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IMPACTS OF PINE AND EUCALYPTUS FOREST PLANTATIONS ON SOIL ORGANIC MATTER CONTENT IN SWAZILAND – CASE OF SHISELWENI FORESTS

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ABSTRACT

This is an experimental study exploring the impacts of pine (*Pinus elliottii*) and Eucalyptus (*Eucalyptus grandis*) forest plantation on soil organic matter content. The objectives of the study were to explore the impacts of these forest plantations on soil organic matter content as well as to ascertain how soil organic matter content influence other soil properties such as soil pH, carbonates, nitrates, porosity, and bulky density. The data of this study were mostly primary data, which was collected directly from the field. The data were collected using a spade and a pick to dig soil pits. Soil samples were then taken and put in plastic bags and transported to the laboratory for analysis. The results of the study reveal that forest plantations have positive impacts on soil organic matter content. However, soil organic matter content influences other soil properties. Furthermore, the nature and type of vegetation, which constitute the organic matter also has an effect on other soil properties.

Keywords: Bulky density, Eucalyptus, Organic matter content, Pine, Porosity

INTRODUCTION

Swaziland covers a total area of 17.363 square meters and has 45% coverage of forests and woodlands, natural forests covering 2.2%, natural woodlands 22%, natural bush lands 13.4%, wattle forests 1.4% and plantation forests 6.4% (Government of Swaziland, 2002). Out of the six physiographic regions Highveld, upper and lower Middleveld, western and eastern Lowveld, and Lubombo Range, forest plantations thrive well in the Highveld. In Swaziland commercial or plantation forests are run by private companies such as Sappi-Usutu, Mondi forests and Shiselweni Forest Company (SFC) (Sessay, 1999). Management of forest plantations is normally associated with impacts on soil organic matter. Forests, in general improve the soil organic matter content through leaf litter falling on the forest floor. However, the type of forests may have an impact on the organic matter quality for example; pine needle shaped leaves may acidify the soil. On the other hand, forest plantations which take longer time to mature, remove large amounts of nutrients and organic remains from the soil in the process of growth. Moreover, when these trees are harvested no nutrients are put back in the soil. Finally, the use of heavy machinery especially during harvesting often yields negative impacts, as it leads to soil compaction.

Soil is a thin layer of material on the earth's surface comprising broken rock particles and decaying organic matter, which serves as the natural medium for the growth of vegetation (Hill, 1999). Organic matter in soil is derived from plants (leaves, stem, and roots) and animals (flesh and bones) decaying and being incorporated into the soil. Notably, organic matter is generally regarded as a vital component of a healthy soil. It is an important part of soil physical, chemical, and biological fertility. According to Sparrow (2008) organic matter in its broadest sense, comprises all living soil organisms and all the remains of previous living organisms in their various degrees of decomposition. The living organisms can be animals, plants or micro-organisms, and can range in size from small animals to single cell bacteria only a few microns long. On the other hand, Sparrow (2008) avers that non-living organic matter can be considered to exist in four distinct pools, namely:

- Organic matter **dissolved** in soil water.
- **Particulate** organic matter ranging from recently added plant and animal debris to partially decomposed material less than 50 microns in size, but all with an identifiable cell structure. Particulate organic matter can constitute from a few percent up to 25% of the total organic matter in a soil.
- **Humus** which comprises both organic molecules of identifiable structure like proteins and cellulose, and molecules with no identifiable structure (humic and fulvic acids and humin) but which have reactive regions which allow the molecule to bond with other mineral and organic soil components. These molecules are moderate to large in size (molecular weights of 20,000 – 100,000). Humus usually represents the largest pool of soil organic matter, comprising over 50% of the total.
- **Inert** organic matter or charcoal derived from the burning of plants. Can be up to 10% of the total soil organic matter (Sparrow, 2008).

Furthermore, soil organic matter influences many of the physical, chemical and biological properties of soil. Some of the properties influenced by organic matter include: soil pH, carbonates, nitrates, porosity, and bulky density. Soil pH (the degree of acidity or alkanity of the soil) influences the rate of decomposition. Soil pH ranges from one to fourteen (1-14), one (1) being the most acidic and seven (7) neutral while 14 most alkaline. Microbial activity at very low or high soil pH will influence the rate of organic matter decomposition. In addition, Sparrow (2008) avows that the process of decomposition produces Carbon dioxide (CO_2) as a by-product. Microbes breathe out carbon dioxide and more than half of the carbon added to soil is lost as carbon dioxide gas during breakdown. Because of their varying reactivity, the turnover times for these different carbon fractions varies from a few months to tens of thousands of years.

