EFFECTS OF EXOTIC TREE'S GROWTH MORPHOLOGY AND LITTER SUBSTRATE QUALITY ON THE ADJACENT NATIVE GRASSES

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OCTOBER, 2022

DECLARATION AND RECOMMEDATION

DECLARATION

This Thesis is my original work and has not been presented for a degree or any other award in any other University

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Philip Mwangi Gichuki AGR-4-0698-3/2014

RECOMMEDATION

This Thesis has been submitted with our approval as University Supervisors

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DEDICATION

To my wife and children, I am greatly indebted to you people for bearing my frequent absence from home and your continuous support and encouragement

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ABSTRACT

Light irradiance, water and litter substrate quality are major plant nutritional factors that control above and below ground plant resources. The study sought to find out the effects of exotic tree's growth morphology and litter substrate quality on the adjacent native grasses. Specific objectives were; to determine the effect of the adjacent tree canopy structure and the above ground processes that affect the delivery of resources to the adjacent native pasture, to analyze the adjacent tree roots structure and their below ground effects on the adjacent native pasture and to analyze the adjacent tree litter quality and below ground processes that affect the delivery of resources to the adjacent native pasture. Three native grass study sites adjacent to Eucalyptus, Cypress and Acacia were marked for the study. There was an additional site with no tree nearby that acted as control. Their crown, roots and litter substrate quality were studied. This was done from a distance of 1m to a distance of 60m away from the tree stand. Crown structure such as the diameter, breast height, total height, foliage transparency, die backs, position, exposure and density were analyzed. Canopy light radiation was determined by measuring photosynthetic active radiation and stomata conductance of the adjacent native grass. Roots growing structure such as branching density, diameter of fine roots, length, and depth were studied. Other roots characteristics such as exudates, fungal biomass, Ecto-mycorrhizal and Arbuscular mycorrhizal association were examined. Litter substrate quality such as phyto-chemicals, microbial biomass, Lignin, Lignin N ratio, Lignin P Ratio, Tannins, Polyphenols, Cellulose, C:N ratio, C:P ratio, mineralization rate, duff and bulk densities were deliberated. Litter bag experiment was carried out to determine litter mass loss and mineralization rate. The experiment had two Seasonal Treatments, four vegetation treatment types and seven different distance treatments. Data collection involved measurements of photosynthetic active radiation, stomatal conductance, quantifying N and P in the sample, analysis of microbial biomass, Ectomycorrhizal, Arbuscular mycorrhizal, fungal biomass, leaf chemistry and root exudates. Data was summarized using excel package and then analyzed using Statistical Package for Social Sciences (SPSS) for window version 22. All the hypotheses were tested at $\alpha=0.05$ and regression analysis made. The study results did not find much difference in the two exotic trees compared to Acacia in terms of changes in soil pH. The rate of decomposition and litter chemistry of the two exotic trees were different compared to Acacia. Likewise, the performance of adjacent pasture in terms of species composition, richness and cover also varied greatly. This was due to differentiated light quality in terms of Photosynthetic Active Radiation, soil porosity and competition for available Nitrogen. In addition, Competition for the available moisture is another considerable factor. Dense roots network was found to affect adjacent grass soil moisture in their root zone. Microbial biomass N, C and P was found to influence the rate of decomposition and release of nutrients to the soil. The study concludes that some of the valued exotic trees have potential of influencing negatively the adjacent crops/grasses if associated risks and benefits have not been studied well. The study recommends that any establishment of tree adjacent to crops or grasses, should consider tree species space requirement, potential spread of roots and contextual dependency relationship between N input pool and changes in soil properties

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LIST OF ACRONYMS & ABREVIATIONS

AM	Arbuscular Mycorrhizal
ANOVA	Analysis of Variance
C:N	Carbon is to Nitrogen ratio
ECM	Ectomycorrhizal
F:B	Fungi Bacterial ratio
KFS	Kenya Forestry Service.
LSD	Least Significant Difference
NEMA	National Environmental Management Authority
MBC	Microbial Biomass Carbon
MBN	Microbial Biomass Nitrogen
MBP	Microbial Biomass Phosphorus
pH	Unit of measure of H+ ions in the soil to determine soil acidity or alkalinity
UNFCCC	United Nation Frame Work Convention On Climate Change
PAR	Photosynthetic Active Radiation
(LAI)	Leaf Area Index
R:FR	Red to Far Red ratio

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Tropical tree species tend to have highly variable canopy structure in terms of size as well as twig and leaf density. Canopy stress limits some of the understory plants resources that are essential for their successful performance (Semwal et al., 2003). Canopy stress reduces grass dry weight, tiller density, leaf area index, degree of coverage and quantity of clipped materials (Pal & Mahajan, 2017). Shade stress interferes with photosynthetic active radiation, performance and durability of the adjacent grass species (Alizadeh & Sayedian, 2017). Light irradiance and litter substrate quality are major plant nutritional factors that support both above and below ground resources. However, growth of roots has showed to increase under low N availability and changes in Carbon allocation (Semwal et al., 2003).

Researchers have also evidenced significance interaction between light and mineralization of Carbon in different light irradiance (Rezai et al., 2018). Higher Carbon mineralization is associated with higher light passage in the canopy closed areas due to microbial activities (Guo & Sims, 2002). The degree of light intensity influences the rate of photosynthesis, stomatal opening, stem and hypocotyls' elongation (Ibrahima & Halima, 2008). Increase in crown closure affects the photosynthetic active radiation (PAR) transmittance. Short tree canopy closures that are near the ground affects the understory vegetation more than long canopy far away from the ground. This is due to differences in foliage obscuring of light strength (Ibrahima & Halima, 2008). The canopy length illustrates the long pathway that the light has to pass through and may result to transition of more light to the ground than short crown (Rezai et al., 2018). In forest overstorey where light is filtered, response pattern of understory species vary according to limitation caused by overstorey vegetation (Semwal et al., 2003). Leaf area density, height of the tree, depth of the crown, height of crown base, leaf area index (LAI), above and below ground biomass can be controlled to provide light transmittance to the understory vegetation (Ibrahima & Halima, 2008).

Uptake of water and minerals are closely related to the degree of fine roots penetration and the activity of the tree (Hatamian & Roozban, 2001). High growth rate of fine roots mean that large amount of soil is penetrated. The growth of roots is often associated with metabolic process and abiotic factors (Hatamian & Salehi, 2017). A study of effect of temperature on growth of fine roots is often complex because other factors like shoot development and moisture content control their growth (Ibrahima & Halima, 2008). Roots of the trees comprise of dense network which ensure good delivery of plant resources. Roots less than 2mm in diameter are mostly found in surface layer of 1.0 cm from the ground and have rapid turnover (Semwal et al., 2003). Variations of root elongation and branching characteristics create morphological differences in length and diameter of roots. In economic point of view, diameters of roots have strong relationship with investment of tree biomass to its roots (Mahmood & Saberi, 2005). Correlation of root diameter and tensile strength shows negative correlations while positive correlations with its tensile resistance (Hatamian & Roozban, 2001). The thickness of the roots and their lifespan significantly contribute to nutrient cycling in the forest floors (Pal & Mahajan, 2017).

The cortex and stele are the two important tissues that bring variations in diameter of the roots. However, the extent of these influence remain unclear. For example Wang et al. (2010) reported that the diameter of root is strongly influenced by the diameter of the xylem.

Litter bulk and duff contents are significant in determining soil chemical and physical properties. Duff and bulk litter protect the soil from erosion and are significant in determining soil moisture (Gregoriou et al., 2007). They are also critical components when defining soil carbon sequestration (Semwal et al., 2003). The litter fall is an important input for replenishing organic matter and return of nutrients to the soil. This is considered as one of the most important pathways of maintaining the soil fertility in different land use systems (Hasanuzzaman et al., 2013). The effects of leaf traits strongly affect decomposition more than the average rainfall in a given area (Gregoriou et al., 2007). Some of the leaf chemistry that affects the rate of decomposition includes C/N ratios, structural carbon, total phenolic compounds and amount of lignin in the litter (Berg & Laskowski, 2006). Plant exudate influences the microbial function as well as their structure (Verhoef & Gunadi, 2001). Soil microbial organisms are highly influenced by amino acids, sugar, proteins and falconoid that a given species of plant secrete (Gregoriou et al., 2007). Litter deposits of the canopy vegetation have been found to have inhibitory effects on understory grass cover, composition and richness (Rezai et al., 2018).

Plant microbial community structures are highly influenced by soil disturbance, allelopathic, local fauna and flora which impose selective pressure (Chawla, 2008). Short term mineralization and releasing of soil nutrients depends on the effects of litter quantity and physiochemical mineral association with a particular plant (Gregoriou et al., 2007). The elements composition of plants' litter substrate is the key linkages that influence microbial response to nutrients cycling (Alizadeh & Sayedian, 2017). Litter from exotic plants species may alter nitrogen retention, species composition, biodiversity and availability of N for plant growth (Gregoriou et al., 2007). Eucalyptus plant species are associated with leaf litters that are produced in large quantity. The litter contains high C.N ratios, high content of lignin as well as phenolic compounds (Brady & Weil, 2010).

Low decomposition rate of Eucalyptus leaves and recalcitrant materials may explain low level of the available soil N, P and K concentration in Eucalyptus plantation soils (Gregoriou et al., 2007). Some of the exotic trees species have been found to alter N cycling by having changes in nutrients and microbial processes (Ade-Ademilua & Craker, 2013). They also decrease environmental stability by interfering with resource supply and microbial ecosystem (Alizadeh & Sayedian, 2017). Other associated features include; decreased root density, chlorophyll and carotenoid contents (Alizadeh & Sayedian, 2017).

There are several complex models of research that have been developed to analyze photosynthetic active radiation (PAR). However, majority of them do not provide practical use in native grass adjacent to forest trees. Rather, what were found according to Timling et al. (2010), are models that are based on relationship between shade, litter quality and roots morphology on variables from a standard forest canopy management (Trewick et al., 2001). If light and photosynthetic active radiation (PAR) can be managed effectively from structural data, forest management could control tree and structure of canopy. This would promote the light environment necessary for the management and development of desirable canopy that would encourage growth of grass both in between forest stands and those from the adjacent crops (Trewick et al., 2001).

In Africa, report of negative effects of some exotic trees in terms of soil depletion, organic matter, physio-chemical properties and hydrology have been documented (Kumar & Pathania, 2013). In Sudan, report of reduced crop yields, nutrient reduction as well as toxic exudates production has been reported (Rathinasabapathi & Ferguson, 2005). A comparative study of Ethiopia Eucalyptus *globulus* and Cyprus plantation on nutrients status shows that nutrients content in Eucalyptus is lower than that of Cyprus (Rathinasabapathi & Ferguson, 2005). Dense roots network in Eucalyptus plantation have also been reported in Koga watershed in Ethiopia with reduced surface water that was previously functioning (Ouimette et al., 2013). Report of Eucalyptus in Ethiopia also shows increase in hydrophobicity caused by litter decomposition and poor undergrowth that does not support infiltration of water (Food and Agriculture Organization [FAO], 2011).

In Kenya, the effects of some exotic trees have been felt in adjacent crops and riparian land (FAO, 2011). Some contrary studies on the effect of some exotic trees have shown an increase in micro-nutrients such as Fe and Mn under Eucalyptus plantations compared to tea plantations estates of the same age (Kenya Forestry Service [KFS], 2009). However, a report on the high C/N ratio by FAO (2011) has shown that Eucalyptus plantations have reduced efficiency in cycling nutrients such as Nitrogen and Phosphorous. Other reports on the effects of exotic trees on the understory vegetation have been reported during re-forestation and continuous weeding during tree establishment and growth. Only a few studies have tried to determine the effects of the understory species in different plantations (KFS, 2009).

1.2 Problem Statement

In recent years, researchers have reported the depletion of world native grass cover in a semi-arid and arid regions at an alarming rate (Alizadeh & Sayedian, 2017). The economy of Kenyan individuals -own small land, scale livestock farmers in arid and semi-arid, and depend on native grass for livestock feeding (FAO, 2014). Forest destruction has primarily contributed to this through climate change. The government has made an effort through public-private partnership participation to regain back forest cover and reduce the effect of climate change. Sparing 10% of every farmland for exotic trees planting has been recommended by current and previous government authorities. However, this would increase the forest cover percentages and alleviate the effects of climate change. A general assessment of the affected region revealed gaps in published reports of below-ground processes affecting the above-ground native grass biomass (KFS, 2014).

Though a considerable amount of research has been done in other areas about the broad-scale influences of some exotic trees on soil properties, attention to the native grass response to some bio-geochemical processes that affect the above-ground grass biomass seemed not to be adequate. Moreover, the potential of native grass to withstand the effects of these exotic trees and survive in soil mineral-limited conditions is often questioned. It is alleged to have received little attention. This study, therefore, seeks to explore the responses of native grass to changes brought about by the introduction of these valued exotic trees in native pastures and establish a connection to the livestock farming systems in areas of study.

1.3 General Objective

To evaluate the effects of growth morphology and litter quality of valued exotic trees on adjacent native grasses.

1.4 Specific Objectives

To analyze the adjacent tree's canopy structure and the above-ground processes that affect the delivery of resources to the native grass to explore the adjacent tree's roots structure and the below-ground processes that affect the delivery of resources to the adjacent native grass.

