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PEDOGENESI DEI SUOLI RECENTEMENTE FORESTATI E IN AMBIENTE PROGLACIALE DELL'ISLANDA

PEDOGENESIS OF RECENTLY FORESTED SOILS IN PROGLACIAL ENVIRONMENTS OF ICELAND

Tesi di laurea di:

Davidh Stelluti

Relatore:

Prof. Giuseppe Corti

Correlatore:

Prof.ssa Stefania Cocco

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Abstract

Il presente lavoro verte sulle analisi morfologiche, chimiche, fisiche e mineralogiche incentrando e valutando l'evoluzione ecologica di una successione a bosco di recente riforestazione. Si è fatto un transetto dividendolo in area erbacea, arbustiva ed arborea. In ognuno di essi sono stati aperti due profili per cercare di avere una maggiore attendibilità.
Dalle prime analisi si evince come si ha sia una diversa stratificazione del suolo, dovuto dai fenomeni di esondazione del letto di fiume per lo scioglimento del ghiacciaio che lo alimenta, sia l'azione battente dei venti che in certe aree d'Islanda sferrano a gran velocità trasportano particelle di suolo, tale fenomeno crea erosione con l'abbassamento del piano di campagna. Nei risultati si può vedere come il suolo analizzato sia di recente formazione a dimostrazione del fatto che ci sono minerali come anorthite e pyrite. I suoli di queste aree non si evolveranno più di molto, sia per le condizioni climatiche avverse con temperature che rimangono sotto ai 5°C per gran parte dell'anno sia perché si hanno esondazioni che riportano particelle di suolo non permettendo la corretta pedogenizzazione dei suoli. Da queste prime analisi si possono prendere degli spunti e analizzare le specie vegetazionali che sono presenti per poter verificare se la riforestazione di queste aree creerà dei benefici al territorio oppure bisogna lasciare ad un'evoluzione naturale, dal momento che si è in luoghi con clima sub artico ed in queste aree è la natura che prende il sopravvento nell'ecosistema non gli altri esseri viventi che ci abitano.

1.Introduction

Iceland is the island in the middle of the North Atlantic Ocean between the 63° and 66.6° northerly latitudes, and 13–24° westerly longitudes. The island has active volcanism, is subjected to more intense freeze–thaw processes than any other country, and geomorphic processes are both diverse and extremely active in places. Aeolian and floods activity, with widespread redistribution of dust by wind and flood erosion, shapes the character of all soils of Iceland. The soils of the deserts are the largest volcaniclastic sandy deserts in the world, dark in colour due to the basaltic nature of the volcanic materials. Volcanic eruptions in Iceland occur every 3–5 years, fed by the mantle plume or hotspot under the island (Thordarson and Höskuldsson, 2008). About 11% of the country is covered by glaciers (Björnsson and Palsson, 2008) with many active volcanoes located under the ice. This enhances production of volcanic ash during ''wet explosive eruptions". The glaciers also produce glacio-fluvial plains covered with sediments that might be termed ''volcano-fluvial" deposits. These materials are primarily basaltic in composition, while andesite and rhyolite also occur in smaller amounts. The influence of the dust deposits on ecosystems is amplified by the volcanic nature, basaltic composition and rapid weathering of the materials.

Additionally to this peculiarity, due to the presence of young volcanos, the Iceland soils are unique also because they receive large inputs of eolian additions, generally of basaltic origin, and occur in low temperatures range with a wide amount of precipitation. High rates of precipitation, melting glaciers, eruptions that induce abundance of relatively friable volcanic sediment and enhanced geothermal heat fluxgenerate frequent *jökulhlaups* (floods) (Björnsson, 1992, 2002; Einarsson et al., 1997, Stefánsdóttir et al., 1999). Repeated *jökulhlaups* have built vast outwash plains which form much of the southern coast of Iceland, in proglacial environment (Maizels, 1991; Nummedal et al., 1987). In this scenario, Iceland's main problem is the inability to reforest areas that were previously vegetated with pioneer species that adapt to the local climate and volcanic substrate. It has been estimated that 15–30% of Iceland had been covered with forests before the time of settlement (874 AD) (Blöndal,1993). After the settlement, deforestation started as a result of the agrarian lifestyle of the settlers, and within less than 200 years human beings had removed the original forest cover almost completely. With the loss of forests, soil erosion increased, causing the loss of valuable fertile land. Soil protection and carbon sequestration must therefore be considered the main goal of afforestation in Iceland. However, it was not before the year 1899 that organised forestry took place in Iceland. Forests of downy birch (*Betula pubescens*), the only native forest forming tree species left after succeeding glaciations, cover about 1.2% of the land area, and afforestation with exotic tree species adds another 0.3% (Sigurdsson et al., 2005a). Low average temperatures, short vegetation periods, strong winds, frost heaving in winter, and damages by grazing sheep and horses are all factors that are detriment to the survival of seedlings and hamper the successful establishment of forests.

Most Icelandic soils form on volcanic parent materials and the majority of the soils are classified as Andosols or Vitrisols according to an Icelandic soil classification scheme. Drainage and eolian deposition play a major role in soil formation in addition to periodic tephra deposition. While Andisol are the main soil type in Iceland, vast areas are desertified, with 44% of the land surface covered with premature and degraded mineral soils (Arnalds, 2004). Research information on soil formation in proglacial areas in Iceland is rather limited. Persson (1964) briefly discussed the subject while investigating primary succession on the moraines of Skaftafellsjökull, SE-Iceland. Proglacial areas are sites of high geochemical reactivity due to the abundance of ground permeable parent material and water percolation (Egli et al., 2010; Gíslason, 2008). Thus, these are excellent sites for studying soil formation on a temporal scale, which is of primary interest to envision future soil development under specific climate scenarios. Mineralogical studies showed that the glassy nature of basalts exhibits high weathering rates despite the prevalence of cool climate. Through water-rock/tephra interaction, some minerals are dissolved completely and leached out of the parent material while others are tied up in the weathering residues of the primary mineral, such as clays and hydroxides (Gíslason, 2008). Soil development is strongly influenced by both vegetation and the cool climate of northern latitudes where low decomposition rates predominate enrichment in SOM, OC and N. The slow decomposition of organic material in cool climates can influence the composition and accumulation of organic matter (Mankasingh and Gísladóttir, 2019). In addition to this, soil nutrient supply is restricted: Icelandic ecosystems are generally nitrogen (N) limited, and phosphorus (P) availability is poor owing to the high P fixation capacity of the volcanic soils (Arnalds et al., 1995).

The aim of the present study was to investigate a soil transect developed on fluvial sediments of reworked glacial volcanic till made of basaltic pyroclastites in lowland of Iceland. Early stage of pedogenesis has been approached assessing morphological description, chemical, physical and mineralogical analysis of soils involved in the ecological evolution under a reforestation project.

