kruskal-Wallis rank sum test values are given.

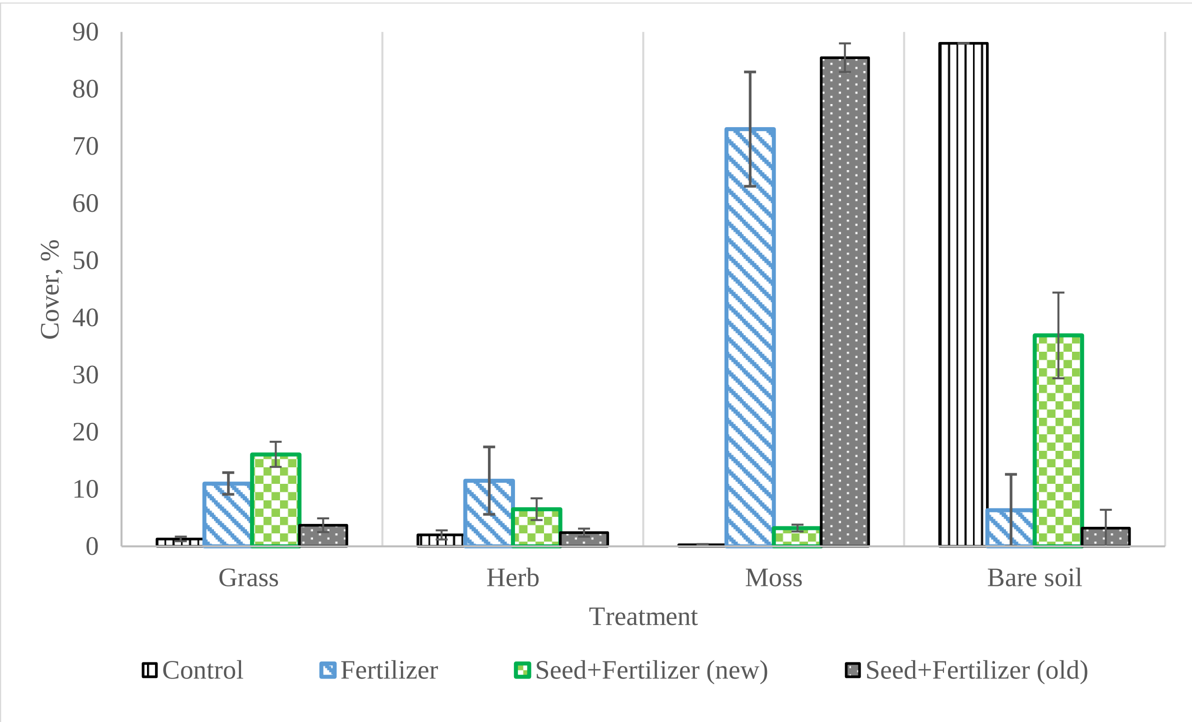

Figure 6. Mean values and standard error for grass, herb, moss and bare soil cover (%) of different reclamation treatments in Gunnarsholt, Iceland.

Mean vascular plant species richness per 100 m^2 quadrat was not significantly different between treated and untreated areas ($\chi^2 = 4.99$, $p > 0.05$) in Gunnarsholt, Iceland (Fig. 7).