To analyze the adjacent tree's litter quality and below-ground processes that affect the delivery of resources to the adjacent native grass

1.5 Research Hypothesis

There is no significant difference between the adjacent tree's canopy structure and the above-ground processes that affect the delivery of resources to the native grass.

There is no significant difference between the adjacent tree's root structure and the below-ground processes that affect the delivery of resources to the adjacent native grass.

There is no significant difference between the litter quality and below-ground processes that affect the delivery of resources to the adjacent native grass.

1.6 Justification / Significance of the Study

Although several studies have been done on the effects of exotic trees in shaping various responses to understory vegetation, only some studies have been conducted in Kenya. Moreover, their contribution to nutrient cycling in terms of nitrogen use, gains and losses are often questioned and thought to have yet to be adequately studied. Given the above reports, this study aimed to investigate the effects of growth morphology and litter quality of valued exotic trees on adjacent native grasses. It was thought to provide valuable information to National Environmental Management Authority (NEMA), community leaders, Kenya Forestry Services (KFS), opinion leaders, extension officers, farmers and NGOs. This would help them understand, redesign and improve as well as take steps to recommend some exotic stands to the farmers. The findings would further generate policy dialogues and act as baseline data for further research. This would enable them to make competent land use decisions and integrate them into day-to-day modern pasture management and economic investments. The findings would also help to increase the socio-economic benefits of exotic trees while maintaining soil fertility.

CHAPTER TWO

LITERATURE REVIEW

2.1 Canopy Structure and the Above-Ground Resource influence

2.1.1 Canopy Structure

A *canopy* can be defined as a dense layer of leaves plus shoot branches and the position of the crown to the external surface of the tree (Haque & Rahman, 2009). A long protruding canopy characterizes some tropical trees. The availability of light depends on the position of the crown relative to the apex (Gregoriou et al., 2007). Some trees show heritable crown shapes. The humidity and temperature of the understory are strongly influenced by the morphological Structure of the tree canopy (Smith & Read, 2010). Differences in crown shape on the overstorey vegetation directly influence understory species composition (Alizadeh & Sayedian, 2017). Understory grass vegetation varies according to the light requirement for maximum growth. Crown shapes, such as the diameter of the breast height, crown length and spatial arrangement of leaves, strongly influence the community structure of understory plants (Smith & Read, 2010).

Water is another resource that affects the vegetation growing under or adjacent to the tree. In French forests, species can be grouped according to water requirements, from xerophytes to hydrophytes (Smith & Read, 2010). Regarding overstorey crown structure, trees differ greatly in transpiration rate more than in water content in the soil (Bajad et al., 2017). Root water uptake also depends on the species and growth morphology of the roots. The understory grass vegetation may indicate the acidity or a special response to slight pH variations (Hague & Rahman, 2009). The litter nitrogen production is directly related to nitrogen-fixing microorganisms (Trewicket al., 2001). Coniferous forests have been found to have lower soil pH, making the soil more acidic than most hardwood trees (Thébault et al., 2010).

Differences in understory grass species are parallel to overstorey tree growth structure and litter quality. They are also found to be directly associated with resource influences in the soil (Thébault et al., 2010). Several studies have confirmed higher C: N ratios, less nutrient content and lower pH in Cypress tree stand compared to Acacia tree (Stoll et al., 2001). Ecological and systematic features of understory grass can better explain the species composition under certain overstorey vegetation (Haque & Rahman, 2009). The amount of litter's chemical composition strikes a balance between production and decomposition rates (Guo & Sims, 2002). Decomposition of litter is directly affected by the presence of microbial communities and soil fauna (Gregoriou et al., 2007).

Some exotic trees have phytotoxic substances from overstorey leaves carried down by rainwater. Most of these phytotoxic chemicals negatively affect the germination or development of understory vegetation roots. The allelopathic influence of eucalyptus leaves can better explain the slow development of understory vegetation compared to the Acacia tree. Studies have investigated species of grass pasture responses to shade. It has been established that there is a significant interaction between shade responses to various lights. The quality of light transmission measured by the red-to-far red ratio (R: F.R.), light on the growth morphology was smaller than those attributable to reduced photosynthetic flux density (Thébault et al., 2010). It has also been evidenced that understory grass species with reduced R: F.R. light on the growth morphology was smaller than those attributable to reduced photosynthetic flux density (Thébault et al., 2010).An understanding of how much distinct light quantity and composition affect the pasture can help us find the turning point at which manipulation of grass pasture is affected by R: F.R. light quality (Thompson et al., 2004). Researchers have tried to define and characterize forest canopy structures. They have also tried to associate them with structural attributes to the light intensity reaching the forest floor. Several complex models of research have been developed to analyze PAR transmittance precisely. However, most do not provide practical use in native grass adjacent to forests (Trotter, 2005). Rather, what is required, according to Timing et al. (2010), is a model that is based on the relationship between shade, litter quality and root morphology under standard forest canopy management (Trewick et al., 2001). Forest management can control enlarged Canopy if light PAR can effectively be managed from structural data. Parameters such as Leaf surface area, density, height, depth of the crown, crown base height, leaf area index (LAI) and above and below-ground biomass can be modified. This can be done with an effort to find the relationship between light transmittance and canopy structure (Trewick et al., 2001).

Researchers in most tropical forest stands have evidence that the vertical arrangement of leaves is highly correlated to PAR transmittance (Trotter, 2005). Dense forest stands and closely packed leaves with low canopy heights produce the lowest PAR transmittance (Trotter, 2005). Moreover, to determine the amount of light transmitted to the forest floor, the canopy structure act as a spectral light energy filter. It is also expected that the spectral composition of light is highly associated with the canopy structural arrangement of the forests (Verhoef & Gunadi, 2001). In dense canopy areas, the passing of light would spectrally have been altered due to wavebands' differential reflectance and absorption (Wei et al., 2005). The spectral nature of light reaching understory vegetation depends on various sources of relative light strength. This presents a gap that influences the light environment in the understory vegetation (Smith & Read, 2010).

Ecological researchers have evidenced that the Canopy vegetative colour of light, in the ratio of red light to far-red light (R: F.R. ratio), has significant effects on germination, growth and development of understory plants (Alizadeh & Sayedian, 2017). The degree of light intensity significantly alters growth parameters like pigmentation, photosynthetic rate, hypocotyls, stem elongation, leaf expansion rate and physiological processes such as stomata opening (Gregoriou et al., 2007). The overstorey vegetation selectively absorbs red and blue wavebands but transmits green and far red wavelengths to the understory vegetation. These light transmissions affect physiological processes necessary for the growth of understory plants. Plants that are tolerant to shade respond more positively to reduce R.FR ratio (Guo & Sims, 2002). Active photosynthetic radiation has been found to influence developmental qualities in the root's diameter, growth height and photosynthetic allocation of starch (Haque & Rahman, 2009).

The effects of crown structural characteristics determine the quantity and quality of light being transmitted. This is evidenced by evaluating the significant differences between narrow leaves Cypress vegetation and broadleaf Eucalyptus trees species (Bajad et al., 2017). Aponte et al. (2013) also found that among the four studies of forest plantation trees, active photosynthetic radiation of light within the plantations is based on features of the Canopy. Moreover, the broadleaf eucalyptus plantations with open crowns transmit higher R: F.R. ratios than the cypress tree stands with dense crowns closer to the ground (Bajad et al., 2017). Light availability and intensity affect biomass distribution, growth height and root diameter. These parameters increase with light intensity (Baroli et al., 2008). The maximum functional level of light quantity exists some degrees above 27%, which can produce considerable height and diameter of the stem (Alizadeh & Sayedian, 2017). In a study of 10%, 25%, 50%, and 100% full sun, Aponte et al. (2013) noted that after growing grass for two seasons, the tallest species were found in 50% full sun treatment, followed by 25% full sun treatment. Fadil (2006) also examined a similar study with Eucalyptus globular, where parameters like height, diameter and root–shoot ratio were examined. The light intensity ranged from 9 %-9.4% full sun. The study results show that the longest growth height was found in seeding with 20% full sun. The least growth height was seedling with 8% full sun treatment.

In most natural and plantation forests, the quality of light on the floor of the forest decreases with an increase in the Canopy's area coverage and the content of its pigments (Fadil et al., 2006). Increased canopy area coverage and light reaching the understory vegetation are spectrally altered because of the differences in reflectance and absorption wavebands (Bajad et al., 2017). The light colour of 20% full sun would differ from that of 50% full sun. Ecological researchers have evidence that the colour of overstorey vegetation significantly affects the germination of plants, growth height and development (Fernandes et al., 2013). Light intensity that comprises red and blue wavebands has higher significance effects on growth and biomass accumulation (Gregoriou et al., 2007).

2.1.2 Above-Ground Resources Influenced by the Canopy

Shade causes a reduction of active photosynthetic radiation, and it influences the performance and durability of the grass surface. These factors also alter understory plants' micro-environmental, morphological and physiological responses (Mahmood et al., 2007). Increased canopy level, dry grass weight, tiller density, leaf area index, degree of coverage and quantity of clipped materials are affected. Other effects are reduced contents of carotenoids and decreased root density (Pal & Mahajan, 2017).

At low irradiance, net photosynthesis is reduced, and respiration in the dark is affected (Shao et al., 2014). Recently published data on characteristics of the photosynthetic rate of native grass species shows significant differences in grass species and also their varieties of existence (Pal & Mahajan, 2017). Canopy level affects the quantity and composition of roots' mycorrhizal association. Microbes surrounded by rich rhizosphere produce signals that enhance a plant's fitness and growth in a given environment. It is also found to be influenced by inter-plant communication in a tranquil environment (Shao et al., 2014). N limited imposes selective pressure on grass species diversity. This favours specific understory grass species that match a certain mycorrhizal species that can enhance N mineralization. This relationship with mycorrhizae enhances the acquisition of limited resources to the rhizosphere (Bajad et al., 2017).

Canopy is a significant factor in mineralization and changes in pH in areas that the shadow casts (Rezai et al., 2018). Higher N mineralization rates and concentration in fewer canopy areas may be due to suitable temperature, moisture conditions and substrate quality of the litter (Shao et al., 2014). Light irradiance and litter substrate quality affect the biomass of understory vegetation. Microbial activities respond to substrate quality, temperature and quality of the light (Stoll et al., 2001). Significant positive effects in root-shoot ratio under reduced irradiance levels have been reported severally (Rezai et al., 2018). However, the growth of roots has shown an increase under low N availability and changes in C allocation (Semwa et al., 2003). The researchers have evidenced significant interaction between light and mineralization of Carbon in different light irradiance. Higher Carbon mineralization is associated with a higher light passage in closed canopy areas. This is due to microbial activities. (Shao et al., 2014).

Different tree species of grass have been shown to differ depending on the effect of light available and irradiance on the understory pasture and the duration of its availability (Souri, 2010). Other pasture-developing studies have shown that pasture yield quality is low under an increased level of shade (Stoll et al., 2001). However, in some cases, there is no clear evidence of which components of the pasture reduction are attributed to the low light availability. The extent to which shade affects grass pasture is significant in assessing the diverse patterns of light requirement in most grass species (Strassburg et al., 2010). Most reports on eradicating native grass have been reported in re-forested areas. This is mainly due to continuous weeding during tree establishment. Some of these examples are lotus *(Lotus peduncuiatus)* and bracken *(Pteridium aquilinum)* (KFS, 2009). Low light levels cast by some exotic stands have affected grass stomata conductance, growth and species composition. This is one of the contributing factors in native grass regeneration failure. It has also contributed to the ecological selection of valuable species of native grass that can only tolerate deep Canopy (Timling et al., 2010).

Some exotic trees species tolerate shade, while those that do not tolerate much shade permit higher light penetration. All these factors are closely related to the crown's depth, which influences subsequence factors like soil temperature (Thompson et al., 2004). In a forest environment, light quality on the floor of the forest decreases with an increase in the area of the Canopy. This became spectrally altered when different wavebands are absorbed by the canopy structure (Bajad et al., 2017). Aponte et al. (2013) observed that the colour of vegetative light significantly affects plant growth, development, and germination. Thompson et al. (2004) observed that red and blue waveband influences growth and biomass production. The degree of light intensity influences plant characteristics such as rate of photosynthesis, stomata opening, stem and hypocotyls' elongation. An increase in crown closure affects PAR transmittance.

Temporary canopy closure affects the understory vegetation more than long Canopy due to foliage obscuring light strength.

The canopy length illustrates the long pathway the light has to pass through and may result in transmitting more light to the ground than a short canopy (Thompson et al., 2004). Some grass species may tolerate low light caused by the dense Canopy. The crown ratio accounts for about 37% of the light variation in RFR. As the tree canopy height increases, more light is allowed and, therefore more species richness of the understory vegetation (Stoll et al., 2001). Grass species, cover and richness, decreases with an increasing proportion of canopy depth (Hasanuzzaman & Mahmood, 2014). The ecological filter of light by the overstorey vegetation plays a greater role in the distribution of native grass species adjacent to it. This serves as an important driver of nutrient cycling in the soil. Understory grass species are dynamic and respond to processes in overstorey (Hatamian & Salehi, 2017).