In addition, soil organic matter is a source of nitrates. For example, in the later stages of decay of most kinds of organic matter, nitrogen is liberated as ammonia and subsequently converted into the soluble or nitrate form (Albrecht, 2007). Thus the level of crop production is often dependent on the capacity of the soil to produce and accumulate this form of readily usable nitrogen. Conversely, it is also imperative to note that the movement of the microbes in the soil while feeding on decaying organic matter is influenced by the compactness of the soil. Therefore, if the soil is compacted these animals cannot adequately move in it. At the same time the movements create pore spaces within the soil. Thus, the compactness of a soil is related to its content of water and air, which indicates the porosity of the soil (Saini, 1966). If the soil is porous it will have more water and air content. Furthermore, the bulky density provides a more correct overall picture of the physical conditions of a soil. Loosely packed soils, which have a lower bulk density, will usually have better aeration, better drainage. In addition, the bulky density is correlated with the organic matter levels in the soil. As such soils with a high bulky density are likely to have low organic matter levels and are more prone to nutrient leaching.

On the other hand, mature pines plantations keep soil fertile (Science Daily, 2001). Moreover, soils under pines have been found to store as much carbon as pasture soils. This suggests that replacing pasture with pine plantations will not lead to a long-term reduction in soil carbon or a large net release of carbon to the atmosphere with adverse greenhouse effects. Therefore, pine plantations have a positive impact on the soil. Furthermore, Science Daily (2001) argues that pine plantations do not change soil properties instead they improve them. For example, organic matter is normally abundant in pine plantations compared to native eucalyptus plantations.

Forest plantation management can generally affect soil organic matter content. For instance, it may be removed from the soil during the removal of logs and organic matter may be burnt. The study investigated and compared the impacts of pine and eucalyptus forest plantations on soil organic matter content. This study is inspired by the serious lack of information on the impacts of forest plantations on soil organic matter content in Swaziland, yet forests cover a large expanse of land in the country (Menne and Carrere, 2007). As such forests have both positive and negative impacts on soil properties such as bulky density; however, these impacts have not yet been studied in Swaziland (Menne and Carrere, 2007).

Objectives

The main objective of the study was to investigate the impacts of pine and eucalyptus plantations on the soil organic matter content in Swaziland.

The specific objectives were to:

1. determine the positive and negative impacts of pine plantations on the soil organic matter content.
2. determine the positive and negative impacts of eucalyptus plantations on the soil organic matter content.

Hypothesis

1. $H_{o:}$ Pine plantations have negative impacts on soil organic matter content, pH, carbonates, nitrate-nitrogen, porosity, and bulky density.

   H_1**:** Pine plantations have positive impacts on soil organic matter content, pH, carbonates, nitrate-nitrogen, porosity, and bulky density.
2. $H_{o:}$ Eucalyptus plantations have no positive and negative impacts on soil organic matter content, pH, carbonates, nitrate-nitrogen, porosity, and bulky density.

   H_1**:** Eucalyptus plantations have positive and negative impacts on soil organic matter content, pH, carbonates, nitrate-nitrogen, porosity, and bulky density.

LITERATURE REVIEW

The impacts on the organic matter content

Organic matter is the remains, residues, or waste products of any organism. It is also the Contaminants derived from living organisms. It includes leaves, urine, perspiration, bugs, animals, and other environmental debris or organic compounds containing carbon. According to Science Daily (2001) mature pine plantations keep soil fertile. Soils under pines have been found to store as much carbon as pasture soils. This suggests that replacing pasture with pine plantations will not lead to a long-term reduction in soil carbon or a large net release of carbon to the atmosphere with adverse greenhouse effects. This indicates that pine plantations have a positive impact on the soil. Science Daily (2001) also says that pine plantations do not change soil properties and in essence they improve them for example organic matter seemed to be in abundance in pine plantations as compared to native eucalyptus plantations. Science Daily (2001) further suggests that organic matter levels are marginally higher in the plantation soil. This has important implications for carbon accounting and carbon credits as it indicates that the long-term effect of converting land from pasture to pine is neutral. This shows that pine plantations have a positive impact on the environment as they contribute to the ozone gases. They also add more organic matter to the soil thus making the soil fertile.