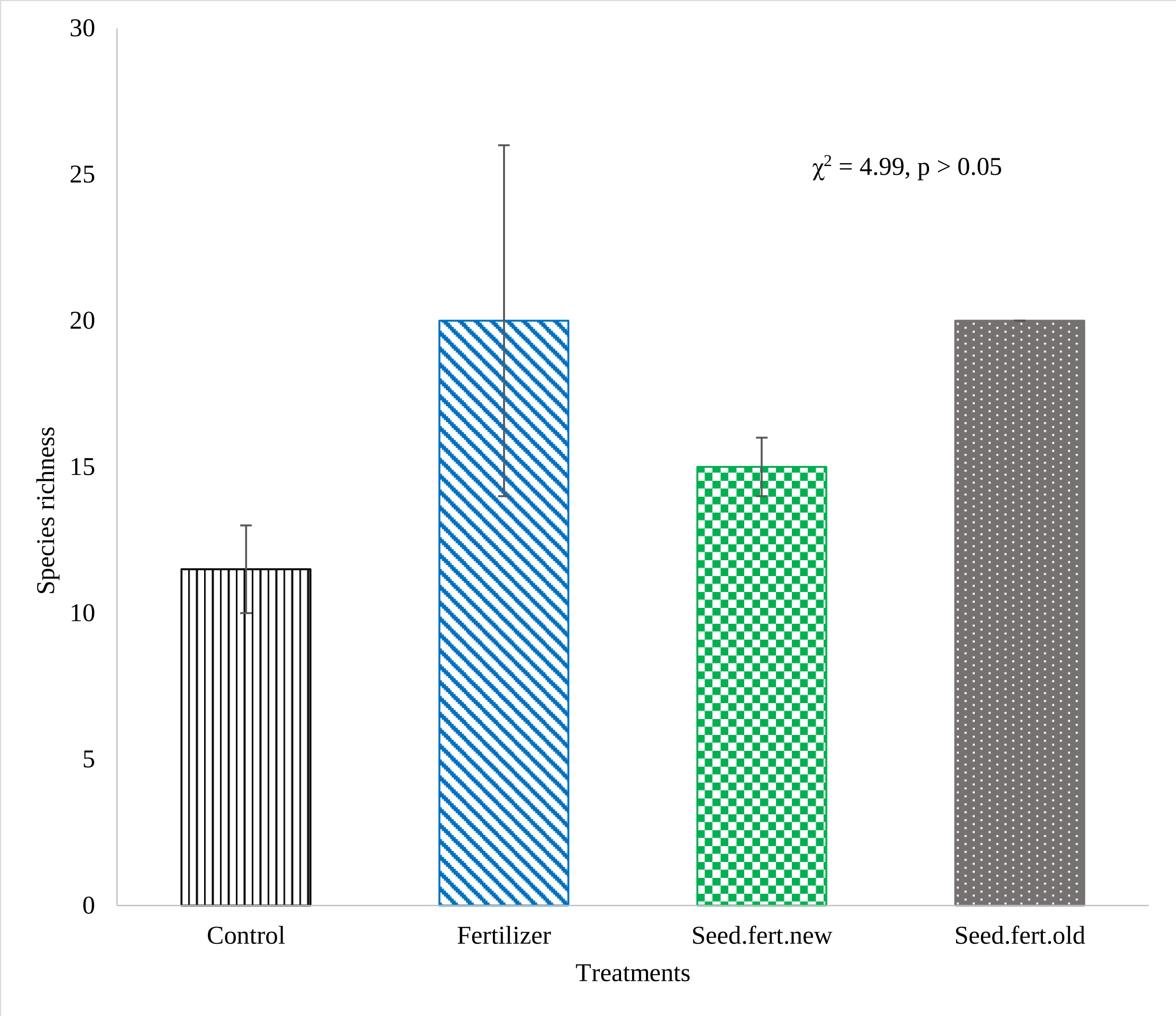

Figure 7. Mean, standard error, chi-square and p values of vascular plant species richness in different reclamation treatments in Gunnarsholt, Iceland.

The flora of control and sown seeds and fertilizer applied (new) were characterized by perennial low-growing herbs and grasses. Shrubs and trees were not found at the control site and sown seeds and fertilizer applied (new) treatment plots. The seeded grass species (*Lolium multiflorum*) was not found in the sown seeds and fertilizer applied (new) treatment plot. The highest vascular plant species richness was found in fertilizer, and sown seeds and fertilizer applied (old) treatments (Table 3).

Table 3. Species list and mean and total vascular plant species richness in different reclamation treatments. Control: untreated site; Fertilizer: only inorganic fertilizer applied in 1991; Seeds.fert.new: grass seeds and fertilizer applied in 2013; Seeds.fert.old: grass seeds and fertilizer applied in 1962–1975. x = plant species were found in this treatment. Plant species sown are denoted with an [a]

