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EFFECTS OF BONE MEAL ON PHYSIOCHEMICAL SOIL PROPERTIES OF A FERTILIZED RECLAMATION SITE IN ICELAND

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ABSTRACT

The need for restoration of degraded lands has become necessary to ensure sustainable living. Fertilization has been applied to improve soils in order to enhance vegetation growth. Application of different organic fertilizers has shown varied effects on soil physiochemical properties. This study was conducted to investigate the effects of bone meal on soil physiochemical properties in a sandy loam soil in Iceland. No significant effect was observed for bone meal on nitrate, bulk density, porosity, pH and electrical conductivity ($P > 0.05$). Furthermore, total nitrogen, total carbon and carbon: nitrogen (C/N) ratio were not affected by the bone meal treatment. However, significant effects of bone meal were observed on organic matter content and water holding capacity of the treated soil ($P<0.05$). The treated area had 10.9% more water retention capacity than the control.

Key words: Bone meal fertilizer, land reclamation, soil properties

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1. INTRODUCTION

The overexploitation of natural resources and its associated environmental problems globally has prompted awareness of the need for sustainable development. Certainly, sustainable development is deeply rooted in the United Nation`s sustainable development goals, with goal fifteen focused on sustenance of life on land (United Nations Department of Global Communications 2019). Until recent times, anthropogenic impacts on the environment and the natural ecosystem have received minimal consideration (Wong et al. 2016; Chen et al. 2017). One of the consequences of this is land degradation. Land degradation has been defined by Hoffman and Ashwell (2001) as the loss of biological or economic productivity of an area caused primarily by human activity. This refers to degradation of the soils, water and vegetation and declining ecosystem functions (Gao et al. 2016). Soil is a complex and multifunctional component of the ecosystem providing multiple ecosystem services (Rinot et al. 2019; Calzolari et al. 2016; Andrea et al. 2018). Most of the services that the ecosystem provides are connected to different soil functions; hence the ability of the soil to support the necessary ecosystem services may be linked to its inherent attributes, or land management practices (Rinot et al. 2019; Dominati et al. 2010).

Restoration of degraded lands has become crucial to compensate for the disturbances of ecosystems and to restore the soil´s functionality. Soil serves as an anchor for plant roots and is a water reservoir for effective plant growth (Sung et al. 2017). The ability of the soil to store and supply nutrients to plants is referred to as soil fertility (Sung et al. 2017). Some soil properties that are known to support plant growth and serve as indicators of soil health are organic matter content, bulk density, soil texture, porosity, aggregate size and water holding capacity (Motsara & Roy 2008; Sung et al. 2017).

To improve soil health, organic amendments such as bone meal, sewage sludge and manure have been applied to soils and reports have been made on their positive effects on soil structure, stability, and nitrogen and carbon content (Moral et al. 2002; Sánchez-Monedero et al. 2004; Bouajila & Sanaa 2011) as well as biological properties (Tejada et al. 2006). The way land is managed is also reported to have a significant influence on organic carbon and total nitrogen content in the soil (Zhang & Fang 2007). This implies that different management practices affect soil properties.

In Ghana, despite the general recognition of land health improvement using organic fertilizers, little effort is directed to its usage in land reclamation activities. However, several efforts are being directed towards effective ways of improving soil conditions in the degraded areas of the country, but the focus is mostly on its usage in agriculture. Again, the potential of organic fertilizers as soil amendments in land restoration activities is rarely investigated. Meanwhile, about 4.2 million tons of agricultural waste are produced annually in Ghana (Duku et al. 2011). In addition, 760,000 tons of municipal solid waste is generated per year of which 50-60% is organic (Asase 2011; Duku et al. 2011). In the cattle industry 22.8 million tons of wet matter and 2.9 million tons of dry matter manure are produced annually (Duku et al. 2011). All these waste materials, including sewage sludge, that could be composted or used directly as organic fertilizer are disposed of in landfills or are left to rot.

Therefore, there is need to investigate the effects of organic fertilizers on soils on land under reclamation to influence policy decisions on the upscaling of composting of organic waste for improvement of degraded lands and to improve environmental quality in Ghana.

