CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Agrobiology, Food, and Natural Resources

Department of Soil Science and Soil Protection

Comparison of Organic Carbon Stock in the Soil under Different Landuses

DIPLOMA THESIS

Author: MSc. Saven Thai

Supervisor: Prof. Dr. Ing. Luboš Borůvka

Consultant: Ing. Petra Vokurková, Ph.D.

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Declaration

I hereby declare that this MSc. Thesis titled "Comparison of organic carbon stock in the soil under different landuses" is my own work and original. All the sources that I quoted are cited and acknowledged in the references. Being an author I certify that I did not copy from the third persons.

Prague, April 12, 2019

Signature:..

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Abstract

Soil plays an important role in organic carbon stock. Organic carbon stock also depends on different types of land use. Thus the study was aimed to estimate and compare the soil organic carbon stock (SOCs) under different land uses (cropland, grassland, and forestland) and depths (0-10 cm, 10-20 cm, and 20-30 cm) in the Czech Republic. Ninety samples of disturbed soil and 30 samples of undisturbed soil were collected within different land uses and within different depths. The content of soil organic carbon (SOC) was determined by modified Tyurin method. Soil bulk density, porosity, water retention were determined on the samples as well as some chemical characteristics such as pH. In addition, SOC stock was calculated. The data was subjected to statistical analysis through SPSS version 20. The results showed that the pH_{H2O} is significantly different among the land uses. Cropland had highest values with the range from 7.38 to 7.46, followed by grassland range 6.64 to 6.83 and forestland range from 4.62 to 4.47, respectively. The bulk density among the three land uses is also significantly different; cropland had the highest bulk density, followed by grassland and forestland, 1.59 g/cm^3, 1.52 g/cm^3, and 1.42 g/cm^3, respectively. Additionally, the stock of soil organic carbon is statistically different for the first depth (0-10 cm) and 20-30 cm, while the depth 10-20 cm showed no difference among the land uses. However, the total SOCs was significantly different in the whole sampled depth 0-30 cm where forestland retained the highest amount of organic carbon compared to grassland and cropland, 116.31 t/ha, 79.02 t/ha, and 61.57 t/ha, respectively.

Key words: soil organic carbon, land uses, sequestration, bulk density

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1. Introduction

Organic carbon plays a crucial role to contribute soil nutrients, soil structure, microorganisms, environmental sustainability, agricultural productivities, and the global carbon cycle. Organic carbon forms about 58% in the mass of organic matter (Government of Western Australia, 2018). Organic carbon sequestrated into the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota. (Edwards 1999). About 1500 x 10^9 t C in form of soil organic material (SOM) is stored in the world (Oelkers & Cole 2008). A large portion of carbon in the soil helps not only to reduce carbon dioxide (CO_2) concentration of the atmosphere, but also adjusts the balance of carbon between land and atmosphere (Murty et al. 2002). A large number of suggested SOC conserving activities need to be taken in action in order to approach the maximum potential of climate change mitigation and adaptation and food productivity (FAO 2017).

The variation of SOC within a landscape is complicated to evaluate in its contributions to the ecosystem because the distribution of soil organic carbon and soil properties depend on the environmental variables such as slope, elevation, topography, temperature, and soil types and certain land uses (FAO, 2017). Unfortunately, nowadays human activities make the changes of organic carbon stock in the terrestrial ecosystem and exchange between soil and atmosphere through land use, land use changes and the conversion from forest to pasture and agricultural land. According to the research of Murty (2002) reported that agricultural activities are the main factor to deplete organic carbon through tillage and chemical applications. About 30% of carbon has been lost since the conversion of land in the tropical area (Murty et al. 2002). The change from one system to another system could result in the naturally affected to carbon. Additionally, land use change can have consequences on a larger scale. The soil organic carbon stocks in the soil can influence the global C cycle not only by sequestering CO_2, but also by releasing it (Bleuler et al. 2017).

The fluctuation of SOC in horizontal depths is largely debated. There are some reviews reporting that most soil carbon stock at the subsoil less than 30 cm because it is the most biologically active (Chandler 2016). However, according to the research of Gray et al. (2016) found that the concentration of SOC can be further than 30 cm till 100 cm depth. The research revealed that the proportion of SOC stock in the 30 to 100 cm interval as a proportion of the top 100 cm varies from a low of 41% in wet climates up to a high of 59% in dry climates.

Climate appears to be the dominant controller of subsoil SOC storage proportion, with parent material and vegetation cover also having restricted influence (Gray et al. 2016).

2. Scientific hypothesis and objectives

2.1. Hypothesis

Soil organic carbon stocks generally decrease exponentially with depths, but the dynamic of these changes of SOC depends on the locations which are influenced by series of complex interaction between plants growth, climate, soil pH, soil bulk density, soil water retention, soil porosity, topography and site management, and especially biological activities (decomposition).

2.2. Objectives

The aim of this study is to estimate the vertical distribution of soil organic carbon stock in soil within the land-use. The main objectives of this research are 1) to determine the distribution of soil organic carbon stock in the soil at different depths; 2) to identify the organic carbon stock in the soil with different land use; 3) to compare the concentration of soil organic carbon stock between land uses and depths.

3. Literature Review

3.1. Soil organic matter

Soil organic matter is the fraction of soil which consists of plants and animals tissue in different stages of decomposing. Organic matter retains organic carbon and nitrogen. The living biomass including microorganisms such as bacteria, viruses, fungi, protozoa, and algae breaks down the plant residues or detritus and animal waste into humus or organic matter by using carbon as an energy source and nitrogen as a protein source. It even includes plant roots and insects, earthworms, and larger animals, such as moles, woodchucks, and rabbits that spend some of their time in the soil (Kosobucki & Buszewski 2014). The portion of these living microorganisms represents about 15% of the total soil organic matter (FAO 2005). The organic matter is highly related to the soil microorganisms and other organisms living in the soil (Allison et al. 2007). Soil organisms such as insects, earthworms, bacteria, and fungi get their energy by decomposing the plant residues or other animal excrements in the soil (Frey 2005). Sometimes the energy which is stored in the plant residues can be used by the organism to create new cells and chemicals. They can also change the organic matter by mineralization and recycle nutrients for plants growth. The decomposition of fresh plants residues and manure gives off the organic chemical compounds and helps to cling together the soil particle which improves the soil physical structure of soil. The fresh debris or residues such as protein, sugars, amino acids, and starches produce the organic molecules directly. Generally, these molecules will be used by soil microorganisms as food quickly (FAO 2005).

Humus could be described as soil organic matter transformed by specific processes in soil. It can be created by well-decomposed organic residues in the soil. The average period of creating humus in the soil is more than 100 years and it is not food for organisms. Its size is very tiny and consists of chemical properties which are very important for the soil (Bullock 2005). Humus helps to improve the water holding capacity in the sandy soil by reducing soil density and improving aggregation. Humus also helps to prevent harmful chemicals to damage the crops or plants and it reduces the drainage and soil compaction which frequently occur in the clay soil (Ulery 2005).

Black carbon is also considered as organic matter lately. This type of organic matter contains some small pieces of charcoal which are caused by the past fires (cooking fire, in field burning of crops and plants residues and other organic materials or wild burning under low oxygen with the temperature around 370 ^{o}C to 880 ^{o}C) (Magdoff & Es 2009). The uncompleted process results from the carbon retains in the char. Charcoal material maintains the form of carbon, biological activity and keeps the high cation exchange capacity. It probably tends to increase pH and also nutrient availability and it also increases the crop yield while the biochar is applied (Magdoff & Es 2009).

Most of the productive agricultural soil contains of organic matter in amount between 1 and 6 %. Soil productivity has been contributed by the soil organic matter in many different ways such as physical, chemical and biological ways (Magdoff & Es 2009). Soil organic matter contributes in a physical way by enhancing aggregate stability, improving water infiltration and soil aeration, reducing runoff, improving water retention, and reducing the stickiness of clay soil. In chemical ways, the soil organic matter helps by increasing the soil's exchange capacity, improving the ability of soil to resist pH changes, accelerating soil mineral composition and making nutrients in the minerals available for plants. In a biological way, it helps to provide food for the living organisms in the soil, improve soil microbial biodiversity and activities and enhance pore space through the actions of soil microorganisms which help to reduce runoff and increase infiltration (Rumpel & Kögel-Knabner 2011). The recognition of increasing SOM is the source of nitrogen (N), phosphorus (P), sulphur (S) which is stored in the soil (Chenu et al. 2015). The application of nutrients through SOM mineralization can cause to decrease the requirement of inorganic fertilizers. A rapid release of SOM is caused by freshly added residues and the slow release is caused by the old residues. The amount of soil organic matter could be the result of a wide range of agronomic, soil, and environmental effects. Agriculture affects on the level of soil organic matter through tillage, crop rotation, and manure application (Ocio et al. 1991).

3.2. Soil organic matter distribution in the soil profiles

Soil organic matter decomposition in various stages is often clearly measurable within organic soil horizons and underlying mineral A-horizons. The concentration of organic matter in mineral horizons depends on a number of factors such as frequency and duration of decomposition, residues, roots, relative amounts of fine material, types of decomposers (microorganisms), pH, and plant community and temperature (Stolt & Lindbo 2010). Generally, organic matter is found near the surface rather than to the deeper soil depth which makes the topsoil more productive than subsoil. Plant residues sometimes turn to be a part of soil organic matter. The roots of the plant system are more cooperative to the soil organic matter than the plant's leaves and shoots. Organisms such as earthworms and insects decompose the dead leaves, branches and plants on the surface and transfer the nutrients deeper in the soil profile. Normally, the highest part of organic matter is accumulated the surface 30 cm of soil (Magdoff & Es 2009).

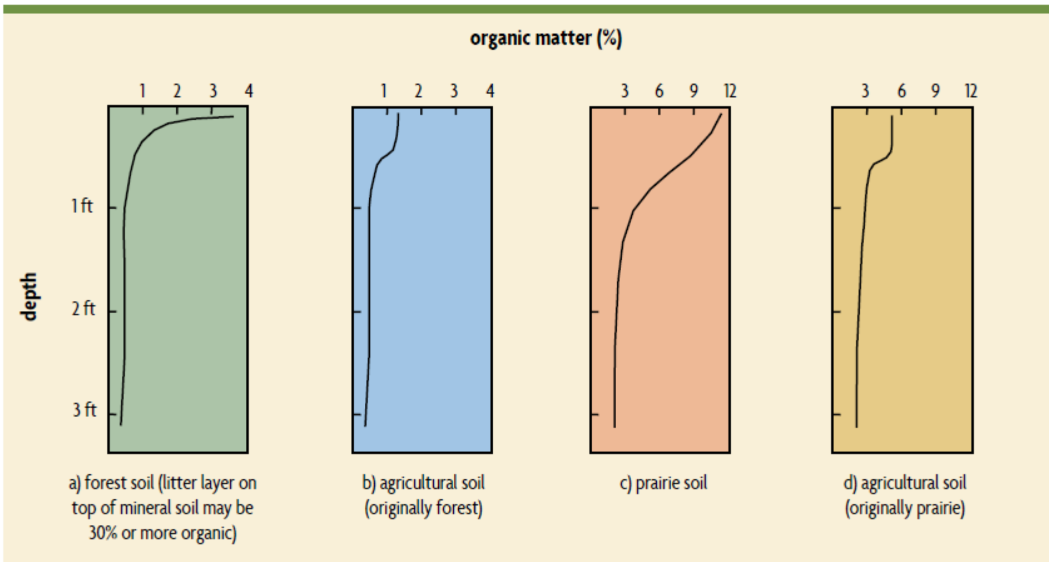

Figure 1.Soil organic matter content distribution in soil depths. (Magdoff & Es 2009)

3.3. Soil organic carbon

Soil organic carbon (SOC) is the component of organic matter which consists of plant residues and animal manure. It defines the carbon in the soil after the partial decomposition of the organic residues through microorganisms (FAO 2007). Soil organic carbon levels are directly involved in the amount of organic matter retained in the soil and SOC is measured according to the organic matter in the soil. Soil organic matter (SOM) consists of about 58 % of soil organic carbon. It is influenced by microbial activity, organic residues availability for microbes and other conditions and management. SOC levels derive from the interaction of the photosynthesis, decomposition, and respiration (Ontl & Schulte 2012). Photosynthesis is the process of plant capture of atmospheric CO_2 into the plant biomass. SOC inputs are not only mainly identified by the root biomass of the plant but also included the residues deposited from plant shoots. Soil carbon derives directly from the growth and death of plant roots and indirectly from the plant roots by transferring the carbon to soil microorganisms. For instance, it is known that most of the plants symbiotic have associated between their roots and fungi which are called mycorrhiza. It means that the roots feed the fungi by energy in the form of carbon while the fungi provide the root back such nutrients for the plant growth as nitrogen, phosphorus, and potassium (Ontl & Schulte 2012).

Organic carbon plays an important role as it improves soil structure, soil fertility, water holding capacity, water use efficiency, biological activity, plant growth and yields, resilience to dry periods, and erosion risk reduction (Liu et al 2006). Soils are the big reservoir for carbon and balancing the global carbon by exchanging greenhouse gas and regulating dynamic biogeochemical processes. The soil degradation happens while the soil organic carbon is lost. Organic carbon in soil is based on the local geology, climate condition, land uses, and management. Soil organic matter stocks in the upper part of soil profile about 800 GtC within the depth 0-40 cm (FAO 2005).

The fluctuation length and rate of SOC accumulation in the soil are highly associated with the productivity of vegetation, physical and biological conditions in the soil, historic inputs of soil organic carbon, and soil disturbance (Rice 2005). The highest accumulation rate of C occurs during the first step of aggrading perennial vegetation growth. It is less than 100 g $C.m^{-2}yr^{-1}$. The average accumulation rate of C in the forestland or grassland is estimated about 33.8 g $C.m^{-2}yr^{-1}$ and 33.2 g $C.m^{-2}yr^{-1}$ (Post & Kwon 2000).

