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# Soils of the Gunnarsholt experimental plantation

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## SUMMARY

Soil physical and chemical properties were studied for a newly established plantation forest. The soil classifies as an Andisol as it exists in a region prone to periodic volcanic and aeolian deposition. In this paper, two pedons are described.

Soil texture is predominantly silty loam with weak structure. The constant influx of material has lead to a rapid thickening of the profile of about 0.6 cm $yr^{-1}$ this century. Major eruption features (Hekla 1510) and regional erosional episodes (ca 1920, 1880) are identified in the profiles. The soils have $Al_{ox}$, $Si_{ox}$ and $Fe_{ox}$ typical of Icelandic Andisols with high $Fe_{ox}$ reflecting the basaltic nature of the parent materials. Clay content ranges between 15–20% based on oxalate extraction. Particle size analysis by hydrometer method yields lower clay content because of the flocculation which is common for Andisols.

Organic matter ranges between 2–13%. Two distinct bulk density layers were evident: 10–90 cm (0.73 g $cm^{-3}$) and 100–170 cm (0.58 g $cm^{-3}$). Particle density in the upper layer was 2.12 g $cm^{-3}$ with a porosity of 0.66. A strong relationship was found to exist between organic matter and dry bulk density ($r^2$=0.79). No relationship was found between field-moist colour and organic matter. The soil moisture characteristic curve (based on desorption) was compared with the theoretical curve for a silt loam. Both curves fit field-collected data well.

Key words: Andisols, bulk density, Iceland, moisture characteristic, silt loam.

## YFIRLIT

*Jarðvegur í aspartilrauninni í Gunnarsholti*

Birtar eru niðurstöður fyrir rannsóknir á jarðvegi í svokölluðu Asparholti í Gunnarsholti. Jarðvegurinn er dæmigerð Eldfjallajörð (Andosol), sem ýmist hefur verið kallaður áfoksjarðvegur eða móajörð á íslensku. Jarðvegurinn hefur myndast í fokefni og gjósku sem einkum er ættuð frá Heklu. Jarðvegurinn hefur þykknað um 0,6 sm á ári á þessari öld, sem telst mjög hröð þykknun. $Al_{ox}$, $Si_{ox}$ og $Fe_{ox}$ eru svipuð eða nokkru lægri en samkvæmt niðurstöðum mælinga á jarðvegi annars staðar á landinu. $Si_{ox}$ gildin benda til að allófan-leir sé um 10–12% jarðvegsins, sem telst nokkuð lágt gildi er skýrist af óstöðugu umhverfi vegna mikils áfoks. Ferrýhýdrat er metið sem 5–8% jarðvegsins, sem telst hátt gildi er endurspeglar járnrík, basísk einkenni gjósku á Íslandi. Sýrustig er lægst í yfirborðslögum en hækkar eftir því sem neðar dregur í jarðveginum. Sýrustigið er almennt hærra en í svipuðum jarðvegi í Alaska. Lífræn efni eru mjög misdreifð í jarðveginum eins og þekkist í annarri Eldfjallajörð, en þau eru allt að 13% samkvæmt mælingu með glæðitapi. Það er eitt einkenna Eldfjallajarðar að binda lífræn efni, enda þótt efnaveðrun sé jafnan hröð í eldfjallaösku. Rúmþyngd er lág eins eins og einkennir Eldfjallajörð í heiminum, eða frá 0,58–0,73 g $sm^{-3}$, og er nátengd heildarmagni lífrænna efna. Jarðvegurinn getur haldið miklu magni af vatni, líkt og mjög leirríkur jarðvegur, en hegðun þess í jarðveginum líkist því sem einkennir jarðveg sem inniheldur mikið magn kornastærðarinnar silt (méla). Þessi einkenni, sem auka mjög á vatnsleiðni (gegndræpni) jarðvegsins, magna upp frostvirkni íslensks jarðvegs.