2.Materials and methods

2.1 Study site and soil sampling

The study area is located between Hveragerdí and þorlákshöfn (63°53'57.21"N 21°25'23.60"O), in the South of Iceland, 45 kilometres east from Reykjavik and 7 km from the ocean coast (Fig. 1 and Fig. 2).

Fig.1 Hveragerdi study site

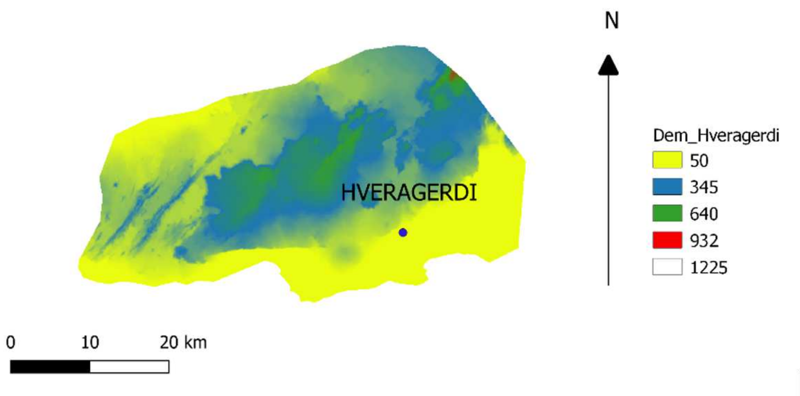


Fig. 2 - DEM (Digital Elevation Model)

The area stans on the seismic zone which lies on the western flank of the active boundary between the North American and European crustal plates. This is highlighted by the presence several volcanos. Flóvenz and Saemundsson (1993) recorded, in this area, one of the highest temperature for active volcanic rift zones, above 200°C of temperature at 1 km in depth. This is an index of the intensity of the geothermal activity of Hveragerdi central volcano part. Volcanic eruptions occur on average every 4–5 years and produce both solid lavas and volcanic tephra. The terms '*tephra*' and '*tephrochronology'* were originally introduced by the Icelandic geologist Thorarinsson (1944). Larsen et al. (1999, 2001) and Larsen (2000) discussed the importance of Holocene tephras in Iceland, including their geochemistry and other characteristics. Since the last glaciation, during the Quaternary period, the surface of Iceland has been extensively mantled by eolian and tephra materials in which the Icelandic soils have developed.

Specifically, the area of interest for the present study is located at 50 m above sea level, and the mean annual precipitation in the area is 905 mm, whereas the mean annual temperature is 2.6 °C. In Iceland the pedological classification of the whole island was made by Arnalds and Gretarsson (2001) Figure. 4 and in particular on the basis of their maps of the area of interest was extracted their pedological classifications using the Qgis software shown in the figure 4. The woodlot, which spans about half ha, it was divided in three different areas, in order to define a transect where soil are involved in an ecological succession of the forest: *i)* multiannual plants area, with scarce presence of young tree; *ii)* shrubs area, with medium presence of trees of about 20 years old ; and *iii)* wood area, with an abundance of different tree species of greater highs and age. In the first area were hosted several annual and multiannual plants such as *Festuca vivipara*, *Empetrum nigrum*, *Gallium* spp., *Equisetum arvense*, lichens, *Rumex acetosa*., *Taraxacum* spp. Additionally, trees of 6-7 years old such as *Betula pubescens*, *Pinus contorta*, with different highs (from 55 to 160 cm) and moss. In the second area prevalent vegetation is*: Callium vulgaris*, moss, lichen and *Poa pratensis*, *Erica tetralix,* leaves lichen, *Equisetum arvense*, *Taraxacum* spp., *Vaccinum uliginosum*. The trees species are *Betula pubescens,* of 20-23 years old and with the high range that goes from 150 to 380 cm, *Pinus contorta*, *Sorbus aucuparia* (high range of 210 to 240 cm), *Salix alaxensis* (high range 110 to 280 cm), *Populis trichocarpa*, *Salix phylicifolia*. The third area we have: moss, *Equisetum arvense*, *Poa pratensis*, leaves lichen; mushrooms: *Boletus* spp. and *Betula pubescens* of 30-35 years old, *Salix alaxensis*, *Acer* spp.

In September 2019, for each area, were dug, to the depth of 60-70 cm, two soil profiles, for a total amount of six profiles. The profiles were described according to Schoeneberger et al.

(2012), with the identification of the genetic horizons. Some of the profiles shown the presence of loëss and till volcanic glacial material, with the presence, in the area were the profile was opened of *roche moutonée*. Samples were collected by each horizon in large amounts (at least 3 kg) and put into plastic bags.

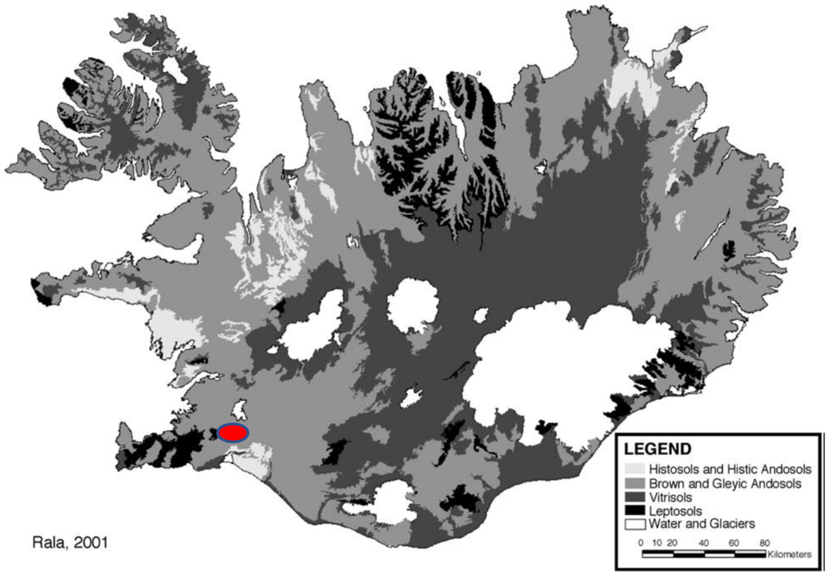


Fig 3 Simplified soil map of Iceland, based on Arnalds and Gretarsson (2001). Most of the Vitrisols classify as Andosols according to WRB and Andisols according to Soil Taxonomy

The study's area in south Iceland have Brown and Gleyic Andosols.