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Table 1. The specific SOC stocks for central European countries within the depth of 30 cm (Smith et al. 1997)

Experiment	Crop/Rotation	No. years	Treatment	Rate per y (t ha^{-1} y^{-1})	SOC to 30 cm (t ha^{-1} y^{-1})	Difference (%) from inorganic only
Bad Lauchstadt, Germany	Sugar bedspring barley/ potatoes/winter wheat	90	30 t ha^{-1} $2y^{-1}$ 20 t ha^{-1} $2y^{-1}$ Inorganic only	15 10 0	87.1 80.2 71.7	21.5 11.9
Praha-Ruzyne, Czech Republic	Sugar beet/spring wheat (since 1966)	38	21 t ha^{-1} $2y^{-1}$ Inorganic only	10.5 0	62 55.8	12.2
Broadbalk. UK	Continuous wheat	144	35 t ha^{-1} y^{-1} Inorganic only	35 0	99.1 49.6	100
Askov, Denmark	Winter cereals/root crops/spring cereals/clover + grass	100	13.5 t ha^{-1} y^{-1} 9 t ha^{-1} y^{-1} Inorganic only	13.5 9 0	57.2 52.2 52.2	9.6 0
Hoosfield, UK	Continuous barley	123	35 t ha^{-1} y^{-1} Inorganic only	35 0	113.2 32.9	244.5
Wohurn Market Garden, UK	Various vegetable crops	30	50 t ha^{-1} y^{-1} 25 t ha^{-1} y^{-1} Inorganic only	50 25 0	72.5 56.9 42.1	72.2 35.2
Deherain, France	Wheat/sugar beet	112	10 t ha^{-1} y^{-1} Inorganic only	10 0	48.7 40.6	20.0
Ultana. Sweden	Arable only	31	9.54 t ha^{-1} $2y^{-1}$ Inorganic only	4.78 0	74.9 53.0	41.2
Woburn Stackyard, UK (1877-1926)	Continuous wheat & barley[2]	49	17.6 t ha^{-1} y^{-1} Inorganic only	17.6 0	72.0 52.8	36.4
Skiemiewice, Poland	Continuous potatoes	70	30 t ha^{-1} y^{-1} Inorganic only[3]	30 0	36.9 27.7	33.0
Skiemiewice, Poland	Continuous rye	70	30 t ha^{-1} y^{-1} Inorganic only[3]	30 0	46.9 34.1	37.6
Thyrow Nutrient Deficiency, Germany	4 maize/barley/potatoes/ barley	25	30 t ha^{-1} $2y^{-1}$ Inorganic only	15 0	28.8 24.2	19.2
Halle, Germany	Continuous rye to 1961; arablerotation since	75	12 t ha^{-1} y^{-1} Inorganic only	12 0	65.5 49.1	33.3
Weihenstephan, Germany	3 course arable rotation	47	30 t ha^{-1} y^{-1} Inorganic only	10 0	38.1 34.8	9.8

3.4. Soil organic carbon loss

Now soils are disturbed by many human activities - land use change in terms of cultivation, constructions and other purposes. The storage of soil carbon has been increasingly depleted. This could affect carbon flux and soil organic carbon dynamics in the soil (Palpanwar & Gupta 2013). It was estimated that the global soil organic carbon loss approximately from 50 to 100 billion tons released to the atmosphere, certainly from the land-use change which results in depletion of soil organic carbon (Lal 2009). The other research showed that the historic SOC loss was estimated about from 115 to 154 Pg C. The average of historic SOC about 20-30 mg C/ha in forest/woodland and about 40-50 mg C/ha in steppe/grassland/savanna in ecosystems has been lost (Lal 2018).

The conversion from natural grassland to cropland causes about 50 % of SOC loss and soils to retain 90% of all C in the grassland ecosystem (Lal 2018). The estimated loss of organic carbon was about 195±65 Pg C. The loss of SOC stock is more serious after the drainage and conversion of peat land (Lal 2018). Depletion of SOC may also occur in various factors including land use pattern, land management, topographic heterogeneity, and climate. The increase of CO_2 release into the atmosphere and the soil temperature may influence to the soil organic carbon inputs via controls on the rate of photosynthesis and carbon loss through decomposition and respiration of both plants and soil microbes (Ontl & Schulte 2012). The sensitive temperature of SOC decomposition also depends on a number of factors such as substrate quality, residues quality, accessibility, molecular structure, enzymatic mechanisms, and microbial physiology (Lal 2018). The capacity of carbon sequestration may be also influenced by local soil management on ecosystem processes such as rainfall infiltration, deposition of sediment and soil erosion. These may affect the rate of carbon loss and carbon inputs in the soil and result in the differences of SOC content sequestrating along the soil profile or across the landscapes. It is estimated that global sediment load is about 36.6 Pg yr^{-1}. Carbon sequestration potential has to consider not only history of SOC stock under the natural vegetation in conversion to other land use, but also the impacts of land use to the carbon loss. The use of the land and management may reduce the carbon inputs and increase the carbon losses. This process may impact the organic carbon level sequestrated into the soil profile and loss from the soil (Ontl & Schulte 2012).

3.5. Factors affecting SOC and SOM

3.5.1. Temperature

Soil organic matter levels and carbon can be affected by the temperature. Soil organic matter can be less while the average temperature gets higher. High temperature may also influence carbon balance by limiting the water availability for the plant and microorganisms in soil, so it reduces the rate of photosynthesis and microbial activity (Ontl & Schulte 2012). According to the United States; Department of Agriculture (1989) reported that when the climate gets warmer, two things will happen; the rate of decomposition of organic matter (residues) in the soil increases because the soil organisms work more rapidly and more actively when more vegetation is produced. It can be a dominant influence to determine the organic matter in the soil. While there is less of vegetation growth and the soil is dry, the decomposing rate is also lower because there is low amount of organic residues or inputs which lead to reducing the microorganism activities. However, when there is rainfall, the decomposition rapidly turns into soil organic matter. In general, the amount of organic matter increases while the average rainfall increases because plants and grasses are growing and they can feed the soil microorganisms. Meanwhile, soil with high precipitation has less decomposition of organic matter than well-aerated soil (Magdoff & Es 2009). For instance, soil temperature has an influence on microbial activity. The best soil temperatures for bacterial activity are between 20 to 38 ^{o}C, but some activity may occur in temperature as low as 5 ^{o}C, in spite of greatly reduced rates. The decomposition of SOM can be reduced if the soil is compacted and fully saturated because the microbes in soil require oxygen and water for their respiration. Due to acidity of soil (low pH), the bacterial activity that is responsible for the decomposition of organic matter is reduced. However, there are some fungi that can breakdown SOM in acidic soil (Petterson 2004).

3.5.2. Soil texture

Soil texture can influence soil organic matter and SOC. Clay and silt tend to have a higher concentration of organic matter than the coarse-textured sands and sandy loams. The organic matter contains in the sands is about 1 %, 2 - 3 % in loams, about 4 or more than 5 % in clays (Magdoff & Es 2009). Clay and fine-textured can combine with organic matter to form tiny aggregates in terms of the protection of the organic matter inside against microorganisms and their enzymes. The bonding of chemical substances can also develop the organic matter and clay soil and fine silt to protect molecules from the attack and decomposition which is done by the microorganisms and their enzymes (Nimmo 2005). The fine textured soil tends to have smaller pores and less oxygen. Thus it can be limiting to the decomposition rate. That is why the fine-texture has a higher concentration of organic matter than coarse soil (Magdoff & Es 2009).

The content of SOC also depends on the soil types, about 12 to 18% of SOC in Histosols, less than 0.6 % of SOC in Arenosols, over 1 % of SOC in the Chernozems known as one of the black soils. Sustainability of agriculture and land uses are well-known to manage SOC, enhance the resilience of the ecosystem, desertification and recover the soil health (FAO, 2005). Soil organic carbon is decomposed by bacterial activities and stabilized in clay or silt size. The maximum concentration of SOC is related with < 5 µm mineral particles. SOC has been identified to be strongly associated with the mineral particle sizes. A greater accumulation and less rapid loss rates are in clay-size organomineral complexes than silt-SOC (Post & Kwon 2000).

3.5.3. Soil drainage and position in the landscape

The organic matter decomposition happens slowly in the poorly-aerated soils; also lignin in plants is not easy to decompose in the anaerobic condition (Inglett et al 2005). When the soil extremely wet for a long time, the organic soil such as peat and muck which consist about 20% of organic matter develop. The organic matter will decompose quickly when the soil is well drained for agriculture or other purposes. The landscape tends to influence of organic matter stability. At the bottom of the hill soils will be rich of nutrients and organic matter which are provided by the runoff, sediments (organic matter) and seepage from the upslope. Thus the bottom of the hill can accumulate the organic matter (Quideau 2002). Topographic position, elevation, and slope can also influence the content and distribution of soil organic carbon in the soil profile. They may occur through soil erosion and sedimentation. Erosion transported the SOC through runoff over the lands and deposits in the lakes, rivers, or the lower place in form of sediment (Sun et al. 2015).

3.5.4. Types of vegetation

The varieties of crops, vegetation, and plants are the main source influencing organic matter. Generally, soil which is under grassland, vegetation provides more organic matter and distributes the organic matter deeper than in the soil under forest vegetation. This should be caused by the deep and extensive root system of forest and grassland species. The forest litter accumulated about 50 % of organic matter on the surface layer or on the topsoil. In contrast, the subsurface of mineral layers in the forest consists of organic matter only about 2 % (Magdoff & Es 2009). Sun et al (2015) found similarity that the shrubland had about 30%, grassland 42%, and forestland 50% of organic carbon in the depth between 20 cm to 1 m. Thus the horizontal distribution of SOC is always fluctuating and is influenced by the subsurface soil inputs of C and then transport the carbon deep into the soil profile. Vegetation characteristics can be assessed from normalized difference vegetation index which relates to the density of vegetation, plant leaves, and biomass. The decay and formation of soil organic carbon can be affected by the interaction of organic residues, soil organisms and soil condition in a certain place and can be different by land cover and land use (Sun et al. 2015).

3.5.5. Soil pH

Normally the soil organic matter decomposes slower in the acidic soil than neutral acidic soil. Acidic soil reduces the earthworm activity and increases accumulation of organic matter at the soil surface rather than distributed through the soil profile (Magdoff & Es 2009). Acid or alkaline soil cause poor production of biomass and decrease the organic matter input to the soil. Soil organic matter and soil pH are connected to each other through decomposition and biomass production. When the soil has strongly acid or alkaline reaction, it can adversely affect the microorganisms which results in reduced plant nutrients. In general, acidic soil is much more favorable for fungi than bacteria (FAO 2005). Otherwise, when the pH is low, it may improve the positive charge group on humus and cause it less soluble in the water. For instance, when pH is decreasing, the hydrogen ion (H^+) will bind to COO- sites of humus and cause it to reduce the cation exchange capacity. Low pH with less soluble SOC will interrupt the microbial activities to use nutrients and energy of SOC (Bot & Benites, 2005). There was an experiment about adding lime in forest land to identify the effect of humus after the pH changes. The result showed that in the added-lime soil sample, CO_2 emission increased yet in the acidified soil samples (Melvin et al. 2013). According to the observation of soil development in England for 25 years, the content of C increases while the soil pH decreases (Kemmitt et al. 2006). The involvement among soil organic matter and pH can differ in reaction when we want to increase the soil pH. For example, when we add the lime to the soil, it means that Ca^{2+} will bind negative charge on the soil particles and humus and stabilize it (Römkens et al. 1996).

3.5.6. Human influences

Organic matter can be lost by erosion and gradually reduced from the soil when the agriculture starts to cultivate it (Parikh & James 2012). Erosion including wind erosion and water erosion is a severe problem for soil fertility (Bullock 2005). A study in three Midwestern soils showed that erosion greatly influences not only organic matter, but the ability of water retention. The organic matter will decrease when there is a great amount of erosion. Additionally, organic matter can be lost from the soil while the microorganisms decompose more organic residues. However, intensive tillage and cropping can turn over the amounts of residues and accelerate decomposition. The rapid loss of organic matter depends on the conversion of grassland to agricultural land by reduction the residue input because of erosion and tillage (Schertz et al. 1985).

3.5.7. Tillage practices

The topsoil erosion and rate of organic matter decomposition can be influenced by tillage (Ping 2005). Tillage is one of the important and basic components of the evolution of agricultural production. There are several tillage effects on the soil such as chemical, biological and physical effects. Tillage can affect soil aggregation, infiltration, water holding capacity, and temperature (Liu et al 2006). Chemical properties change based on the content of organic matter in the soil. Aeration of soil can be also affected by tillage which is an influence on water infiltration rate (FAO, 1993).

The more tilled is the soil, the more break down of organic matter occur in the natural soil aggregates. The soil organic matter is quickly decreased and lost because the organic residues are rapidly decomposed by the organism while the soil intensively is plowed (Liu et al. 2006). The topsoil which consists of high organic matter content will be eroded through the rainfall and wind. Other research found that about 20 % of organic matter was decreased after five years of cropping corn on a clay soil. The huge amount of soil organic matter is lost in the early first year because most of the dead material was decomposed by soil microorganisms (Magdoff & Es 2009). Yeboah et al. (2016) reported that conventional tillage causes soil disturbance and less organic matter or residues on the soil surface comparing to the no-tillage soil. Actually, no-till planters can help increase and improve soil organic matter.

3.5.8. Cover crop and crop rotation

The crop rotation can influence the amount of soil organic matter. The fluctuation of soil organic matter is in the first stages of crop rotation. It could decrease, then increase, and then decrease again. Normally the soil organic matter decreases while annual row crop practice under conventional tillage. Organic matter accumulates in the soil through the plant root production which is covered by hay and pasture crops with less soil disturbance. This tends to increase the soil organic matter and improve soil structure and soil fertility. The increased amount of organic matter in the soil depends on the types of crops we are growing. Some crops could provide a lot of organic residues such as alfalfa (soybean, wheat, potatoes and so on) (Luna et al. 1991).