## INTRODUCTION

The Gunnarsholt area is situated in close proximity to one of Iceland's most active volcanoes, Mt. Hekla. It has erupted at least twice each century on average (Thórarinsson, 1970) and is the primary local source of the vast tephra (ash) deposits to the north of Gunnarsholt. As these deposits became increasingly unstable during the past several centuries, eolian erosional activity in the area intensified. The latter part of the 19th and beginning of the 20th centuries were characterised by sand encroachment in the area, devastating many farms and leaving infertile sandy desert in place of arable land (Sigurjónsson, 1958). The land in the vicinity of Gunnarsholt was totally desertified and the eolian activity caused rapid sedimentation of airborne materials at sites where vegetation remained. The resulting soil at the Gunnarsholt experimental site consists of a thick mantle of reworked and *in situ* volcanic materials.

Soil that forms in volcanic ejecta develops unique characteristics that are referred to as andic soil properties and they are classified as a special soil type such as Andosols (FAO-Unesco, 1988) or Andisols (USDA, 1994). The unique properties of Andisols include their low bulk density, and high water retention ability, with water infiltration and hydraulic conductivity resembling very silty soils (Maeda *et al.*, 1977; Wada, 1985).

The clay mineralogy is most often dominated by allophane, and its unique chemistry and morphology are responsible for many of the andic properties. Other common clay minerals in Andisols include imogolite and ferryhydrate. An important feature of Andisols is their ability to accumulate organic matter (Shoji *et al.*, 1993; Shoji *et al.*, 1996; Wada, 1985), such that Andisols are capable of storing much larger quantities of carbon substances than other dry-land soil types (Eswaran *et al.*, 1993). As materials are continuously added to the top of the soil, development in unweathered materials occurs at the top rather than towards the bottom of the profile in the C horizon. Old soil materials are buried as the surface rises during the addition of volcanic and eolian materials.

Generally, Icelandic soils can be separated into three major groups (Helgason, 1963, 1968; Jóhannesson, 1960) on the basis of site characteristics: soil of poorly drained sites (including Histosols and Andisols); typical Andisols of freely drained sites; and soils of barren areas which constitute about 40% of Iceland's surface (Arenosols, Leptosols, Regosols, Gleysols, usually exhibiting andic soil properties) according to the FAO soil classification system (Arnalds and Grétarsson, 1998). The soils of the Gunnarsholt experimental site are freely drained Andisols. The clay mineralogy of freely drained Andisols in Iceland is dominated by allophane and ferryhydrate (Arnalds *et al.*, 1995; Wada *et al.*, 1992).

Two pedons are described in this paper. Pedon A is used to characterise the physical-chemical properties. Pedon B is used to describe the physical layering and properties which may influence soil hydrology. A companion paper describes the soil hydrology in more detail (Strachan *et al.*, 1998). Sigurdsson *et al.* (1998) describe the broader research conducted at the Gunnarsholt research site.

## METHODS

Pedon A was described and sampled according to standard methods (USDA, 1981). Samples were air dried (40°C) and passed through a 2-mm sieve. The soils were analysed for organic carbon using dry combustion (model CR-12, LECO). Soil reaction was determined in water suspension (1:1), in 1 M KCl and in NaF solution according to the Fields and Perrot method as outlined by Blakemore *et al.* (1987). Ammonium oxalate soluble Al, Fe, and Si ($Al_{ox}$, $Fe_{ox}$, and $Si_{ox}$) were determined using ICP equipment, following Tamm's method with 1:100 soil extract ratio and 0.2 M ammonium oxalate adjusted to pH 3.0. Samples were shaken for 4 hrs in the dark prior to extraction (Blakemore *et al.*, 1987). Water contents at –0.1, –0.3, –1.0, and –15 bars were determined in pressure chambers using thirteen air dried samples between 15–75 cm depth to develop the characteristic desorption curve.

Pedon B was sampled using standard methods except where indicated. Field-moist and air-dry colour were determined using the Munsell scheme. Organic matter was determined by loss on ignition analysis as a percentage of the oven-dry weight. Samples were heated in a muffle furnace (Funatrol 1, Thermolyne) in a stepwise fashion: 105°C for 24 hours to remove water, then to 650°C for 24 hours. A temperature of 650°C provides complete oxidation of organic matter with no potential contamination from carbonate decomposition if present.