Since its establishment in 1907, the Soil Conservation Service of Iceland (SCSI) has put considerable efforts into restoring eroded landscapes to reduce drifting sand by, e.g., direct seeding of lyme grass (*Leymus arenarius*) and birch (*Betula pubescens*) (Aradóttir et al. 2013). In its work, the SCSI has used different fertilizers, including organic and inorganic, in the reclamation of different sites (M. H. Jóhannsson 5 June 2019, Soil Conservation Service of Iceland, personal communication). In a recent study, Brenner (2016) compared the effects of multiple types of fertilizers on vegetation and soil attributes in gravel soils in Iceland. She found that there were no significant effects of bone meal or other organic fertilizers on the soil but did find that the vegetation cover increased. The fertilizer rates were rather low (50 kg N/ha) and only applied once. Studies have shown that bone meal contains essential elements needed for plant growth such as calcium, potassium, nitrogen and phosphorus, and therefore is recommended for soil enrichment (Deydier et al.2005; Garcia & Rosentrater 2008). Hence the focus of this study was on how bonemeal affects physiochemical soil properties in a fertilized reclamation site.

1.1 Study goal and objectives

The goal of this project was to assess the effects of bone meal on the physiochemical properties of soil in a fertilized reclamation site in Iceland. Specifically, the study aimed to:

- Evaluate the effect of bone meal on the quality of soil from a fertilized reclamation site compared with a control.
- Determine soil moisture content, pH, electrical conductivity, porosity, bulk density, water holding capacity, nitrate, organic matter content, and the C/N ratio of soil from the fertilized site compared with a control.
- Compare differences in the above variables between soils from the fertilized reclamation site and an unfertilized control.

1.2 Gender and policy effects

Environmental and socio-economic effects that result from pollution from improper organic waste management affect the entire society. A study by Doss (2006a) reported that women have limited access to land in Ghana. Thus, women held land in 10% of Ghanaian households whereas men held land in 16-23% of the households. The women`s limited access to land has resulted in continuous farming on the same piece of land, which reduces the soil fertility (Muniru 2013). However, using organic fertilizer amendments to restore these degraded lands could improve the livelihood of the rural women who are more dependent on resources from nature for their livelihood.

In addition, the protection of water resources and reduced emissions of carbon dioxide (CO_2) that could result from restoration of degraded lands would help in reducing climate change impacts on communities. Ecosystem services that could result from the restored lands, such as the use of the sites as grazing fields or farmlands, would boost the livelihood of both genders in the communities. Also, in areas where these degraded lands serve as farmlands or the people depend on resources from the land, improving soil fertility would improve the land productivity and, as a consequence, improve the livelihood of the people.

The intention of the study is to make recommendations on the use of organic fertilizers in the reclamation of degraded lands and thus to improve ecosystem functions and services in Ghana. The study could serve as a guide to city authorities and land users, such as farmers, in identifying the use for organic waste through converting it into fertilizers like compost. This will provide low-cost fertilizer to farmers to improve their lands for increased land productivity and indirectly reduce importation of fertilizers into the country. The study could furthermore serve as a guide for restoration ecologists to employ the use of biodegradable waste such as bone meal, as organic fertilizers in fostering faster re-vegetation of degraded lands without having to expand financial resources on alteration of soil conditions.

Again, it could help metropolitan assemblies in Ghana to reduce the quantity of biodegradable waste disposal and help in reducing the cost of municipal waste management as well as reduce the pollution effects on the environment. The study adds to existing knowledge on the use of organic fertilizers in restoration and could stimulate more research on the use of biodegradable waste as soil conditioners. Ultimately, this study seeks to influence policy decisions on the use of organic fertilizer in Ghana.

2. LITERATURE REVIEW

2.1 Effect of organic fertilizers on soil physiochemical properties

There are several reports on studies that have employed different organic materials for soil improvement and have recorded significant positive effects on soil properties in different soil types (Tejada et al. 2006; Zhang & Fang 2007; Mondini et al. 2008; Zingore et al. 2008). For instance, a study by Bouajila and Sanaa (2011) in Tunisia used farm manure and household waste at different application levels (40, 80 and 120 tons/ha) and reported high increases in soil organic carbon and nitrogen content, though the increase was dose dependent. The infiltration rate of water in the manure treated plots was nearly twice as much as that of the control. According to Bronick and Lal (2005) addition of organic materials to soils causes a decrease in bulk density and increase in porosity and hence influences the water holding capacity of the soil. By the same token, Guo et al. (2016) reported an 87% increase in soil organic matter at 0-20 cm soil depth with application of cattle manure compost. Also, Rawls et al. (2003) reported a positive effect of organic matter content and composition on soil structure and absorption properties and inferred that water retention may be affected by changes in soil organic matter.