Excessive crop residues removal may negatively impact the soil physical properties by causing SOC depletion. However, C input within high biomass produced from crop rotation (with no tillage) and residue mulch can not only sustain and enhance soil physical characteristics, but also increase SOC concentration. Increased SOC concentration within good-crop residues management is highly related to soil compatibility and water retention and protect the soil surface from erosion. Otherwise, it also helps to reduce the changes of soil temperature (freezing, wetting and drying cycles) and reduce the net C emission to the atmosphere (Blanco-Canqui & Benjamin 2013).

Changes in agricultural practices by reducing tillage intensity, decreasing or ceasing the fallow period, using winter cover crops, changing from monoculture to crop rotation or altering soil input to increase the main products are some alternative methods to increase SOC in the soil (Smith et al. 1998). For instance, grassland and reforestation restoration on the previous crop field can help to reduce the carbon deficit caused by many years of crop cultivation and sequester carbon to root productivity of plants and crops. Moreover, ponds and wetlands improvement help sequester huge amounts of carbon through the soil profile by reduced decomposing by microorganisms in the waterlogged region with less oxygen. This can cause the carbon gains that exceed the deficits which result from the previous land use. Irrigation of the rangelands and pasture might help to improve carbon levels beyond the historic soil organic carbon stock in the soil unless the inputs of carbon which is under new management exceed levels under natural condition (Magdoff & Es 2009).

There was a study showing that soil carbon loss by the cultivation of forest or grasslands leads to a decrease by 20% of the initial SOC or around 1500g per m^2 in the topsoil 30 cm (Davidson & Ackernman 1993). The similarity research for about 20 years also showed that about 30 % of SOC loss occurs in the first 5 years. SOC loss can be returned to the original land cover or original vegetation by cultivation of forest or grasslands (Davidson & Ackernman 1993). The estimation of the research of the reforestation effects in the tropical agriculture land and pasture on carbon sequestration rate showed that it is about 130 g C m^{-2} yr^{-1} in the first 20 years by abandoning the reforestation and about 41 g C m^{-2} yr^{-1} after 80 years in average (West & Post 2002). Intensive agricultural practice by changing from monoculture to rotation cropping could increase the SOC in the soil. For instant, there was a research showing that changing from conventional tillage to no-tillage sequester a large amount of C in the topsoil 8 cm and lesser amount in between 8 – 15 cm (Kern & Johnson 2009). It also stated that the C sequesters into the soil about 22 g m^{-2} yr^{-1} by using an average of experiment duration 13 years. Likewise, the estimation of the 17 European tillage experiments showed that the average of SOC increase 0.73 g m^{-2} yr^{-1} and it could approach the new equilibrium in about 50 to 100 years (Smith et al. 1998). Along term research in Canada showed that SOC could be sequestered at the rate of 50 to 75 g C m^{-2} yr^{-1} for about 25-30 years. This sequestration also depends on the soil types (West & Post 2002).

3.5.9. Soil erosion

The sediment can transport and redistribute the carbon about 4-6 Pg over the landscape and some of it can emit into the atmosphere. So soil erosion can impact the global carbon cycle. The effects of erosion lead to degrading quality of soils; decrease topsoil depth, and reduce nutrient and water availability for plants including plant growth and productivity. Erosion also influences soil hydrological process and causes floods. Erosion can affect both directly and indirectly on plants growth and soil. Wind erosion and water erosion can remove and wash away SOC. The raindrop and flowing water, blowing wind and gravity can disturb soil aggregates and microbial activity. Olson (2012) stated that accelerated soil erosion is the main issue affected to CO_2, CH_4, and N_2O and influence on SOC sequestration. Emission of carbon by water erosion has been predicted about 1.1 Pg C/year. Erosion–induced transport is caused differently by removing SOC fraction. It means that the minerals bind organic C while particulate organic C is taken off by raindrop (inter-rill erosion) (Olson 2012). Soil erosion which has a high content of C in the sediments leads to losing the SOC to the river, stream or lake and to the atmosphere. The fraction of labile SOC carried by surface runoff and the hydrological process is sensitive to decay and release CO_2 within aerobic conditions. Similarly, a study showed that SOC about 75 Tg C yr^{-1} lost by wind erosion (Hao et al. 2005)

3.6. Effect of organic carbon on soil compaction

SOC content change depends on the management. It may cause soil compaction. SOC is the main component for estimating bulk density due to the soil compaction. Bulk density may decrease gradually when the concentration of SOC is increasing (Liu 2006). SOC interact frequently with soil particle size distribution to affect the bulk density. The bulk density and SOC concentration changes may happen quickly after the addition or removal of crop residues (Akker & Soane 2005). The research on sandy loam by using rice straw to no-tillage soil in Nigeria showed that it could help to bulk density reduction about 0 to 5 cm depth after a half year of straw application as inputs. The residues addition helps to both bulk density reduction and SOC concentration in the soil. The water content increases when the SOC concentration increases. Water content and bulk density are very interrelated with each other according to the difference of soil types and soil climate. This means that decreased concentration of SOC results not only in the formation of soil compaction, but also in decrease the water content (Bhatt 2017). SOC concentration changes can affect porosity by improving soil particle density as well. Soil particle density increases when the SOC concentration decreases. The decrease in particle density with increase in SOC concentration is related to the dilution influences of soil organic particles. Particle density changes may influence soil hydraulic properties by improving the porosity of the soil. Many researchers reported that SOC concentration changes regarding residues management could improve water retention capacity. Research on a silt loam by residue addition (wheat straw) to no-tillage plot for 7 years improved both water retention and SOC concentration in the 0 to 10 cm depth. SOC concentration decrease could reduce the capacity of the soil to uptake and keep the water in the soil because the specific surface of soil is reduced. Soil inorganic particle has a lesser specific surface area and the ability of water adsorption than the organic particle (Duiker & Lal 1999).

Soil organic carbon impacts on the soil physical properties are complicated and numerous. Organic particles help to soil aggregates stability by connecting single particles into stable units and building up inter-particle cohesion within aggregates. Organic matter can also improve some of the hydrophobic properties of the soil. Crop biomass consists of elastic properties and provides elasticity, and rebinding ability to the entire soil. Organic particles consist of lesser density than the mineral particles, which causes the dilution of soil bulk density and decreases high risk of exceeding compaction and compression. Root system, fungal hyphae, and other biological properties may entangle particles of minerals and improve friction forces within soil particles. Electrical charge to the soil is caused by the organic particles to develop and react with chemical bonds among particles and improve soil physical properties (Blanco-Canqui & Benjamin 2013).

3.7. Soil organic carbon sequestration

Soil organic carbon sequestration is the process related to the atmospheric carbon capture by plants or the decomposition of organic residues into the soil for a long time. The process of SOC sequestration occurs through these steps. First the trees or plant capture CO_2 from the atmosphere by doing photosynthesis, then transfer carbon from CO_2 to plant biomass and then the plant biomass transfer carbon to the soil in the form of soil organic carbon (SOC) as the terrestrial ecosystem (Lal 2009). The SOC sequestration can also occur when the plant leaves fall down on the ground and are decomposed by microbial communities into the form of organic carbon and sequestrated into the soil. Soil carbon sequestration can also happen by converting CO_2 from atmospheric into the soil in an inorganic form such as secondary carbonates but the inorganic carbon formation is relatively low (Lal 2008).

Recently, the world soil plays an important role to store the global carbon cycle and a pool for active carbon. The total carbon which has been found in the terrestrial ecosystem is about 1500 billion tons in organic forms and 900 billion tons in inorganic carbonates (Paustian 2005). Some carbon also exists in the elemental carbon and carbonate components such as dolomite, gypsum, and calcite. The amount of carbon stored in the living plants and animals is lesser than in the soil but the larger carbon pool was found in the ocean, mostly in organic form. Soils can stock much more carbon about 2.5 to 3.0 times more than the plants and from 2 to 3 times more than atmospheric carbon dioxide (CO_2) (Oelkers & Cole 2008). Soil organic carbon pool has been recognized that it is one of the major carbon pools for land-use change. Soil organic carbon is stored in the upper 30 cm of the soil layer (Palpanwar & Gupta 2013)

3.8. Carbon Cycle

Carbon is an essential element for all life on earth, which is contained in the atmosphere, animals, plants, fossil fuels, rock and oceans. Carbon is considered as the sixth-most abundant element in the universe. Agricultural cultivation, fossil fuel consumption, and forest clearing have resulted in an increase of CO_2 to the atmosphere since the mid to late 1800s (Rice 2005). Currently, the concentration of CO_2 is about 385 ppm by volume or approximately 582 ppm by mass. However, the CO_2 concentration has increasingly grown from about 325 ppm in 1970 to 380 ppm in this early century (Oelkers & Cole 2008). There is the danger that the increased levels of CO_2 in the atmosphere could lead to global warming (Rice 2005). Besides that, carbon which entered into the soil almost exclusively derives from plants and photosynthetic soil bacteria. Approximately fifty percent of the carbon which is photosynthesized by plants emits through plant respiration into the atmosphere (Cambardella 2005). The carbon is largely stored in the sedimentary rocks within the planet's crust. These rocks are formed partly by the hardening of mud which contains organic matter into the shale or by combination of calcium carbonate particles. Sedimentary rocks accumulate roughly 100 000 000 Pg of carbon on the earth (University of New Hampshire 2008). Another relevant CO_2 storage is the oceans. Isolated from the atmosphere it is captured in depths greater than 1000 metres normally (Oelkers & Cole 2008). About 38 000 to 40 000 Pg of carbon is stored in the oceans (Rice 2005).

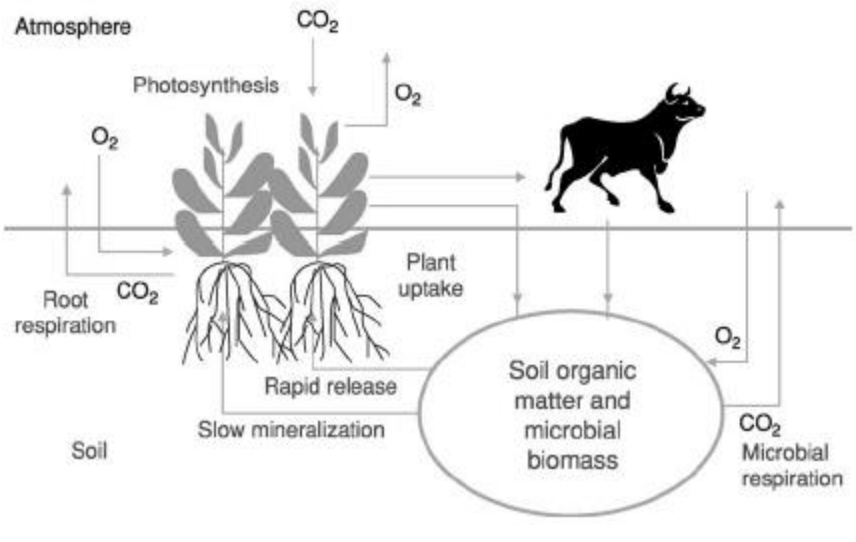

Figure 2. Soil carbon cycle (Cambardella 2005)

As it is shown in the figure 2, the carbon goes through several stages: At first the CO_2 of the atmosphere is converted to carbohydrates by photosynthesis of the plants. Next there are animals and microorganisms which consume and decompose these carbohydrates and then release carbon dioxide and other products through respiration. However, the carbon cycle is more complicated to describe as it is also affected by carbon stored in fossil fuels, soils, oceans and rocks (Rice 2005).

3.9. Decomposition process

The rate of biomass decomposition is caused by exopedonic and endopedonic factors. Endopedonic factors are involved in soil characteristics while exopendonic factors are involved in C: N ratio and other chemical components such as suberin, cellulose and lignin content. Biochemistry of plant residues regularly controls soil C cycle and soil C storage (Lal 2018). Various residues of manures and crops consist of many different properties, so there are different influences on soil organic matter. Materials which contain low amounts of polyphenols, lignin, and hemicellulose such as cover crop (soybean residue) are easily and fast to decompose with a short term influence on SOM levels compared to the materials consisting of high levels of these chemicals. For instance, cornstalks and wheat or rice straw are longer decomposing by microorganisms. Manures containing high hemicellulose, lignin, and polyphenol are decomposed slowly and take longer effects on soil organic matter (Cambardella 2005). Cattle's manures contain high fiber because cattle eat lots of forage and it is not completely decomposed so its process on the soil takes longer than hogs, or chicken which is fed by grains containing low fiber. Normally, materials consisting of lots of cellulose or other easy-decomposed materials are greatly affecting on soil aggregation. Aggregates are created from the end products of decomposition by soil microorganisms, an organic application like manure, straw and cover crops. Many types of residues are added to provide to feed the diversity of microorganism population, provide nutrients for plants or crops and also improve the soil aggregates. Materials with low lignin and hemicellulose normally provide high nutrient levels for plants. Otherwise, rice or wheat straw consisting of lots of lignin could be applied to promote organic matter but it can affect to nitrogen deficiency and imbalance of microorganism population in the soil (Magdoff & Es 2009).

So the available materials of nitrogen need to be added at the same time to improve the nitrogen deficiency. The ratio between the amount of residues nitrogen and carbon can affect the available nutrient and decomposition rate. The ratio which focuses on the C:N ratio could be from the young plants, 15:1, and about 50:1 and 80:1 for the old straw. Generally, the comparison ratio of C:N of soil organic matter may be about 10:1 and 12:1 and the C:N of soil organisms is approximately 7:1. Low C:N residues result in high content of nitrogen and high C:N residue result in low content of nitrogen. Crop residues consist of 40 % of carbon in average but its figure doesn't fluctuate much from plant to plant while the amount of nitrogen changes much on the types of the plants and the growth stage. It is differently considered of nitrogen availability. Residues such as green plants, young or fresh plants are easily and rapidly decomposed and may release nutrient for plants and crops. Some resides consist of lignin in old plants and in the woody portion of trees may not quickly decay in the soil as well as well-composted organic residues because they are stable and have already undertaken a specific amount of decaying (Hoyle 2013).