N	Vascular plant species name	Treatments			
		Control	**Fertilizer**	**Seeds.fert.new**	**Seeds.fert.old**
1	*Achillea millefolium*		x		x
2	*Agrostis capillaris*			x	
3	*Agrostis vinealis*		x		x
4	*Alopecurus geniculatus*			x	
5	*Arabidopsis petraea*	x		x	x
6	*Arenaria norvegica*	x		x	
7	*Betula pubescens*[a]				x
8	*Bistorta vivipara*				x
9	*Botrychium Iunaria*		x		x
10	*Calluna vulgaris*		x		x
11	*Carex bigelowii*		x		x
12	*Cerastium alpinum*		x		x
13	*Cerastium fontanum*	x		x	
14	*Corallorhiza trifida*		x		
15	*Deschampsia beringensis*[a]			x	
16	*Deschampsia caespitosa*		x		x
17	*Empetrum nigrum*		x		x
18	*Epilobium palustre*				x
19	*Equisetum arvense*	x	x	x	x
20	*Festuca richardsonii*[a]	x	x	x	x
21	*Festuca rubra*			x	
22	*Festuca vivipara*		x		x
23	*Galium boreale*		x		
24	*Galium normanii*	x	x	x	x
25	*Galium verum*	x	x	x	x
26	*Juncus trifidus*		x		x
27	*Kobresia myosuroides*		x		x
28	*Leontodon autumnalis*				x
29	*Luzula multiflora*		x		x
30	*Luzula spicata*	x	x		x
31	*Poa glauca*	x		x	
32	*Poa pratensis*		x	x	x
33	*Rumex acetosella*	x	x	x	
34	*Salix herbacea*		x		x
35	*Salix lanata*		x		x
36	*Salix phylicifolia*				x
37	*Silene acaulis*	x	x	x	x
38	*Silene uniflora*	x		x	
39	*Taraxacum sp.*				x
40	*Thalictrum alpinum*		x		
41	*Thymus praecox*	x	x	x	x
42	*Trisetum spicatum*	x	x		x
	Total species number	14	27	17	30
	Mean species richness	**11.5**	**20**	**15**	**20**

The mean soil bulk density values of the control plots were found to be higher ($\chi^2 = 8.49$, $p < 0.05$) than the fertilizer, sown seeds and fertilizer applied (new), sown seeds and fertilizer applied (old) treatment plots (Table 4). The analysis of average soil organic matter (loss on ignition) concentration, due to reclamation treatments, illustrated that the reclamation treatment had a significant effect ($\chi^2 = 9.36$, $p < 0.05$) on SOM. This significant difference was mainly contributed by the fertilization treatment. Sown seeds and fertilizer applied (new), sown seeds and fertilizer applied (old), however, did not differ in SOM from the control. Fertilization treatment had more soil organic matter and carbon content than the control, sown seeds and fertilizer applied (new and old) treatments (Table 4).

Table 4. Mean, standard deviation (Sd) and standard error (SE) of bulk density, soil organic matter, carbon content and carbon density for different reclamation treatments near Gunnarsholt, South Iceland.

Treatment	Bulk density, g/cm^3			Soil organic matter, %			Mean carbon content, %	Mean carbon density, t/ha
	Mean	Sd	SE	Mean	Sd	SE		
Control	0.98	0.14	0.08	4.68	0.62	0.36	1.8	17.97
Fertilizer	0.55	0.07	0.04	8.35	0.11	0.06	3.6	20.14
Seeds.fert.new	0.87	0.08	0.05	3.45	0.06	0.03	1.2	10.59
Seeds.fert.old	0.61	0.07	0.04	4.64	0.44	0.25	1.8	11.03

3.2 Correlation between biomass, vegetation cover and soil organic matter

I assessed the correlation of biomass, vegetation cover and soil organic matter in different reclamation treatments. The results of the analysis showed no significant correlation ($p>0.05$).

4. DISCUSSION

The data showed that the different reclamation treatments of degraded land in South Iceland had an effect on vegetation biomass, cover, soil bulk density and organic matter.