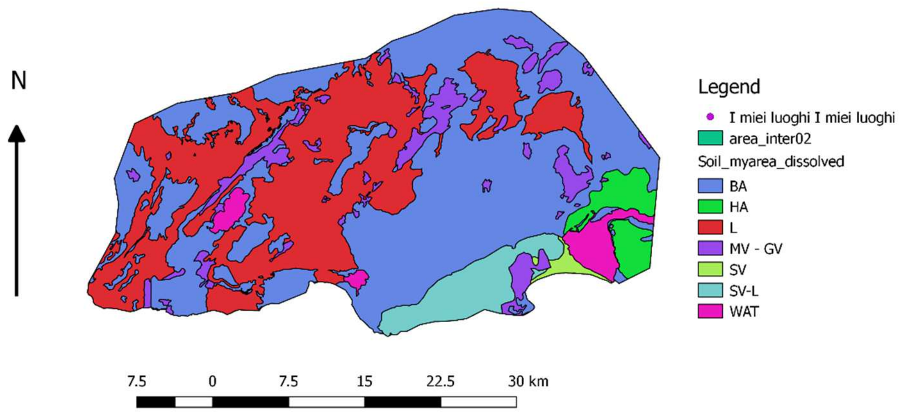


Fig.4 rappresentation of the area in Qgis where we did soil samples

2.2 Soil preparation and analyses

Once in laboratory, the soil samples collected in field were air-dried and sieved with 2 mm mesh. Succesivelly, the Hveragerdi samples were characterized for their physical, chemical properties, in order to evaluate possible changes of pedogenetic process. Soil pH was determined potentiometrically in water (pH in H_2O) with a solid: liquid (w:v) ratio of 1:8 and 1:2.5 for O and A horizons, respectively. Total organic C (TOC) content was estimated by K-dichromate digestion, heating the suspension at 180 °C for 30 min (Nelson and Sommers, 1996). Particle-size distribution was determined after maintaining aliquots of 20 g submerged in deionised water with a solid: liquid ratio (w:v) of 1:25 for 24 h at room temperature. We choose to avoid any treatment of organic and inorganic cement dissolution to preserve the state of aggregation as much as possible. Sand was recovered by sieving at coarse >1mm, 1< medium >0.25, fine> 0.053mm, while silt was separated from clay by sedimentation maintaining the columns at 19–20 °C for 24h by stocks law. Mineralogical characterization was determined on each sample by X-ray diffraction with a Philips PW 1830 diffractometer, using the Fe-filtered Co Kα1 radiation (35 kV and 25 mA); the step size was 0.02°2θ and the scanning speed was 1 sec per step. For all samples, diffractograms were acquired on powdered and manually compressed aliquots. The mineralogical composition was obtained by identifying the minerals on the basis of their characteristic peaks (Brindley and Brown, 1980, Dixon et al., 2002).

3.Results and discussions

3.1 Morphological description

Table 1 reports morphological description of soil profiles while picture 1 represents soil and vegetation transect, which was subdivided in: multiannual plants, shrubs and wood area. As above mentioned, two profiles were opened for each of these pedo-environment of the Hveragerdi for a total of six profiles. These soils show an averaged O horizon of about 8 cm, with minimum thickness in the soil of the shrubs area. This O horizon is followed by an A horizon, less expressed (about 5 cm). Successively, is evident that flooding and windblown material have shaped the morphological, physio-chemical properties of these soils.

In profiles 1 and 1BIS (multiannual plants) four lithological changes were reported (2Cb, 3Bwb, 4Cb, 5CBw) and is evident that the pedogenesis process were interrupted by several material covering. Particularly, the horizons 3Bwb1, 3Bwb2 (in profile 1) were characterized by the presence of particles carried by the wind (loess). In this area of the transect soil were depth about 65 cm.

In the shrubs area, were opened profile 2 and 2BIS. The area is characterized by plant of 20-25 years old some variations between profile 2 and 2BIS, where horizons were generated by the covering material transported by water that induced different stratification from one profile to another. The depth of the soil is more or less 67 cm.

In the last area of the transect, profile 3 and 3BIS were opened, until a depth of about 60 cm, and was evident the succession of material transported by wind (loess) with a less impact of flooding compared to the other profiles. However, the succession of flooding is equal to those observed in the other two sets of profiles, but at different depth due to different sequence based on the floods over time.

Fig.5 (multiannual plants, shrubs and wood area)

Table 1. Morphology of six profiles forming a vegetal transect at Hveragerdi, southern Iceland. Codes according to Schoeneberger et al. (2002). For symbols see legend.

Parent material: fluvial sediments of reworked glacial volcanic till made of basaltic pyroclastites.
Climate (3-years records): mean annual air temperature 2.6°C; mean annual precipitation 970 mm.
In the surrounding presence of rock outcrops and *roches moutonnées*.

Horizon	Depth[a]	Mean thickness	Colour[b]	Structure[c]	Consistence[d]	Roots[e]	Boundary[f]	Observations
	cm	cm						
Hveragerdi: profile 1 (sparse plantation 6-7- years old)								
Vegetation. Trees: *Betula pubescens*, *Pinus contorta* (heights 55-160 cm); Shrubs: *Empetrum nigrum* L.; Grasses: mosses, *Calluna* spp., *Gallium* spp., *Equisetum* spp., foliar lichen, *Rumex* spp., graminaceae, *Taraxacum* spp.								
Soil cover: 100%.								
Soil: Vitrandic Humicryept, sandy, mixed, frigid (SSS, 2014).								
Oi	8-0	7-11	5YR3/4	-	-	3, mi,vf; 2 f; 1m	cw	
A	0-6	5-8	5YR 2.5/1	2 f gr	fr		cw	
2Cb	6-26	16-21	2.5YR 3/2		fr	1 mi,vf,f	cw	
3Bwb1	26-49	22-25	2.5YR 3/2	2-3 tk pl	fr	1 mi,vf; 2 f	dw	loess
3Bwb2	49-72+	-	2.5YR 2.5/3	2-3 tk pl	fr	1mi, vf	cw	loess
C			2.5YR 3/2	sg			-	
Hveragerdi: profile 1bis (sparse plantation 6-7- years old)								
Vegetation. Trees: *Betula pubescens*, *Pinus contorta* (heights 55-160 cm); Shrubs: *Empetrum nigrum* L.; Grasses: mosses, *Calluna* spp., *Gallium* spp., *Equisetum* spp., foliar lichen, *Rumex* spp., graminaceae, *Taraxacum* spp.								
Soil cover: 100%.								
Soil: Vitrandic Humicryept, sandy, mixed, frigid (SSS, 2014).								
Oi	10-0	8-12	-	-	-	3 mi,vf,f	cw	
A	0-5	4-7	2.5YR 3/2	2 f gr	fr	3 mi,vf,f	cw	
2Cb	5-17	12-17			fr	1 mi,vf,f	cw	

3Bwb	17-41		2.5YR 3/2	2-3 m,tk pl	fr	2 mi,vf,f	cw	
4Cb	41-62	23-29	5YR 2.5/1		fr	1 mi,vf,f	cw	
5CBw	62-65+	-			fr		-	

Hveragerdi: profile 2 (plantation 20-25 years old)
Vegetation: Trees: *Betula pubescens* (2-3 m), *Pinus contorta*, *Sorbus aucuparia (2.10 m-2.4 m)*, *Salix alaxensis (1.10-2.8m)*, *Populus trichocarpa*, *Salix phylicifolia*.
Grasses: mosses, foliar lichen and *Poa pratensis*, Equisetum, *Taraxacum* spp., *Vaccinum myrtillus*. Soil cover: 100%.
Soil: Vitrandic Humicryept, sandy, mixed, frigid (SSS, 2014).