Decomposition of plant residues by soil microorganisms occurs leading to the carbon loss as CO_2 due to the microbial respiration. Decomposition, photosynthesis, and respiration rate depend on the climate such as soil temperature and soil moisture. For instance, in the cold region, the photosynthesis surpasses decomposition which increases the SOC levels. In arid regions, the levels of SOC is low because of low primary production while the tropical region has intermediate levels of SOC due to warm temperature for decomposition and high rate of primary production and rainfall availability as well. Climatic factors can increase the productivity during summer when the temperature and moisture are high while the cold temperatures slow down the decomposition rate and low productivity results in lower organic matter or organic carbon over the time. Changes of the quantity and quality of soil organic matter may affect the soils to conserve the ecosystem and biodiversity in the soil (Ontl & Schulte 2012).

3.10. Soil microorganisms

Microorganisms are very tiny forms of lives which sometimes can live as single cells. A microscope is used to capture the individual microorganism cells. Most of the microorganisms live in the topsoil where they can find food easily. They are mostly found in the abundant area especially close to the plant roots which is called rhizosphere. These microorganisms are the main composers of organic matter and produce nitrogen fixation, detoxify harmful chemicals, produce more products for plant growth. Soil microorganisms also can be a source of antibiotic medicine to fight against diseases for human health and for other purposes (Magdoff & Es 2009).

3.10.1. Bacteria

Bacteria can be found in the soil, sea water, fresh water, and the animal digestive, in the compost pile with a temperature of about 54 ^{o}C. Some species of bacteria live in the flooded soil without oxygen and wetland. Bacteria generally can boost the better pH soil. Bacteria have more activities in the neutral pH soil than in acidic soil. Bacteria provide some benefits to plants by releasing nutrients when it begins to decompose the litters or residues (Rousk et al. 2009, & Magdoff & Es 2009). Most of the bacteria can dissolve phosphorus for plant uptake and it is very useful for nitrogen fixation for plants and soil improvement. Nitrogen gas can be taken from the atmosphere and transformed as nutrient available in the soil by some types of bacteria and plants can uptake it as amino acids and proteins. Nitrogen fixation bacteria can beneficially associate with plants by doing symbiotic relationship which is good for agriculture involving the rhizobia group bacteria that live inside nodules formed on the roots of legumes. Then the bacteria produce the nitrogen in a usable form for plants and the plants will provide back sugars for energy for bacteria. Nitrogen can fix hundred pounds of nitrogen in the alfalfa region. Peas, or soybean, alfalfa can produce high nitrogen around 33 to 56 kg/ha. Another group of bacteria like actinomycetes can break down lignin molecules into smaller pieces (Wuest & Gollany 2012). The large and complex lignin can be found in plant tissues which are difficult to decompose by microorganisms. Lignin can protect other molecules like cellulose from breaking down by bacteria or other microorganisms. Characteristic of actinomycetes is similar to fungi but they can form in a group by themselves sometimes. Soil bacteria are also the abundant and diverse groups of soil organisms which help to regulate the ecological processes such as soil carbon. Bacteria including *Bradyrhizobium japonicum, Burkholderia sp, Mycoberium sp* in soil C fixation improve the rate of soil carbon sequestration and storage. The majority of bacteria depend on soil carbon storage to gain energy. Therefore there are strongly related to soil bacteria and soil carbon storage. For instance, soil bacteria directly decay the soil organic matter and contribute to increasing soil carbon storage into the soil profile. Soil bacteria also have indirect influences on the soil carbon storage through improving soil aggregation due to the byproducts of microbial degradation (Yang et al. 2018).

3.10.2. Fungi

Some fungi can be used to produce some antibiotics. We can find fungi growing on the bread if we keep it a long time. The fungus is identified that it can cause many diseases such as damping-off, downy mildew, apple scab, and various types of the rotten plant root. Fungi decompose the fresh residues or debris. They help other soil microorganisms decompose the organic residues by softening it. Fungi are a type of soil organisms and a main decomposer of lignin and can tolerate more acidic soil than bacteria do. Low disturbed soil tends to promote fungal growth and accumulation of organic matter at or near the surface. Fungi and plants have good interaction between root and soil. Fungi can infect the plant root system and send the root out like hyphae which are about 1/60 diameter of the plant root (Baskaran 2017).

These hyphae are able to absorb water and nutrients and then feed the plants and exploit the water and nutrients into the small pore of the soil. Hyphae help plants to uptake the nutrients and water and plants provide sugar as energy for fungi by producing in its leaves and send to the root systems. This interaction between fungi and roots is called mycorrhizal relationship. These hyphae of fungi help soil aggregation stability by sticking gel which clings together the mineral and organic particles (Wetterstedt 2010). Mycorrhizal fungi which form symbiotic has highly associated with plants by gaining photo assimilated C and provide the plant nutrient availability (Smith & Read 2010).

3.10.3. Algae

Algae are one of the diverse groups of microorganisms that capture energy from sunlight for photosynthesis. Algae are really important for agriculture practices as bio-fertilizer and soil stabilizers. Algae such as seaweeds are used as fertilizers, resulting in less nitrogen and phosphorous runoff than the use of livestock litters (Abdel-Raouf et al. 2012). Algae are also important for the freshwater environment and aquatic systems. They act as an aquatic food chain, remove nutrient and pollutants from water, sediments stability, and produce oxygen and uptake carbon dioxide (Carole 2003). Algae can be found in the fallow area like in the flooded soil, swamp and rice field, on the surface of poorly drained soil and in the wetland. Algae can occur in the dry soil by forming a beneficial relationship with other organisms. For example, lichens on the rock are the formation between fungus and an alga (Magdoff & Es 2009). When algae grown in the ponds, they uptake the nutrients from the wastewater for their cell synthesis. They extracted the nutrients for the synthesis of cell mass which is called ammonia nitrogen. The algae growth and cell division depends on the activity of photosynthesis and nutrient availability (Paul & Cheremisinoff 1995)

3.10.4. Protozoa

Characteristic of soil protozoa can range up to 100 μ in some species but the most common size is about 50 μ or less. Protozoa can live in a small drop of moisture and bear with hot temperature, high carbon dioxide and low oxygen (Stout 1952). Protozoa are a single-celled microorganism. Protozoa can be a secondary decomposer of organic residues, feeding on fungi, bacteria, other protozoa and other organic molecules which are dissolved in the soil water. Protozoa release nutrients from organic molecules by mineralizing into the agricultural soil (Magdoff & Es 2009).

3.10.5. Nematodes

Nematodes are simple multicellular soil organisms and microscopic, worm-like organisms that live in soil pores which are filled by water. Mostly, they live in the upper soil layers where plant roots, organic matter, and other sources are (Peterson & Luxton 1982). Nematodes help to feed on fungi, protozoa, bacteria, and other nematodes and help breakdown of the organic residues. So they can be moderate the population of bacterial growth and help regularly maintain the population of plant-parasitic nematodes. Nematodes feeding can produce about 50% or more of mineralized nitrogen. Many of nematodes can kill and parasitize insects such as Japanese beetle and larvae of cabbage looper. Other nematodes can cause serious diseases such as heartworm and blindness by infecting animals and humans (Ugarte & Zaborski 2014).

3.10.6. Earthworms

Earthworms play important roles as the restorers and maintainers of soil fertility. Earthworms live in the soil and dead or degraded organic residues. There are more than 2000 earthworm species which have been identified and about 300 more are still recorded. Different kinds of earthworms including field worm, night crawler, and manure worm can be identified by their behavior and feeding habitat. Earthworm's activities perform as biological, physical, and chemical in the soil profile. Some earthworms feed on organic matter and other types can feed on the plant residues which remain on the soil surface. The surface-feeding earthworm breakdown and mix the fresh organic matter with bacteria, enzymes and soil mineral particle through their digesting system. The dead plant material can be recycled and improve available nutrients, from humus by the earthworms by decomposing and deepen the organic material through the soil profile. They provide burrowing which improves aeration, soil structure, soil physical properties, infiltration, porosity, and loosen soil, and plant root growth (Myburgh 2017). Earthworms grow and function in well-aerated soil which could supply a sufficiency of organic matter into the soil. They can release the sticky substances from their skin and the other substances which are released by the fungi or other organisms help improve and bind to make soil structure and soil aggregate stability. Georgia's research found that the soil with high amounts of organic matter exists in the high number of earthworm population. The plenty of earthworm populations are mostly found under no tillage soil compared to the conventional tillage soil. Insecticide, pesticide, and fertilization application are very harmful and affect earthworm growth (Hendrix et al. 1990).

4. Materials and Methods

4.1. Site Selection

The research area was conducted at the outskirt of Prague, Suchdol, Prague 6, Czech Republic. It is about 10 km from the study site to Prague airport. It is located in latitude 50°06'N and longitude 14°15'E. The area is situated 380 m a.s.l. and has the mean annual precipitation about 470 mm and the mean average temperature 8^{0}C (http://www.weatherbase.com). The study focused on three main land uses, namely cropland, grassland and forestland in order to identify the organic carbon stock in the soil vertically in various land uses. The sites selections were selected based on the locality in the Czech Republic. Roztocky Haj was selected as forestland where forest is conserved and biodiversity protected for many years.

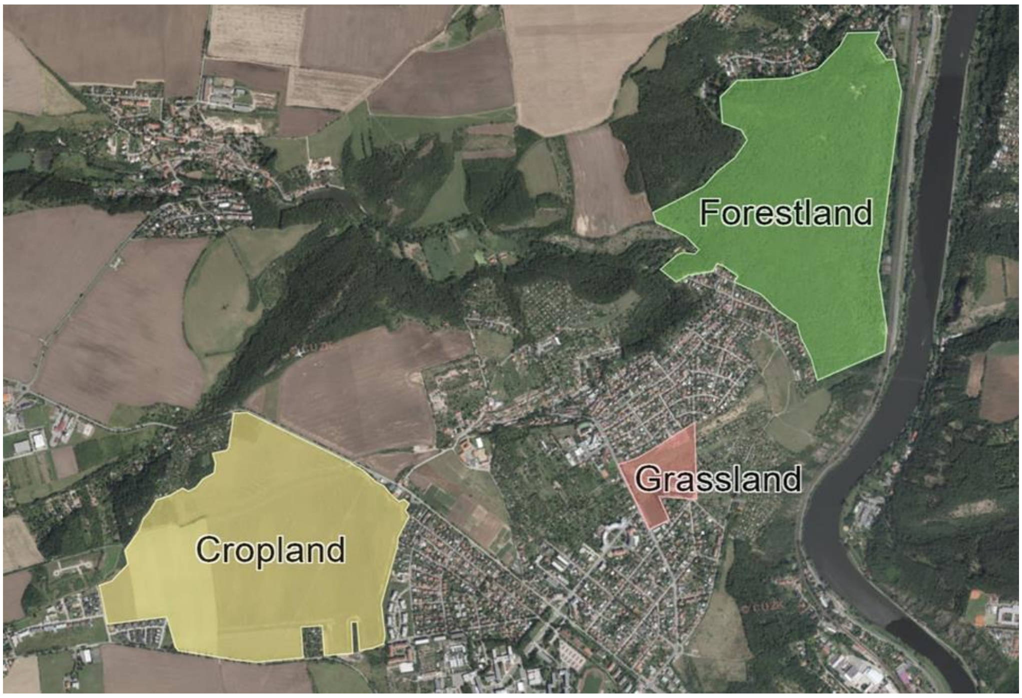

Figure 3. Localization of research sites on cropland, grassland and forestland in Prague-Suchdol

4.2. Soil Sampling

Soil samples were collected in April and May 2018. Triplicate samples cores of 100 cm^3 were used for undisturbed soil samples to determine water retention, bulk density, and porosity. Auger was used for disturbed soil samples collection to determine the pH value and organic carbon. To take the same soil sample, all the cover grass and vegetation had to be cleared before taking the sample and for undisturbed soil samples dug it gently and some roots of grass and vegetation are removed by using knives and the cover it. Before sampling all the triplicate samples cores were weighted and recorded the number of rings. Ninety soil samples of disturbed soil were collected in horizontally in different depth, 0-10, 10-20 and 20-30 cm, 30 soil samples on each land use and 30 soil samples of undisturbed soil were taken, 10 samples in each land use. For undisturbed soil samples, we collected interval depth, from 0-10 and 20-30 cm depth. All samples including disturbed and undisturbed samples were collected in S shape spatial distribution order to figure out the average of organic carbon content in the whole area.

Table 2. The soil samples within different land uses and depths

Depth (cm)	Cropland	Grassland	Forestland
Disturbed soil		Samples	
0-10	10	10	10
10-20	10	10	10
20-30	10	10	10
Undisturbed soil			
0-10	5	5	5
20-30	5	5	5
Total	40	40	40

4.3. Soil preparation

After taking the samples from the field, disturbed soil samples were air dried in the laboratory for several days until there is no humidity in the soil samples. After that, they were ground and sieved with 2 mm sieve to remove the debris, rock, and stone from the soil. The undisturbed soil samples were kept in the room and quickly taken them to analyze the bulk density, water retention, porosity, and soil particle density because the soil samples might be interrupted from microorganisms in the soil.

4.4. Soil analysis

4.4.1. Soil pH

pH was determined by analyzing the soil pH_{H2O} and $pH_{KCl.}$ Testing pH is to define the negative logarithm of H^+ concentration. The pH_{H2O} determination was done as follows: firstly 10 g of dry soil (fine soil < 2mm) was weighted to put into the 50 mL beaker and then add 20 mL of deionized water in the beaker too. The deionized water is boiled for 5 minutes to remove CO_2 and cooled before adding to the soil. Then the suspension was stirred with the glass stick for 5 minutes. Finally, the glass electrode carefully submerged and after reaching equilibrium, the pH value is recorded. The determination of pH_{KCl}, 20 g of dry fine soil was used, put it into the 100 mL beaker and 50 mL 0.2M KCl solution added. Glass stick was used to stir the soil for 5 minutes. Finally, the electrode was submerged in the suspension and the pH value recorded. The pH_{KCl} determination is to define the exchangeable acidity caused by free hydrogen ions and by hydrogen ions which are released by neutral salt solution from organo mineral soil complex.