However forest management under pine plantations may have a negative impact on the organic matter content. According to Marietta *et al*. (2004) Herbicide application in plantation forests may affect soil properties. The organic matter content seems to decrease in plantations where the forest was treated with herbicides. This implies that some forest management practices affect the soil organic matter content.

In addition to that continuous cultivation can decrease the organic matter content. Titus and Pereira (2008) gives an example of coffee plantations where by continuous cultivation decreases the organic matter content. Titus and Pereira (2008) further say that the organic matter content varies from soil to soil. For example in cultivated soils it ranges from 1-15%, pit soils it is 90- 100%. In tropical soils for example the soil organic matter content is high due to the fact that decomposition of organic residues is more rapid in warm regions. However, one must bear in mind that the rich organic matter content in the soils is a result of a slow and deliberate process, over thousands of years where in the leaf litter, wood wastes, wild berries, animal droppings, subterranean portions of weeds and shrubs, above ground tissues, animal tissues got mixed up in the forest floor bed and slowly by the action of microorganisms converted it into precious organic matter. This indicates that forests are rich in organic matter content.

The importance of soil organic matter on plants cannot be over-emphasized as it improves root growth, uptake of minerals, and aid the plant in a host of physiological activities (Marietta *et al.,* 2004). Moreover, it increases mobilization of nutrients both major and minor from the soil. It also produces growth promoting substances and higher nitrogen fixation by bacteria. Furthermore, it enhances formation of soil aggregates and soil structure, which has a direct bearing on soil aeration. In addition, soil organic matter enables the production of antibiotics which are essential for keeping in check soil borne pathogens. Finally, organic matter also influences the soil pH.

Impacts on soil pH

Soil pH is the "acidity" of the soil and is measured by the number of Hydrogen ions present in the soil solution. It affects the solubility of minerals or nutrients essential for plant growth (Sawyer, undated). Soils tend to become acidic as a result of decay of organic matter, ammonium and sulfur fertilizers. Moreover, the combination of carbon dioxide (CO_2) from decomposing organic matter and rain water forming weak organic acids may change the soil pH. On the other hand, pine plantations are normally associated with acidic soils and their needle leaves have been found to contribute to acidification of the soil (Gilman and Watson, 1994). Apart from pine plantations, Ringrose and Neilson (2005) argue that management of eucalyptus plantations involving the use of fertilizers contributes to a significant reduction in soil pH, from 4.5 to 3.6 in the surface soil. The reduction in soil pH is associated with a highest rate of fertilization. This is indicative of the fact that management of forest plantations has an effect on the soil pH. Furthermore, eucalyptus leaves have a poisonous effect, hence they inhibits the growth of grasses and weeds (Zewdie, 2008).

The impacts on soil carbonates

Despite the noted demerit of forest plantation in acidifying the soil and out-competing other plant species (allelopathy), they store more carbon than unmanaged forests (Cannel, 1990)**.** For instance, afforestation with pine and eucalyptus plantations may rebuild about 93% of the initial soil carbonates in degraded marginal land (Kudrick, 2003).

Impacts on soil nitrates

Nitrate is a vital element of the soil, which influences plant growth and productivity (yield). The availability of nitrates in the soil depends on the management practices employed. For instance, in forest plantation nitrates are normally added into the soil through nitrogen (N) fertilization.

Impacts on soil porosity

The successful application of fertilizers in the soil depends on the availability of air spaces (voids) within the soil, which is termed porosity. Forest management *per se*, may lead to negative effects which can directly affects the soil porosity. For instance, McLellan (2009) avers that forest harvesting involving the use of heavy machinery may increase soil density by packing the particles closer together and reducing pore space (*i.e.* soil compaction). This result to poor soil aeration, poor root penetration, limited water movement and reduced activity of soil organisms involved in nutrient cycling. Soil compaction can also increase surface water runoff, which may lead to soil erosion and increased sedimentation in watersheds.

Impacts on bulky density

Closely related to soil porosity is bulky density, which is defined as the density of soil in loose form, granular, nodular, structure expressed as a ratio of weight to volume. The soil bulky density is prone to destruction by forest management practices especially where heavy machinery is used such as in harvesting. Once the bulk density is severely affected shallow roots may have a problem in extension. However, forest plantations normally do not have a profound effect on bulky density since they are grown once in decades and during harvesting precautions to minimize compaction are taken through using one and the same path.