Oi	6-0	4-7	-	-	-	3 vf,f	cw
A	0-3	2-3	5YR 3/2	sg - 1 m sbk	fr	3 mi,vf,f	cw
2Cb	3-25	21-23	5YR 2.5/1	sg - 1 m sbk	fr	3 mi,vf; 2 f; 1m	cw
3Bwb	25-49	23-27	5YR 3/3	2-3 m,tk pl	fr	1 mi,vf,f	as
4R	49-51+	-	-	-	-	-	-

Hveragerdi: profile 2bis (plantation 20-25 years old)
Vegetation: Trees: *Betula pubescens*, *Pinus contorta*, *Sorbus aucuparia*, *Salix alaxensis*, *Populis trichocarpa*, *Salix phylicifolia*.
Grasses: mosses, lichen and *Poa pratensis*, lichen, *Equisetum*, *Taraxacum* spp., *Vaccinum myrtillus*. Soil cover: 100%.
Soil: Vitrandic Humicryept, sandy, mixed, frigid (SSS, 2014).

Oi	6-0	-	-	-	-	-	cw	
A	0-7	5-8	5YR 3/2	2 f gr	fr	2 mi,m,f	cw	
C	7-34	25-29	5YR 2.5/1	sg	fr	2 mi,vf; 1,2 f	cw	
2Bwb	34-60	25-29	5YR 3/3	2 m pl	fr	1 mi,vf; 2 f	cw	tyxotropic
3Cf	60-65+				fr			loess

Hveragerdi: profile 3 (plantation 30-35 years old)
Vegetation: Trees: Betula pubescens, Salix alaxensis, Acer spp.
Shrubs: *mosses*, E*quisetum* spp, *Poa pratensis*, foliar lichen. Mushrooms: *Boletus* spp. Soil cover: 100 %.
Soil: Vitrandic Humicryept, sandy, mixed, frigid (SSS, 2014).

Oi	10-0	-	-	-	-	-	cw	birch's leaves
A	0-4		5YR 2.5/2	2-3 f abk-sbk & gr	fr	3 mi,vf; 2 f,m	cw	
Bw	4-29		5YR 3/3	1-2 f,m gr & sbk	fr	2 mi,vf,f; 1 m	cw	
2Bwb	29-60+		5YR 3/3		fr	1 mi,vf,f	cw	loess
Hveragerdi: profile 3 bis (plantation 30-35 years old) Vegetation: Trees: Betula pubescens (4.9-6 m), Salix alaxensis(6-7.5m), Acer spp. Shrubs: *mosses*, *Equisetum*, *Poa pratensis*, foliar lichen. Mushrooms: Boletus spp. Soil cover: 100 %. Soil: Vitrandic Humicryept, sandy, mixed, frigid (SSS, 2014).								
Oi	7-0	5-8	-	-	-	-	cw	
A	0-4	4-8	5YR 2.5/2	3 f gr	fr	3 m,vf; 2 f,m	cw	
Bw	4-18	13-16	5YR 2.5/2	2 f,m abk-sbk	fr	2 vf,f; 1 m	cw	
2Bwb1	18-32	13-17	5YR3/2	2 m,tk pl & f,m abk	fr	1 mi,vf; 2 f; 1 m	cw	loess
3Bwb2	32-71+	-	5YR 2.5/1	sg - 2 f,m abk-sbk	fr	1 mi,vf,f	-	loess

[a]Numbers separated by slash (/) indicate the range of depths observed in the three profiles, while the hyphen (-) means "from (what is before the sign) to (what is after the sign)".

[b]moist and crushed, according to the Munsell Soil Color Chart (1954 edition).

[c]1'=little, 1=weak, 2=moderate, 3=strong; th=thin, tk=thick, f=fine, m=medium, c=coarse; abk=angular blocky, sbk=subangular blocky, pl=platy; sg=single grain.

[d]m=moist, fr=friable, vfr=very friable; w=wet, ss=slightly sticky.

[e]0=absent, v_1=very few, 1=few, 2=plentiful, 3=abundant; mi=micro, vf=very fine, f=fine, m=medium, c=coarse.

[f]c=clear, a=abrupt, d=diffuse; w=wavy, s=smooth, i=irregular.

3.2 Physical analysis

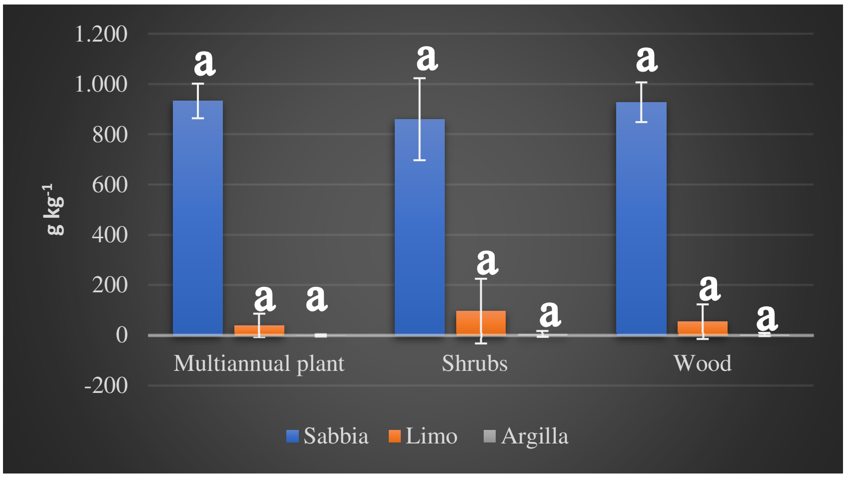
Physical properties were investigated through the separation of soil particles in sand, silt and clay. The results shown no significant differences in texture among soils along the transect. The predominant textural class in all six profiles is sandy, meaning a strong presence of sand (90%), followed by silt, in the deeper horizons (10%), and a content of clay equal to zero (Table 2). This is an indication of young soils due to the consecutive floods that occurred during geological Eras, that led to the stratification of the whole area where sampling was done.

Additionally, these soils of recent formation do not evolve much since the environment is characterized by low temperatures for most part of the year (MAAT 2.6°C).

Table 2 – Results from physical analysis of soils of the transect.