Sánchez-Monedero et al. (2004) reported 7% -14% more stored C in green manure treated soil than the untreated control. In the same study, the treated soil had 22% - 36% greater organic carbon storage than plots treated with chemical fertilizer. Zhang and Fang (2007) reported that application of organic manure significantly increased soil pH compared to the control after application of organic manure. In the same study, organic manure treated soil had lower bulk density and more water stable aggregates and saturated hydraulic conductivity than untreated soil and soil treated with chemical fertilizer. Zhang and Fang (2007) concluded that the source of fertilizer is the main distinguishing aspect on the effects of fertilization on soil properties.

2.2 Effects of bone meal on soil physiochemical properties

Meat- and bone meal (MBM) is a by-product of rendering industries obtained after cooking mammal carcasses, eliminating fat content, and finally drying and crushing (Cascarosa et al. 2012). The product comes in either powdered or pelleted form. Bone meal is estimated to contain about 8% nitrogen, 5% phosphorus, 1% potassium and 10% calcium (Garcia &

Rosentrater 2008) and is classified under category 3 of animal waste, which is considered low-risk material from safe animals and can be used as agricultural fertilizer and pet food.

2.2.1 Soil organic matter and carbon:nitrogen ratio

Soil organic carbon (SOC) is a measure of the total amount of organic carbon (C) in soil, independently of its origin or composition (Stolbovoy et al. 2005). SOC is an indicator of soil quality and its variations can affect many environmental processes such as soil fertility, erosion and greenhouse gas fluxes. It is generally assumed that, on average, organic matter (OM) contains about 58% organic carbon and organic matter can therefore be used as an indicator for the content of organic carbon in the soil (Motsara & Roy 2008). Soil organic matter (SOM) content can also be used as an index of N availability, or the potential of a soil to supply nitrogen to plants, because the nitrogen content in soil organic matter is relatively constant (Motsara & Roy 2008). Tenuta and Lazarovits (2004) observed an inverse relationship between soil organic carbon and NH_3 concentration in soils; as soil carbon decreases, the concentration of NH_3 increases. Mondini et al. (2008) found no significant difference in organic carbon between bone meal treated soil and the control.

According to Flavel and Murphy (2006), the C:N ratio is an important factor that predicts nitrogen mineralization in soils treated with organic residues. A study by Khalil et al. (2005) reported an inverse relationship between C:N ratio and nitrogen mineralization. Mondini et al. (2008) reported a low C:N ratio of meat and bone meal soil treatments (4.4 and 3.6) compared to other treatments. Brenner's (2016) study reported significant effects of organic fertilizer on C:N at 0.5 cm and 5-10 cm depths, but total nitrogen was not affected by fertilizer treatments.

Stępień and Wojtkowiak (2015) did not find a significant difference in organic carbon, total nitrogen, and C:N ratio in meat and bone meal treated soils compared to the control, but observed that nitrate concentration tripled after the dose was increased from 1.0 t ha^{-1} to 2.0 and 2.5 ha^{-1} similar to findings by Nogalska et al. (2013). Stępień and Wojtkowiak (2015) also reported high nitrate concentrations in meat and bone meal treatments compared to other treatments. Arable soils, according to their study, had lower levels of nitrate which they attributed to possible leaching of nitrate due to time of application (early spring and late autumn). Similar findings were made by Tammeorg et al. (2013) in a loamy sand textured soil with wood chips.

2.2.2 Water holding capacity, bulk density and nitrate

Soil moisture is a physical property of soil that controls many physical, biological, and chemical processes and can be expressed in two ways, either on a volumetric or a gravimetric basis (Robinson et al. 2008). The volumetric measurement is expressed in cubic meters whilst the gravimetric measurement is based on per gram of oven-dried soil at 105°C (Robinson et al. 2008). The water holding capacity (WHC) of the soil is, however, defined by Veihmeyer and Hendrickson (1931) as the amount of water held in the soil after the excess gravitational water has drained away and the rate of downward movement of water has virtually ceased. The lower limit of plant available water is at -15 bar (Okalebo et al. 1993). Organic matter and soil texture are the main components that determine the water retention capacity of the soil. Therefore, the higher the organic content of the soil, the greater the soil's capacity to retain water (Sudan et al. 2014). Organic matter in the soil has a direct effect on the soil's ability to retain water due to the affinity of organic matter for water (Sudan et al. 2014). A study by Tammeorg et al. (2014) revealed that the addition of bone meal did not have a significant effect on soil moisture at 0-15 cm depth. Brenner`s (2016) study observed no significant differences in water content among fertilizer treatments and control.