4.4.2. Soil water retention

Soil water retention is to identify the water retained in the soil. The water retaining in the soil depends on the soil porosity, soil particle, and bulk density. To determine the soil water retention: first undisturbed soil samples in the 100 cm^3 ring were soaked with glass covering and filter paper at the bottom in water for one day to let the soil fully saturated with water. Then the saturated soil samples were weighed according to the time interval which 0 minutes is the initial time, then 30 minutes, 120 minutes, and 24 hours. For the glasses covering, filter paper and rings, weights were recorded.

4.4.3. Bulk density

Soil bulk density was used to express how compact the soil is and it is used to calculate soil organic carbon stock in order to identify the amount of SOC in the soil. Bulk density is expressed as mass per unit volume of soil (units of g/cm^3). For measurement of soil bulk density, first, the empty cylinder core (100 cm^3) was weighed and read the number of the ring before going to take the soil samples at the field. After collecting the soil samples were dried in the oven until stable weight. Finally, the dried samples were taken to weigh again to measure the weight. The soil bulk density was calculated using the following equation:

$$\rho_d = \frac{m_z}{V_s}$$

- ρ_d is soil bulk density (g/cm^3)
- m_z is the mass of dry soil (g)
- V_s is volume of the soil samples (cm^3)

4.4.4. Soil particle density

Soil particle density is a measurement to identify the average density of all the components composing the soil. Soil particle density focus on the soil particles without pores in the soil. To measure soil particle density: first, fill a pycnometer to the top with distilled water without adding the stopper during this step, then place the pycnometer to the water bath which is set to 20 ^{o}C and leave it for 20 minutes. After 20 minutes, the pycnometer was removed from the water bath and added the stopper. The pycnometer has to be dried outside the glass and then weigh it with the distilled water inside H_2O. Besides that, the soil samples which are already sieved were weighed 10 g and put into a metal bowl and then add a small amount of water over the soil and gently heat the soil mixture over a flame for 5 minutes. And then the solution was cooled down. After that, empty the pycnometer, then using a wash bottle and funnel, the soil suspension was gently added into the dried pycnometer. Then the pycnometer has to be filled till the top with distilled water and place soil suspension into the 20 ^{o}C of water bath without stopper. Leave it till 20 minutes, and remove the pycnometer from the water bath and add the stopper. The pycnometer has to be dried outside the glass and weigh it with the soil suspension. The soil particle density was calculated using the following equation:

$$\rho_z = \frac{N_z \cdot \rho_v}{N_z + P_{H2O} - P_z}$$

- ρ_z is particle density (g/cm^3)
- ρ_v is density of water (1g/cm^3)
- N_z is mass of soil (g)
- P_{H2O} is mass of pycnometer with distilled water (g)
- P_z is mass of pycnometer with soil suspension (g)

4.4.5. Soil porosity

Soil porosity is that portion of the soil volume occupied by pore spaces. This property does not have to be measured directly since it can be calculated using values determined for bulk density and particle density. Soil porosity was calculated through the following equation:

$$\mathrm{P} = 1 - \frac{\rho_d}{\rho_z}\, x\, 100$$

- P is porosity (%)
- ρ_d is soil bulk density (g/cm^3)
- ρ_z is soil particle density (g/cm^3)

4.4.6. Soil organic carbon

Soil organic carbon can be measured with several different methods. In this research, modified Tyurin's method was used to determine the soil organic carbon. For the procedure of the method: firstly grind a small amount of soil and sieve it through 0.25 mm sieve. The soil samples were weighted between the range 0.05–0.4g. The different weight is according to the expecting of organic carbon content. It means that the weight of the sample to be used is determined usually according to the color of soil: darker color means in most cases higher organic matter content, less weight is taken if the soil is rich in organic matter. Then take the weighted soil sample into the 100 mL beaker. Dichromate solution ($K_2Cr_2O_7$) in sulphuric acid (H_2SO_4) was added (10 mL) into the beaker and covered with the glass and shaken softly. After that put it into the oven heated to approximately 125 ^oC and let it react for 45 minutes. After 45 minutes, take the heated soil solution and wash the covering glass and walls of the beaker with distilled water. And then add some distilled water before titrating so it doesn't affect the result. On other hands, the electrode must be submerged and should not disable the stirring. Finally, the solution with dichromate was titrated potentiometrically with the Mohr salt $(NH_4)_2Fe(SO_4)_2$ within a stirrer to mix the solution. The titration reaction is accompanied by a color change from orange to blue-green and the clockwise of the electrode move upward and stop. Then the consumption of Mohr salt is recorded. Three blank samples of dichromate solution ($K_2Cr_2O_7$) without soil were determined through the same procedure above in order to know the concentration of dichromate solution.

The organic carbon content was calculated in percentage (%) using the following equation:

$$C_{org} = (12 - 0.3 \times S \times f) \times 100/N$$

- f is the dichromate factor (f = 40/a)
- a is mean consumption for blank sample titration (mL)
- S is consumption for titration of the samples (mL)
- N is the sample weight (mg)

4.4.7. Organic carbon stock

Organic carbon stock is to identify how many kilograms per hectare of carbon is stocked in the soil with different land uses and depths. Organic carbon stock was calculated according to the following formula:

$SOC_{stock} = SOC_{content}$ x BD x depth

- SOC_{stock} is the soil organic carbon stock (t/ha)
- SOC_{conten}t is the soil organic carbon content (C_{org}) in the soil (%)
- BD is the bulk density ($\rho_{d,}$ g/cm^3)
- Depth is the depth of the respective soil layer (cm)

4.5. Data analysis

SPSS version 20 (IBM, SPSS, USA) was used to analyze the data. In order to run the data properly, the homogeneity of variances was applied to check its normality. One-way ANOVAs were also applied to figure out the statistical difference among the groups of land uses and depths at significance level description $p<0.05$. To compare the data which is higher or lower, Tukey test was used to identify the land uses and depths which contain higher organic stock with describing a, b, c, where “a” is the highest value, followed by “b”, “c”.

5. Results and Discussion

5.1. Soil pH_{H2O} and pH_{KCl} values in all the land uses

Table 3: The differences of pH_{H2O} and pH_{KCl} among the land uses

Depth (cm)	Cropland	Grassland	Forestland	p_value
pH_{H2O}				
0-10	7.38 ±0.24[a]	6.64 0±0.76 [b]	4.62±0.18 [c]	0.000***
10-20	7.31±0.36 [a]	6.80±0.67 [b]	4.34±0.16 [c]	0.000***
20-30	7.46±0.46 [a]	6.83±0.63 [b]	4.47±0.20 [c]	0.000***
pH_{KCl}				
0-10	6.76 ±0.37 [a]	5.93± 0.60 [b]	3.58±0.21 [c]	0.000***
10-20	6.76±0.34 [a]	5.72±0.79 [b]	3.34±013 [c]	0.000***
20-30	6.86±0.43 [a]	5.91±0.69 [b]	3.65±0.099 [c]	0.000***

****, **, * , indicating significance at p < 0.001, 0.01, 0.05, respectively. ns= non significance*

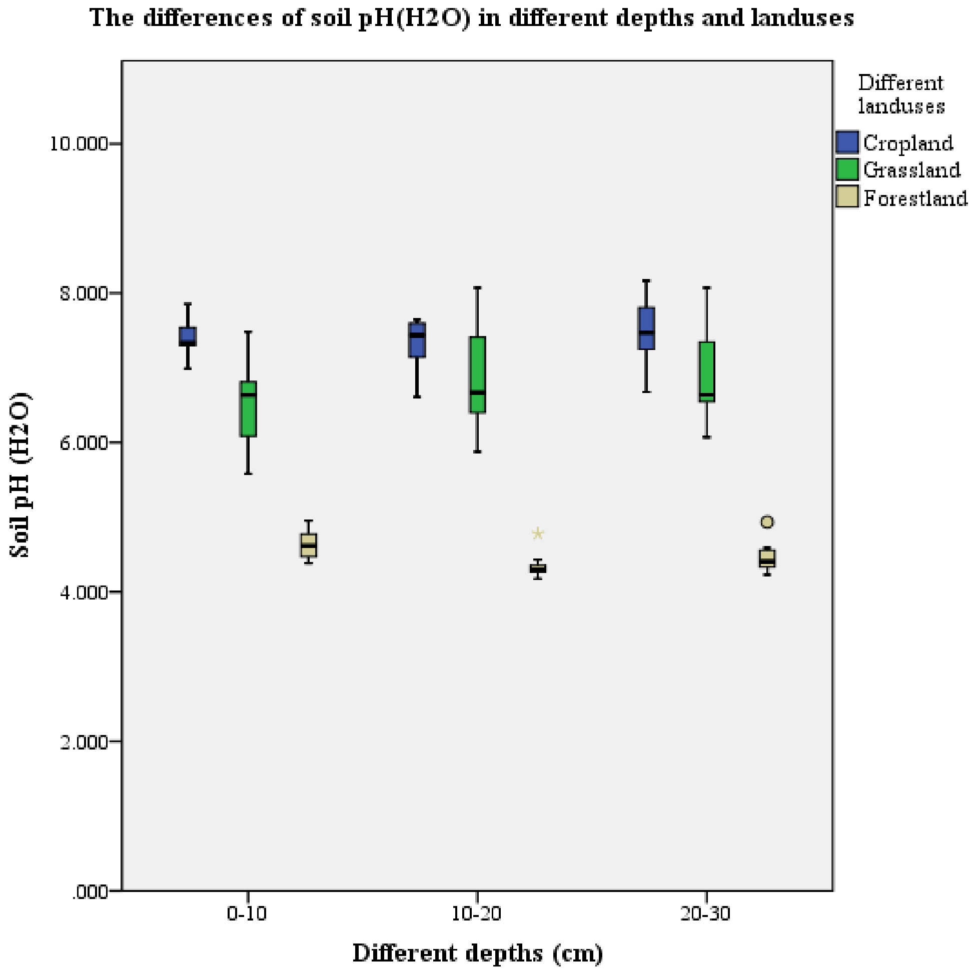

Figure 4. pH_{H2O} in soil of various of land uses in each depth ($p < 0.05$)

According to the analyzed data above showing that the pH values in the depth between 0 and 10 cm are significantly different between the three land uses, cropland, grassland, and forestland (at p-value <=0.001). The value of pH_{H2O} in the table (Table 3) showed that the cropland had the highest value, compared to grassland and forestland with the average values of 7.38, 6.64, and 4.62, respectively. It is the same as the pH in the depth from 10 to 20 cm and 20 to 30 cm which is also showing significant differences (p_value < 0.05) between the three land uses. This means that the cropland is more alkaline soil with pH value 7.38 while the forestland has more acidic soil with the pH value 4.62 (Table 3).

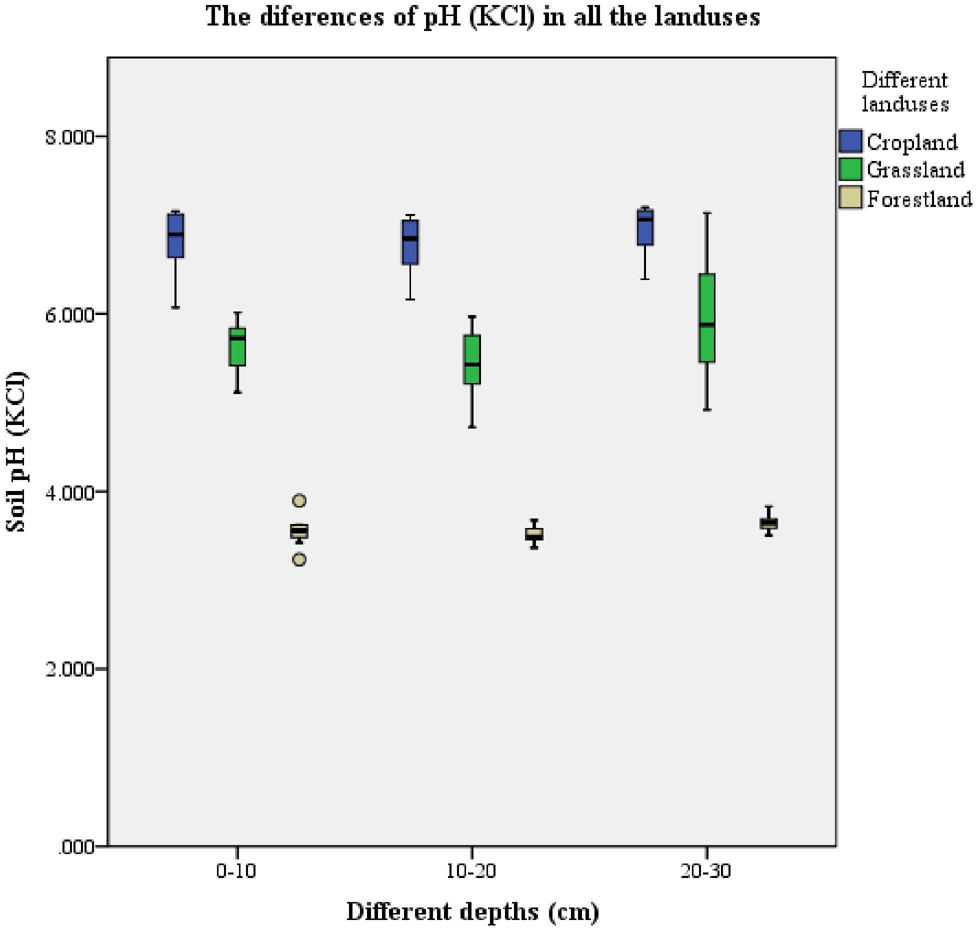

Figure 5. Differences of pH_{KCl} between land uses in each depth (p <0.005). (Note: a- highest value, b- second highest, c- lowest)

The pH which is determined with KCl also showed that it is significantly different in all the three depths (0-10, 10-20, and 20-30 cm) (Table 3) between the land uses (cropland > grassland > forestland). Moreover, the highest pH value was cropland, then grassland and the forestland is the lowest pH value.