Profilerofile	Horizon	Texture class	Sand	Silt	Clay
			g kg^{-1}		
1					
	A	sand	991	9	0
	2Cb	sand	998	2	0
	3Bwb1	sand	924	76	0
	3Bwb2	loamy/sand	844	152	4
1BIS					0
	A	sand	996	4	0
	2Cb	sand	998	2	0
	3Bwb	sand	951	49	0
	4Cb	sand	981	19	
2					
	A	sand	989	11	0
	2Cb	sand	987	13	0
	3Bwb	sandy/loam	676	318	7
2BIS					
	A	sand	995	5	0
	C	sand	975	25	0
	2Bwb	loamy/sand	734	264	2
3					
	A	sand	986	14	0
	Bw	sand	969	31	1
	2Bwb	loamy/sand	796	203	1
3BIS					
	A	sand	983	17	0
	Bw	sand	982	18	0
	2Bwb1	sand	954	45	1
	3Bwb2	sand	970	29	1

The absence of differences among the three different areas in physical soil properties were confirmed by the statistical analysis (ANOVA). Independently by the above ground vegetation, these soils were equally unable to pedogenize. Starting from annual plants to the tree-lined area there are no textural variations and in the Graphic 1 it is clear that sand and silt do not vary.



Graphic 1 - Sand, Silt, Clay content and statistical analysis. Histograms with the same letter meaning no differences in mean.

In Figure 6 Texture triangle is reported to highlight the three classes present in these soils, with a greater presence of the sand class.

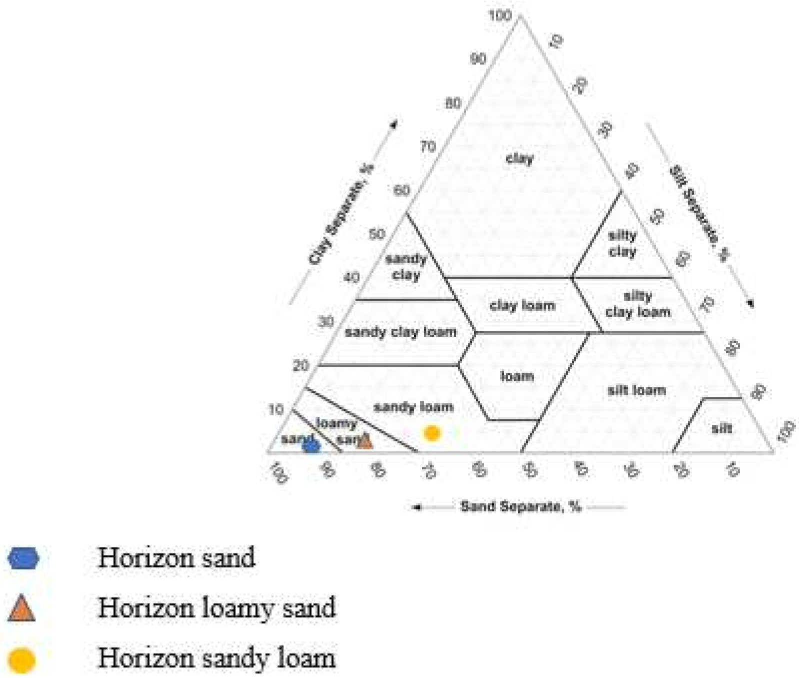


Fig. 6 Texture triangle

3.3 Chemical analysis

In Table 3 it is shown the reaction of each horizon per profile and their Total Organic Carbon (TOC) content. For the chemical analysis, the O horizons were sieved at 2 mm and analysis were performed in the two obtained fractions (Oi < 2mm and Oi > 2mm).

Table 3 – Results of chemical analysis of soils of the transect

Area	Profile	Horizon	pH	TOC
				g kg^{-1}
multiannual plants area	1			
		Oi<2mm	6.02	236.05
		Oi>2mm	5.86	352.59
		A	2.84	12.29
		2Cb	6.48	1.02
		3Bwb1	6.49	15.96
		3Bwb2	6.49	35.78
	1BIS			
		Oi<2mm	6.05	230.12
		Oi>2mm	6.09	370.37
		A	3.29	24.77
		2Cb	6.41	15.96
		3Bwb	6.25	11.56
		4Cb	6.43	2.43
shrubs area	2			
		Oi<2mm	5.92	234.07
		Oi>2mm	5.80	348.64
		A	6.09	24.60
		2Cb	6.70	0.55
		3Bwb	6.35	42.75
	2 BIS			
		Oi<2mm	6.45	162.96
		Oi>2mm	5.85	269.63
		A	6.21	8.62
		C	6.72	3.37
		2Bwb	7.02	43.08
wood area	3			
		Oi<2mm	6.16	62.22
		Oi>2mm	6.15	184.69
		A	6.12	7.99
		Bw	6.48	6.11
		2Bwb	6.63	41.83
	3BIS			
		Oi<2mm	6.18	68.15
		Oi>2mm	5.96	204.44
		A	6.15	18.33
		Bw	6.51	4.23
		2Bwb	6.59	5.80
		3Bwb	6.78	2.27

From Figure 7 to 9 is reported the graphical representation of Table 3 to better understand variation and trends of these two parameters. In the first profiles (1 and 1BIS) (Figure 7), organic carbon is greater in the Oi horizons, with higher content in the fraction > 2mm (350 g kg^{-1}). In the deeper horizons greater less organic carbon was recorded, with an averaged content of 15 g kg^{-1} (maximum value of 35 g kg^{-1} in 3Bwb2 of and minimum value of 1.02 in 2Cb, both in profile 1). The pH is sub-acid for the entire profile (6.5-6.0) with the exception of the A horizon that is firmly acid (2.84 and 3.29 in 1 and 1BIS respectively).

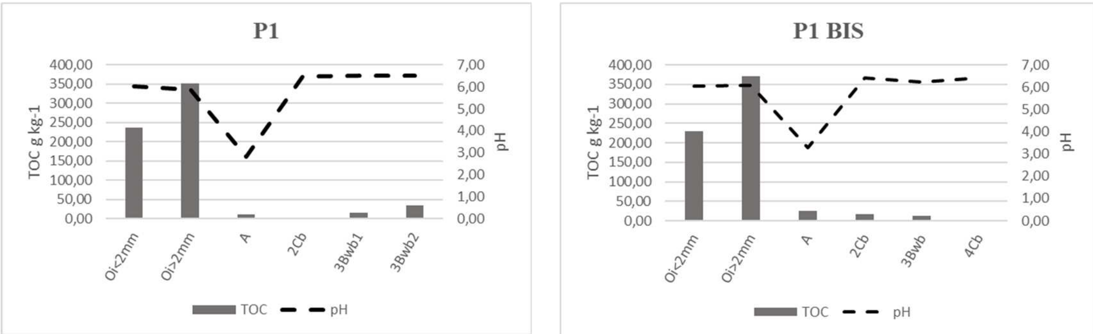


Figure 7 – Variation of pH and TOC along the profile 1 and 1BIS.