Although grass species may exhibit other variations in biotic and abiotic factors, the understanding mechanism is poor. In forest canopy where light is filtered, the response pattern of understory species composition may vary according to limitations induced by Canopy structure (Mattana et al., 2010). Canopy structure affects the supply of resources to the forest floor. It affects resources such as nutrients, moisture, light, litter chemical quality and biomass yield (Hatamian & Salehi, 2017). Changes in overstorey vegetation may affect soil acidity, light availability, soil nutrients and substrate quality (Sullivan et al., 2007). Forest canopy is an important influence of microclimate and light intercept variants. In a closed canopy, only a small percentage of the incident solar energy is transmitted to the forest floor (Sullivan et al., 2007).

This has adverse effects on understory plant establishments. The percentages of incident light radiation transmitted are dynamic due to stem density, basal area and Structure of the crown (Hasanuzzaman & Mahmood, 2014). A phonological distribution such as gaps, dieback and live crown ratio may directly affect resource influence on understory plants (Mattana et al., 2010).

2.2 Roots Structure and Below Ground Effects

2.2.1Roots Structure

Fine root growths differ in size, season, type and species. The growth pattern of fine roots shows a considerable variation of fine roots in different seasons. This is due to the high rate of root turnover during the dry season (Hasanuzzaman & Mahmood, 2014). Water and mineral uptake are closely related to the degree of fine root penetration and tree activity (Hatamian & Roozban, 2001). A high growth rate of fine roots means that a large amount of soil is penetrated. The growth of roots is often associated with metabolic processes and abiotic factors like temperature, which control their growth (Hatamian & Salehi, 2017).

A study on the effects of temperature on the growth of fine roo**ts is often complex since other** factors like shoot and moisture content control their development (Ibrahima & Halima, 2008). Roots are forced to penetrate into the soil against hard-packed soil layers. The ability of roots to penetrate the soil is often related to soil oxygen (Ibrahima & Joffre, 2010). The trees' roots comprise a dense network, of course, which ensures the overall roots structure of the system. Roots less than 2mm in diameter are mostly found in the surface layer of 1.0 cm from the ground and have rapid turnover (Sullivan et al., 2007). The biomass of fine roots is inversely related to the availability of calcium and phosphorus. Roots shoot ratio is also found to decrease with a decrease in soil fertility (Bohra & Singh, 2015).

A study of below and above-ground roots and shoots establishment shows that the highest root biomass is found in soil with high aluminium and iron concentration (Rivana, 2012). Major current environmental condition controls the allocation of plant resources to root and shoot meristem (Bohra & Singh, 2015). If plants have adequate nutrients and water supply, the root system will set a larger share of carbohydrates. It will also increase in size compared to the shoots. There is a correlation between how plant adjusts rapidly to adverse conditions and what extent of adjustment to modify the conditions (Bohra & Singh, 2015). Rivana (2012) experimented on bulk density of litter in a eucalyptus plantation. The study results found an increase in bulk density of 0.58mg/m^{3}to 0.70mg/m^3. Auto et al. (2005) also found an increase of 1.24g/cm^3 bulk density in Eucalyptus forest compared to 1.66g/cm^3 in natural forests within a depth of 0-20cm. Wang et al. (2010) also found an increase in bulk density under eucalyptus plantations compared to acacia forests. High bulk density in particular forests results to low water infiltration, surface increases runoff and low soil moisture (Bohra & Singh, 2015).

Understanding root distribution to the adjacent crops and seasonal variations is important in determining the competition and complementarity of trees to the adjacent grass pastures (Mattana et al., 2010). Roots depth better explains the nature of competition for minerals and water (Rezai et al., 2018). Perennial trees also rely on water for establishment but have adaptations of roots that can reach below the groundwater table for alternative water supply (Mattana et al., 2010). Annual trees and shrubs are less vulnerable to surface water shortfall once they become established (Pal & Mahajan, 2017).

Surface tree roots remain competitive with the adjacent crops. This depends not only on the density or distribution of roots but activities of the roots in different species within the layers of the soil (Sullivan et al., 2007). Plant species may differ in their characteristics. This includes the production of detritus partitioning of above and below-ground tissues. They also differ in the distribution of roots in terms of depth and chemical composition, as well as physical attributes of tissues (Pal & Mahajan, 2017).Plant roots are heterogeneous. They differ in diameter, physiology and anatomy. The most common classification of roots is by diameter and length (Mattana et al., 2010). Many studies define roots as those between 1-2mm in diameter. The anatomy and physiology depend on the type of root. An increase in the diameter of the roots may significantly increase root length but decreases root surface area (SRA) (Aweto et al., 2005). In addition, thinner roots have a short lifespan than thicker roots. The roots' thickness and lifespan significantly contribute to nutrient cycling in the forest floors (Pal&Mahajan**,** 2017).

The cortex and stele are the two important tissues that bring variations in the diameter of the roots. However, the extent of these influence remain unclear. Wang et al. (2010) reported that the diameter of the xylem strongly influences the diameter of the root. However, Bohra and Singh (2015) observed that the diameter of the roots is strongly correlated with the diameter of the stele rather than the diameter of the roots. Species evolution history has also been associated with root diameter. However, it is difficult to study. Although there is a lack of evolution history of root fossils, presence of root extract can provide insight into this phenomenon (Bohra & Singh, 2015). Thinner roots have been found to have higher mycorrhizal colonization than thicker roots. They are also associated with high absorptive and shorter lifespans (Sullivan et al., 2007). Variation in root elongation and branching characteristics create morphological differences in length and diameter. From an economic point of view, the diameter of root has a strong relationship with an investment of tree biomass to its roots. Root diameter strongly affects tensile properties. The correlation of root diameter and tensile strength shows a negative correlation but a positive correlation with tensile resistance (Mattana et al., 2010).

An increase in root length decreases tensile strength. Root tensile strength is positively correlated with a chemical composition such as cellulose and lignin (Bohra & Singh, 2015). Root traits are functional and maximize soil exploration for nutrient acquisition. Root diameter and specific root length are independent of the root growth rate (Hatamian &Salehi, 2017).

Root hair is considered an integral part of the root system. Root hair formations are more influenced by the environment rather than the root length (Rezai et al., 2018). Increased moisture content stimulates root hairs to emerge from epidermal cells (Hatamian &Salehi, 2017). Root distribution and density is closely related to soil shear strength. Total anchorage is related to tree root biomass and root tensile length. This may vary from species to species (Mattana et al., 2010). The type of root length and branching pattern are important in controlling how roots reinforce and anchor to soil particles. Roots with many branches hold large amounts of soil. It also shows greater resistance to pull than with fewer roots branching density (Bohra & Singh, 2015).

2.2.2 Below-Ground Resources Influenced by the Roots Tree roots systems are often complex plant organs. They are composed of fine, coarse roots and stumps. Some microorganisms do associate with them, whereby some are damaging (pathogens) and others are beneficial (mycorrhizal fungi) (Hagen-Thorn et al., 2006). The turnover rate of roots builds soil organic matter during forest life since the dead roots act as a source of soil organic matter (Hasanuzzaman et al., 2013). Mycorrhizal associations with fine roots are an important part of the plant nutrient cycle. Roots less than 2mm in diameter are mostly found in the surface layer of 1.0 cm from the ground and have rapid turnover (Sullivan et al., 2007). Following their death, they contribute to nutrient cycling in the soil by adding soil fertility. Early agriculturalists found that root developments in the plant are positively correlated with crop yield (Rezai et al., 2018). This provided a basic law in agricultural production that root growth by adverse moisture or restricted conditions may lead to reduced crop yield. In shade levels, there is a higher increase in shoot development relative to root development. This leads to low crop yield (Chawla, 2008). Smaller root systems can enhance plant productivity if they meet daily nutrients and water supply. Forest soil properties such as quality, organic Carbon and tree species can differ in their influence on soil properties (FAO, 2011). Plant species may differ in their characteristics, such as the production of detritus roots and partitioning of above and below-ground production of tissues.

They also differ in the distribution of roots in terms of depth, chemical composition, and physical attributes of tissues (FAO, 2011). Other attributes of plant to biogeochemical soil process are mineralization and control of soil invertebrates' population. Any plant characteristics influencing the quality, quantity and decomposition rate affect soil properties and nutrient turnover (Gregoriou & Vemmos, 2007). Deforestation of natural forests, followed by cultivated forest plantation, can have severe changes in soil chemical, biological and physical properties. Most of these associated disturbances in roots alter soil organic matter and reduce microbial biomass and soil structure (Gregoriou et al., 2007). It is uncertain how the alteration of soil properties and microbial Structure affects the stability and function of soil roots which help to withstand stress and resilience to hatch environmental conditions (Mahmood et al., 2009). It is thought that the functional stability of the soil is generated by the functionality of soil microbial diversity (Ngoran et al., 2006).

Nitrogen is an essential element for roots, shoots and the growth of microorganisms. Both fungi and bacteria have the potential to utilize organic sources of Nitrogen (Ngoran et al., 2006). Heterotrophic micro-organisms prefer NH_4^+ over NO_3^-(Pal & Mahajan, 2017). When N mineralization increase, assimilations of NO_3^- in roots decreases. Some empirical studies show that assimilations of $NO_3^-$is regulated by NH_4^+ and can be inhibited at a high level of NH_4^+ (Pal & Mahajan, 2017). Moreover, studies of ^{15}N isotope in many environmental conditions have shown a higher immobilization rate of NO_3^- in the natural forest than in cultivated plantation forest (Rathinasabapathi & Ferguson, 2005).

Simlai and Roy (2012) studies have shown that the immobilization of minerals can be facilitated by adding the available Carbon. Nitrification and immobilization of NO3- positive correlation are puzzling.This is because of the high nitrification rate associated with a high level of NH4+ in the rhizosphere, inhibiting the assimilations of NO3-.This conundrum of assimilations of NO3- in the root zone can be explained by heterogeneous microbial organisms requiring a high level of Carbon and a low level of NH4+ (Thuiller et al., 2013). This can be evidenced where NO3- immobilization is found to be greater in undisturbed root zone compared with that have physically been disturbed (Trewick et al., 2001). One of the measures of the composition of microbial community structure is bacteria and fungi relative proportion. Through this may take a broad metric to qualify, it is important to consider this relative proportion. This is due to their physiological and morphological differences that facilitate different role in Carbon and nutrient cycling in the root zone. This phenomenon may occupy different ecological niche (Thompson et al., 2004). The fine developing roots that bind the soil particles stabilize the developing aggregation (Angel et al., 2010).

In Africa, report of devastating effect of Eucalyptus plantations in terms of soil depletion, organic matter, physio-chemical properties and hydrology has been documented (Aweto et al., 2005). In Sudan, report of reduced crop yield, nutrient and toxic exudate production have been reported (Tererai et al., 2014). A compassion study of Ethiopia's Eucalyptus *globulus* and Cyprus plantation on nutrient status shows that nutrient content in Eucalyptus is lower than that in Cyprus and Cedar forest (Zhang et al., 2010). Dense root network of eucalyptus species plantation has also been reported in Koga watershed in Ethiopia. This has been associated with drought in water stores that were previously functioning (Oballa et al., 2010). Teketay (2003) report in Ethiopia also showed some potential sucking of water in eucalyptus plantations and an increase in hydrophobicity caused by litter decomposition. Poor undergrowth was found not to support water infiltration (FAO, 2011).

Zhang et al. (2010) found a reduction in soil moisture content in a eucalyptus species plantation ranging from 20.2 to 30.5 % in to the soil of depth of 0-10 cm. A study by Tererai et al. (2014) on the hydrological impact of eucalyptus species exhibited enhanced water use than the recorded rainfall over the same time. This indicates a shortage of medium-term soil moisture reductions. Wang et al. (2010) found eucalyptus tree species with the ability to tap into deeper soil layers than other plant species as a way of soil water mining. The study result found some disturbances in the water table and draining of underground aquifers. Tererei et al. (2014) also found a lower moisture content level in invaded areas of eucalyptus tree species than their counterparts of other tree species.

2.3 Litter Quality and Below-Ground Processes

2.3.1 Litter Quality

Duff substrate consists of partly decomposed and unrecognizable plant matter, while bulk litter, which is found on top of the duff layer, consists of recognizable plant materials like leaves and flowers (Ottmar et al., 2007). Litter bulk and duff contents determine soil chemical and physical properties. Duff and bulk litter protect the soil from erosion and are significant in determining soil moisture. They are also critical components when defining soil carbon sequestration (Hiers et al., 2005). Johnston et al. (2004) found minimal differences in litter bulk and duff density among hardwood trees. Higher percentage differences in litter bulk and duff density were found in pine trees. A weak correlation was found in the confiner forest between bulk and duff depth. Litter depth was greater in winter than in summer, but the bulk density was lower in winter than in summer (Ottmar et al., 2003). Hiers et al. (2005) found seasonal duff and bulky density differences. Higher bulky density was found during the wet season than in the dry season. Johnston et al. (2004) found differences in duff and bulk density between hardwoods and pine forests. Pine litter decomposes more easily than hardwood litter, thus creating denser duff over a shorter period. (Ottmar et al., 2003) found that eucalyptus litter had a higher leaf surface area and often create large area space within the litter layers. This makes its mass lower than those in pine leaves. This creates a distinction between the two stand bulk densities.