Soil bulk density is the ratio of the dried mass of soil to its total volume (Pan et al. 2013). Bulk density is an indication of the soil's ability to function for the transport of water and solute movement, and soil aeration (USDA 2008). Soil bulk density is regarded as a key factor of soil compaction and correlates with other physical, chemical, and biological properties of soil (Al-Shammary et al. 2018). Bulk density depends on soil texture and the densities of soil mineral (sand, silt, and clay) and organic matter particles in the soil, and how the particles are arranged (USDA 2008). Mostly, loose, porous soils and soils rich in organic matter have lower bulk density. Sandy soils have relatively high bulk density since they have less total pore space than silt or clay soils. Medium textured soil with about 50 percent pore space will have a bulk density of 1.33 g/cm^3 (USDA 2008).

In sandy soils, ideal bulk density for plant growth is less than 1.06, whereas densities above 1.80 restrict plant growth (USDA 2008). Shiri et al. (2017) asserted that soil bulk density significantly affects land drainage and reclamation and can be used as an indicator of soil drainage properties. Mohawesh et al. (2014) argued that soil bulk density can be used to estimate soil moisture which is a key property used to control irrigation.

Porosity is the fraction of the total soil volume that is taken up by the pore space (Nimmo 2004) and thus the amount of space available to fluid within a specific body of soil. Soil porosity can be calculated after bulk density determination as: soil porosity (%) = 1 – {bulk density / 2.65} where 2.65 is the bulk density of rock (Motsara & Roy 2008). Soil structure and macropores are vital for sustaining biological productivity, regulating and supporting of water and solute flow, and cycling and storing nutrients (USDA 2008). The nature of soil structure and macropores is vital based on its influence on water and air exchange, plant root exploration and habitat for soil organisms.

2.2.3 Soil pH, nitrate and electrical conductivity

Soil pH is a measure of soil acidity or neutrality. It is a simple but very important estimation for soils as soil pH has a considerable influence on the availability of nutrients to plants where the optimal uptake range lies in pH 6-7 (USDA 1998). The pH also affects the microbial population in soils (Motsara & Roy 2008). Atuah and Hodson (2011) reported a significant increase in soil pH as a result of increased concentrations of bone meal. Tenuta and Lazarovits's (2004) study in Canada recorded an increase in soil pH in some of the bone meal treated soils studied in contrast to the other treatments and the control. A study by Gatima et al. (2006) in lead-contaminated soil found much more alkaline pH (8.41) for bone meal treatments than for red earth and pulverised fly ash amendments. Stępień and Wojtkowiak (2015) reported no significant difference in soil pH between bone meal amendments and the control. Brenner`s (2016) study in Iceland in an area close to where this study was conducted observed a general significant effect of fertilizer treatment on pH_{water} at depths of 0-5cm and 10-20 cm, but no significant differences among different fertilizers and control.

Nitrate (NO_3^-) is a form of inorganic nitrogen that occurs naturally in soils. Sources of soil NO_3^- include decomposing plant residues and animal manure, chemical fertilizers, exudates from living plants, rainfall, and lightning (USAD 2014). Nitrate ions are immobilized by microorganisms and converted into organic forms which are released back to the soil in a form that can be utilized by plants. Nitrate is usually deficient in soils with soil pH <5.5 due to reduced nitrification. Nitrification stops at pH <4.5, and the optimum pH for nitrification is between 6 and 8. Soil texture is known to influence NO_3^- mobility. Coarse soil texture (sandy), with the high water infiltration rates typical of sandy soils, aids faster NO_3^- leaching due to lack of adhesion between NO_3- ions and particles (USAD 2014). A study in Norway by Jeng et al. (2004) found relative nitrogen utilization efficiency for grains to be 91% in bone meal treated soils comparable to mineral nitrogen treated soils in silt loam soil.

Electrical conductivity (EC) is considered a measurement of dissolved salts in a solution (Motsara & Roy 2008). The EC values are an indication of the soluble salt content in the soil extract and an indication of the salinity status of the soil sample. It has been found that the ratio of the soil solution in saturated soil paste is about 2-3 times higher than that at field capacity (Motsara & Roy 2008). Soil EC has an indirect effect on plant growth and is used as an indirect indicator of the amount of nutrients available for plant uptake, and salinity levels (USDA 2011). High EC (EC >4dS/m) indicates salinity problems which impede the plants' ability to absorb water (USDA 2011). Soils with high EC due to high sodium concentration usually have poor structure and drainage, and the sodium becomes toxic to plants (USDA 2011).