The pH of cropland had the highest value, followed by grassland and forestland. In general, the pH of cropland and grassland is higher than in forestland. The low pH results is reducing the biological activity and reduced SOM decomposition (Jones et al. 2017). Normally, biological processes depend on pH because organisms and cells need to maintain and keep pH in equilibrium and specific for their enzymes (Simon & Beevers 2012). Otherwise, high pH in cropland may result from adding of the lime to neutralize the soil pH for crops cultivation by the owner of cropland. Adding lime in the crop field, it makes soil neutral or improves pH from acid soil. Liming materials consist of calcium (Ca) or/and magnesium (Mg) which dissolve and will neutralize acidic soil. Calcium hydroxide has a strong base and quickly ionizes to Ca^{2+} and OH^- ions (United States, Department of Agriculture, 1989). The calcium ions take place of the absorbed H ions on the soil colloids and acidic soils are neutralized. The variation of pH may also be affected by other land uses and depends on the rainfall, and vegetation types, and tree species (Goulding et al. 2010). In general, varieties of plants are known as source of natural residues and organic materials. Some specific trees are well recognized to produce organic residues and organic acids which tend to acidify the soil (Liu et al. 2013). Furthermore, some kinds of trees may also result in the soil acidity through their respiration and base cation absorbed and released. Over adsorption of cations and sequestration by trees could turn the soil to become more acidified in the forest and caused the pH below 5 (Sala et al. 2003). Therefore, this may result in the fact that forestland had the lowest pH in this research.

5.2. Vertical distributions of the soil pH, SOC, bulk density, porosity and SOC stock in the soil in cropland

The results (Table 4) showed that no significant differences between different depths were identified in both pHs which are determined with water and KCl. The cropland is more alkaline through the soil profile from 0 to 30 cm.

Table 4. The distributions of pH, SOC, SOCs, bulk density, porosity in cropland through the soil profile.

Depth (cm)	pH_{H2O}	pH_{KCl}	SOC	Bulk density	SOC stock	Porosity
			%	g/cm^3	t/ha	cm^3/cm^3
0-10	7.38±0.24	6.79±0.37	$1.37±0.17^a$	$1.49±0.14^b$	$20.44±2.68^{ab}$	$0.42±0.081^a$
10-20	7.31±0.36	6.76±0.33	$1.41±0.20^a$	$1.59±0.07^{ab}$	$22.43±3.13^a$	$0.36±0.03^{ab}$
20-30	7.38±0.46	6.85±0.43	$1.11±0.13^b$	$1.69±0.04^a$	$18.70±2.32^b$	$0.32±0.02^b$
p_value	0.689^{ns}	0.852^{ns}	0.001***	0.019*	0.018*	0.049*

****, **, * , indicating significance at p < 0.001, 0.01, 0.05, respectively. ns= non significance*

However, in the distribution of SOC there are significant differences through the soil profile from 0 to 30 cm (p_value <0.05). The results showed that the concentration of SOC in the soil is mostly contained in the surface soil at the depth 0-10 cm (1.37%) and 10-20 cm (1.41%), while the depth 20-30cm (1.11 %) has the lowest concentration of soil organic carbon. It can be also observed that the SOC stock horizontal distribution through the soil profile is significantly different by p_value is smaller than 0.05 which is mentioned in the table 4. SOC stock is mainly in the first depth (20.44 t/ha) and the second depth (22.43 t/ha), and the depth 20-30 (18.70 t/ha) was the following. Overall, the highest SOCs in the soil profile in the cropland is mostly in the second depths. This might be that the second depth has less disturbance of the soil and more organic matters all the land uses can sequestrate and stock into the soil within the depth 10-20 cm. While taking the soil samples in cropland, the field was just plowed so it could adversely affect to the SOC and SOCS in the first depth of the soil layer. According to Magdoff & Es (2009) reported that the more tillage on soil, the more break down of organic matter. Therefore, the organic matters are decomposed quickly by soil microorganisms which results in SOC loss through their respiration and temperature exposure. SOC and SOCs accumulated within the organic residue, less soil disturbance, and less decomposition of organic matter (Luna et al. 1991).

Soil bulk density in cropland is statistically different between the depths at p_value is lower than 0.05 (Table 4). The results showed that the depth 20-30 (1.69 g/cm^3) had the highest bulk density, comparing to the depth 10-20 (1.59 g/cm^3) and the depth 0-10 (1.49 g/cm^3). It means that the bulk density is higher and higher through the soil profile for the cropland. If we observe the porosity data, they show that the first layer of soil (0-10 cm) has more porosity compared to the second depth and the third depth. This might result from the uses of agricultural machinery for plowing, fertilizing, and harvesting which make the soil more compacted in the subsoil. Furthermore, during the data collection, the crop field had just been plowed, so it might result in the fact that topsoil has lower bulk density and gain more porosity.

5.3. Vertical distributions of the soil pH, SOC, bulk density, porosity and SOC stock in the soil in grassland

According to the analyzed data (Table 5), it showed that no significant differences were identified for the pH which is determined both in water (H_2O) and KCl between the depths of grassland soil (0-10, 10-20, and 20-30 cm). However, the pH in grassland is moderately acidic soil which is in the average of good pH for plants and crops grown.

Table 5. The differences of pH, SOC, SOC stock, bulk density and porosity in grassland through the soil depths (0-10, 10-20, 20-30 cm)

Depth cm	pH_{H2O}	pH_{KCl}	SOC %	Bulk density g/cm^3	SOC stock t/ha	Porosity cm^3/cm^3
0-10	6.65±0.77	5.93±0.60	2.11±0.31[a]	1.46±0.088 [b]	30.96±4.61[a]	0.41±0.045
10-20	6.80±0.67	5.73±0.79	1.58±0.25[b]	1.52±0.049 [ab]	24.13±3.82[b]	0.38±0.035
20-30	6.82±0.62	5.91±0.70	1.51±0.38[b]	1.58±0.038 [a]	23.93±4.54[b]	0.35±0.046
p_value	0.825 [ns]	0.788 [ns]	0.000 ***	0.036*	0.001***	0.104 [ns]

****, **, * , indicating significance at p < 0.001, 0.01, 0.05, respectively. ns= non significance*

Soil organic carbon is significantly different between the three depths of grassland. The first depth from 0 to 10 cm (2.11%) had the highest organic carbon content compared to the depth from 10-20 (1.58 %) and 20-30 cm (1.51%). Additionally, the SOC stock among the three depths in the grassland was statistically different ($p\_value < 0.05$). SOC had the highest stocks (30.96 t/ha) in the depth from 0 to 10 cm compared to the depths 10-20 cm (24.13 t/ha) and 20-30 cm (23.93 t/ha). It means that the distribution of SOC stock is decreasing through the soil profiles (0-10 > 10-20 > 20-30). The decreasing of SOC stock in the soil profile may result from organic matter, plant residues and decomposition deposited mainly on the topsoil. And it tends to have more microorganism activities. All of these factors tend to have more organic carbon stock in the first layer of soil rather than in the deeper soil layers.

According to the analyzed data in the table 5 above, bulk density is significantly different in the grassland between the three depths. Bulk density in the 3^{rd} depth had the highest value (1.58 g/cm^3) while the depth 10-20 and 0-10 come after, 1.52 g/cm^3 and 1.46 g/cm^3, respectively. In this case, the soil bulk density gets bigger and bigger when the soil is getting deeper. This might be that the first layer has more organic matter and organic carbon stock than the deeper layer. There might have more microorganism activities which lead to higher porosity and looser soil than the deeper layers. In general, the deeper soil, the higher soil bulk density. It can be also observed values of the soil porosity in the analyzed table (Table 5) clearly showing that it has decreased downward through the soil depths (0.41 > 0.38 > 0.35).

5.4. Vertical distributions of the soil pH, SOC, bulk density, porosity and SOC stock in the soil with different depths in forestland

According to the data in the table 6 above showing that the pH determined with the distilled water (H_2O) is significantly different between the depths while pH determined with KCl is not. The pH_{H2O} in the depth 0-10 cm (pH=4.62) had the highest value the forestland comparing to the depth 10-20 (pH=4.34) and 20-30 cm (pH=4.46). In total, the soil in the forest has more acidity comparing to the grassland and cropland which is mentioned above.

Table 6. Differences of pH, SOC, SOC stock, bulk density, porosity in forestland through the soil depths

Depth cm	pH_{H2O}	pH_{KCl}	SOC	Bulk density	SOC stock	Porosity
			%	g/cm^3	t/ha	cm^3/cm^3
0-10	4.62 ± 0.18^{a}	3.59 ± 0.21	5.64 ± 2.54^{a}	1.32 ± 0.24	74.72 ± 33.89^{a}	0.45 ± 0.083
10-20	4.34 ± 0.16^{b}	3.52 ± 0.13	1.78 ± 0.49^{b}	1.42 ± 0.12	25.33 ± 6.92^{b}	0.43 ± 0.05
20-30	4.46 ± 0.20^{ab}	3.65 ± 0.099	1.06 ± 0.34^{b}	1.52 ± 0.11	16.26 ± 5.18^{b}	0.42 ± 0.056
p_value	0.008 **	0.206 ns	0.000 ***	0.21^{ns}	0.000 ***	0.884^{ns}

****, **, * , indicating significance at $p < 0.001, 0.01, 0.05$, respectively. ns= non significance*

According to the data in the table 6 above showing that the pH determined with the distilled water (H_2O) is significantly different between the depths while pH determined with KCl is not. The pH_{H2O} in the depth 0-10 cm (pH=4.62) had the highest value the forestland comparing to the depth 10-20 (pH=4.34) and 20-30 cm (pH=4.46). In total, the soil in the forest has more acidity comparing to the grassland and cropland which is mentioned above.

The content of soil organic carbon (SOC) in various depths in forestland is statistically different. The SOC in the depth 0-10 cm (5.64 %) had more content, followed by the depth 10-20 (1.78 %) and 20-30 (1.06%). It means that the organic carbon is lesser and lesser when the soil depth gets deeper. It is the same as the SOC stock in the soil. The analyzed data showed that it is a significant difference between the depth layers. SOC mainly stock in the depth 0-10 cm (74.72 t/ha), the following is the depth 10-20 cm (25.33 t/ha), while the depth 20-30 cm (16.26 t/ha) has least SOC stock. This clearly showed that the distribution of SOC stocks into the soil profile decrease when the soil gets deeper. It might result from the components of organic matter, residues, and soil microorganism activity.

Bulk density through the depths in the forestland is not significantly different (Table 6) but it has different values in the analyzed data. The results revealed that the bulk density in the depth 20-30 cm was highest compared to the depths 10-20 and 0-10 cm, 1.52 >1.42 > 1.32 g/cm^3, respectively. It assumes that the soil bulk density gets naturally more compact when the soil is deeper.

5.5. Water retention in soil in various land uses

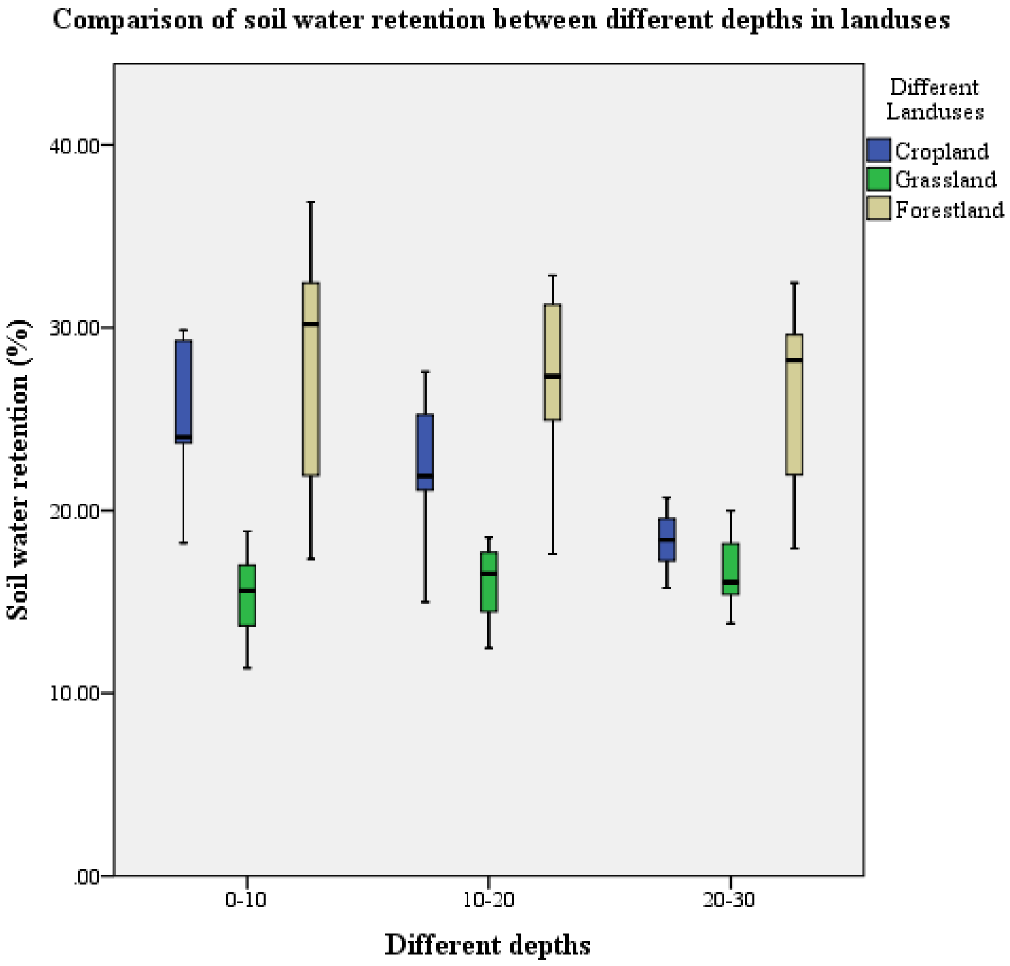

Figure 6. Water retention within different depths in various land uses (p <0.05)

The water retention is to identify how much water can be retained in the soil. The results of the research above (Figure 6) showed that it is significantly different between the land uses and depths ($p < 0.05$). The forestland had the highest value, followed by cropland and grassland with the range values from 27.76 to 26.03%, 25.01 to 18.33%, 15.31 to 16.89%, respectively (appendix 1).