Some leaf chemistry that affects the decomposition rate include C/N ratios, structural Carbon, total phenolic, polyphenolic compounds and the amount of lignin in the litter (Berg & Laskowski, 2006). Eucalyptus plant species are associated with leaf litter produced in large quantities. The produced litter consists of high C.N. ratios high content of lignin and phenolic compounds (Tererai et al., 2014).As a result, lower N mineralization as the soil available Nitrogen is bound to microorganism decomposition process with low nitrogen litter content. This creates large litter bulk depth due to carbon sequestration (Ehrenfeld, 2003). The low decomposition rate of Eucalyptus leaf litter and resistant materials may explain the low level of the available soil N, P and K in the soil. It may also explain reasons for high litter bulk depth than duff on the forest floor (Prescott et al., 2013). Many exotic plants, unlike the eucalyptus species, have been reported to produce a litter with high content of N, therefore speeding up the rate of decomposition for plant uptake (Ehrenfeld, 2003). However, in the majority of mono-culture Eucalyptus plantations, reports of poor nutrient litter production with a slow decomposition rate are reported with little addition to soil nutrient pools (Prescott et al., 2013).

Variation in soil pH significantly affects the growth and function of Arbuscular mycorrhizal fungi. This further leads to a higher concentration of hydrogen ions creating toxicity in the soil (Bardgett et al., 1998). In most acidic soil, Aluminum and Manganese prevail while inhibiting the presence of Calcium, Molybdenum and Magnesium in the soil (Chen et al., 2013). Increased C/N and C/P ratios lead to greater recalcitrance of mineral content which affects the mutual association of plants and their heterotrophic partner. This leads to an inability to access the key recourses needed (Aweto et al., 2005). A major driving factor that strongly influences biotic factors is soil pH. It influences carbon availability and microbial community structure. Soil *pH* is associated with simultaneous changes in phospholipids and fatty acids (Zhang et al., 2010).

In contrast, pine forest ecosystem mineralization of Nitrogen is more in fungi-based food web than the bacteria (Liu et al., 2098). Mineralization and immobilization of organic Nitrogen occur simultaneously in the soil, but net nitrogen mineralization occurs when microorganisms have a limited amount of Carbon. Net immobilization, on the other hand, occurs when microbes are Nitrogen limited (Wang et al., 2010). Many researchers across the world have reported the negative ecological effect of Eucalyptus. Some of these issues include depletion of soil fertility, high transpiration rate, and effects of allopathic inhibition of the growth of other plants (Aweto et al., 2005; Teverai et al., 2014; Evans et al., 2001). Expansion of Eucalyptus species has been associated with the lowering of water tables, water availability reduction for immigration, and reduced area coverage by grasses due to soil hydrophobicity and dense root network (Zhang et al., 2010). In China, the cultivation of eucalyptus plantations has been found to affect the chemical and physical properties of the soil as well as the species diversity of the plant community (Tererai et al., 2012). Many controversies have been reported in Argentina on nutrient cycling capacity and the economic and ecological effects of Eucalyptus in terms of sustainable forestry management (Zhang et al., 2010).

Various stages of decomposition can be affected by seasonal variations in temperature. Forest degradation alters the abiotic environment in the floor of the forest, which is likely to influence various biological processes. Finally, this may affect the decomposition rate of fungi and bacteria in varying soil environments (Berg & Laskowski, 2006). Eucalyptus forest microbial activity is affected by the litter's allelopathic effects (Bohra et al., 2015). Litter decomposition and soil nutrient release depend on the effects of litter substrate quality and physio-chemical mineral association with a particular plant (Gregoriou et al., 2007).

The elemental composition of litter and substrate quality is the linkages that influence microbial response to decomposition (Alizadeh & Sayedian, 2017). A critical factor contributing to the differences in the mineralization and immobilization of organic compounds is C/N ratios. With a higher leaf litter C/N ratio over 30:1, microbes become N limited; therefore, the immobilization of exogenous sources of inorganic nitrogen starts (FAO, 2011). Fungi have the capacity to mineralize more Nitrogen than bacteria because they can access the inorganic Nitrogen simultaneously with their hyphal networks (FAO, 2009). Plant nutrient cycling is mainly obtained via litter production and organic matter decomposition (Guo & Sims, 2002). A study was done by Haque and Rahman (2009) found out that eucalyptus plantation aged 14 to 23 years, average litter pool in N, P, Ca and Mg was 474.44, 12.9,74.2 and 30kg /ha respectively. Nutrient pools are obtained through litter decomposition, and released nutrients are mainly absorbed through the fine roots on the forest floor (Haque & Rahman, 2009). Prescott et al. (2013) compared nutrients released between twigs and leaves. The age of the plantation site and the density of tree litter are among the factors that cause variations in nutrient biomass concentration (Hasanuzzaman & Mahmood, 2014). Eucalyptus trees have been found to considerably alter microbial community structure and affect processes such as mineralization and nutrient distribution (Hasanuzzaman et al., 2013). Changes in the eucalyptus species' quality and quantity of litter a likely mechanism that causes greater N immobilization and reduces N availability (Isaac & Nair, 2005). Kabir and Webb (2008) described various mechanisms that lead to negative or positive feedback mechanisms. One of these mechanisms is a difference in litter conversion rate between several plants species. Another aspect is an intra-specific competition of resources other than N and differences in the quality of litter available on the forest floor (FAO, 2009). In a semi-arid ecosystem, enough supply of N is an important factor that makes exotic tree species maintain dominance (Kabir & Webb, 2008). Major changes involve resource supply or accumulation of these resources at a faster rate than resident species can utilize (FAO, 2009). Nitrogen pool, mineralization and immobilization increase when microorganisms have high Carbon and net N is limited (Kabir & Webb, 2008). C.N. the ratio of the substrate is a critical factor that strikes the balance between mineralization and immobilization of organic Nitrogen (Kumar et al., 2013). If an ecosystem C:N ratio is higher than 30, microorganisms result in N limited, enhancing exogenous immobilization of other organic Nitrogen sources (Kumar et al., 2013). Soil microbes are sensitive to changes in forest land practices. Different tree species may have distinct grounds soil microorganisms types (Tererai, 2012). Some forests consist of various layers of decomposition. These forests consist of various layers of organic materials, which include highly decomposed materials, moderately decomposed and minimally decomposed materials (Parton et al., 2009). In boreal forests, the organic layer is the most active layer where most biological activities occur. These layers often vary in substrate quantity and presence of soil microbial development and production (Díaz-Pinés et al., 2011). Overperforming of Eucalyptus more than other species of exotic trees is very common in Ethiopia. This can be attributed to physiological and biological characteristics such as tolerance to various climatical conditions and soils. Other competitive advantages are a high fecundity rate of growth and allelopathy (Cortez et al., 2014). Moreover, Aweto (2005) also found that Eucalyptus contains phenolic compounds and oils in their leaves, reducing the decomposition rate. These allelochemicals slow down the decomposition rate and have inhibitory effects that prevent microorganisms from acting on them. These chemical properties alter soil microbial community structure mostly in the organic layer (Luan et al., 2011). Forest biomass can be classified as living and dead organic matter. These can be located either below or above ground. The above-ground Carbon includes branches, stumps, forage seeds and stems. Below-ground biomass covers the growth of roots (FAO, 2009). In most tropical forests, favourable climatic conditions increase forest litter's decomposition rate. Dead biomass of soil organic matter is increased compared to boreal and temperate forests (Tererai, 2012). Rapid mineralization of soil organic matter is trigged by favourable temperature, increasing microbial activity rate (Díaz-Pinés et al., 2011).

2.3.2 Below-Ground Resources Influenced by the Roots

Plants' litter decomposition is a vital ecosystem process. It is the key pathway to transfer above-ground Carbon to the soil and the nutrient cycling process. It also provides the primary source of microbial energy and one of the global carbon cycles, which provides more than three types of carbon dioxide than fossil fuel combustion (Ibrahima & Halima, 2008). Forest degradation alters species composition and affects the contribution of biotic communities. This makes the effects of these hetero-specific processes complex, and understanding their effects needs to be improved (Baroli et al., 2008). Climate and leaf chemical composition are major factors in determining the decomposition rate. Ibrahima and Halima (2008) found a strong relationship between the decomposition rate and average rainfall among diverse tropical forests. Soil invertebrates speed up decomposition by stimulating microbial activities and breaking down physical organic matter (Bohra et al., 2015).

The abiotic environment, temperature and content of the moisture in the litter determine the decomposition activity and abundance of soil fauna. Litter quality also determines the invertebrate decomposition rate (Bohra et al., 2015). The symbiotic plant network is highly influenced by the soil microbial community. It acts as the greatest microbe reservoir that affects plants' growth. It also affects their fitness to the environment and tolerance to environmental stress (Thébault et al., 2010). Plant exudates influence microbial function and Structure (Verhoef & Gunadi, 2001). Soil microbial organisms are highly influenced by amino acids, sugar, proteins and flavonoid that a given species of plant excrete (Thébault et al., 2010).

Plant community structures are highly influenced by soil disturbance, allelopathic influence, and local fauna and flora, which impose selective pressure (Chawla, 2008). The type of forest tree species can induce a significant shift in the type of microbes through biotic and abiotic factors. Some of these biotic factors include soil substrate, below-ground species, quantity and substrate quality, which are associated with soil microbial processes (Bakker et al., 2011). The structure and function of microorganism studies have shown that they are influenced by forest species composition, which exhibits evidence of a strong link between above and below-ground processes (Handa et al., 2014). Studies have shown that clearance of natural forests to exotic tree plantation or shifting to agricultural land crop production significantly shifts the Structure of the fungi community and greater the chances of soil properties (Díaz-Pinés et al., 2011).

Microbial community structure is an important factor in the soil ecosystem process. Identifying microorganisms' composition is important in predicting ecosystem responses to environmental changes (Wang et al., 2010). Soil moisture can change community structure along the topographical gradient (Zhang et al., 2013). Moreover, changes in the chemical composition of soil organic matter, such as carboxyl alkyl and aryl content, may alter the composition of the microorganism structure (Díaz-Pinés et al., 2011).

Plant exudates influence microbial function and Structure (Bakker et al., 2013). Soil microbial organisms are highly influenced by amino acids, sugar, proteins and falconoid that a given species of plant excrete (Wang et al., 2010). Plant development stages affect the quantity and composition of root exudates which reduces with the age of the plant (Díaz-Pinés et al., 2011). Microbes surrounded by rich rhizopheres produce signals that enhance plants fitness and growth in a given environment. Differences influence the entire community structure in soil pH and C/N ratios (Parton et al., 2009). However, active community composition is influenced by soil moisture content. This provides an insight into how environmental factors affect total and active microbial community structure (D'Antonio et al., 1992).

Litter quality alters soil properties and microbial Structure, which play a significant role in withstanding stress and resilience to hatch environmental conditions (Mahmood et al., 2009). It is thought that the functional stability of the soil is generated by the functionality of soil microbial diversity (Ngoran, et al., 2006). Berg and Laskowski (2006) observed that various stages of decomposition could be affected by seasonal variations in temperature. Floor litter is likely to influence various biological processes and shift mycorrhizal association (Gregoriou & Vemmos, 2007). Variation in the redox potential, determined by the moisture content, significantly affects bacterial community structure and functions. Further, soil pH, bio-available Carbon, moisture condition and C/N ratio positively correlate with microbial community structure variations (Six et al., 2006). Litter quality affects roots mycorrhizal association. Microbes surrounded by rich rhizosphere produce signals that enhance plants fitness and growth in a given environment. It is also found to be influenced by inter-plant communication in a calm environment (Bajad et al., 2017). The litter substrate composition and quality determine the abundance of selective mycorrhizal association (Gaertner et al., 2011). It also determines the microbe the plant can associate with. Mycorrhizal rhizosphere diversity is influenced by the type of plant species (Gregoriou & Vemmos, 2007).

Introducing exotic trees after clearing natural forests reduces forest tree species diversity, total litter production and the pattern of litter released through microbial organisms. It is also associated with a high scarcity of organic matter content in forest floors (Gaertner et al., 2011). High C: N ratios can only stand for species adapted to nutrients poor soils (Bartz et al., 2014). Elevated soil nutrients have been reported in areas where Eucalyptus species have been planted together with acacia tree species (Prescott et al., 2013). Exotic tree species have been found to alter N cycling. This is through changes in nutrient content from plant litter which interfere with microbial processes (Cortez et al., 2014). Exotic trees are also thought to decrease environmental stability by interfering with resource supply, altering topographic structures and creating microbial ecosystem disturbance (Bartz et al., 2014). Soil nitrogen ensures good ecosystem stability and enhances the nitrogen transformation rate (Cortez et al., 2014). Excessive nitrogen loading in many agricultural regions in the United States poses some challenges to water quality management. Exotic plants disturb the ecosystem, interfering with nutrient uptake and leaf litter biomass density (Bakker et al., 2011).

Some warm exotic trees enable high nitrate production, while others cause high removal of Nitrogen to the atmosphere through denitrification as inert di-nitrogen gas (Evans et al., 2001). Plants litter is the soil's main source of organic N and C. Some of the easily accessible sources of Carbon are simply fatty acids, carbohydrates and organic acid, which facilitates microbial activities (Cortez et al., 2014). Plant litter acts as an insulating layer of the soil that protects it from extreme temperature and moisture changes (Evans et al., 2001).