4.1 The effect of restoration treatment on biomass, species richness and vegetation cover

Total biomass increased with reclamation efforts, with sown seeds and fertilizer applied old and fertilizer treatments having the highest total biomass. However, almost all of the biomass was found in mosses, mostly *Racomitrum lanuginosum*, which is one of the most common moss species in Iceland. If moss is growing on degraded land, it implies that the soil nutrient and water capacity has been improved. The highest biomass of vascular plants was however found at the site with sown seeds and fertilizer applied (new) treatment (mean = 1.22 t/ha). Vascular plant growth conditions (enough nutrients) were very good at the site with sown seeds and fertilizer applied in 2013 and therefore biomass was higher there than with other treatments. Total vegetation biomass was significantly different between restoration treatments. The biomass rate observed at the control site was similar to that found by Aradottir et al. (2000) for untreated areas near Gunnarsholt. Moss biomass in the old treatments was double the moss biomass in Aradottir et al. (2000) research.

Higher biomass usually depends on vegetation cover. Enhanced vegetation cover is one of the first signals of primary success within restoration areas. I found significant differences in total vegetation cover between treated areas and the control plot. Grasses, herbs, mosses and bare ground occurred in all four reclamation treatments. Moss cover is very good to protect and restore degraded land, but is not useful for livestock grazing. The vegetation cover rate observed in this study ranged from 4.4 (untreated) to 56.5–97.5% (treated) depending on reclamation treatment (Fig. 6). The observed vegetation cover rate was similar to that found by Gretarsdottir et al. (2004) at reclamation sites with similar treatments and age near Gunnarsholt.

The vascular plant species richness was not significantly different between different restoration treatments. Fertilizer treatment and the sown seeds and the fertilizer applied old treatment had higher vascular plant species richness, probably because they were the oldest (24–53 years). Long term treatments were beneficial in the sense of forming a persistent plant cover and species richness. The species richness rate observed at my site was higher than at Petursdottir et al. (2013) reclamation site with similar treatments and younger age in west Iceland. In the sown seeds and fertilizer applied new treatment, three different species of grass seeds were sown, but for one of them, *Lolium multiflorum*, no plants were found. This species is an annual plant.

4.2 The effect of restoration treatment on bulk density and soil organic matter

Bulk density is an important component in determination of soil carbon. Bulk density values at the control site were found to be higher than for the other treatment sites. Accumulation of soil organic matter was significantly affected by different restoration treatments. Soil organic matter values of the fertilizer treatment were found to be higher than sown seeds and fertilizer applied new, sown seeds and fertilizer applied old, and control. Soil organic matter was significantly different among restoration treatments. The fertilization treatment had more carbon content than other treatment areas. Soil organic matter is defined as the summation of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and well-decomposed substances (Schnitzer & Khan 1975). This was seen as the treatment (fertilized) with the highest vegetation biomass and cover also had the highest soil organic matter. A carbon content study by Gessesse (2009) also demonstrated clearly that the amount of carbon content in fertilization treatment was higher than in other reclamation treatments in Iceland. That is why I was expecting to find a correlation between vegetation biomass and soil organic matter in different reclamation treatments, but it was not significant. Carbon content increased with sown grass and fertilizer treatment in Gunnarsholt, as was reported by Gretarsdottir et al. (2004). In this study fertilizer treatment was the only one with higher carbon content than the control. In my study the result of carbon density was similar for the control and fertilizer applied treatments and for the treatments of sown seeds and fertilizer applied (new and old). That result depends on soil bulk density values. Bulk density value was highest at the control site. Also carbon density values seen here might be reflecting differences in carbon content of the soil before the start of restoration treatments. The treatment where fertilizer was applied was the most effective for improving the degraded land near Gunnarsholt, South Iceland.

5. CONCLUSIONS

The reclamation treatments considerably improved degraded land near Gunnarsholt, South Iceland. The result showed that biomass and vegetation cover of areas fertilized in 1991 and the areas where sown grass seeds and fertilizer were applied in 1962–1975 had a positive effect on degraded land. Also, the bulk density and SOM in the area with fertilizer added in 1991 was higher than on degraded land. The treatment where fertilizer was applied was the most effective for improving the degraded land near Gunnarsholt.

Icelandic long term restoration practices and experience show that the fertilizer applied and sown native grass seeds treatment was the most effective treatment for the degraded land. I am therefore going to continue this work of restoration of grassland, mining and urban areas and try to adapt it to Mongolian conditions.

ACKNOWLEDGEMENTS

First, I am very grateful to my supervisors Bryndis Marteinsdottir and Agusta Helgadottir for their support and clear guidance and advice to complete this report. They helped me to focus my ideas for the project work and how to write in a more broadly and precise way.