METHODOLOGY

Study area

The study focused on forest plantations which are located in Gege (Figure 1). In terms latitude and longitude the plantations stretch from 26^0 58′ to 27^0 02′ S and 31^0 01′ to 31^0 05′ E. Gege is physiologically located in the Highveld region of Swaziland at an altitude of 950 metres above sea level. Basically, the Highveld is composed of igneous and metamorphic rocks with granite being the dominant rock. Regarding vegetation, the most predominant is short sour grasses and patches of *montane.* There are also some natural forests and riparian forests that occur along river valleys. On the other hand, there are commercial forests comprising pine, wattle, and eucalyptus plantations, which belong to Shiselweni Forest Company.

Research design

This is an exploratory study and it employed an experimental research design. According to Singleton (2005) the main reason of carrying out an experiment is to test a hypothesis and indicate whether or not one variable affects another. Tevera and Peter (2008) notes that the advantage of an experimental method of data collection is that it allows a researcher to determine cause and effect relationships. To select sampling points (experimental and control) the study employed judgmental sampling, which is a non-probability sampling technique. All in all six sampling points were selected where soils were sampled. Out of the six two sampling points were located in pine (*pinus elliotti)* forest, two in eucalyptus (*eucalyptus grandis)* forests and two on a grassland adjacent to the pine and eucalyptus forests. The control site was used as a benchmark in examining the impacts of these forest plantations on soil organic matter content. The control site was on the same region as the experimental site which is the Highveld, so that both are somehow influenced by the same climatic conditions.

Data collection techniques

Firstly permission to dig soil pits in the forest plantations was sought from Shiselweni Forest Company. Then with an aid of a pick and a spade six sampling pits in the sampling points measuring 1.5 m length, 1.2 m width and 1.2 m depth we excavated. The size of the pits was influenced by the fact that pine (*pinus elliotti)* forest plantations have a maximum depth of 0.8 metres. Therefore, it was necessary to use the same depth for comparison. In each pit the colour of the soil was used to separate the horizons. Nails were also used to mark boundaries of the