The litter quality and quantity and microbial processes play an important role in maintaining soil fertility in carbon budgeting, nutrient cycling and soil organics matter formation (Evans et al., 2001). After harvesting plantations forests where part of the biomass accumulates during production periods, continuous cropping with short rotation crops depletes and declines soil physical and biochemical activity (Cortez et al., 2014). Eucalyptus forest, associated with a high C: N ratio, phenolic content and high lignin exhibits low total N mineralization as the available Nitrogen. This slows down microbial processes (Wang et al., 2013). The low decomposition rate of the floor litter under eucalyptus plantation and recalcitrant litter quality explains the low level of P, N and K under eucalyptus plantation soils (Cortez et al., 2014). Berg and Laskowski (2006) observed that various stages of decomposition could be affected by seasonal variations in temperature and moisture content. This will likely influence various biological processes by altering the soil environment (Evans et al., 2001).

Many exotic plants speed up the litter decomposition rate, having a labile litter that is easy to decompose. However, monoculture eucalyptus plantations have been reported to produce poor litter nutrients that slow down the decomposition rate. This results in poor overall nutrient pools in the soil (Forrester et al., 2006). Elevated eucalyptus floor litter quality has been reported to have improved nutrients quality by vegetation assemblage when mixed with luminant trees like acacia (Cortez et al., 2014). C and N sources are readily available in root exudates, such as vitamins, enzymes, amino acids and nucleotides, which stimulate microbial activity (Parton et al., 2009). Some compounds, such as polyphenolic substances, inhibit the activity of microorganisms. Others may render N inaccessible to most decomposition microorganisms where N mineralization may occur (Zhang et al., 2013). N uptake by plants may be slower than N uptake by microorganisms. These lower the rate of C and N transformation (Parton et al., 2009).

N can also be immobilized by being fixed into soil minerals or incorporated through chemical reactions into organic matter (Zhang et al., 2013). Microorganisms act on these deed forest biomass to produce overall soil organic matter. Carbon is released through mineralization (Liu et al., 2010). This biological process results in to close carbon cycle between soil organic carbon, forest and the atmosphere. This carbon input and output balance can be enhanced through forest conservation with no anthropogenic disturbances action in the cycle (FAO, 2010). Oxygen's presence facilitates decomposition derived from high precipitation (Wang et al., 2010). The type and the number of residues in the soil determine the amount of carbon gain (Aerts et al., 1997). The rate of decomposition of litters depends on seasons and the quality of lignin and phenolic compounds within the litter substrate (Wang et al., 2010). Several forms of Carbon are stored in the soil, varying in the degree of protection. These can be grouped as stable or labile pools (Cao et al., 2010). The two types of pools contribute to atmospheric carbon release (Evans et al., 2001). O-horizon in the forest stores the labile Carbon in the organic matter, which is the size of the sand particles (Lugo, 1993).

Most of the total global carbon storage (5-40 %) is in the labile fraction that is highly exposed to decomposition (Tererai, 2012). An estimate of 1/3 to 1/5 of soil organic carbon can be both 20% humic carbons, 5% live biomass and approximately 5% stored as non-humic Carbon (Cao et al., 2010). Recovering forests from pasture land and agricultural abandonments are important physical features that sink a large amount of Carbon in the tropical biome (Tererai, 2012). These recovering secondary forests give us a lot of ecosystem services, such as the ability to sink atmospheric Carbon in the soil and plant biomass (Evans et al., 2001).

CHAPTER THREE

RESEARCH METHODOLOGY

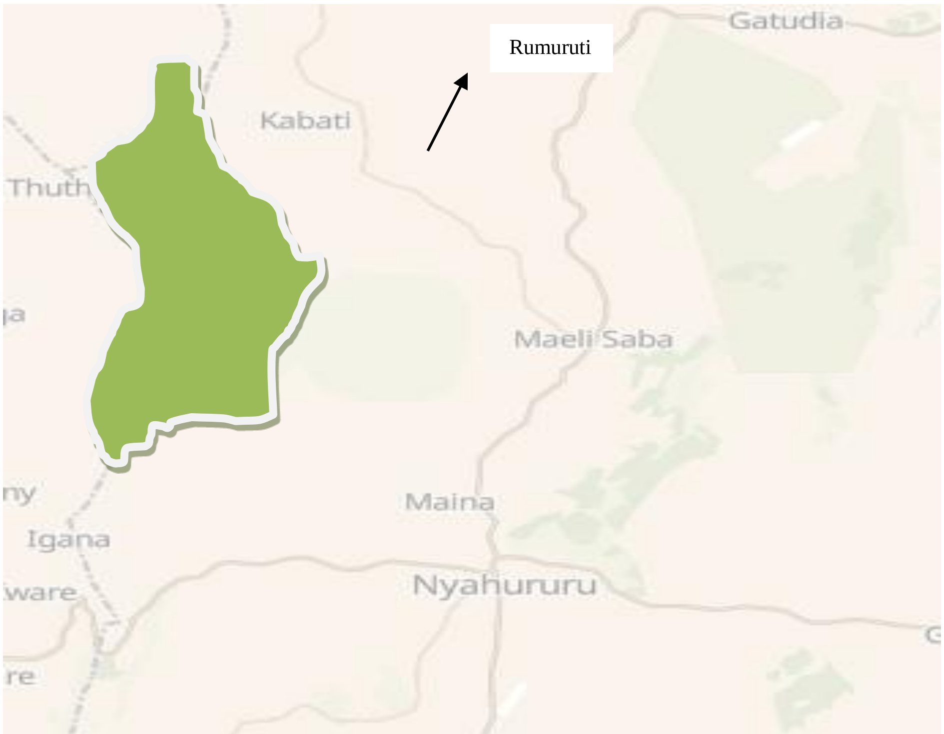
3.1 Site Description

i) **Study Location**

The study was conducted in Semi-arid South Marmanet forest. The study site was approximately 300 kilometers from Nairobi. The topography of the area was a gentle slope with well drained clay-loam soil, covering approximately $3km^2$. The West and East touch the equator (0^0) and extend to 0^0 15 South and North. The longitude of the area was $36^0$40" East to $37^0$20" East.

Figure 3.1

A map of South Marmanet Forest



(ii) Climate

Average daily temperature at night was 14^0C and 25^0C during the day time. The altitude was between 2200 to 2400 m above sea level. On average, the warmest month(s) are January and February. The average rainfall ranges between 500 mm - 700 mm (KFS, 2009).

3.2 Experimental Design

(i) Sample Preparations

Cypresses cupressus and *Acacia mearsii* were identified. There was also an additional site with open native grass (No existing tree), which acted as a control. Each experimental plot had an area of 10 m x 70 m. A radial circle sampling method was used during the selection of the sample. This involved a radius of 1m with eight systematic points in the direction of 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°. This ensured that a collective soil/litter sample was taken from each marked point.

Eucalyptus and Cypress were approximately 15-20 years old. Acacia trees had an average of 50 years old. The information about their ages was sought from the forest records. A total of 4 experimental plots were marked for sample collections.

(ii) Canopy Light Exposure

The crown casted shade on the ground was visually divided into four equal sides; (a) Receive full light from top or one side (b) receive full light from two sides(c) receive full light from three sides and (d) receive full light from four sides. Crown inclination was established whether it had spread all over or exposed to one side.

(iii) Diameter of the Crown

Measurement of Diameter of the Canopy

The radius of the crown was measured from the tree stand to the length of the projected branch. Vertical sighting method was used to establish the projection of the largest branch. The radius was multiplied by two to get the diameter.

(iv) Total Height of the Tree

An optical reading clinometers and a tape measure were used to determine the height of the tree. Clinometer showed percentile scale of the height of the tree while a tape measure was used to measure the distance from the tree stand. The height of the tree was calculated as Percentile scale /100 x distance from the tree stand.

(v) Crown Breast Height

An optical reading clinometers and a tape measure was used to determine the crown breast height. Clinometer showed percentile scale of the height of the tree while a tape measure was used to measure the distance from the tree stand. The crown breast height of the tree was calculated as Percentile scale/100 x distance from the tree stand

(vi) Crown Density

Crown density was measured using crown Density-Foliage Transparent Card. The card estimated the percentage of the outlined area of the tree that blocked the sunlight. The Card defined the amount of the branches, reproductive structures and foliage that block visibility of the light. The Density-Foliage Transparent Card indicates the percentages of the light exposure. The percentages indicated were then recorded

(vii) Foliage Transparency

Foliage transparency was measured using crown Density-Foliage Transparent Card. The card estimated the amount of skylight visible through micro-holes in the live portion of the crown. The Card defined the amount of missing foliage without leaves and dead benches without foliage.

(vii) Crown Dieback

Foliage transparency was measured using crown Density-Foliage Transparent Card. Diebacks was only considered when it occurs to the upper part of the tree. Dead branches on lower portion were not considered. The card estimated the amount of crown gaps/holes and snag branches.

(viii) Stomata Conductance and Photosynthetic Active Radiation

Stomata Conductance and Photosynthetic Active Radiation was measured using Quantum Sensor (LI1-191-LICOR) Biosciences. The instrument was assembled with high precision temperature sensor and internal light sensor. Since the stomata conductance is the work of leaf temperature, deliberate measurement of leaf temperature was important. Photosynthetic Active radiation was measured in the mid-morning (8-11 am) and in the afternoon (2-3 pm). The Quantum Sensor (LI1-191-LICOR) Biosciences instrument was placed side by side in the affected region under the shade. The result was then expressed in μmol m^{-2} s^{-1}

(ix) Root Density/Branching

To measure root density/branching, a vertical removal of top soil up to 60cm was done by use of a jembe and a spade. Using vertical soil profile exposed after removal of soil, a small grid cell measures 5x5cm was used to mark the area where roots were exposed. A small knife was used to remove the surrounding soil. The exposed roots were counted inside area marked by the grid cell. The number of intersection roots were classified using three diameters (fine roots between 0.1-1mm,medium roots

1mm-1cm and large diameter roots over 1cm). The collected roots were stored in a temperature of 5°C. They were later taken to the lab for further analysis.

(x) Diameter and Depth of the Roots

To determine diameter and depth of the roots, a vertical removal of top soil up to a depth of 60cm was done. A volume of 100cm³ soils was collected from a depth of 5cm to a depth of 60cm. The soil samples were put in Petri dish. Visible roots were observed after washing the attached soil with water. Roots diameter was measured using Ocular micrometer with magnification of x 100.The diameter of the roots were later recorded.

(xi) Length of the Roots

To determine root length, soil samples were collected from a distance of 1-60m away from the tree stand. Soil auger was used to dig out soil samples. A volume of 100cm³ soils contain roots was collected. Visible roots were observed after washing the attached soil with water. Roots samples were then obtained from each distance away from the tree stands.

(xii) Litter Samples

A composite sample of freshly fallen leaves was collected at various distances from the tree stand at the start of the experiment. The collected leaf litter from each point was mixed thoroughly to get a composite litter sample. They were put in nylon litter bag of 2mm mesh size and 25g mass.

(xiii) Litter Bulk and Duff Depth

To measure bulk and duff depth, a vertical removal of top soil up to 60cm was done. Vertical observation of soil profile that include litter (composed of layer of debris, dead twigs and recent fallen leaves), duff layer (semi-decomposed material above mineral soil and beneath the litter layer) and mineral soil were determined. A plastic ruler was used to measure litter depth position and duff depth where it separate from the mineral soil.

(xiv) Litter Bulk Density

A quadrat 0.25m² was used to mark the area where sample litter was corrected. Litter was excavated carefully using a trowel around the quadrat area. Care was taken to avoid mixing litter and the duff layer. The mass of the litter was weighed using sensitive mass balance instrument. Average litter depth was marked. The volume of litter collected was calculated by multiplying area (0.25m²) X depth of the litter. The bulk density was calculated by dividing dry mass of the litter by volume of litter collected.

$$\text{Litter Bulk Desity} = \frac{\text{Dry mass of the litter}}{\text{Volume of the litter collected}}$$

(xv) Litter Duff density

A quadrat 0.25m² was used to mark the area where sample duff litter was to be collected. Leaf Litter was excavated carefully using a trowel around the quadrat area up to a depth where the soil surface was reached. Care was taken to avoid mixing litter and the duff layer. Duff layer was then excavated until where mineral soil reaches. Duff litter was collected and put in plastic bag for analysis. Average duff depth was marked. The mass of litter was established by weighing it using a sensitive mass balances instrument. The volume of litter collected was calculated by multiplying area (0.25m²) X depth of the litter. The bulk density was calculated by dividing dry mass of the litter by the volume of litter collected. Litter duff was measured in g/cm3

$$\text{Litter Duff Desity} = \frac{\text{Dry mass of the duff litter}}{\text{Volume of the litter collected}}$$

(xvi) Soil Porosity

To determine soil porosity from different adjacent pastures, sample soil was put in a beaker at the same level. The soil sample was placed in a beaker and filled up to the same level. A predetermined volume of water was then poured into each of the beakers until it reaches the top level. The soil porosity was determined by dividing the volume of water that was able to be poured into the soil inside the beaker by total volume of the soil in the beaker. The result was the expressed as percentage

$$Ŋ = \frac{V\ Void \times 100}{V\ total}$$

Where Ŋ is soil porosity

V Void –Pore space volume

V Total –Total volume

(xvii) Litter Nitrogen

Leaf dry samples were powdered and stored with air tight jars at temperature of 20°C in the dark for 4 weeks. Total soil N was measures, followed by digestion it with H_2SO_4, salicylic acid, H_2O_2 and selenium (Novozamsky et al., 1984). The same procedure was used to determine N mineralisation rates.