Bulk density was initially determined from four 95-cm-profiles in the south-west quadrant of the site which were averaged to produce a single profile. Auger samples with a volume of 31.5 $cm^3$ were used such that each sample covered 10 cm of depth and was centred on increments of 10 cm to correspond with the soil moisture sampling protocols outlined in Strachan *et al.* (1998). Bulk density from pedon B was sampled twice at 10 cm increments by pressing a tin of known volume (172.5 $cm^3$) into the exposed face of the pedon. All samples were dried at 105°C for 24 hours, the dry weight recorded and the bulk density determined. Particle density was determined for nine samples taken from pedon B using a 50 ml picnometer. A rough estimate of grain size was determined by hydrometer (model 152H, ASTM) for 14 samples excluding ash layers, and the dominant coarse layers. The hydrometer determines particle size distribution by measuring the density of the soil suspension at various times during settling (Sheldrick and Wang, 1993). This method generally underestimates clay content of Andisols, and has lead to an erroneous assumption of low clay contents of Icelandic soils (Arnalds, 1993). The results do, however, give valuable information for the coarse particle fractions and water behaviour of the soils.

## RESULTS AND DISCUSSION

### *Pedon A – General description*

The soil at the Gunnarsholt experimental site classifies as Typic Vitricryand according to the US Soil Taxonomy, but the 1.5 MPa water contents for air dried samples are near 15%, and the soil nearly meets the criterion for Typic Haplocryand. General profile descriptions of pedon A and pedon B are presented in Table 1.

Distinctive layers marking singular eolian deposition events and volcanic eruptions are evident. At the base of the described pedon is a 5 cm thick coarse sand and gravel layer which corresponds to the primary fallout from the 1510 eruption of Mt. Hekla. The composition of the eolian materials and tephra ranges from rhyolitic to basaltic silica contents.

The texture is silt loam throughout the pedon

**Table 1**. Profile description of pedon A and B.
*1. tafla. Jarðvegslýsing á sniði A and B.*

| Horizon<br>*Lag* | Depth, cm<br>*Dýpt, sm* | Description<br>*Lýsing* |
|---|---|---|
| **Pedon A**[a)] | | |
| A | 10–18 | Very dark grayish brown (10YR 3/2) silt loam; weak fine to medium subangular blocky structure parting to weak fine granular structure; friable; roots common; abrupt wavy boundary |
| A2 | 18–20 | Black (5YR 2.5/1) sandy loam; single grain; loose; roots common; eolain sand layer or tephra; abrupt wavy boundary. Horizon not sampled |
| Bw1 | 20–32 | Dark brown (10YR 3/3) silt loam; weak fine granular structure/single grained; loose; very friable; few roots; abrupt wavy boundary |
| Bw2 | 32–55 | Dark brown (10YR 3/3) silt loam; very weak fine subangular blocky structure; friable; few roots; abrupt wavy boundary |
| Bw3 | 55–73 | Dark brown (10YR 3/3) silt loam; very weak fine subangular blocky structure; friable; abrupt wavy boundary |
| **Pedon B**[b)] | | |
| Ap | 0–12 | 10YR 2/2, m (10YR 3/4, d), very dark brown; silt loam; granular; many roots; abrupt irregular boundary |
| Ah | 12–12.5 | Black; fine grained; single grain; depth of boundary varies from 12 to 20 cm over 2 m distance; volcanic ash layer attributed to Hekla 1947 AD; abrupt boundary |
| Bw | 20–25 | 10YR 2/2, m (10YR 3/4, d), very dark brown; loam; granular; many roots; abrupt boundary |
| Ahb1 | 25–26.5 | Black; fine grained; contains coarser white material; abrupt boundary |
| Bwb1 | 27–29 | 10YR 3/3, m (10YR 3/3, d), dark brown; sandy loam; roots present; abrupt boundary |
| Ahb2 | 29–30 | Black; fine grained; contains coarser white material; abrupt boundary |
| Ahb3 | 31–31.5 | Black; fine grained; single grain; abrupt boundary |
| Bwb3 | 31.5–43 | 7.5YR 3/4, m (10YR 3/6, d), dark brown; silt loam; granular; roots present; abrupt boundary |
| Ahb4 | 43–44 | Black; fine grained; contains coarser white material; abrupt boundary |
| Bwb4 | 44–49 | 10YR 3/4, m (10YR 3/6, d), dark brown; silt loam; granular; roots present; abrupt boundary |
| Ahb5 | 49–50 | Dark brown; sandy loam; abrupt boundary |
| Ahb6 | 50–53 | Black; fine grained; single grain; abrupt wavy boundary |
| Ahb7 | 53–53.1 | Black; fine grained; single grain; abrupt boundary |
| Bwb7 | 53–57 | 7.5YR 3/2, m (10YR 3/6, d), dark brown; silt loam; granular; abrupt boundary |
| Ahb8 | 57–57.5 | Very dark brown; sand loam; granular; contains large amounts of white material; abrupt boundary |
| Ahb9 | 57.5–58.5 | Dark brown; sand loam; granular; abrupt boundary |