My deepest thanks go to Berglind Orradottir and our Land Restoration Training Programme (UNU-LRT) managers, for their assistance and warm care during the whole training period. Their friendly qualities helped and encouraged us UNU-LRT fellows to develop good relations and friendships.

Many thanks to UNU-LRT participators in 2015, dear fellows for your nice company, discussions and mutual support during the six months we spent together. I also highly appreciate the UNU-LRT fellow Aytenew Endeshaw Tatek, from Ethiopia, for translating and technical support.

LITERATURE CITED

Aradóttir A, Svavarsdóttir K, Jonsson TH, and Gudbergsson G (2000) Carbon accumulation in vegetation and soils by reclamation of degraded areas. Icelandic Agricultural Sciences 13:99-113

Arnalds A (2004) Carbon sequestration and the restoration of land health. Climatic Change 65:333-346

Arnalds O, Gudbergsson G, and Gudmundsson J (2000) Carbon sequestration and reclamation of severely degraded soils in Iceland. Búvísindi 13:87-97

Arnalds O. (2015) The soils of Iceland. Springer, New York London

Askelsdóttir S, and Guðmundsson Þ (2009) Samband glæðitaps og heildar kolefnis í jarðvegi. Fræðaþing Landbúnaðarins 6:481-484 (in Icelandic)

Braun-Blanquet J (1932) Plant sociology. The study of plant communities. New York

Burt R. (2004) Soil survey laboratory methods manual. Natural Resources Conservation Service, USA

Crofts R. (2011) Healing the land. Soil Conservation Service of Iceland, Iceland

Flora of Iceland. (n.d.) http://www.Floraisland.is/ (accessed 01 August 2015)

Gessesse TA. (2009) Assessment of the impact of different revegetation methods on soil carbon stocks in Iceland. United Nations University, Land Restoration Training Programme (final project), Reykjavik

Gretarsdottir J, Aradottir AL, Vandvik V, Heegaard E, and Birks H (2004) Long-Term Effects of Reclamation Treatments on Plant Succession in Iceland. Restoration Ecology 12:268-278

Jamsranjav C (2009) Sustainable Rangeland Management in Mongolia: The Role of Herder Community Institutions. United Nations University Land Restoration Training Programme (final project), Reykjavik

Kristinsson H. (2005) A Guide to the Flowering plants and ferns of Iceland. Mál og menning, Reykjavik, Iceland

Ministry of Food and Agriculture of Mongolia, (2013) URL http://www.mofa.gov.mn/new/index.php?option=com_content&view=article&id=73&Itemid=130 (accessed 10 April 2015) (in Mongolian)

Mongolian Government (2006) Minerals law of Mongolia, Ulaanbaatar http://www.mram.gov.mn/images/stories/mram/AMG/Legalinfo/ashigt_maltmaliin_huuli.pdf (accessed 10 April 2015) (in Mongolian)

Petursdottir T, Aradottir AL, and Benediktsson K (2013) An Evaluation of the Short-Term Progress of Restoration Combining Ecological Assessment and Public Perception. Restoration Ecology 21:75-85

R Development Core Team, (2008) The R for Windows and MacOs, R 3.2.1. GNU Operating system

Salehi M, Beni OH, Harchegani HB, Borujeni IE, and Motaghian H (2011) Refining soil organic matter determination by loss-on-ignition. Pedosphere 21:473-482

Schnitzer M, and Khan SU. (1975) Soil organic matter. Elsevier, Amsterdam

Sundermeier A, Reeder R, and Lal R. (2005) Soil Carbon Sequestration — Fundamentals. Extension Factsheets. The Ohio State University Extension, Columbus, OH

Suzuki Y (2013) Conflict between mining development and nomadism in Mongolia. Pages 269-294 In: Norio Y, Noboru F, Ai M (eds) The Mongolian Ecosystem Network. Springer, Japan

The Icelandic Meteorological Office. http://en.vedur.is/, unpublished data (accessed 01 June 2015)

Wang Y, Fu B, Lü Y, and Chen L (2011) Effects of vegetation restoration on soil organic carbon sequestration at multiple scales in semi-arid Loess Plateau, China. Catena 85:58-66