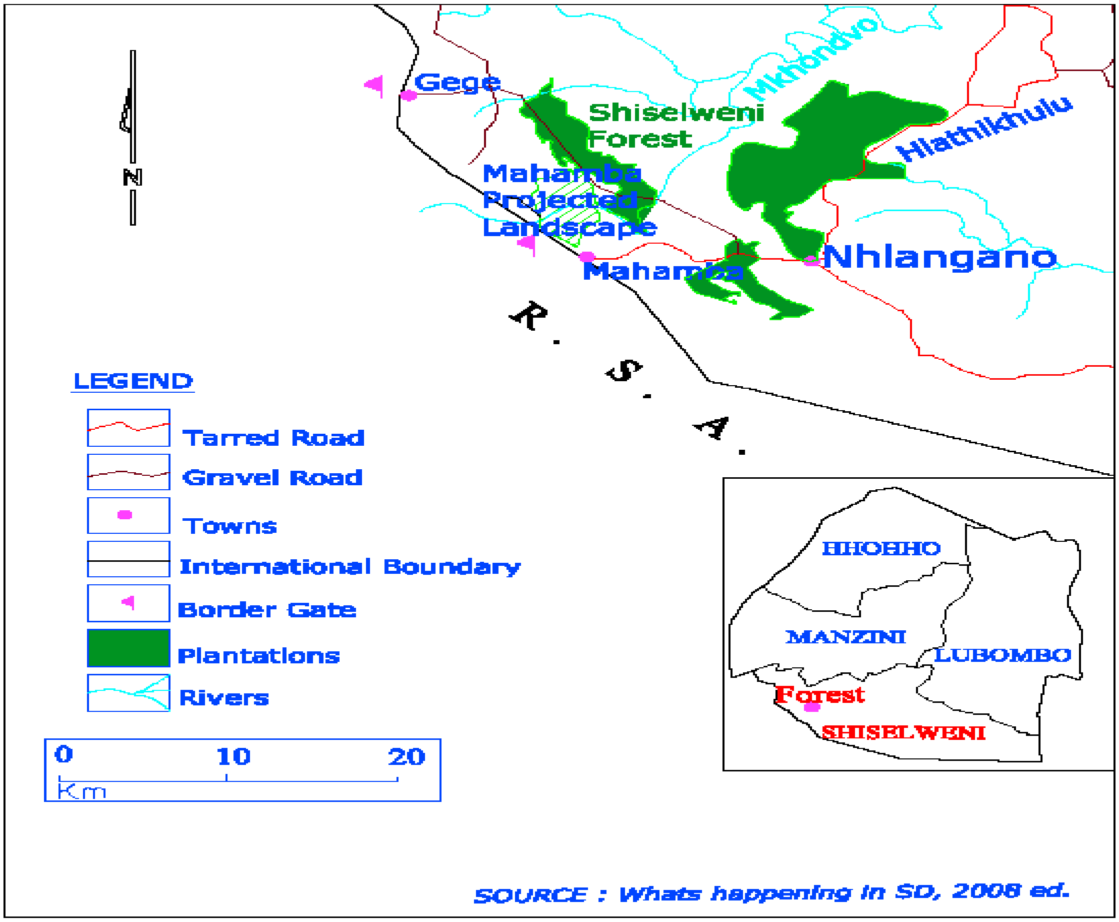

Figure 1: Shiselweni forests in Swaziland

horizons and a tape measure used to measure the depth of each horizon from the top to the bottom (Figure 2). Soil samples were then collected from all the horizons using a shovel. The samples were collected from the bottom to the top of the soil pit to avoid sample contamination. It is important to note that in the pine forest and control sites the soil had two horizons (A and B) while in the eucalyptus forest there were three horizons (A, B and E). Therefore, all in all fourteen samples were collected (four from the pine forest, six from the eucalyptus forest, and four from the control sites).

Figure 2: Measuring the depth of a soil horizon in a sampling pit

Source: Fieldwork (2010)

Laboratory Analysis

The soil samples were tested for soil pH, bulky density, soil nitrate- nitrogen, soil carbonates, porosity, and organic matter content. To test for the soil pH, the study employed an electrometric method. This method is based on the use of a pH meter and electrodes. Moreover, to measure the bulky density, a core sampler was used. This method involves pushing into the horizon a sampling can with a known mass then the moist weight of the soil is measured, thereafter the soil is dried in an oven for 24 hours and re-weighed. The difference between the moist and dry weight gives the bulky density of a sample. Furthermore, to test for nitrate-nitrogen the study employed a Micro-Kjedhal Digestion followed by Steam Distillation in a Markham Stiller. When using this method the soil is first digested in the digester for two hours. The digest is then distilled in the Markham stiller, whereby nitrogen is liberated from the steam. The distillate is then titrated against a standardized Hydrochloric acid. Another property which was tested for in the soil samples is carbonates, rapid titration method was used. In addition, the soil samples were tested for organic matter content, where the wet oxidation method was used. Finally, soil samples were tested for porosity, where the study employed the water saturation method.

Methods of data presentation and analysis

The data of the study are presented in tables. Interpretational analysis was used to analyze the data. According to Kitchin and Tate (2006), this analysis is undertaken to fully understand the generated data. The chi-square (X^2) was used to test whether the observed relationship/difference between the pine/eucalyptus and the control site is significant or a result of chance. The test is restricted to nominal (frequency) data and is nonparametric (Ebdon, 1985). It is a very flexible test which can be applied in one sample, two samples and more than two sample situations, hence ideal in this study since there were three samples (control site, pine, and eucalyptus forest plantations). When using the chi-square (X^2) a large calculated value than the critical value indicates that there is a large amount of difference between the observed and expected frequencies, thus suggesting a rejection of the null hypothesis (Ebdon, 1985). A significance of 0.05 was decided upon in this study.

FINDINGS AND ANALYSIS

Eucalyptus and pine forests on the soil organic matter content

Generally, organic matter constitutes only 5% of the soil components, (Scott, 1996). The findings depicts that topsoil of pine forest plantation had the highest organic matter content. Horizon A of pine forest plantations had the highest organic matter content, 3.7% compared to 2.9% in the control site, and 2.24% in eucalyptus forest plantations, respectively (Figure 3). Furthermore, in horizon E, pine forest plantations had 2.6%, while eucalyptus plantations had 2.24% and 1.49% in the control site. Finally, the soil in pine forest plantations and in the control site had no horizon B save only in the eucalyptus forest plantations.