Continued on next page—*Framhald á næstu síðu*

| Horizon<br>*Lag* | Depth, cm<br>*Dýpt, sm* | Description<br>*Lýsing* |
|---|---|---|
| Ahb10 | 59–62 | Very dark brown; fine grained; contains large amounts of white material; abrupt boundary |
| Bwb10 | 62–66 | 10YR 3/4, m (10YR 3/6, d), dark yellowish brown; silt loam; granular; abrupt boundary |
| Ahb11 | 66–67.5 | Black; sandy loam; contains some coarser white material; abrupt boundary |
| Bwb11 | 67.5–79 | 10YR 3/4, m (10YR 3/6, d), dark yellowish brown; silt loam; granular; abrupt boundary |
| Ahb12 | 79–80.5 | Black; fine grained; contains some coarser white material; abrupt boundary |
| Bwb12 | 80.5–94 | 10YR 3/4, m (10YR 3/6, d), dark yellowish brown; silt loam; granular; abrupt boundary |
| Ahb13 | 94–94.5 | Black; fine grained; single grain; abrupt boundary |
| Bwb13 | 94.5–99 | 7.5YR 3/4, m (10YR 4/6, d), dark brown; silt loam; granular; abrupt boundary |
| Ahb14 | 99–105 | Brown; sand; depth of boundary varies from 90 to 120 cm over 2 m distance; volcanic layer attributed to Hekla 1510 AD; abrupt irregular boundary |
| Ahb15 | 105–107 | Black; fine grained; single grain; abrupt boundary |
| Bwb15 | 107–133 | 7.5YR 3/4, m (10YR 4/6, d), dark brown; silt; granular; abrupt boundary |
| Ahb16 | 134–136 | Brown; sand; thickness of horizon varies from 1 to 2.5 cm over 2 m distance; volcanic layer possibly attributable to Hekla 1389 AD; wavy boundary |
| Ahb17 | 141–142.5 | Black; fine grained; single grain; abrupt boundary |
| Bwb17 | 142.5–146 | 7.5YR 3/4, m (7.5YR 4/6, d), dark brown; silt loam; granular; abrupt boundary |
| Ahb18 | 146–146.5 | Dark brown; sandy loam; granular; abrupt boundary |
| Bwb18 | 146.5–152 | 7.5YR 3/4, m (7.5YR 4/6, d), dark brown; silt; granular; irregular boundary |
| Ahb19 | 152–161 | Black; fine grained; single grain; thickness of horizon varies from 3 to 6 cm over 2 m distance; abrupt wavy boundary |
| Bwb19 | 161–165 | 7.5YR 3/4, m (7.5YR 4/6, d), dark brown; silt loam; granular; abrupt boundary |
| Ahb20 | 165–170 | Black; fine grained; single grain |

a) Description by Ólafur Arnalds, August, 1992, from locations within the Gunnarsholt field site—*Jarðvegslýsing Ólafs Arnalds (ágúst 1992) á sniði A.*