3. MATERIALS AND METHODS

3.1 Description of study area

The study was conducted in the Kot reclamation site located in southern Iceland on latitude 63°47'27.7" N and longitude 20°16'22.7" W. The Kot reclamation site was established in 2013 by the SCSI and is about 8 km from Gunnarsholt, the headquarters of the SCS1. The landscape at the site is flat and covers about 340 ha.

Generally, the soils of Gunnarsholt and its surroundings are classified as Vitric Andosols with sandy loam in the A and B horizons. Organic carbon content is estimated to be 0.2% in the top 10 cm of the soil (Arnalds et al. 2013). According to Nasare (2018), meteorological data obtained from a nearby weather station for 1971-2000 indicated an average annual precipitation of 1,260 mm for the area and an average monthly temperature for July and January of 11°C and -2°C, respectively. During summer, the soil temperatures of the area are usually above the average air temperatures due to the dark basalt parent material (Arnalds et al. 2013). Bone meal fertilizer was applied in Kot (the study site) in 2016 and 2017 at 1.2 tons/ha in order to improve the soil condition and vegetation growth in the site. Since then, there has been some observable improvement in the vegetation cover as shown in Figure 1 below. Figure 2 shows a map of the study area and the study sampling points in both the treated area and the control area.

Figure 1. Spreading of bone meal at the Kot reclamation site and improvement in vegetation cover after 3 years of application. (Photo: Á. Þórisson, April 25, 2016).

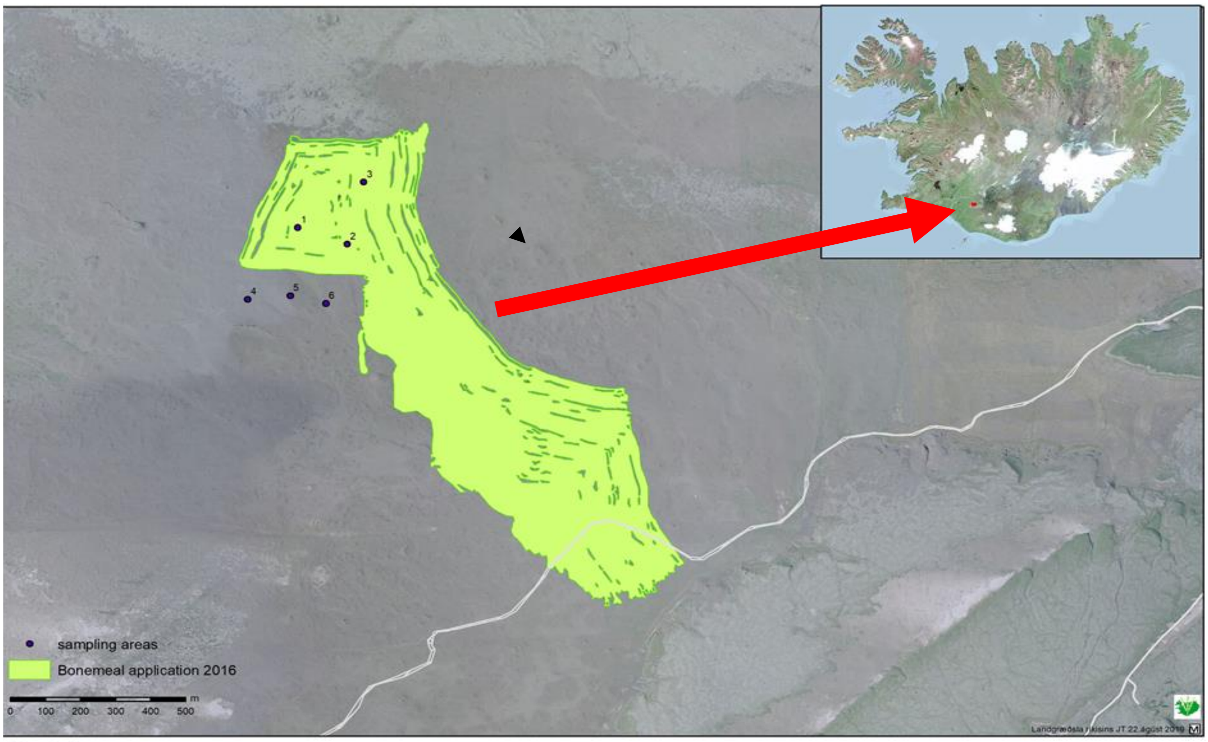

Figure 2. Map of the study area showing sampling points in the treated area (1-3) and the control area (4-6). (Source: Soil Conservation Service of Iceland 2019).