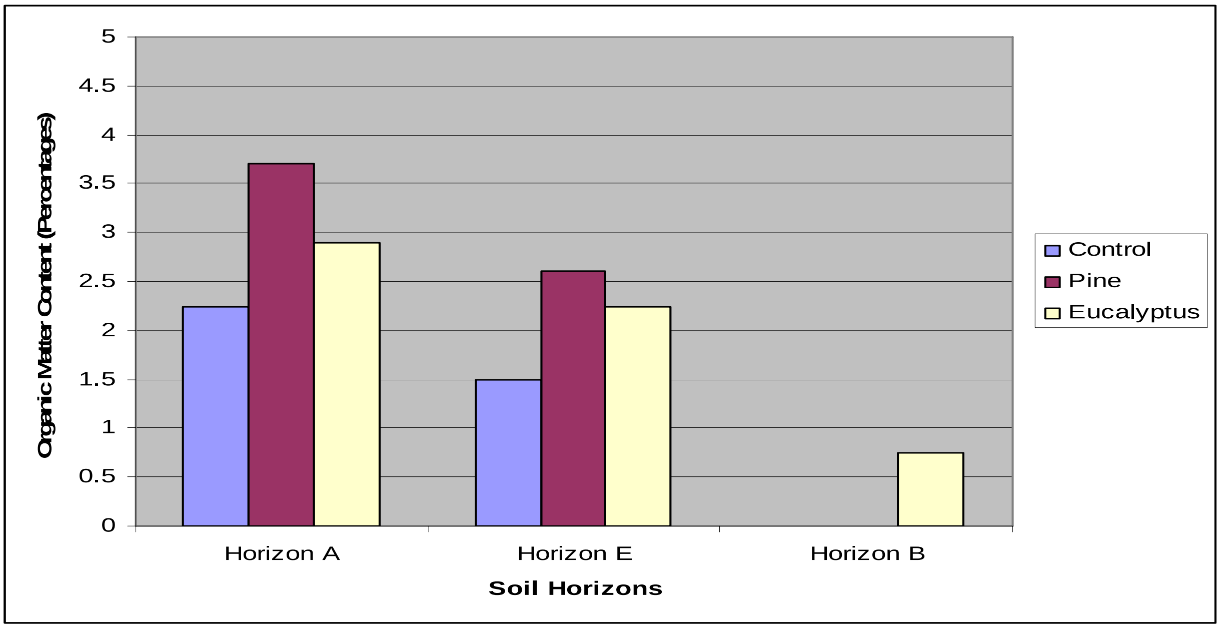

Figure 3: Soil organic matter content.

Source: Fieldwork (2010)

Soil organic matter content and pH

The findings reveal that in pine and eucalyptus plantations the soil becomes less acidic when the organic matter content decreases. For instance, in horizons A and E the organic matter content in pine forest plantations was 3.7% and 2.6% with a pH of 3.9 and 4.3, while in eucalyptus forest plantations it was 2.9% and 2.24% with a pH of 5.18 and 5.2 (Table 1). However, in the control site it was the inverse as organic matter content decreased with an increase in soil acidity. Notably, in the control site organic matter content was the lowest ranging from 2.24% to 1.49% with the highest pH values of 5.6 and 5.4 (Table 1). This implies that pine trees' needle shaped leaves contribute immensely to soil acidity.

Table 1: Soil Organic Matter Content and pH

Soil Horizons	Organic Matter Content (%)			Soil pH		
	Control	Pine	Eucalyptus	Control	Pine	Eucalyptus
A	2.24	3.7	2.9	5.6	3.9	5.18
E	1.49	2.6	2.24	5.4	4.3	5.2
B	*	*	0.74	*	*	5.7

*No data due to non-existence of the soil horizon

Source: Fieldwork (2010)

Soil organic matter content and carbonates

The findings indicate that soil organic matter content decreases with decreasing soil carbonates, which implies that these parameters decreases as you go down the soil profile. For instance, in the control site, as the organic matter content decreased from 2.24% to 1.49%, soil carbonates decreased from 1.08% to 0.52% (Table 2). Furthermore, in the pine and eucalyptus forest plantation the decline was also evident.