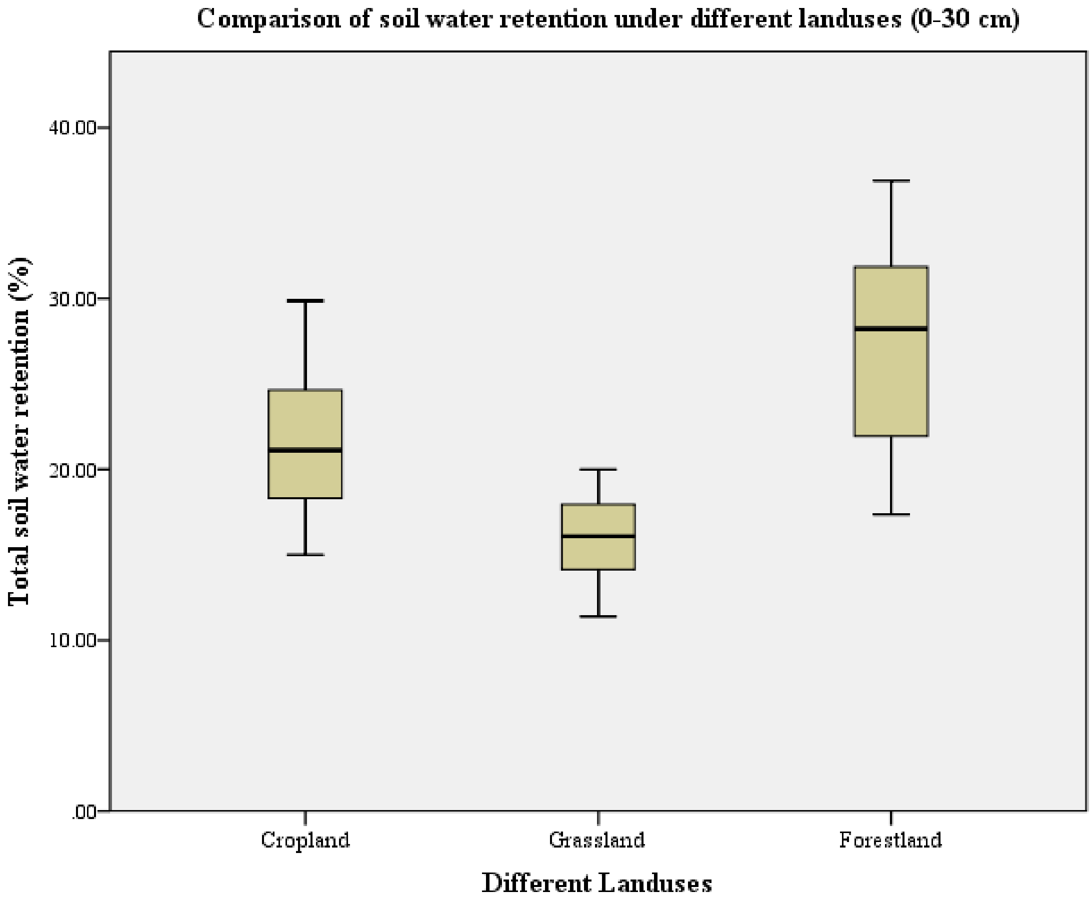

Figure 7. The different water retention in various land uses within the depth 0-30 cm (p < 0.05)

The depth of 0-30 cm shows that the water retention is significantly different among the land uses (Figure 7). Forest had highest value, 26.86%, followed by 21.83% for cropland, and 15.98% for grassland, respectively which are significantly different ($p <= 0.001$) (appendix 1). It means that the water retention in forestland had higher than cropland and grassland. The water holding capacity had decreased with increasing depth through the soil profile in all the land uses (Figure 7). This results from the fact that the first depth had higher water retention. Tillage in cropland can affect soil aggregation, infiltration, and water holding capacity. Therefore, the cropland in this research had the second weakest holding water. Because tillage causes the soil has more aeration which is an influence on water infiltration rate (FAO 1993).

5.6. Soil bulk density (BD) in all land uses

Based on the analyzed data shown in the table 7, it is revealed that the bulk density in the first depth (0-10 cm) has no significant difference between the three land uses while the bulk density in the depth between 10-20 cm and 20-30 cm is significantly different with the p_value which is lower than 0.05 (p-value < 0.05).

Table 7. Differences of soil bulk density between various land uses in each depth according to the Tukey test and ANOVA in SPSS (p <0.05)

Bulk density (g/cm^3)				
Depth (cm)	Cropland	Grassland	Forestland	p_value
0-10	1.49±0.14	1.47±0.088	1.32±0.17	0.288 ns
10-20	$1.59±0.069^{a}$	$1.53±0.05^{ab}$	$1.42±0.12^{b}$	0.032 *
20-30	$1.69±0.036^{a}$	$1.58±0.038^{ab}$	$1.53±0.11^{b}$	0.01**
0-30	$1.59±0.12^{a}$	$1.52 ±0.08^{ab}$	$1.42 ±0.18^{b}$	0.006**

Note: a-highest value, b- second highest, c- lowest, ns-non significant
****, **, * , indicating significance at p < 0.001, 0.01, 0.05, respectively. ns= non significance*

This means that the bulk density in the depth 0-10 cm is not significantly different among the land use (cropland, grassland, and forestland). However, the depth of 10-20 cm showing the cropland and grassland has higher bulk density comparing to the forestland, 1.59, 1.53, and 1.42 g/cm^3, respectively. It is also the same at the depth from 20 to 30 cm. The cropland and grassland have higher bulk density than forestland with the value 1.69, 1.58, and 1.53 g/cm^3, respectively. The depth 0-30 cm also clearly showed that cropland had highest bulk density compared to grassland and forestland with the value of 1.59 g/cm^3, 1.52 g/cm^3, 1.42 g/cm^3, respectively ($p<0.05$). Lower bulk density in forestland may result from the high organic matter and it is an untouched place which produced larger soil porosity by soil microorganisms.

Even though the first depth of soil profile is not significantly different but the second depth, the third depth layer, and the total depths (0-30 cm) are significantly different. Research on soil structure under different land uses also found that arable land and grassland had higher bulk density forestland within the range from 1.54 g/cm^3 to 1.41 g/cm^3 due to the moisture content of soil, machinery utilization which put pressure on the soil (soil compaction) (Aggarwal & Sharma 1984; Bessah et al. 2016) Various reports showed also similar findings that the bulk density in the cropland was higher than forestland and grassland in depth 10-20 cm but no significant difference was found between grassland and forestland in soil bulk density (Evrendilek et al. 2004). Furthermore, the results of Muktar et al (2018) reported that bulk density was significantly different among the land uses with the range from 1.18 g/cm^3 to 1.42 g/cm^3. It added that cropland had higher bulk density than grassland because it was related to the organic matter. The findings of Teixeira and Huwe (2000) research found that agricultural land had higher bulk density than other land uses such as agroforestland and grazing land.

However, the data (Table. 4, 5, & 6) showed that the bulk density is gradually increasing when the soil is getting deeper for all the land uses. And it is significantly different between the depths for the cropland and grassland with the value range from 1.49 - 1.69 g/cm^3 and 1.46 -1.58 g/cm^3, respectively. Unfortunately, no significant difference was found in the forestland, though the mean values seem to be different, from 1.32 g/cm^3 at the first depth (0-10 cm) to 1.52 g/cm^3 at the third depth (20-30 cm). It could be assumed that the bulk density is higher through the vertical soil profile. Generally, bulk density increases with the soil profile depths due to the changes of organic matter, porosity and compaction stated (Chaudhari et al. 2013). The lowest bulk density was in the surface layer in all the land uses due to the high organic matter, particle size distribution, root penetration and better soil aggregation in the top of soil layers (Muktar et al. 2018). It is also consistent with the finding of Bessah (2016) who reported that bulk density tends to increase with the soil depths in all land uses.

5.7. Comparison of the soil organic carbon (SOC) content in all land uses

Table 8. Differences of soil organic carbon content between the various of land uses (cropland, grassland, forestland) in each depth

Soil organic carbon (%)				
Depth (cm)	Cropland	Grassland	Forestland	p_value
0-10	1.37±0.17^b	2.11±0.31^b	5.64±2.54^a	0.000***
10-20	1.41±0.20	1.58±0.25	1.77±0.49	0.067^{ns}
20-30	1.11±0.14^b	1.51±0.29^a	1.06±0.34^b	0.001***
0-30	1.29±0.22^b	1.73±0.39^a	1.88±0.81^a	0.000***

****, **, * , indicating significance at p < 0.001, 0.01, 0.05, respectively. ns= non significance*

Soil organic carbon content in the depth 0-10 cm is statistically different between the land uses with p_value smaller than 0.05 (p_value <= 0.001). This indicates that SOC has significant differences among the three land uses in the first depth. According to the data above showing that the SOC in the forestland (5.64±2.54) had the highest value, followed by the grassland (2.11±0.31) and cropland (1.37±0.17). It is the same at the depth from 20 to 30 cm, while the SOC in the second depth (10-20 cm) is not significantly different between the land uses. For the 20-30 cm depth, SOC in the grassland (1.51±0.29) is the highest, while the SOC in the cropland and forestland is almost the same in value (1.11±0.14 and 1.06±0.34). Overall, the SOC in the depth 0-10 and 20-30 cm is significantly different among the groups of land uses while the depth 10-20 cm is not.

5.8. Comparison of soil organic carbon stock (SOCs) in all land uses

Table 9. Differences of SOC stock within various land uses

Soil organic carbon stock (t/ha)				
Depth (cm)	Cropland	Grassland	Forestland	p_value
0-10	20.45±2.68 [b]	30.96±4.60 [b]	74.72.77±33.70 [a]	0.000***
10-20	22.44±3.13	24.13±3.82	25.33±6.92	0.428[ns]
20-30	18.71±2.32 [b]	23.93±4.52 [a]	16.26±5.18 [b]	0.001***

****, **, * , indicating significance at $p < 0.001, 0.01, 0.05$, respectively. ns= non significance*

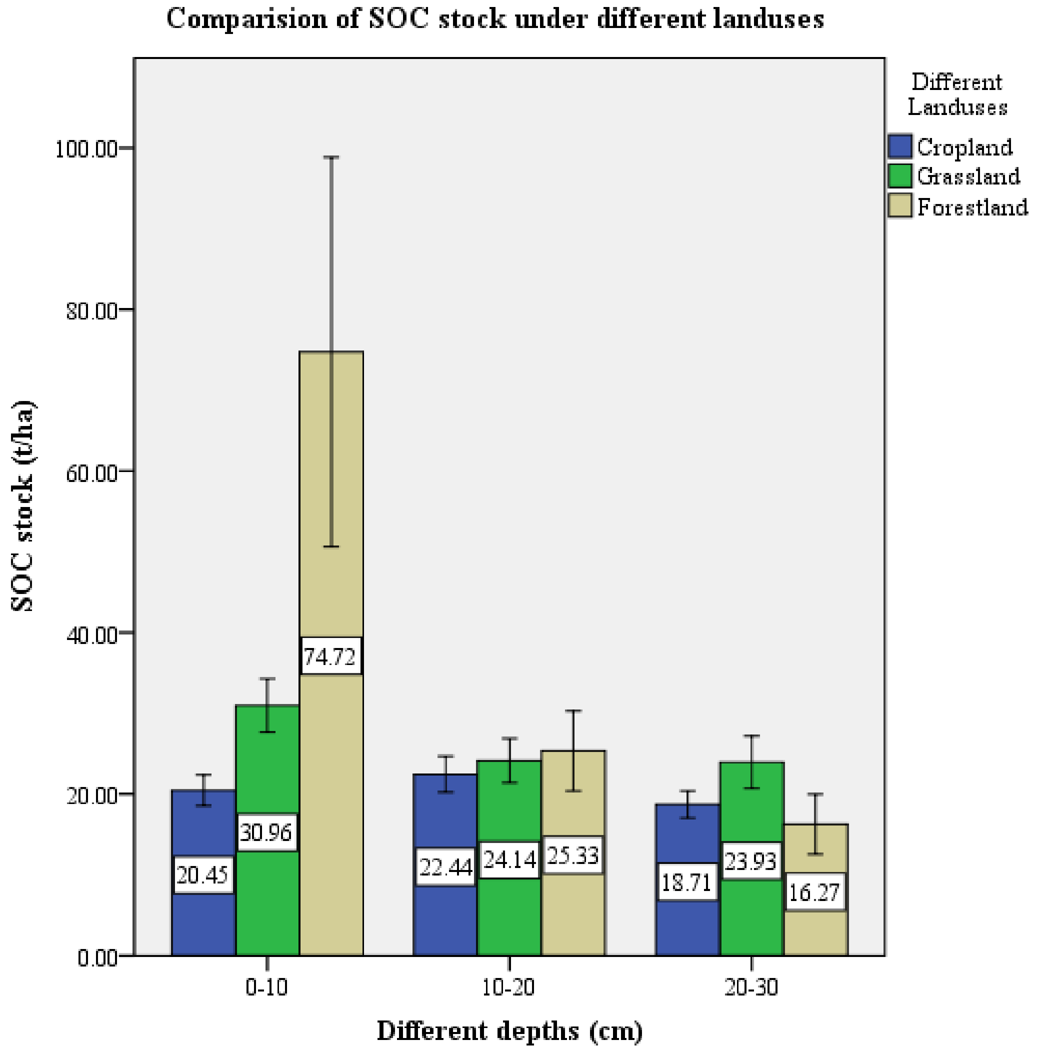

Figure 8. Differences of soil organic carbon stocks with various land uses in each depth according to ANOVA and Tukey test in SPSS (p <0.05)

Among the land uses, the soil organic carbon stock (SOCs) in the depth 0-10 cm is significantly different (p_value < 0.05). The results showed that SOCs in the forestland (74.72 t/ha) had the highest of SOCs among the land use groups, while grassland (30.96 t/ha) and cropland (20.45 t/ha) were following. No significant different was found in the depth of 10-20 among the land uses. This means that the amount of SOCS is similar in the depth 10-20 cm among all the land uses. Otherwise, SOC stock varied with land-use types and in the depth 20-30 cm it is significantly different. Grassland (23.93 t/ha) had a higher SOC stock than cropland (18.71 t/ha) and forestland (16.26 t/ha).