3.2 Data collection methods

3.2.1 Soil Sampling and laboratory analysis

Soil samples were collected from the site that had been fertilized with bone meal in 2016 and an adjacent untreated control site. Samples were taken from three areas randomly selected from the treated site and the control site (three replicates for each treatment factor). At each of the six spots, a 10x10 m grid was set up. Within each of the 10x10m grids, soil samples were taken with 4.8 cm^3 auger at 0-10 cm depths at 10 randomly selected points. Samples were combined within each replicate and the composite sample used for laboratory analyses. A subsample was taken from each composite sample for determination of moisture content. The rest of each soil sample was air-dried, homogenized and passed through a 2 mm sieve before analysis of the other parameters. For the analysis of bulk density, four undisturbed core samples (1000 cm^3) were taken at four randomly selected spots in each replication of both treated and untreated sites. Variables such as C:N ratio, organic matter content, electrical conductivity, nitrate, soil pH, bulk density and water holding capacity were measured in the laboratory. Figure 3 below shows soil sampling at Kot.

Figure 3. Soil sampling at Kot. (Photo: M. H. Jóhannsson, 1 July 2019).

3.2.2 Methods for soil analyses

The organic matter content of the soil was measured using the Loss on Ignition method (Motsara & Roy 2008). The dry matter content was measured on a sieved (<2mm) air dried soil sample. A subsample of a known weight of soil was transferred into a crucible of known weight. The sample was than dried at 104°C for 24 hrs after which the weight of the sample with the crucible was recorded. The samples were then transferred into a muffle oven and burned for 4 hrs at 550°C and weighed again. The percentage of organic matter was calculated using the formula W_1 - W_2/ W_1 X 100 - (1) where W1 is the weight of soil at 105°C and W_2 is the weight of soil after 550°C. Total nitrogen and total carbon were estimated by catalytic tube combustion under an excess oxygen supply at 900°C using VarioMax C:N analyser (Elementar Analysensysteme GmbH, Germany).

Water holding capacity was determined at the laboratory using the method as described by Sudan et al. (2014). Plastic containers of equal size with the inside lined with filter papers and the bottom of the containers sealed with a nylon fabric were filled with oven-dried soil of known mass. The mass of container, filter paper, and dry soil sample was recorded and the containers then placed in a shallow plastic bowl filled with water allowing only the bottom few centimetres of the containers to become wet. The soil became saturated from the bottom of the containers to the surface in about six hours. The containers were then removed and placed in a humid enclosure for 30 mins after drainage was complete. Percentage water holding capacity was calculated as mass of wet soil - mass of dry soil/ mass of dry soil x 100 - (2).

Bulk density was determined using the field core method (Casanova et al. 2016). A solid square of 10 by 10 cm^3 was hammered into the soil and an intact soil core was taken and its weight recorded. The samples were dried for two days at 105°C and the weight of the dry soil sample mesured. Bulk density (g/cm^3) = dry soil weight (g) / soil volume (cm^3). Porosity is a measurement of how much of a material volume is open pore space. It is usually expressed as a percentage of the material's total volume. Soil porosity was calculated after bulk density determination as: soil porosity (%) = 1– (bulk density / 2.65) - (3) where 2.65 is the reference bulk density of rock (Casanova et al. 2016).

Soil pH was measured using a pH meter in a 1:1 soil to deionized water ratio mixture, shaken in a shaker for two hours (Zhang & Fang 2007). The electrical conductivity and nitrate were measured in 1:1 soil to water suspension (Motsara & Roy 2008) with the use of an electrical conductivity meter and nitrate meter.

Figure 4. Measuring pH at the laboratory. (Photo: J. Jumaev, 19 July 2019).

3.2.3 Statistical analysis

A paired sample t-test was performed on each of the soil properties to test whether there were significant differences in the soil parameters investigated for the bone meal treated area and the control using SPSS version 20. Mean comparisons were done for all pairs at an alpha value of 0.05 to evaluate the main effects of bone meal on the soil parameters studied.

4. RESULTS

The results of the study are summarized in Table 1.

Table 1. Means and significant differences in physiochemical parameters measured in soil sampled at 0 - 10 cm depth in treated and control areas.