Table 2: Soil organic matter content and carbonates

Soil Horizons	Soil Organic Matter Content (%)			Soil Carbonates (%)		
	Control	Pine	Eucalyptus	Control	Pine	Eucalyptus
A	2.24	3.7	2.9	1.08	0.0075	0.036
E	1.49	2.6	2.24	0.52	0.007	0.03
B	*	*	0.74	*	*	0.025

*No data due to non-existence of the soil horizons

Source: Fieldwork (2010)

Soil organic matter content and nitrate-nitrogen

The findings depict that as organic matter content decreases so is the soil nitrate-nitrogen. For instance, in the control site, organic matter content decreased from 2.24% to 1.49%, and nitrate-nitrogen decreased from 3.13 me/100g to 2.6 me/100g (Table 3). However, when looking at the proportion of organic matter content versus that of nitrate-nitrogen there is no standard relationship. This is because in the control site the soil organic matter content is the lowest of all the sites with the nitrate-nitrogen being the highest. This implies that forest plantations somehow influence the soil nitrate-nitrogen content.

Table 3: Soil organic matter content and the nitrate-nitrogen

Soil Horizons	Organic Matter Content (%)			Soil Nitrate-nitrogen in Millie-equivalents per 100g of soil		
	Control	Pine	Eucalyptus	Control	Pine	Eucalyptus
A	2.24	3.7	2.9	3.13	1.2	0.25
E	1.49	2.6	2.24	2.60	1	0.20
B	*	*	0.74	*	*	0.19

*No data due to non-existence of the soil horizons

Source: Fieldwork (2010)

Soil organic matter content and porosity

From the findings it appears that soil porosity increases with decreasing soil organic matter content. For instance, in the control site where the organic matter content decreased from 2.24% to 1.49%, the porosity increased from 32 to 49%. Moreover, in the eucalyptus forest plantations the organic matter content decreased from 2.9 to 2.24% while the porosity increased from 22 to 35% (Table 4). On the other hand, in the pine forest plantation is was an inverse of the preceding relationship since the organic matter content decreased from 3.7% to 2.6% with the soil porosity also increasing from 56% to 42% (Table 4). Such a relationship can be attributed to the use of heavy machinery during harvesting.

Table 4: Relationship between Soil Organic Matter Content and the Soil porosity

Soil Horizons	Organic Matter Content (%)			Soil Porosity (%)		
	Control	Pine	Eucalyptus	Control	Pine	Eucalyptus
A	2.24	3.7	2.9	32	56	22
E	1.49	2.6	2.24	49	42	35
B	*	*	0.74	*	*	34

* No data due to non-existence of the soil horizons

Source: Fieldwork (2010)

Soil organic matter content and bulky density

The findings indicate that as the soil organic matter content decreases so is the bulky density. For instance, in the control site the bulky density decreased from 1.82 g /cm^3 to 1.8 g /cm^3, in pine and eucalyptus forest plantations it decreased from 1.81 g /cm^3 to 1.79 g /cm^3 and 1.79 g /cm^3 to 1.74 g /cm^3 (Table 5).

Table 5: Relationship between Soil Organic Matter Content and the Soil Bulky Density

Soil Horizons	Organic Matter Content (%)			Soil Bulky Density (g/cm^3)		
	Control	Pine	Eucalyptus	Control	Pine	Eucalyptus
A	2.24	3.7	2.9	1.82	1.81	1.79
E	1.49	2.6	2.24	1.8	1.79	1.74
B	*	*	0.74	*	*	1.72

* No data due to non-existence of the soil horizons

Source: Fieldwork (2010)

Chi-square (X^2) analysis

The data of the research was analyzed using the chi-square (X^2) test. The study used the chi-square (X^2) test to compare the control site and the pine and eucalyptus forest plantations. The comparison was based on the relationship between organic matter content and soil pH, carbonates, nitrate-nitrogen, porosity, as well as bulky density. The findings indicate that there is a difference between the sites. The difference is proven by the calculated values of (X^2), which are greater that the critical values (Table 6).

Table 6: Relationship between soil organic matter content and pH, carbonates, nitrate nitrogen, porosity, as well as bulky density

Soil parameters	Chi-square (X^2)	Degrees of freedom	Critical value
Organic matter and pH	9.316	5	2.015
Organic matter and carbonates	9.316	5	2.015
Organic matter and nitrate-nitrogen	6.702	5	2.015
Organic matter and porosity	7.632	5	2.015
Organic matter and bulky density	6.053	5	2.015

Source: Fieldwork (2010)

DISCUSSIONS

The study area is located in marginal land, hence it was not used for any cultivation purposes instead it was used as grazing land. Therefore, the findings of study indicate that forest plantations have improved the soil through speeding up soil formation. For instance, the control site was rocky and it was therefore not easy to differentiate the colours between the soil horizons. Conversely, in the experimental sites (pine and eucalyptus plantations) different colours were easily noticeable between the soil horizons. Moreover, the soils in the study area belong to 'G' Set which is the lithosols on ferrigimus crust (Sutcliffe, 1975). The structure of the soil ranges from almost massive to openly cellular. The pan may be very thick and overlies a mottled sandy clay or weathered rock (Sutcliffe, 1975). In terms of soil texture, it belongs to Gege series which is very dark grey humic sandy loam often wet over hard iron pan. Therefore, it can be safely concluded that it is the shallowness and hard iron pan that limits cultivation.