In the shrubs area (Figure 8) the organic carbon varies from 200 g kg^{-1} to 350 g kg^{-1} for Oi horizon and the organic carbon is about 20 g kg^{-1} . The 2Cb horizon of profile 2 and the A and C horizons of profile 2 BIS had extremely low value of TOC (0.55, 8.62 and 3.37 g kg^{-1} respectivelly). pH of the Oi horizon is slightly lower in P2 than in P2BIS and the higher value were 6.70 and 7.02.

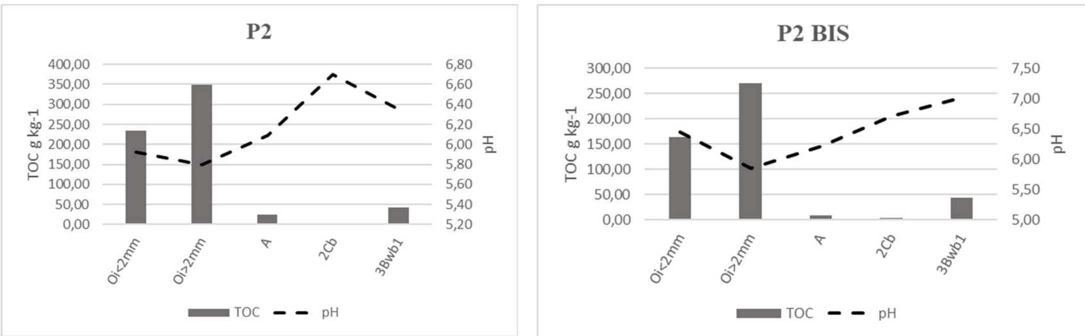


Figure 8 - Variation of pH and TOC along the profile 2 and 2BIS.

The organic carbon in P3 and P3BIS of the wood area is for the Oi<2mm 62.22 g kg^{-1} and 68.15, respectively, while Oi < 2mm 184.69 g kg^{-1} and 204.44 g kg^{-1}. In others horizon TOC is grater lower with minimum values in 3Bwb of P3BIS (2.27 g kg^{-1}) and maximum 41.83 in P3 (41.83 g kg^{-1}). The pH is about 6 for Oi and slightly greater for the others horizon. (Figure 9)

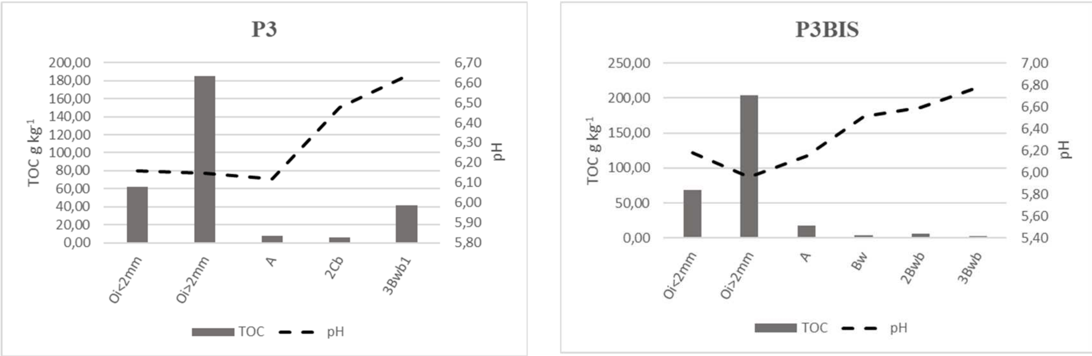
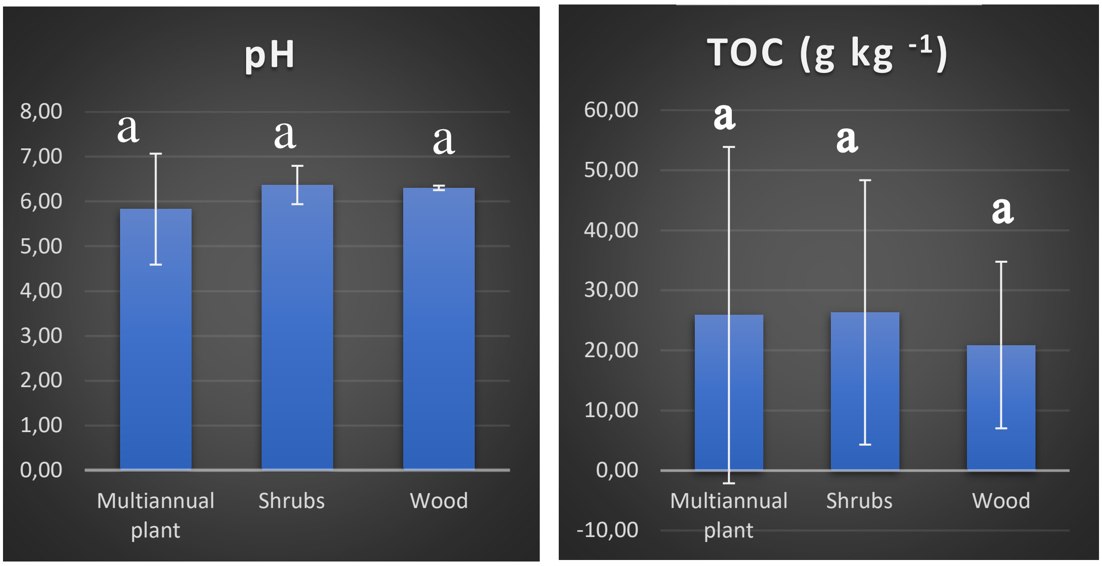


Figure 9 - Variation of pH and TOC along the profile 3 and 3BIS.

From the data is evident that do not exist differences along the area of the transect in terms of pH and TOC content, as confirmed by statistical analysis reported in Graphic.2.



Graphic.2– Graphical representation of the statistical differences among profiles in the transect area. Histograms with the same letter meaning no differences in mean.

Even if, statistically, the carbon content is equal among areas, the less amount in the mineral soil is from the soil under the most vegetated part of the transect. This was an unexpected result. The hypothesis is about the capability of this soils to evolve due to the volcanic substrate and harsh environmental conditions. The young tree ecological succession (trees in the wood area have an estimated age of 30 years) has not the ability to accumulate carbon and to induce changes in the soil properties, probably this process required decades. (Einarsson,1984)

3.4 Mineral soils along the vegetational transect.

To resume and to conduct a deeper analysis of physical and chemical properties, the same genetic horizons between profile belonging to the same area, were weighed. The organic horizons were excluded and treated separately later in the text. This allowed to appreciate differences along the profiles. In Table 4 to 6 are reported the averaged values of physical and chemical soil properties under herbaceous and multiannual plants. In this mineral soil, the sand fraction decreases irregularly along the profile, while the silt increase. The pH is extremely acid in the upper horizon and is sub-acid in the remaining part of the profile with not changes. Conversely, the TOC content does not change along the profile with the higher value in the 3Bwb2 horizon that is, statistically, the horizon with the higher content of organic carbon. The sand fraction decreases irregularly along the profile, while the silt increases.