Variables (Soil properties)	Treated area (mean)	Control (mean)	P -value
Organic matter (%)	2.82	1.00	0.008 ***
Total Carbon (%)	0.47	0.32	0.16 NS
Total Nitrogen (%)	0.42	0.29	0.24 NS
C:N ratio	11.99	11.35	0.40 NS
Water Holding Capacity (%)	59.10	53.27	0.05**
Bulk density	1.61	1.62	0.19 NS
Porosity (%)	39.09	38.76	0.92 NS
pH	6.87	6.84	0.19 NS
Electrical conductivity (µcm)	38.66	31.56	0.11 NS
Nitrate (ppm)	23.44	18.22	0.48 NS

****means highly significantly different, NS means non-significant difference*

4.1 Organic matter, total carbon, total nitrogen and carbon:nitrogen ratio

The results show significant differences in organic matter content between the treatment and control. No significant difference was seen in total nitrogen (N%), total carbon, and the C:N ratio between the treated area and the control (Table 1).

4.2 Water holding capacity, bulk density and porosity

The water holding capacity was significantly greater in bone meal treated soils than in the control ($P<0.05$). The mean water holding capacity of the treated area was 59.1% while that of control was 53.3% (Table 1). Computation of % mean difference of water holding capacity in the treated area and control showed that water holding capacity of the soil in the treated area was about 10.88% higher than that of the control.

The bone meal treated area had bulk densities ranging from 1.5 g/cm^3 to 1.7 g/cm^3 with a mean of 1.6 g/cm^3 while that of the control area ranged from 1.6 to 1.7 g/cm^3 with a mean of 1.62 g/cm^3 (Table 1). The results in Table 1 indicate that the mean porosity % for the treated area was 39.09% and that of the control was 38.76%. There were no significant differences in bulk density and % porosity between the treated area and the control.

4.3 Soil pH, electrical conductivity and nitrate

The results of the study indicate that the bone meal treated area had a higher electrical conductivity (mean = 38.66 µcm) compared to the control (mean= 31.56µcm). However, the EC for both the control and the treated area were all below the levels detrimental to plant growth. No significant difference was seen in the EC between the bone meal treated area and control ($P = 0.11$). In the case of pH_{water}, no significant difference was seen between the treatment area and the control (Table 1). The pH_{water} of both the treated area and the control area were moderately acidic and near neutral, with a mean of 6.87 for the treated area and 6.84 for the control (Table 1). Nitrate concentration in the treated area and the control showed no significant differences either. The mean for the treated area was (23.44 ppm) while that of the control was (18.22 ppm).

5. DISCUSSION

5.1 Organic matter, total nitrogen, total carbon and C:N ratio

The study showed significant differences in organic matter content between the treatment area and the control. Therefore, the application of bone meal probably contributed to the improved organic matter content in the treated area, which is a possible indication of improved soil conditions at the treated site. Rawls et al. (2003) and Bouajila and Sanaa (2011) also reported that addition of organic fertilizers have positive effects on the organic matter and nitrogen content of the soil. However, total nitrogen content was not significantly different between the treated area and the control. This may be attributed to one single application of the bone meal in the treated area and rapid mineralization of nitrogen from the fertilizer which may have decreased the amount of available N in the soil. Roy et al. (2018) observed that rapid mineralization occurs more with organic fertilizers which deplete the amount of N in the soil with time. The low nitrogen content in the treated soil may also be attributed to plant uptake of the nitrogen since observation of the treated area gave an indication of more vegetation cover than in the control area three years after the application of the bone meal fertilizer (refer to Fig. 1). This may be attributed to availability of nitrogen to plants as a result of the bone meal fertilizer, as indicated Roy et al. (2018) that rapid mineralization occurs in organic fertilizer, probably making nitrogen available for plant utilization. This is also supported by Jeng et al. (2004) in a study from Norway as they found relative nitrogen utilization efficiency for grains in bone meal treated soils to be as high as 91%, comparable to mineral nitrogen fertilizer. However, a study that connects soil physiochemical properties to vegetation cover may portray the connection better.

No significant effect was observed for bone meal on total carbon. This is similar to a study by Mondini et al. (2008) in acidic and alkaline arable soils where no significant difference was noticed in organic carbon content in meat and bone meal treated soil compared to the control. Stępień and Wojtkowiak (2015) also found no significant difference in organic matter, total nitrogen, and C:N ratio in meat and bone meal treated soils compared to the control. The low C:N ratio observation in this study was like the study of Mondini et al. (2008), where they reported a low C:N ratio for meat and bone meal (4.4 and 3.6) soil amendments compared to other treatments. The findings of this study were also in line with Brenner`s (2016) study where no significant differences were observed in C:N ratios between bone meal and other treatments.