In total, SOCs in the depths of 0-10 and 20-30 cm are significantly different between the land uses, while in the depth 10-20 it is not significantly different. It is revealed that the forestland had the highest SOC stock with the value of 74.72 t/ha in the surface layer (0-10 cm) while the sub-soil layer (20-30 cm) was grassland with the values of 23.93 t/ha.

The differences among the land uses in the depth 0-10 cm might result from organic matter input and content, soil porosity, soil aeration, soil compaction, and also soil pH affecting the rate of SOM decomposition. The research on relationship between soil phenolic acids and the soil microbial community under different land uses showed that the microbial communities are promoted in the topsoil but inhabited in the greater depths of the soil (Li et al. 2019). Balesdent et al. (2018) also reported that SOCs accumulate in the first depth (0-10 cm) and forestland stock highest amount of SOC, followed by grassland and cropland. However, cropland had lowest SOCs at the 10 cm due to the reduction of incorporation of carbon and high SOM mineralization in the surface layer compared to the deeper layers.

The differences of SOCs in the depth 20-30 may result from a low concentration of organic matter, soil types, and less microbiological decomposition. Generally, microorganisms accumulated more in the topsoil because there are many varieties of food feeding them (Magdoff & Es 2009). The result showed that grassland had the highest SOCs compared to cropland and forestland. Similarly, various the findings showed that grassland had the highest content of SOC stock in the soil among the land uses (grassland > forestland and cropland) (Yuan et al. 2018). Muktar et al. (2018) also had the same result which reported that highest SOC and SOCs in the grazing land was found due to lack of tillage, high amount grass roots, and high root biomass turnover rate which could prevent soil from erosion.

In the deeper layer from 0-30 cm, forestland had rapidly decreased organic carbon and consisted of less organic carbon than cropland and grassland. Similarly, the research is reported that cropland could increase subsoil SOC storage and that the higher subsoil SOC stability is not only a result of selective preservation of more stable SOC fractions (Alcántara et al. 2017). Magdoff & Es (2009) reported that soil under grassland and vegetation provides more organic carbon and distributes the organic carbon deeper than in the soil under forestland. It could result from the deep and extensive root system of forestland and grassland species. Additionally, forest litter mostly accumulated about 50 % of organic matter on the surface layer or on the topsoil comparing to cropland and grassland (Magdoff & Es 2009).

5.9. Comparison of the total of soil organic carbon stock in all land uses

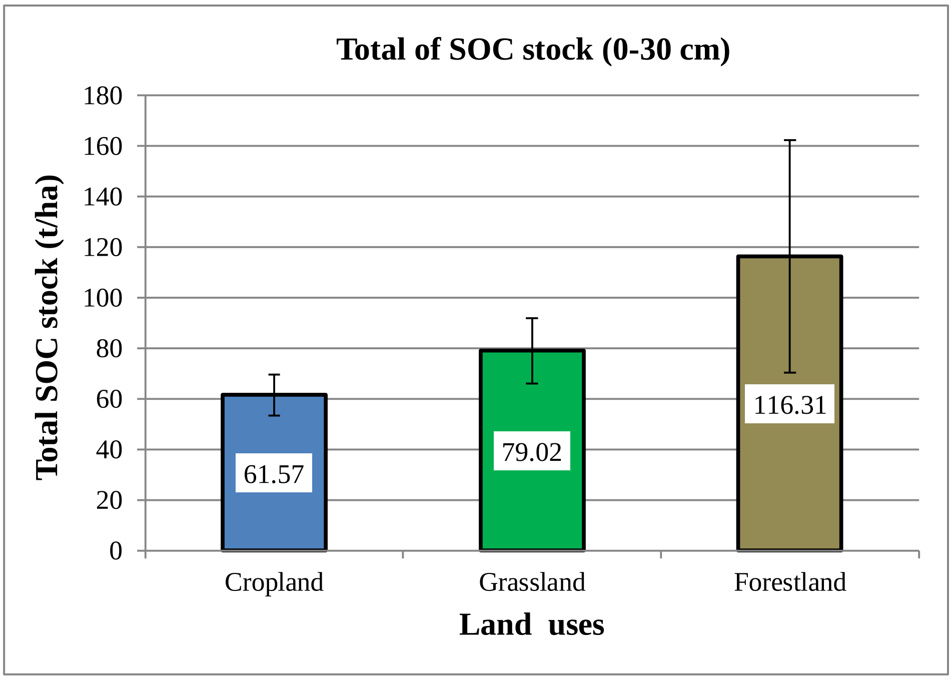

Figure 9. Comparison of the total SOC stock in various land uses in the whole sampled depth (0-30 cm)

The total of SOC stock in various land uses (Figure 9) revealed that the forestland stocks higher organic carbon than grassland and cropland with the mean values of 116.31 t/ha, 79.02 t/ha, and 61.57 t/ha, respectively (forestland > grassland > cropland). Generally, organic carbon stock is found mostly in the forestland and grassland rather than cropland. Lower SOC stock in the cropland may result from the use of chemical inputs, tillage, and monoculture application. Kempen et al. (2019) had the agreement that forestland and grassland had higher carbon stocks than cropland with the value of 6.9 kg/m^2, 4.8 kg/m^2, and 3.8 kg/m^2, respectively. Another similar research, Dorji et al. (2014) reported that the concentration of SOC had highest in the forestland, followed by grassland and cropland due to the high organic carbon inputs, slow decomposition, and deep rooting depth. It is also added that the lowest in cropland may result from a low incorporation of manure and crop residues and tillage.

According to FAO (2017), the unsustainable agricultural management which is applied in the agro-ecosystems such as extensive tillage, chemical utilization, and monoculture may result in interfere the web of interaction in the community between pests and their natural enemies. Soil biodiversity tends to be decreased through the toxic pollutants by affecting the reproduction, survival, growth of the soil organisms while they are bio-accumulated (Bagyaraj & Ashwin 2017). Microbial decomposition is related inversely to the accumulation of soil organic matter (FAO 2017). On the other hand, more tillage may also lead to a greater breakdown of organic matter by the destruction of soil aggregates and the soil organic matter is quickly decreased and lost because the organic residues are rapidly decomposed by the organisms when the soil intensively is plowed. Furthermore, the topsoil which consists of high organic matter will be eroded through the rainfall and wind (Magdoff & Es 2009 & Rice 2005). On the other hand, the organic matters are decomposed quickly when the soil is drained for agriculture or other purposes. Hence, decreasing soil organic matter may negatively affect SOC stocks (Quideau 2002).

6. Conclusion

Organic carbon stock is significantly different in various land uses. Forestland had the highest organic carbon stock, followed by grassland and cropland. Highest organic carbon stock in forestland results from the high organic matter which covered the surface. However, soil tillage and pH are also important causes why the cropland had the lowest organic carbon. Tillage may break down the soil aggregates, enhance the soil organic matter rapid decomposition by soil organisms and cause erosion through rainfall and wind. High soil organic matter decomposition results in organic carbon lost to the atmosphere through the microorganisms' respiration and climate exposure and quickly absorbed by plants. Therefore, the stability of soil organic carbon stock tends to depend on the various land uses. Nevertheless, even on the cropland the SOC stock can be improved by proper agricultural management, like sufficient organic fertilization and reduced tillage practices. However, forest can still be considered as the land use with biggest ability to stock soil organic carbon.

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8. Appendices

Appendix 1: The table of differences of water retention among the land uses.

Appendix 2: Soil sampling both disturbed and undisturbed soil samples

Appendix 3: Laboratory experiments

Appendix 1: The table of differences of water retention among the land uses.

Land uses	Depth	30 min	120 min	24 hours	Total (0-24 h)
	cm	%	%	%	%
Cropland	0-10	9.69±2.40	5.19±0.76	10.13±2.23	25.02 ±4.76
	10-20	8.26±2.02	4.63±0.96	9.27±1.99	22.16±4.78
	20-30	6.39±0.63	3.91±0.56	8.02±0.95	18.33±1.93
Grassland	0-10	5.14±1.24	3.24±0.75	6.92±1.20	15.32±2.9
	10-20	5.68±1.14	3.25±0.67	7.01±0.99	15.94±2.47
	20-30	6.29±1.13	3.30±1.06	7.10±0.91	16.69±2.42
Forestland	0-10	8.34 ±2.68	5.68±1.53	13.73±3.87	27.76±7.96
	10-20	8.80±2.90	5.56±1.12	12.44±2.64	26.80±6.01
	20-30	9.49 ±4.38	5.46±0.85	11.07±1.85	26.03±5.94

Water Retention (%)

Depth (cm)	Cropland	Grassland	Forestland	p_value
0-10	25.01 ±4.76 ^{a}	15.31 ± 2.90 ^{b}	27.76±7.96 ^{a}	0.011*
10-20	22.16±4.78 ^{ab}	15.94±2.47 ^{b}	26.80±6.01 ^{a}	0.010*
20-30	18.33 ±1.93 ^{b}	16.89 ±2.42 ^{b}	26.03±5.94 ^{a}	0.005**
0 – 30	21.83±4.71^{b}	15.98±2.48 ^{c}	26.86±6.24 ^{a}	0.000***

Appendix 2: Soil sampling both disturbed and undisturbed soil samples

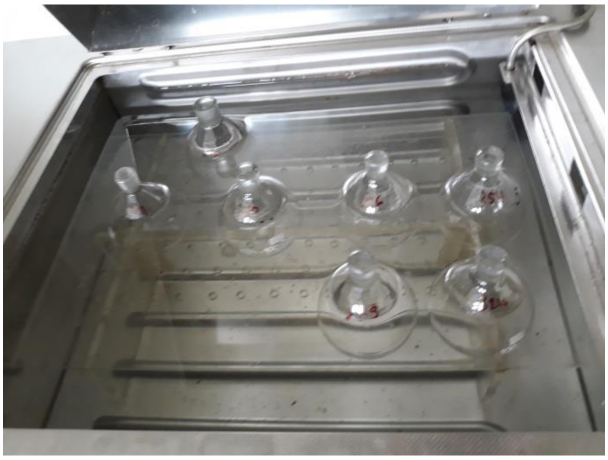
A. Disturbed soil sample

B. Undisturbed soil sample

Appendix 3. Laboratory experiment

Appendix 3.1: Laboratory determination of soil particle density determination

A. Weighted soil sample

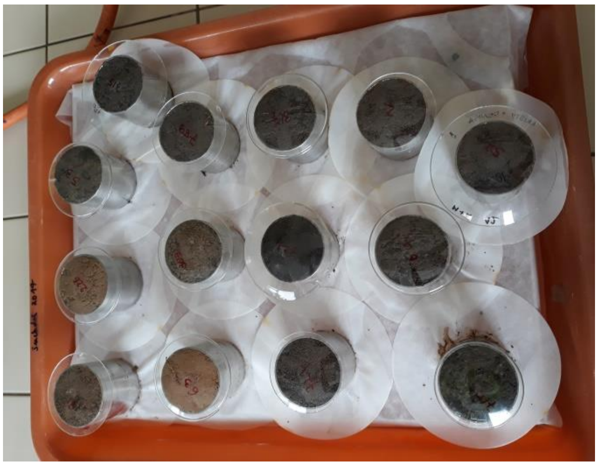


B. Pycnometer with distilled water

C. Soil suspension in pycnometer

D. Weighted soil suspension

Appendix 3.2: Water retention determination

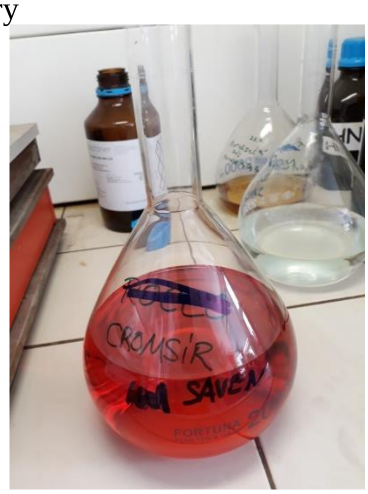


A. Soaked soil samples

B. Determined water retention by time interval

Appendix 3.3: Organic carbon determination in laboratory

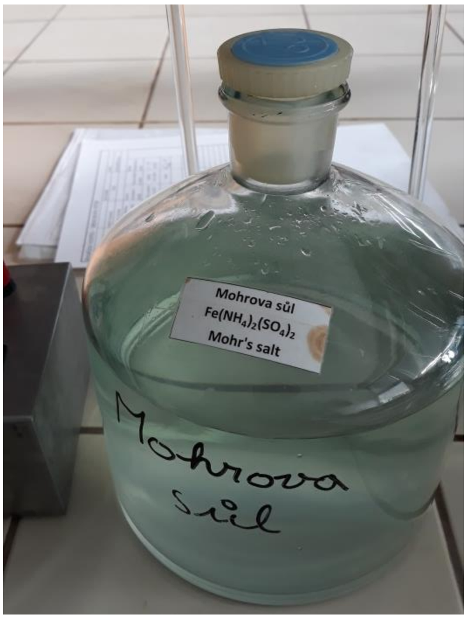
A. Weighted soil samples



B. Dichromate solution ($K_2Cr_2O_7$)

D. Titration with Mohr salt $(NH_4)_2Fe(SO_4)_2$

C. Heated soil suspension



A. Mohr salt $(NH_4)_2Fe(SO_4)_2$

Appendix 3.4: pH determination in laboratory