b) Description by I. Strachan, July, 1995, from a 1.7 m deep pit in the northwest quandrant of the Gunnarsholt field site. Presence of volcanic glass optically verified. Dates of volcanic eruptions for tephra beds at 12 and 99 cm inferred by Grétar Guðbergsson from regionally representative sequences. Coarse-grain layers (49, 57, and 66 cm) may reflect intervals of strong eolian action known to have affected the region ca 1920, 1880, and 1850 (Sveinn Runólfsson, personal communication)—*Jarðvegslýsing I. Strachan (júlí 1995) á sniði B. Grétar Guðbergsson greindi öskulögin.*

based on hand estimates which correspond well to subsequent laboratory analyses on samples from pedon B. The structure is weak as is most common for Icelandic soils. The cambic horizon designation follows the example of Arnalds *et al.* (1995) and is based on colour differ-

**Table 2.** Results of the chemical analysis of pedon A (see text for complete discussion).
*2. tafla. Efnaeiginleikar fyrir snið A.*

| Horizon *Jarðvegslag* | OC | pH $H_2O$ | pH KCl | pH NaF | $Al_{ox}$ % | $Si_{ox}$ % | $Fe_{ox}$ % | Clays[a)] % | CEC[b)] meq 100 $g^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 2.4 | 5.8 | 4.9 | 10.2 | 2.0 | 1.7 | 3.6 | 16 | 19 |
| Bw1 | 2.3 | 6.1 | 4.9 | 10.1 | 2.3 | 2.0 | 4.0 | 19 | 21 |
| Bw2 | 1.8 | 6.5 | 5.0 | 9.8 | 1.9 | 1.7 | 3.2 | 15 | 17 |
| Bw3 | 2.2 | 6.4 | 5.1 | 9.9 | 2.3 | 1.8 | 3.6 | 17 | 20 |

a) Clays estimated as allophane and ferryhydrate—*Leir metinn sem allófan og ferrýhýdrat (Parfitt, 1990; Parfitt and Childs, 1988).*
b) CEC (Cation Exchange Capacity) estimated according to regression equation (Arnalds, 1990)—*Jónrýmd ákvörðuð samkvæmt jöfnu Ólafs Arnalds (1990).*

ences and the development of a weak subangular blocky structure.

The site is freely drained in summer while water impoundment occurs on frozen ground in winter. The silty texture facilitates favourable infiltration rates and hydraulic conductivity, which also intensifies frost heave processes due to water movement to often stationary freezing fronts (Arnalds, 1994). Water retention properties will be discussed in greater detail with respect to pedon B.

### *Pedon A – Chemical characteristics*

Selected chemical characteristics are summarised in Table 2. Organic carbon contents range between 1.8–2.4%. These values are somewhat lower than for Icelandic Andisols that are less influenced by eolian activity. The constant flux of eolian and tephra materials lead to rapid thickening of the profile, of about 0.6 cm $yr^{-1}$ for the past 100 years, with consequent burial of A horizons. For comparison, organic matter determined by loss on ignition in pedon B ranges between 2–13% for coincident depths (Figure 1). The organic distribution is erratic and extends to some depths, which is often characteristic of Andisols as a consequence of Al-Fe complexing of organic carbon and burial by tephra additions.

Soil reaction is lowest at the surface but rises with depth as has been reported for other Icelandic Andisols. These values are higher than commonly reported for Andisols under similar conditions, including Alaska (e.g., Ping *et al.*, 1988, 1989; Shoji and Ono, 1978; Shoji *et al.*, 1982), which has been attributed to the steady flux of eolian materials in Iceland (Arnalds *et al.*, 1995; Jóhannesson, 1960). Potassium chloride pH is up to 1.5 units lower than pH measured in $H_2O$. Sodium fluoride pH is near 10 for all horizons, indicative of andic soil materials. Such very strongly alkaline NaF pH values as compared to $H_2O$ pH values are due to $F^-$ replacing $OH^-$ which is related to poorly crystalline hydroxides and allophane constituents.