The lack of a significant difference in the C:N ratio between treated areas and the control may be attributed to rapid mineralization of nitrogen in the soil, as Khalil et al. (2005) reported an inverse relationship between the C:N ratio and nitrogen mineralization. Thus, as nitrogen mineralization increases, the C:N ratio in the soil decreases. This shows that a single application of bone meal fertilizer may not support long term availability of carbon and nitrogen in treated soils. Therefore, increased frequency of application may be important for nitrogen availability in bone meal soil treatments.

5.2 Water holding capacity, bulk density and porosity

The study revealed significant differences in water holding capacity between the treated area and the control ($P<0.05$). The percentage mean difference between the treated area and the control showed that the water holding capacity of the soil in the treated area was about 10.88% higher than that of the control. This implies that the treated area may have had more available water to support soil biota and plant growth than the control area. This is also an indication that the bone meal application may have contributed to the high water retention in the treated soil.

The finding of this study was like that of Rawls et al. (2003), which indicated increased water retention with increased organic matter in sandy soils. The findings also agreed with Bronick and Lal (2005) who report that addition of organic materials to soils influences the water retention capacity of the soil. Brenner`s (2016) study also reported higher water content at 5-10 cm depth, which is within the range of the soil sample depth of this study, although the bone meal application rate was higher in this study (1200 kg/ha) than in her study (560 kg/ha).

This study found no significant differences in bulk density and percentage porosity of soil treated with bone meal and the control ($P >0.05$). Although no significant differences were seen between the treated area and the control for bulk density and % porosity, there could have been a possible change in soil bulk density with time for the treated area considering the improvement in water and organic matter content. As indicated by Bronick and Lal (2005), this may accompany improvement in vegetation. Brenner`s (2016) study in a sandy soil near the study area supported this observation as the study detected a link between decreased bulk density and vegetation cover for all treatments including bone meal. Walker and de Moral (2008) also demonstrated that vegetation cover usually accompanies changes in soil properties such as carbon, nitrogen and phosphorus and affects soil nutrient balance.

5.3 Soil pH, electrical conductivity and nitrate

According to this study, no significant difference was seen in pH_{water} between the treatment and the control. The pH_{water} of both the treated area and the control may be considered as moderately acidic, close to neutral. These findings were similar to those of Stępień and Wojtkowiak (2015) who reported no significant difference in soil pH in bone meal amendments in arable soils. The study also conformed with Brenner`s (2016) study, where she found no significant difference in pH_{water} among treatments and the control but significant differences in pH_{water} at depths of 0-5cm and 10-20cm for the different fertilizer treatments.

In terms of electrical conductivity and nitrate, the study found no significant differences in their concentrations between the treated area and the control. The concentration of nitrate may have been higher in the early years of application since nitrate ions may have been reduced due to mineralization, as indicated by Khalil et al. (2005). Moreover, the pH of the treated area and the control were within the optimum pH range (6 to 8) reported by USAD (2014) to promote nitrification.

6. CONCLUSIONS

Bone meal treatments applied in sandy soils in Iceland tend to affect soil physiochemical parameters. Based on the present study, significant differences were observed between the treated area and the control for some soil parameters such as organic matter content and water holding capacity. No significant differences were seen between the treated area and the control for other parameters such as pH, nitrate, total carbon and nitrogen, electrical conductivity and C:N ratio. The mean difference of some of the parameters, e.g. nitrate, gave an indication of improvement in the treated area compared to the control. This observation suggests that organic fertilizers have a significant influence on soil physiochemical properties. Other studies have shown that the effects of organic fertilizer on soil physiochemical parameters are dose dependent and may also depend on the type of organic fertilizer used for the treatment. Therefore, different organic fertilizers may present different effects on the soil physiochemical properties with respect to types of fertilizers and doses. Consequently, for achieving the utmost outcome in organic fertilization of soils, the type of organic fertilizer and rate of application are important factors to consider. This study suggests further research into the effects of varying rates and frequencies of bone meal application on soil physiochemical properties.

In Ghana, there has been little research on the use of organic fertilizers for soil improvement and in land reclamation activities. The outcome of this study may trigger more research into the use of organic materials in Ghana as organic fertilizers in land reclamation activities. Such studies would guide future use of organic fertilizers in reclamation work to enhance biodiversity and improve ecosystem services to the Ghanaian communities.

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