(xviii)Microbial Biomass Nitrogen (MBN)

After obtaining total litter N in the sample by digesting it with H_2SO_4, salicylic acid, H_2O_2 and selenium, two litter samples were prepared. One of the samples was fumigated using chloroform to kill all the microbes. The other one was not fumigated. They were incubated for four weeks. The differences in mass of N for fumigated and non- fumigated were compared. This showed the mass of microbes contributing to mineralization of N. The total Microbial biomass Nitrogen (MBN) was then obtained.

(xix) Litter Carbon

Leaf samples were oven-dried at 105°C. Organic matter content was measured by loss-in-ignition (Ball, 1964). Samples were digested with H_2SO_4, salicylic acid, H_2O_2 and selenium (Novozamsky et al., 1984). Total soil Carbon was then obtained.

(xx) Microbial Biomass Carbon (MBC)

After obtaining total litter C in the sample, one of the samples was fumigated using chloroform to kill all the microbes. The other one was not fumigated. They were incubated for four weeks. Samples were later oven dried at105 °C and then weighed. The differences in mass of C for fumigated and not fumigated were compared. This showed the mass of microbes in mineralization of C. The total Microbial biomass Carbon (MBC) was then obtained.

(xxi) Litter Phosphorus (P)

Thirty cubic centimetres of the leaf extracts was made. It was pipetted into a centrifuge tube with 0.5 ml 0.9M sulfuric acid (H_2SO_4). The sample was then neutralized using phenolphthalein indicator (1%), 5M sodium hydroxide (NaOH) and

2M H_2SO_4. Four centimeter cube of colour developing solution was added and the solution was made to up 50 ml with deionized water. After 1 hour (to allow for full colour development) the colour was assessed. Phosphorus content was then calculated using a standard curve ranging from 0-0.5 µg P/mL (Schenck & Péréz, 1988)

(xxii) Microbial Biomass Phosphorus (MBP)

After establishing litter Phosphorus (P) in the samples, one of the samples was fumigated using chloroform to kill all the microbes. The other one was not fumigated. They were incubated for four weeks. The differences in mass of P for fumigated and not fumigated were compared. This showed the mass of microbes in mineralization of P. The total Microbial biomass Phosphorus (MBP) was then obtained.

(xxiii) Soil pH and Moisture Content

Twenty grams of sample soil was oven dried at 105°C for 24 hours .Soil moisture was then calculated as the weight lost per gram after oven drying. Ten grams of the sample was dispersed into 20 ml of deionized water. The soil pH was then measured after 30 minutes using pH meter probe

(xxiv) Leaf Litter Decomposition Rate

The leaf litter which was re-buried and retrieved was brought back to the laboratory for analysis. Samples were oven dried at 80°C. The loss in dry mass of leaves was recorded. This was compared with initial mass before decomposition. The rate of decomposition was calculated from the percentage of mass loss divided by mass before decomposition

(xxv) Ectomycorrhizal (ECM)

Root samples were put in to 50% ethanol at 5 ºC. They were cleaned in 10% KOH and stained with aniline blue following the procedure (Grace & Stribley, 1991). Structures of mycorrhizal (arbuscules or hyphae) was examined in stained roots. This was then expressed as mycorrhizal tips per cm of root.

(xxvi) Arbuscular Mycorrhizal (AM)

To identify AM present, air-dried samples of fungal spores approximately 20 g was extracted. This was done using wet screening-sucrose gradient centrifugation. Colour of the spore, size and mycelia connected were observed using a light microscope. Spores were put in a glass slide mixed with 40% glycerol. A record of spore colour, size and connective mycelia was observed using a light microscope. Using a manual identification of AM fungi by (Schenck & Péréz, 1988), the number of AM fungal spores in a sample of the soil was isolated, counted and recorded.

(xxvii) Root Biomass

Roots production and root biomass were measured by ingrowths method as describe by (Mancuso, 2012).This consists of a bag with 2 mm mesh with root free soil that allows the growth of new fine roots. The mesh permits the ingrowths of fine roots smaller than 2 mm. After one month, the ingrowths roots were taken to the lab for analyses. Roots were separated from the soil, washed and cleaned and separated into life versus dead roots and fine (<2 mm) versus coarse (>2 mm) roots. A record of fine root biomass was recorded.

(xxviii) Fungal Biomass

Microscopic slides were prepared. Fungi counting slides were stained with Differential Fluorescent Stain (DFS) solution. Hyphal lengths were measured using a microscope with 400x magnification. Fungal biomass was calculated by assuming a mean hyphal diameter (width) of 2.5 μm and a specific carbon content of 1.3x10-13g C μm-3 (Bakken & Olsen, 1983).

(xxix) Leaves Extract analysis

Leaves were sorted, washed thoroughly with distilled water. They were cut into small pieces and placed under shade for 3 weeks at a room temperature of 25°C.They were pulverized into fine powder using a blender. Fifty grams of the powdered leaves were extracted with 80g of ethanol for 24 hours with occasional stirring. Samples were sieved using Muslim cloth and filtered using filter paper. The filtrate was subjected into chromatography. Analysis of Chemical substances was done

(xxx) Litter bag Experiment

The litter bag experiment was used to assess the decomposition rate of fresh leaves derived from the selected tree species. A composite sample of freshly fallen leaves was collected at various distances from the tree stand at the start of the experiment. The collected leaf litter from each point was mixed thoroughly to get a composite litter sample. They were put in nylon litter bag of 2mm mesh size and 25g mass. Each 7 marked point (1, 10, 20, 30, 40, 50 and 60m) had 3 samples litter bag weighing 25g. A total of 84 litter bags were collected from the adjacent pastures which include 21 litter bags from Eucalyptus, 21 litter bags from Acacia, 21 litter bags from Cypress and 21 empty bags as control. They were labelled according to the distances from tree stand collected. During the initial analysis of the litter, a total of 28 litter bags from seven collected points were taken to the laboratory for litter analysis. The other 56 out of 84 not selected was taken back to the point where they were collected, reburied at a depth of 15cm. At the end of dry season, a total of 28 litter bags were retrieved back from the point they were be reburied. Finally, at the end of wet season, the remaining 28 litter bags were retrieved back from point they were reburied. They were taken to the laboratory for physical and biogeochemical analysis. All the laboratory litter bags collected were put in plastic bags to prevent moisture loss and stored in temperature of 5°C before taken for analysis.

(xxxi) Grass Roots, Shoot Number, Length and Leaf Growth Rate

The number of shoots produced during the period was manually counted. This was done according to species specifications. The average number of shoots produced during the dry and wet seasons was analyzed and expressed as a percentage. Shoot width was measured using a Vanier caliper as an increase in the diameter of the stem. Shoot length was measured in centimeters and expressed as a percentage increase. A sensitive weighing machine was used to measure fresh shoot weight. The leaf growth rate was measured in centimeters and expressed as the percentage increase in leaf length. To determine the length of the grassroots, the base of each grass was dug to a radius of 20cm. It was excavated up to 40cm with a ball of earth attached. It was soaked in water for three days and placed over wire gauge mesh to drain out the soil. Using a sprinkler, it was washed carefully. A plastic sheet was kept below the mesh to collect the separate fine roots. Fine Root's length and width were measured using a vainer caliper.

(xxxii) Grass Biomass

To obtain the above ground grass biomass, a quadrat $0.25m^2$ was laid on the surface of the grass. A serrated knife was used to harvest the grasses enclosed in the quadrat area. The total wet mass of the harvested grass in each location was taken using a sensitive mass balance. It was then put carefully in labeled bag that included quadrat number and the area collected.

(xxxiii) Species Composition

A taxonomist from Kenya Forest Service (KFS) South Marmanet Forest was was engaged to assist with the identification of grass species encountered at the study site. The names of individual grass species within the quadrat was evaluated by identifying their taxonomical names (both scientific and common names). The frequency of the grass species was also evaluated by counting the number of individual grass species as they occur within the quadrat. Their frequency varied from 0% to 100%.

(xxxiv) Species Cover

After the taxonomist from the Forest Service (KFS) had established the individual grass species composition, the numbers of individual grass species within the quadrat were evaluated by counting the number of individual grass species and dividing them by area of the quadrat.

$$\frac{\text{Number of species in the quadrat X 100}}{\text{Area of quadrat in m}^2}$$

(xxxv) Species Abundance (Richness)

After identification of individual species, the level of disturbance was evaluated.

This was done by comparing relative abundance of species along the adjacent trees 'pastures and the open grass pasture (with no tree nearby).

$$\frac{\text{Number of species in the quadrat X 100}}{\text{Number of species in the quadrat in open grass land(Undisturbed vegetation)}}$$

3.3 Treatments

The experiment had three treatments; seasonal, vegetative and distance treatments. Seasonal treatment was aimed at finding out whether there was variation in decomposition rate, mineralization, grass biomass and behavior of roots at various time of the year. Vegetative treatment was aim at evaluating leaf litter chemical composition o C:N,C:P and microbial biomass. Distance treatment was aimed at assessing whether there was an effects of distance from the tree on photosynthetic active radiation, soil temperature, soil moisture and bulk and duff quantities

(i) Seasonal Treatments

The experiment had two seasonal treatments.

Dry season	**DS**
Wet season	**WS**

(ii) Vegetation Treatments

The experiment consisted of four different vegetation types

Eucalyptus	**EP**
Cypress	**CY**
Acacia	**AC**
Native grass (Control)	**NG**

(iii) Distance Treatments

The experiment consisted of seven different distance treatments (Table 3.1)

Table 3.1

Distance Treatments

Marked point	**Distance(m)**
D1	1
D2	10
D3	20
D4	30
D5	40
D6	50
D7	60

3.4 Data Collection /Procedures

The researcher first obtained a research permit from the Dean of research and post graduate, Kenya Methodist University. This helped him acquire permit from the National Council of Science and Technology as shown in Appendix 2. The researcher later obtained permit from forest management officer at South Marmanet station. The researcher worked with forest officers who helped him to locate study site and provide security. The researcher contacted crop nut laboratory technologist field officer who assisted him in collecting soil samples.

The researcher held training seminars for the research assistants on working with research instruments. Daily recording of data such as temperature and photosynthetic active radiation was done. Collected samples were taken to the laboratory for further analysis. Results obtained were obtained between 2-4 weeks.

3.5 Data Analysis

The data was analyzed on the three main variables covered by the research I.e. canopy, roots and litter. All collected soils samples were analyzed in the lab which include; interactions between species, biomass parameters, soil phosphorus, Nitrogen and Carbon. The data was organised as per the research objectives and subsequently coded. Data was then summarized using excel package and then analyzed using Statistical package for social sciences (SPSS) for window version 22. Statistical significance was determined at $p < 0.05$ level. Pearson correlation analyses were employed to determine the relationships between variables. Linear regression for the relationship between independent and dependent variable was deliberated and drawn to evaluate whether to reject or fail to reject the null hypothesis.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Growth and Crown Structure of the targeted trees

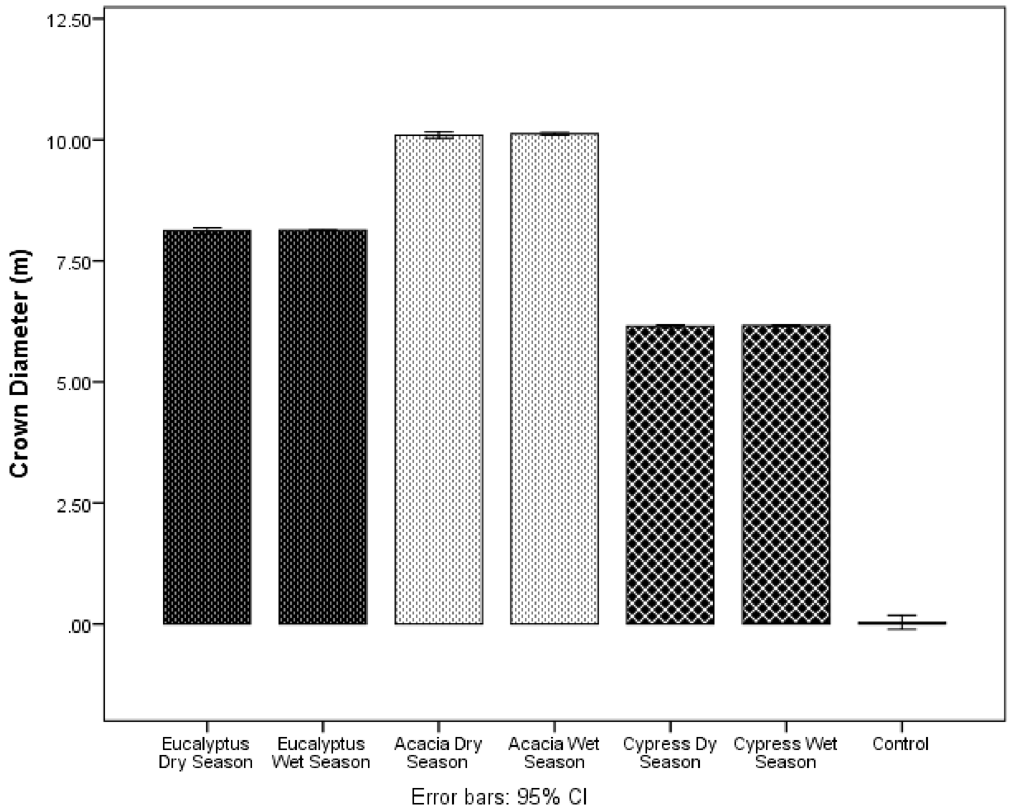
The main aim was to asses canopy structure at various time of the year, determine it crown density, photosynthetic active radiation and temperature