Andisols contain clays that flocculate thus potentially confounding conventional hydrometer methods. It is therefore common to measure oxalate soluble Al, Si, and Fe in order to estimate the amount of clay minerals (Parfitt and Childs, 1988; Parfitt and Hemni, 1982; Parfitt and Kimble, 1989; Parfitt and Wilson, 1985; Wada, 1985). Oxalate soluble Al and Fe are used as a diagnostic property for Andisols (USDA, 1994). A simple method has been suggested to estimate allophane content by multiplying $Si_{ox}$ by six (Parfitt, 1990). This method results in allophane contents in these samples ranging between 10–12%. The Al/Si ratio is lower than is commonly found in Andisols (Parfitt and Kimble, 1989), but is typical for Icelandic Andisols (Arnalds *et al.*, 1995; Wada *et al.*, 1992). By multiplying the $Fe_{ox}$ values by a factor of 1.7 (Parfitt and Childs, 1988) a ferryhydrate content of 5–8% is obtained. This

[redacted]

**Figure 1** . Soil properties of pedon B. Data is available for depths as indicated in Table 1. Darkness index is calculated according to Vreeken (1994); organic matter was obtained by loss on ignition; grain size estimates are by hydrometer.

*1. mynd. Jarðvegseiginleikar fyrir snið B. Gjóskulagasnið lengst til hægri, þá litatala samkvæmt aðferð Vreeken (1994). Lífræn efni mæld með glæðitapi er fyrir miðju, síðan rúmþyngd en lengst til vinstri er kornastærð mæld með vatnssúlu, þar sem hlutfall leirs er vanmetið* .

is unusually high, reflecting the basaltic nature of some of the eolian and tephra sources of the parent materials.

Cation exchange capacity (CEC) was not measured. It has been shown that CEC of Icelandic soils is highly correlated with the colloidal fraction of the soils represented as $Al_{ox}$ and $Fe_{ox}$, precipitation and organic carbon ($r^2$= 0.92; Arnalds, 1990). Based on his method, the CEC for pedon A is estimated to be near 20 meq 100 $g^{-1}$ soil for all horizons. The estimate refers to CEC using 1 M sodium acetate (pH 8.2) replaced with 1 M ammonium acetate (pH 7). The charge of allophanic constituents is pH dependent and CEC under natural conditions is somewhat lower.

### *Pedon B – Physical properties*

Pedon B is represented by a 1.7 m deep pit that was excavated in the northwest part of the site. The northeast face of the pit was cleaned and the resulting observations are given in Table 1. There are numerous layers which were distinguished by colour and or visible texture changes. Soil layers range in colour from dark brown, and dark yellowish brown through to very dark brown for the surface layers. All layers show characteristic lightening with air drying (increase in value and chroma). Many layers vary in thickness on the order of 1–5 cm within a horizontal distance of <1 m. Vertical distance from a layer to the surface can therefore vary by >10 cm. This pattern of wavy boundaries of irregular thickness is indicative of a hummocky terrain. In this environment such topography develops over a few decades by frost heave.

Layer identification and dating were done by Grétar Guðbergsson (RALA) *in situ*. The distinction between erosional and primary volcanic fallout layers was confirmed by subsequent analysis with a petrographic microscope using hand samples collected *in situ*. Samples identified as primary fallout layers (e.g. Hekla 1510) contain particles that are angular and isotropic to light (indicating volcanic glass), and have few anisotropic particles. Isotropic minerals (e.g. volcanic glass) appear dark when viewed under crossed polars. The light from the lower polar is unaffected by the glass and is absorbed by the upper polar (Nesse, 1986). In contrast, samples from erosional layers (ca 1920 and 1880) contain rounded glass particles and large amounts of anisotropic particles (non-glass elements) indicative of weathered material.

Figure 1 provides a composite view of many of the properties in pedon B. The moist Munsell value and chroma were combined into a single darkness index following Vreeken (1994). Darkest layers are found near the surface with layers becoming more pale with depth. No relationship was found between darkness index and organic matter although it should be noted that many of the “dark” layers were not sampled.