Table 4 - Physical and chemical properties of soils under multiannual plants.

	pH	TOC	Sand	Silt	Clay
		g kg^{-1}			
A	3.06 (0.32) ^{b}	18.53 (8.82) ^{b}	994 (3) ^{ab}	6 (3)^{b}	0 (0)^{a}
2Cb	6.44 (0.04) ^{a}	8.49 (10.57) ^{b}	998 (0)^{a}	2 (0)^{c}	0 (0)^{a}
3Bwb1	6.37 (0.17) ^{a}	13.76 (3.11) ^{b}	937(19)^{c}	63 (19)^{a}	0 (0)^{a}
3Bwb2	6.49 (0.00) ^{a}	35.78 (0.00) ^{a}	844 (0)^{d}	152 (0)^{a}	4 (0)^{a}
4Cb	6.43(0.00) ^{a}	2.43 (0.00) ^{b}	981 (0)^{b}	19 (0)^{d}	0 (0)^{a}

As seen for the soil under multiannual plants, also in the soil of the shrubs area, the sand fraction tends to decrease in favour of the silt fraction. pH tends to increase in depth until the 2Bwb horizon. Parallely, TOC content is higher in the deeper horizons.

Table 5 - Physical and chemical properties of soils under shrubs vegetation.

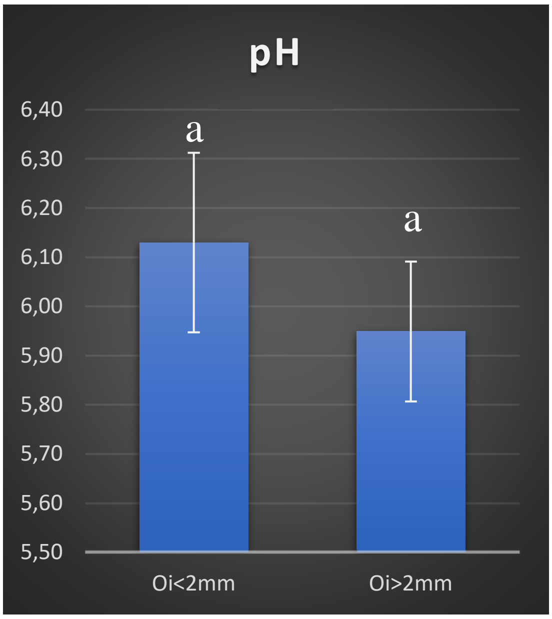
	pH	TOC	Sand	Silt	Clay
		g kg^{-1}			
A	6.15 (0.09) ^{d}	16.61 (11.30) ^{b}	992 (4)^{a}	8 (4)^{c}	0 (0)^{a}
C	6.71 (0.01) ^{b}	1.96 (1.99) ^{b}	981 (9)^{a}	19 (9)^{c}	0 (0)^{a}
2Bwb	7.02 (0.00) ^{a}	43.08 (0.00) ^{a}	734 (0)^{b}	264 (0)^{b}	0 (0)^{a}
3Bwb	6.35(0.00)^{c}	42.75(0.00)^{a}	676 (0)^{c}	318 (0)^{a}	7 (0)^{a}

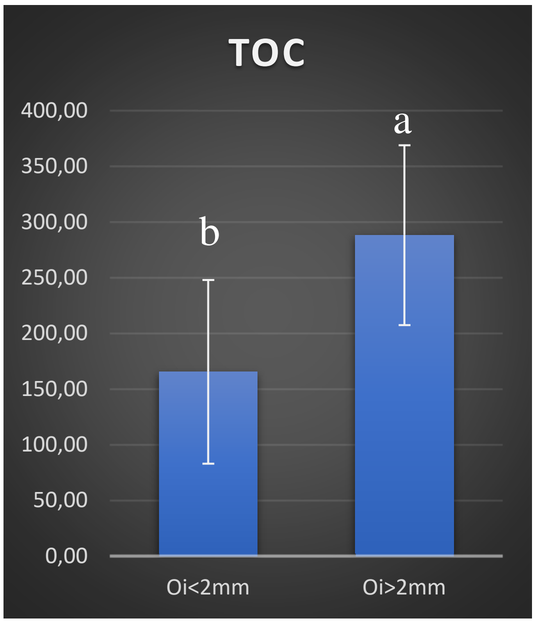
In the wood area less variations could be reported, only the pH follows the same trend of the previous mineral soil, increasing with the depth.

Table 6 - Physical and chemical properties of soils under forest vegetation.					
	pH	TOC	Sand	Silt	Clay
		g kg^{-1}			
A	6.13 (0.02) [c]	13.16 (7.31) [a]	984 (3)[a]	16 (2)[a]	0 (0)[a]
Bw	6.49 (0.02) [b]	5.17 (1.33) [a]	976 (10)[a]	24 (9)[a]	0 (0)[a]
2Bwb	6.61 (0.03) [a]	22.93 (26.72) [a]	875 (112)[a]	124 (112)[a]	1 (0)[a]

3.5 Organic soils.

An accurate analysis was made by differentiating the organic horizons (Oi) in < 2mm and > 2mm. In Graphic.3 the pH does not change significantly between the two fractions, while TOC is greater in the fraction above 2 mm. This fact can be explained considering the strong winds in this land that transport soil particles and when doing the TOC analysis differentiate the Oi<2mm and Oi>2mm there is a lowering of organic carbon in the Oi< 2mm although it should be higher in this ones that because the soil is transported by wind, and when you do the analysis Oi<2mm you consider the particles transported by wind which reduce the presence of organic carbon. Mechanical weathering and translocation of particles in dust storms (Arnalds, 2010).





Graphic.3 - Difference of pH for Oi horizons

3.6 Mineralogy analysis

The last analysis was the mineralogy of all soil samples sampled in Hveragerdi. In Table 7 it is shown the semi-quantitative mineral content of these soils. The peculiarity is the presence of Anorthite (more than 70 % in each horizons of each profile) and Pyroxene (from 20% to

50%). Marginally were detected also Quartz in traces and Magnetite. The above mentioned minerals (Anorthite, Pyroxene) are sings of recently formed soils due both to the transport of the wind and the stratification of successive floods of the river bed caused by the melting of the glaciers (named *Langjökull*) (Roberts et al., 2000a,b).