4.1.1 Crown Diameter

Figure 4.1 shows various crown diameters recorded during the study period. Acacia had the highest crown diameter of 10.10m during the dry season and 10.12m in the wet season. There was a slight increase in the diameter of the crown in the wet season in the wet season. Eucalyptus was the second largest crown diameter of 8.11m in the dry season and 8.13m in the wet season. Cypress had the crown's least diameter. The dry season had 6.14m, while the wet season had 6.15m. A slight increase in diameter was recorded. The result of the study shows that seasons are significant factors in determining crown diameter.). Similar studies by Gregoriou et al. (2007) found that a long protruding canopy characterizes some tropical trees. The availability of the light depends on the position of the crown relative to the apex

Figure 4.1

Crown Diameters

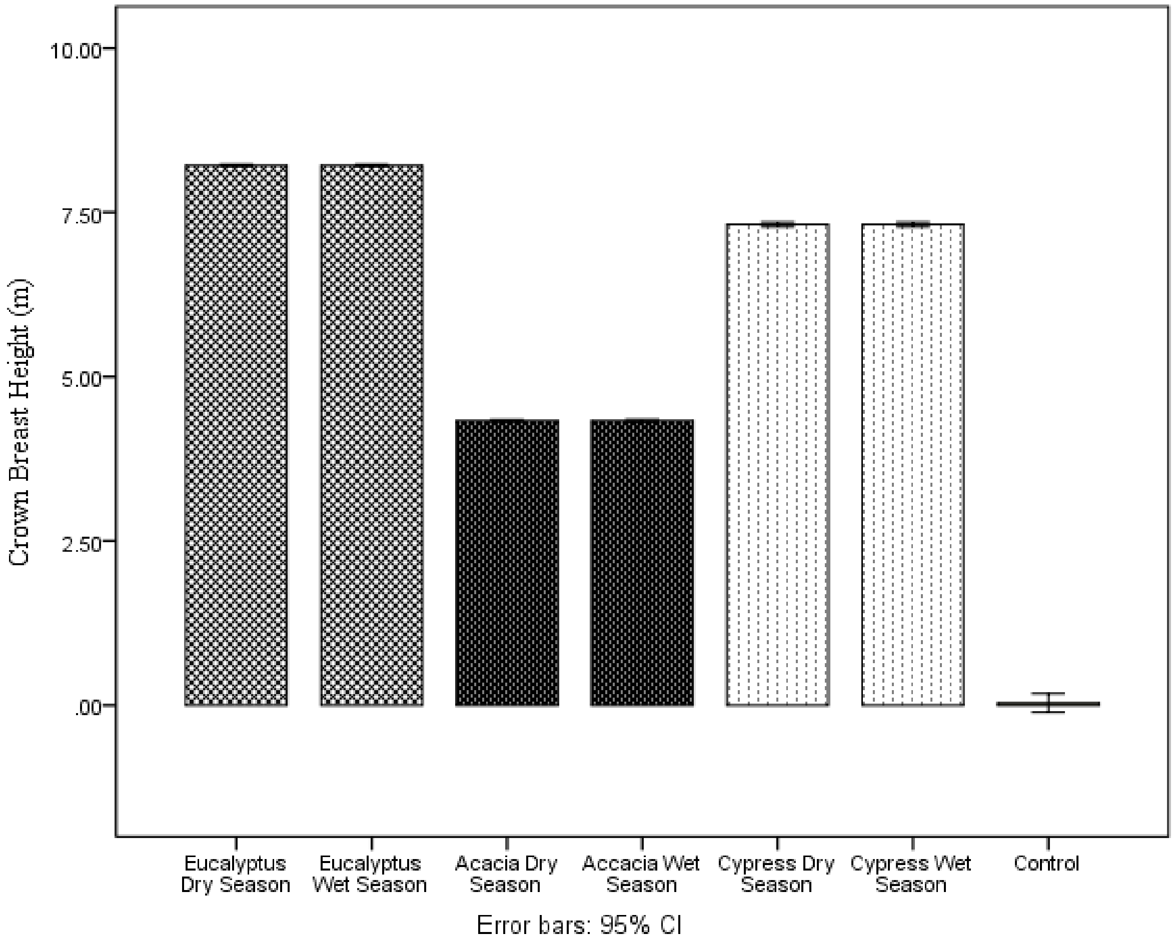


4.1.2 Crown Breast Height (CBH)

Figure 4.2 shows various crown breast heights (CBH) recorded during the study period. Acacia had the lowest crown breast height of 4.3m during the dry season and the same in the wet season. Cypress was the second lowest crown breast height at 7.3m in the dry season and the same in the wet season. Eucalyptus had the highest crown breast height. The dry season recorded 8.21m, while the wet season had 8.22m. A slight increase in crown breast height was recorded. The result of the study shows that crown breast height depends on the tree type and may not change easily in one season, just like the height of the tree

Figure 4.2

Crown Breast height



4.1.3 Foliage Transparency

Table 4.1 shows an analysis of crown structure in terms of foliage transparency. This estimated the amount of skylight visible. Eucalyptus had 15% missing foliage without leaves during the dry season and the same during the wet season. Dead branches without foliage were 17% during the dry season and the same during the wet season. Acacia had 32% missing foliage without leaves during the dry season and 27% during the wet season. Acacia had the highest number of dead branches, with 28% in the dry and wet seasons and 26% during the wet season. Cypress tree crown structure had 19% missing foliage during the dry season and 18% during the wet season. Dead branches without leaves were the same during the dry season and the same in the wet season. The result of the study shows that differences in light passage to adjacent grass pastures depend on the crown foliage characteristic of the overstorey. Similar studies were also founded by Bajad et al. (2017) that increased canopy area coverage, the light reaching the understory vegetation is spectrally altered because of the differences in reflectance and absorption wavebands. The light color of 20% full sun would differ from that of 50% full sun.

Table 4.1

Foliage Transparency

Tree	Missing Foliage		Dead Branches	
	Dry Season	Wet Season	Dry Season	Wet Season
Eucalyptus	15%	15%	17%	17%
Acacia	32%	27%	28%	26%
Cypress	19%	18%	22%	22%
Control	0%	0%	0%	0%

4.1.4 Crown Diebacks

Table 4.2 shows crown analysis in terms of diebacks. This estimated the severity of recent stress due to climate changes. Acacia trees had the highest number of crown gaps, 36% during the dry season and 33% during the wet season. The numbers of snag branches were also the highest, with 27% and 26% during the wet season. Cypress crown gaps were the second highest, with 12.5% during the dry season and 12% during the wet season. The numbers of snag branches were 20% and 19% in the dry and wet seasons, respectively. Eucalyptus trees had 4% crown gaps in the dry season and 3% in the wet season. The number of snag branches is 5% in both dry and wet seasons. The result of the study shows that Acacia trees transmit more light to adjacent pastures due to increased percentages of crown gaps and snag branches. Sun would differ from that of 50% full sun.

Table 4.2

Crown Diebacks

Tree	Crown Gaps/Holes		Snag Branches	
	Dry Season	Wet Season	Dry Season	Wet Season
Ecualyptus	4%	3%	5%	5%
Acacia	36%	33%	27%	26%
Cypress	12.5%	12 %	20%	19%
Control	0%	0%	0%	0%

4.1.5 Crown Densities

Table 4.3 shows the crown density of the adjacent tree. Crown density was defined according to the percentage of reproductive structure, foliage present, and amount of dead branches that block light visibility. The number of dead branches with no leaves in eucalyptus was 17% during the dry season and the same during the wet season. No dead branch produced bands or leaves during the wet season. Acacia had the highest percentages of dead branches, 28% in the dry season and 26% in the wet season. This means some structures that seemed like dead branches later emerged with some leaves. Cypress had the same percentage of dead branches of 22% in dry and wet seasons. Eucalyptus foliage percentage changed from 85% in the dry season and 87 in the wet season. An increase in foliage in the wet season was recorded in the wet season. Cypress increased the amount of foliage percentage by 3% in between seasons. The dry season recorded 89%, while the wet season was 92%. Acacia had the highest foliage percentage increase of 9%. The amount of foliage in the dry season was 68%, while in the wet season was 77%. The number of reproductive structures across all the stands increased. Acacia had the highest, with a difference of 19% between seasons. Eucalyptus and cypress had the same reproductive structures of 13% between seasons. The result of the study shows that active photosynthetic radiation of the adjacent grass is reduced during the wet season due to an increase in the amount of foliage obscuring light penetration. Simial results were also found by Hasanuzzaman and Mahmood (2014) states that the percentages of incident light radiation transmitted are dynamic due to seasons, basal area, and crown structure.

Table 4.3

Crown Density

Tree	Dead Branches		Foliage %		Reproductive Structures	
	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
Eucalyptus	17%	17%	85%	87%	5%	18%
Acacia	28%	26%	68%	77%	4%	23%
Cypress	22%	22%	89%	88%	6%	19%
Control	0%	0%	0%	0%	0%	0%

4.1.6 Crown Position

This aimed to establish the relationship between the tree canopy and its relative crown position. This is to provide reasons for the variation of light passage in canopy-closed areas. Eucalyptus had the highest partial light from one side (25%). Acacia had 15%, while Cypress had 10% partial light from one side. For the canopy with partial light from 2 sides, Eucalyptus had only 5%, while Acacia also had 5%. Acacia had the highest canopy partial light from the 2 sides with 15%. Acacia also had the highest canopy with partial light from 3 sides at 20%, while Eucalyptus and Cypress had 5% each. Twenty-five percent of Acacia had a canopy with partial light from 4 sides, while Eucalyptus and Cypress had 5% each (Table 4.4)

The study results show that through the crown diameter of Acacia may be large (From the previous study), the partial passage of light from different corners of its crown can manage to have light to the understory. A dense canopy with little light passage was found in Eucalyptus and Cypress more than in Acacia.

Table 4.4

Crown Position

Sources of Variations	**% Eucalyptus**	**% Acacia**	**% Cypress**
Canopy with partial light from 1 side	25%	15%	10%
Canopy with partial light from 2 sides	5%	15%	5%
Canopy with partial light from 3 sides.	5%	20%	5%
Canopy with partial light from the 4 sides.	5%	25%	5%

4.1.7 Crown Light Exposure

Table 4.5 shows relative crown light exposure. The main aim was to establish whether the light passage inclined more on one side or the other side had no light passage. This helped to determine variation in the performance of adjacent grass under canopy closed areas. Under no full light, Eucalyptus had 55% light blockage; Acacia had 15%, while Cypress had 45% blockage to full exposure. Partial light from the top or one side, Eucalyptus and Cypress, had 15% each, while Acacia had only 5%. Under the partial light from the top and one side, Eucalyptus had 15%, while Acacia and Cypress had 5% each. Partial light from the top and two sides, Acacia had 35%, while Eucalyptus and Cypress had 5% each. The study result indicates that

Acacia had more exposure to partial light from the top and two sides and was more exposed to light than the other two strands. Eucalyptus and Cypress had either one or two sides exposed but a higher percentage of canopy with no full light. The study results correlated with that of (Mattana et al., 2010). A phonological distribution such as gaps and dieback may create a difference in light passage even in a highly dense canopy tree.

Table 4.5

Relative Crown Light Exposure Percentages

Sources of Variations	**% Eucalyptus**	**% Acacia**	**% Cypress**	**Control**
No full light	55%	15%	45%	100% Full light
Partial light from the top or 1 side.	15%	5%	5%	100% Full light
Partial light from the top and 1 side.	15%	5%	5%	100% Full light
Partial light from the top and 2 sides	5%	35%	5%	100%Full light

4.1.8 Effects of Canopy on Photo-synthetic Active Radiation (PAR) of the adjacent grass

The canopy level i.e. the amount of light intercepted by the tree canopy was measured severally in the two seasons using quantum sensor for Photosynthetic Photon Flux Density (PPFD).

The study results (Table 4.6) indicate variations in photosynthetic active radiation (PAR) reaching the native grass pastures in different seasons. Acacia had the highest coverage in the amount of light in µmol m^{-2} s^{-1} reaching the grass pastures 389 µmol m^{-2} s^{-1} ,389 µmol m^{-2} s^{-1} ,543 µmol m^{-2} s^{-1} , 1245 µmol m^{-2} s^{-1} , 1477 µmol m^{-2} s^{-1} and 1490 µmol m^{-2} s^{-1} with canopy levels percentage 87%, 72%, 34%, 5%, 1% and 0% respectively. Season was significant factor since the PAR increased from 333 µmol m^{-2} s^{-1} , 359 µmol m^{-2} s^{-1} , 534 µmol m^{-2} s^{-1} , 1232 µmol m^{-2} s^{-1} , 1434 µmol m^{-2} s^{-1} and 1490 µmol m^{-2} s^{-1} with shading levels of 87%, 74%, 37%, 6%, 1.5,% and 0%. Acacia shed leaves during dry season enabling light to penetrate hence higher PAR. There was no significance difference after 30m away from tree stand against control. Cypress adjacent pasture had the second highest PAR reaching the native grass. A distance of 1-60m recorded PAR ranging from 287 µmol m^{-2} s^{-1} to 1500 µmol m^{-2} s^{-1} with shading level of 82% to 0% during dry season and 282 µmol m^{-2} s^{-1} to 1490 µmol m^{-2} s^{-1} with canopy levels of 83% to 0%.No significant shading level recorded after a distance of 40m verses the control. Eucalyptus had the lowest µmol m^{-2} s^{-1} reaching the adjacent grass. A distance of 1-60m recorded shading level ranging from 83% to 0% with PAR of 299 µmol m^{-2} s^{-1} to 1490 µmol m^{-2} s^{-1} during dry season and shading level of 87% to 0 with PAR of 266 µmol m^{-2} s^{-1} to 1490 µmol m^{-2} s^{-1}.