Organic matter (OM) measured by loss on ignition is shown to increase sporadically with depth (Figure 1), likewise, bulk density is shown to generally decrease with depth. The relationship between organic matter and dry bulk density is shown in Figure 2. Organic matter has a lower particle density and thus layers with a greater OM content will likely have a lower bulk density due to this simple compositional effect. The increase in bulk density beyond 100 cm is not remarkable considering that the soil detailed here comprises frequent buried A horizons, porous aeolian material and freeze-thaw cycles that override the effect of compaction.

Because wind is the major depositional agent in this region the pedon may feature periodic accumulation of Andisols (containing organic materials) redistributed by the wind. Thus, layers comprised of deposits of redistributed material will have higher OM than layers with OM accumulated *in situ* only. This fact may explain the increase in OM between 30–50 cm; a period of higher aeolian activity in the region (Figure 1).

The bulk density profiles were combined to produce an average profile for the site (Figure 3). Two distinct layers are evident between

10–90 cm, and 100–170 cm yielding significantly different averages of 0.73±0.01 g $cm^{-3}$ and 0.58±0.02 g $cm^{-3}$, respectively ($P<0.01$). Each of these values lie within the typical range given in the literature (e.g., Arnalds *et al.*, 1995; Maeda *et al.*, 1977). The average particle density for the upper 90 cm was determined to be 2.12±0.04 g $cm^{-3}$ which falls in the range of values given by Maeda *et al.* (1977). If the average values for bulk density (0.73 g $cm^{-3}$) and particle density (2.12 g $cm^{-3}$) are applied, the resulting average porosity is 0.66 and the corresponding void ratio is 1.90 $cm^3$ pores $cm^{-3}$ solids.

Notwithstanding the aforementioned problems with the hydrometer technique for Andisols, the results indicate that the majority of pedon B layers can be best described as silt-loam following the classification scheme of the USDA texture ternary diagram (Figure 4). Clay content of pedon B layers are less than those in pedon A and range between 7–14% reflecting the expected underestimation due to the flocculating nature of the clay minerology. Arnalds (1993) reports clay content between 13–46% in four Icelandic pedons of aeolian soils based on ultrasonic dispersion and oxalate extractions. Increasing clay content in samples from pedon B at the expense of silt, however, would not redistribute the samples out of the silt-loam category.

The soil moisture characteristic curve represents the relationship between volumetric soil moisture content and soil moisture potential and represents a unique description of the hydrological properties of the soil. Figure 5 shows the laboratory-derived (desorption) characteristic curve along with the theoretical desorption curve for a silt loam described by Clapp and Hornberger (1978) and Cosby *et al.* (1984) derived using the estimates of grain size from pedon B. The laboratory and theoretical curves are in good agreement over the range of tensions presented. The scatter of points represents the average values of volumetric soil moisture from eight neutron probe access tubes at 30 cm against soil water potential values (obtained using tensiometers) for the same depth (see Strachan *et al.*, 1998 for details) for various times throughout the 1995 season. The scatter of the field-determined moisture data corresponds to the range in rainfall conditions that occured in 1995 including a prolonged dry period that allowed the upper soil to dry somewhat. A small range in tension values was measured; the scatter of points is confined to

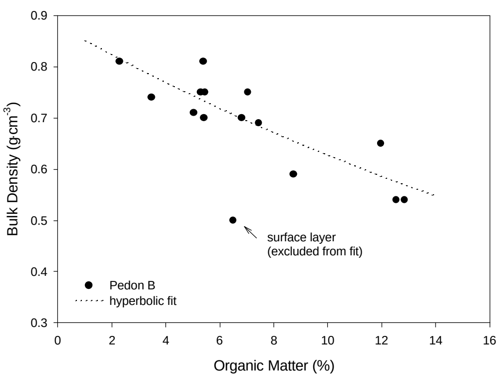


**Figure 2**. Relationship between dry bulk density and organic matter using samples obtained from pedon B. Hyperbolic curve fit is significant ($r^2$=0.79, $P<0.01$, n=14).
*2. mynd. Tengsl rúmþyngdar og hlutfalls lífrænna efna fyrir snið B.*