Regarding soil pH, the topsoil of the "G" set normally has a value of 5.8 in distilled water and 4.9 in potassium chloride (Sutcliffe, 1975). In this study the control site had almost the same pH range with that of "G" set soils, since it was 5.6 in distilled water and 4.6 in potassium chloride. In terms of soil pH in the forest plantations, the pine forests had more acidic soils than the eucalyptus forests due to the fact that the needle shaped pine leaves acidify the soil (Gilman and Watson, 1994). Moreover, Zewdie (2008) noted that the change which takes place in the chemical status of the soil surface is because the litter layer and organic matter becomes dominated by one species. Although the soil pH was lower in eucalyptus than in pine forest plantations it was still higher than in the control site. The high acidity in eucalyptus forests is attributed to the fact that eucalyptus leaves have phenolic acids tannin and flavonoids (Zewdie, 2008).

In terms of bulky density, it depends on how the soil is managed and its mineral makeup. Moreover, bulky density is inversely related to the porosity of the soil, such that if the porosity is high the bulky density is low. For instance, in the pine forest plantation and the control site the porosity of the topsoil was lower than that of the subsoil; hence the bulky density was higher in the topsoil than in the subsoil. On the other hand, the soil under eucalyptus forest plantations was more porous than in the other sites; hence a lower bulky density. Generally, a lower bulky density and a higher porosity results in better infiltration; drainage; and aeration of the soil (Zewdie, 2008). These conditions of the soil ensure survival of soil fauna and this was observed in the present study. For instance, in the study area some animal life (ants) in the lower soil horizons in the eucalyptus forest plantation was observed while there was none in the soil under pine forests and the control site.

Furthermore, regarding plants' nutrients uptake form the soil; fast growing tree plantations such as eucalyptus are associated with more intense uptake of nitrate-nitrogen and carbonates (Zewdie, 2008). This is further compounded by short rotation forest management and harvest cycles coupled with clear felling which results in extensive soil nutrients depletion. For instance, in the study area there was a notable decrease in both nitrate-nitrogen in the eucalyptus and pine forest plantations. On the other hand, the carbonates also decreased in the plantations as compared to the control site.

Finally, the findings reveal that forest plantations increase the organic matter content. Pine plantations had the highest organic matter content. This is because the pine leaves are bulky and they accelerate decomposition, thus pine has got a lot of grasses and other weeds which add the organic matter content. On the other hand, the organic matter content in eucalyptus forest plantations was lower than that of pine forests. This is because eucalyptus forest plantations have a potential to alter the diversity of plant species. For instance, according to Zewdie (2008) a soil bioassay showed clear inhibitory effects on germination and growth of under story plants, particularly in soils under *Eucalyptus globulus* and *Acacia malanoxybn* species. In addition, the allelophatic exudates from eucalyptus tree species have an inhibiting effect on the undergrowth vegetation, regeneration and growth of understory.

CONCLUSION

In conclusion the study observed that pine and eucalyptus forest plantations have both positive and negative impacts on the soil organic matter content. For instance, as much as they increase soil organic matter content, they also increase soil acidity. Moreover, the study reveals that these forest plantations are on marginal land; therefore they improve the soil formation. Furthermore, the forest plantations deplete soil nutrients due to the practice of short rotation forest management and harvest cycles coupled with clear felling. This is because forests under short rotation cropping system are implicated with the removal of a lot of nutrients from the soil into the plant. Thus, there is a need to rectify the problem of nutrients depletion through a use of more sustainable forest management strategies such a selective harvesting. All in all, forest plantations are very useful in rehabilitating degraded land since they improve soil formation; hence they promote sustainable land management.

RECOMMENDATIONS

This study recommends that future studies focusing on an in-depth analysis of the impacts of forest plantations be carried out, which will also include wattle (*Acacia mearnsii*) tree species.

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