Table 7 – Semi-quantitative analysis of mineral content of soils along the transect

Profile	Horizon	An †	Py †	Q †	Magn †
		%			
1	A	70	30	Tr	Tr
	2Cb	75	25	Tr	Tr
	3Bwb1	80	20	Tr	Tr
	3Bwb2	80	20	Tr	Tr
1BIS					
	A	90	10	Tr	Tr
	2Cb	75	25	Tr	Tr
	3Bwb	75	25	Tr	Tr
	4Cb	98	1	Tr	Tr
2					
	A	45	50	Tr	5
	2Cb	50	45	Tr	5
	3Bwb	60	40	-	Tr
2BIS					
	A	50	45	Tr	5
	C	50	45	Tr	5
	2Bwb	75	25	-	Tr
3					
	A	70	30	Tr	Tr
	Bw	70	30	Tr	Tr
	2Bwb	80	20	-	Tr
3 BIS					
	A	80	20	Tr	Tr
	Bw	75	25	-	Tr
	2Bwb	70	30	-	Tr
	3Bwb	70	30	-	Tr

† An= Anorthite Py= Pyroxene Q= Quartz Magn= Magnetite

In the following figure the diffrattograms that allowed the recognition and quantification of the mineral trough the interpretation of the peaks.

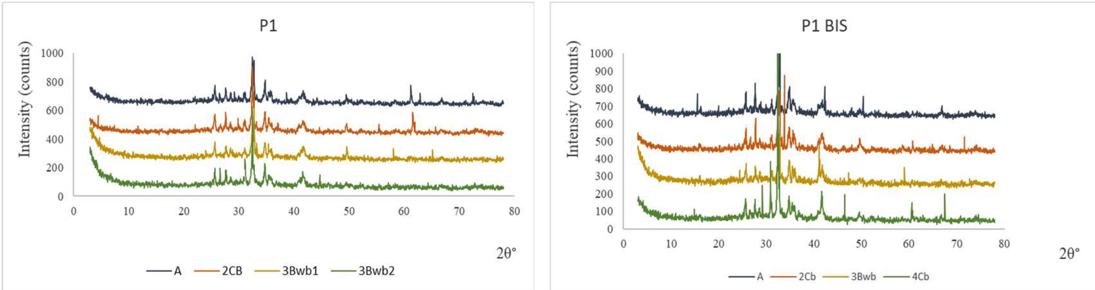


Fig.10

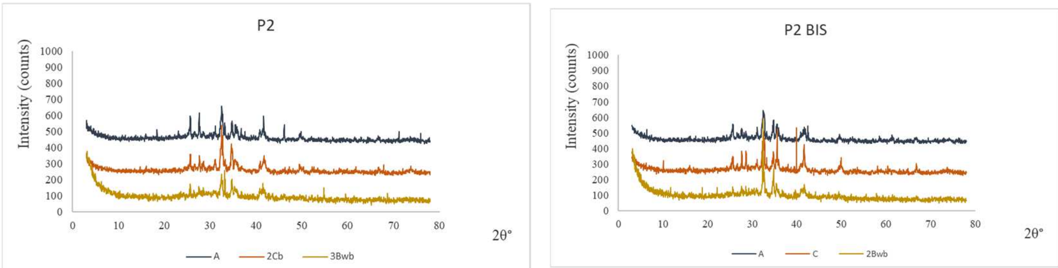


Fig. 11

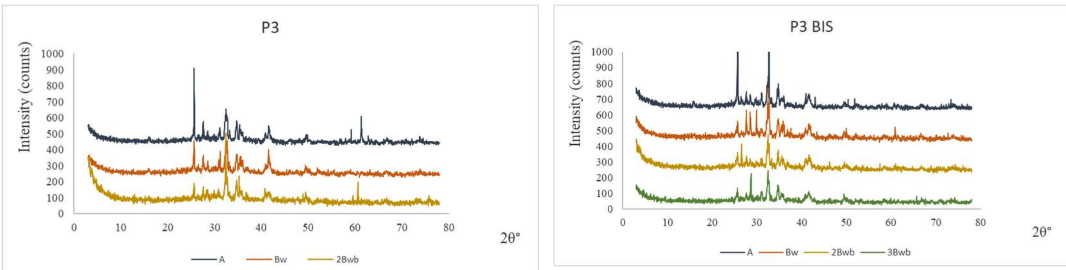


Fig.12

4. Conclusion

In this study a soil transect developed on fluvial sediments of reworked glacial volcanic till made of basaltic pyroclastites in lowland of Iceland, has been investigated. Early stage of pedogenesis has been approached assessing morphological description, chemical, physical and mineralogical analysis of soils involved in the ecological evolution under a reforestation project.

The study area is a valley formed by the transport of materials, by the wind and by the flooding of the river bed (Jökulhlaup). The river has a very sinuous path precisely because it is fed by a glacier (Langjökull). With the withdrawal of the glacier over the centuries it meant that in the period of full flood, the flooding brought volcanic material to the area of interest. The material sedimented several times and not on a regular basis on the surface has created soil stratifications.
The soil was sampled along a transect under three different vegetation stage of evolution.
In each of these areas, profiles have been opened for replicas trying to have greater reliability in the analyses. From the physical analyses all the profiles of the transect have roughly the same texture with purely sand, loamy sand, sandy loam horizons.
This indicates how the soils of the proglacial with soil and climate where temperatures are around 3°all year and the precipitations heavy rainfall, the pedogenesis process doesn't advance so much, in fact there aren't any clay particles. Then with the flooding bring up other materials so the soil can't evolve so much.
As a demonstration of this was carried out mineralogy analysis and we saw the presence of Anorthite, Phyrite, Quartz, Magnetite.
Anorthite which affects more then 60%, and Phyrite which is present more than 30% in each horizon, while others mineral are tracks.
The presence of Anorthite makes us deduce that the soil where the samples were made is recently formations to the phenomena describe above.
pH showed sub-acid and acid values.
The organic carbon analysis shows the difference belong the transect.
All organic horizons have more than 120 g/kg of organic carbon, more of 12% each profile, while the other horizons don't have more than 50 g/kg.
We have tried to average the presence of carbon along the transept and apparently the first area where there are multiannual plants (P1-1BIS) there is an average of 25g/Kg in the shrubs area (P2-2BIS) we have apparently 26.36 g/Kg, and in the wood area we have 20.88 g/kg (P3-3BIS). This is not statistically verifiable also because there are not many replicas but we should keep doing vegetative analysis to see if there is a high presence of nitrogen fixers or microorganisms that use organic carbon. The last

analysis could be carry out to try and verify the decrease of organic carbon due to a presence of microorganisms in the soil.

Statistically is verified the difference between the presents of organic carbon splitting the Oi horizons in Oi<2mm and Oi>2mm. Theoretically in Oi<2mm we must have more organic carbon than in Oi>2mm. But in these cases we have around 150 g/Kg for Oi<2mm and 300 g/kg for Oi>2mm mediate in each organic horizons of each profile. We have less organic carbon in Oi<2mm because the wind transport so other particles and deposit in this fraction, when you do the analysis you calculate the others particles in this analysis and which influence the lowering of the organic carbon respect to Oi> 2mm.

To have the reliability, statistical analysis was made taking into consideration all the samples Oi<2mm and Oi>2mm and you can see it as in R (software) there are statistical variabilities.

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