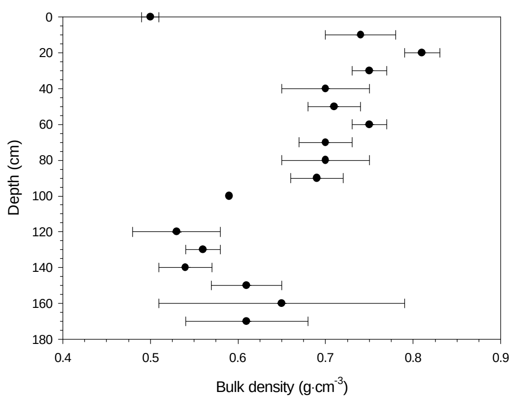


**Figure 3**. Depth profile of average bulk density using samples from pedon B and augered profiles (error bars represent one standard error from the mean).
*3. mynd. Rúmþyngd sem fall af dýpt.*

the portion of the characteristic curve representing water around field capacity. The soil above 30 cm most likely dropped to field capacity during the prolonged dry period in 1995 but water potential was not measured shallower than 30 cm.

The Clapp and Hornberger relationship does not adequately represent the capilarity present in finely-textured soils and contains no estimate of the air entry pressure. This may be of importance given the distribution of ambient soil moisture conditions at the Gunnarsholt site. A more accurate representation may be obtained by applying a Brooks-Corey (1964) or Van Genuchten (1980) relationship, however, each of these require non-linear approximations and the data points available for these are, at present, limited.

In summary, the soils at Gunnarsholt are typical of Andisols exhibiting andic soil properties. The Gunnarsholt soil is fine-grained, porous, and provides excellent water holding capacity. The chemical and morphological characteristics recorded in the described pedons conform well to the andic properties typical of this class of soil. Soil morphology, chemistry and hydrological properties will be used in further studies at the Gunnarsholt plantation forest.

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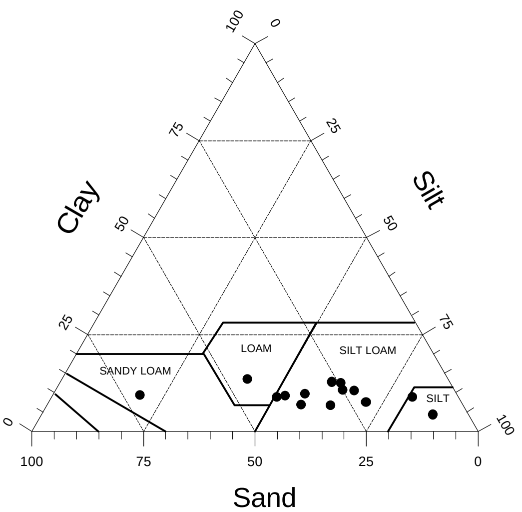


**Figure 4**. Grain size classification for 14 samples from pedon B using the USDA texture triangle.
*4. mynd. Kornastærðadreifing samkvæmt hinni bandarísku USDA flokkun.*

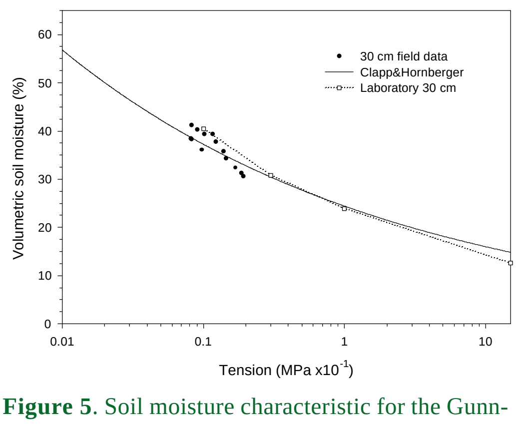


**Figure 5**. Soil moisture characteristic for the Gunnarsholt silt loam Andisol. Curves are Clapp&Hornberger's theoretical silt loam and the laboratory desorption curve for field samples taken between 30–45 cm. Points represent values from neutron probe and tensiometer at 30 cm depth.
*5. mynd. Vatnsheldni fyrir snið B; y-ás sýnir vatnsinnihald (%), en x-ásinn vatnsspennu.*

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