Near distance from the tree stand recorded lower PAR due to effect of shade. The result of the study indicate that though the canopy level of Acacia may be larger than the other two stands, shedding of leaves during dry seasons would enabled it to have higher PAR than the other two stands. The height of the tree stand promoted longer canopy level casted at a longer distance in Eucalyptus than the other two stands. This influences the performance and response of adjacent native grass far away from the tree stand. The finding concur with the work of Mahmood et al.(2007) that delivery of light in closed canopy areas depend on degree of canopy stress that causes reduction in the performance and durability understory plants

Table 4.6

Effects of Stand Canopy on the Photo Synthetically Active Radiation (PAR) Reaching the Native Grass

Light interception		Dry Season		Wet Season	
	Distance	Light μmol m^{-2} s^{-1}	Canopy level%	Light μmol m^{-2} s^{-1}	Canopy level%
Eucalyptus	1m	299	83%	266	87%
	1-10m	356	67%	333	71%
	10-20m	489	55%	444	58%
	20-30m	980	10%	977	11%
	30-40m	1459	5%	1434	6%
	40-60m	1490	0%	1490	0%
Acacia	1m	349	87%	333	89%
	1-10m	389	72%	359	74%
	10-20m	543	34%	534	37%
	20-30m	1245	5%	1232	6%
	30-40m	1477	1%	1434	1.5%
	40-60m	1490	0	1490	0%
Cypress	1m	287	82%	282	83%
	1-10m	366	63%	360	64%
	10-20m	496	50%	491	51%
	20-30m	1067	10%	1069	10.5%
	30-40m	1467	2%	1456	2%
	40-60m	1490	0%	1490	0%
Control		1500	0	1491	0

4.1.9 Effect of Canopy on the Soil Temperatures

Canopy temperature were taken in the mid-morning (8-11) and afternoon (2-3 pm) This was to establish effect of temperature on microbial activities. Table 4.7, eucalyptus shade recorded the lowest temperature at a distance of 1 m (29.5°C) and

1-10m (30.1°C) during 8-11 am in the morning and 12-3 pm in the afternoon. Temperature changes by increasing from 29.5°C to 30.3 °C between 8-11 am and 12- 3 pm respectively. There was a significant difference in temperature of the day between seasons. Wet seasons recorded lower temperature than the dry seasons. The temperature between 8-11 am in dry season and 11-9 pm in wet seasons in 3.4°C.The same results was recorded in the afternoon between 2-3 pm with a difference of 3^0C in a distance of 1 m away from tree stand. Distances between 10-40m away from the tree stand, there was significance linear increase in temperature in both seasons but wet seasons recording lower temperature than in dry season. There was no significance difference in temperature between 40-60 m away from the tree stand against control. Acacia recorded higher temperatures than Eucalyptus adjacent pastures. Higher temperatures were recorded during the day with closer difference of 1°C. The same was recorded between distances of 1-10 m away from tree stands. Increase in temperature during the day could have been brought about by shedding of leaves of Acacia during the dry seasons enabling light to penetrate. There was a significance decline in the temperature during the wet season across all distance against control in the adjacent pastures. The distances between 1-10 m away from the tree recorded the lowest temperature than all the other stands in wet seasons. This could have been drought about increase in vegetative growth during the wet seasons. However no significance difference against control was realized after a distance of 30-60 m away from tree stands. Cypress adjacent pastures had similar temperature recording like Eucalyptus adjacent pastures. However higher temperature was recorded across all distances but lower than Acacia and the control at distance between 1-30 m away from the tree stand. Seasons had a significance difference in the temperature recorded between distances of 1-30 m away. Closer distance like the other stands recorded lower temperature in wet seasons. No significance difference between 30-60 m away from tree stand was recorded against control. The results of the study indicate that season variations had a significant effect on soil temperature across the entire stand and the control. Lower soil temperature was found in dense canopy closer to Eucalyptus and Cypress than in Acacia. This might have been brought about by higher transmission of light in Acacia than the other adjacent trees at a closer distance from the tree stand. The finding support earlier studies by Bajad et al. (2017) that remittance of light to the understory depend on depth of the crown which influence subsequence factors like soil temperatures.

Table 4.7

Effect of Canopy on the Soil Temperatures

	Distance From the Shade	Dry Season		Wet Season	
		Soil Temperatures °C			
		8-11am	12-3pm	8-11pm	12-3pm
Eucalyptus	1	29.5°C	30.3°C	26.1°C	**28.3°C**
	1-10m	30.1°C	32.3°C	26.4°C	**28.7°C**
	10-20m	30.6°C	34.4°C	28.2°C	**29.2°C**
	20-30m	30.9°C	34.7°C	29.4°C	**30.3°C**
	30-40m	31.2°C	35.1°C	30.2°C	**31.6°C**
	40-60m	32.5°C	36.1°C	31.5°C	**32.6°C**
Acacia	1m	30.1°C	31.1°C	25.1°C	**27.8°C**
	1-10m	30.6°C	33.3°C	25.7°C	**27.9°C**
	10-20m	30.9°C	34.9°C	27.2°C	**28.7°C**
	20-30m	31.1°C	35.2°C	30.6°C	**31.3°C**
	30-40m	32.5°C	36.1°C	31.5°C	**32.6°C**
	40-60m	32.5°C	36.1°C	31.5°C	**32.6°C**
Cypress	1m	29.7°C	30.6°C	26.7°C	**28.8°C**
	1-10m	30.4°C	32.9°C	26.9°C	**29.1°C**
	10-20m	30.9°C	34.9°C	28.8°C	**29.7°C**
	20-30m	31.2°C	35.0°C	30.1°C	**30.9°C**
	30-40m	31.2°C	35.6°C	30.7°C	**32.1°C**
	40-60m	32.5°C	36.1°C	31.5°C	**32.6°C**
Control		**32.7**	**36.1°C**	**31.6°C**	**32.7°C**

4.1.10 Effects of Canopy on Soil Organic Carbon (SOC)

The amount of Soil Organic Carbon (SOC) was recorded during wet and dry seasons. The main aim was to determine whether the canopy affects the mineralization of Carbon. Table 4.8 shows the results. Higher organic Carbon was recorded in the dry season than in the wet season across all stands and the control. There was no significant difference in the effect of shade increase as distance increased against control. This means that shade did not decrease the amount of SOC present. Eucalyptus recorded the highest Carbon content at 1m away (4.6% against control 3.9%). Consequence shading 1-10 (4.5%), 10-20 (4.2%) 20-30(4.1%) was higher than the control. Higher Carbon content was also recorded in the wet season than the other stands and the control. Acacia adjacent pastures recorded relatively higher soil organic Carbon content than the two stands. There was a marked difference in the amount of SOC yielded during the wet season, with higher differences in a distance of 1m (4.7 in cypress and 4.9 in eucalyptus). The seasonal difference in the amount of organic Carbon was much higher than that of eucalyptus. An increase in distance lowered SOC by 40-60m, recording a similar result to the control. The study's finding was in line with that of Shao et al. (2014) who found significant interactions between light and the mineralization of Carbon. Higher carbon mineralization was associated with a higher light passage in a closed canopy area due to the effects of temperature on the microbial process.

Table 4.8

Effects of Canopy on Soil Organic Carbon (SOC)

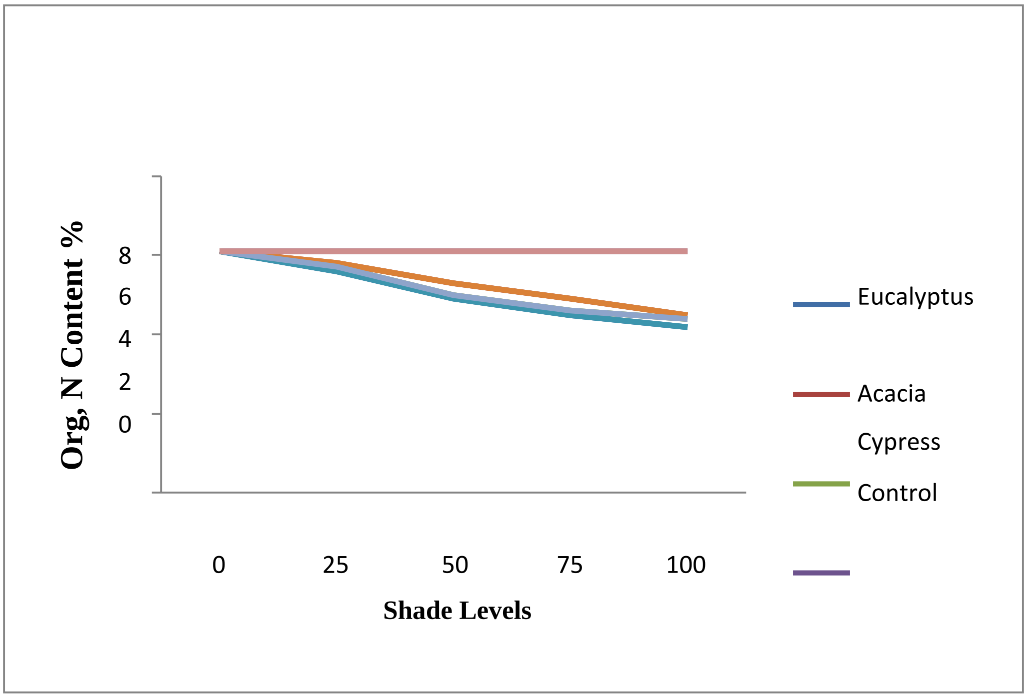
	Distance From the Shade	Dry Season Soil Organic Carbon Percentage	Wet Season Percentage
Eucalyptus	1	4.6%	4.4%
	1-10m	4.5%	4.3%
	10-20m	4.2%	4.1%
	20-30m	4.1%	3.9%
	30-40m	3.9%	3.4%
	40-60m	3.8%	3.2%
Acacia	1m	4.9%	4.2%
	1-10m	4.7%	4.0%
	10-20m	4.5%	3.9%
	20-30m	4.2%	3.6%
	30-40m	3.9%	3.4%
	40-60m	3.9%	3.3%
Cypress	1m	4.7%	4.4%
	1-10m	4.5%	4.2%
	10-20m	4.3%	4.1%
	20-30m	4.0%	3.9%
	30-40m	3.9%	3.4%
	40-60m	3.7%	3.2%
Control		3.8%	3.3%

4.1.11 Effects of Canopy on Soil Organic Nitrogen (SON)

The amount of Soil Organic Nitrogen (SON) was recorded during wet and dry seasons. The main aim was to determine whether the canopy affects the mineralization of Nitrogen. Figure 4.3 below shows the results. High shade levels of 1m across all the adjacent pastures recorded lower organic N content. Eucalyptus adjacent pastures recorded the lowest organic N content in the soil samples (0.24% and 0.23% against control 0.39% and 0.41% in dry and wet seasons). There was a significant progressive increase in organic N content as the distance increased from the eucalyptus adjacent grass pastures. Seasons had significant effects on organic Nitrogen across the stands and the control. Acacia adjacent pastures recorded the highest amount of organic Nitrogen at a closer distance from the tree stand among the three tree stands. There was a progressive increase in the amount of N content as the distance increased. The adjacent pasture to Acacia did not record significant differences in soil organic Nitrogen at a distance between 30-40m and 40-60 against control. Cypress adjacent pastures were second to Eucalyptus like the other adjacent pastures. There was a progressive increase in soil organic content (0.25%-0.39%) in the dry season and (0.24%-0.41%) in the wet season. No significant difference in the amount of N content after a distance of 40m away against control. In general, all the adjacent pastures and the control showed a decrease in soil organic N content during the wet season. This might have been caused by the mineralization of organic Nitrogen into Nitrate. Similar study results were also noted by Trewicket al. (2001) that differences in mineral content in the soil had been associated with increased canopy structure and litter chemistry.

Figure 4.3

Effects of Shade/Canopy levels on Soil Organic Nitrogen



4.1.12 Effects of Canopy on Soil Organic Phosphorus (SOP)

The amount of Soil Organic Phosphorus (SOP) was recorded during wet and dry seasons. The main aim was to find out whether the canopy affects Phosphorus mineralization. Table 4.9 below shows the results. The study results show that the number of Phosphorus increases as the soil moisture increases during the wet season. The amount of soil organic phosphorus was higher as the distance increased from the tree stand (0.13% versus 0.28% for the dry season and 0.15% versus 0.33% for wet seasons in distances of 1m and 40-60m, respectively).

Eucalyptus recorded the lowest (0.13%) amount of Phosphorus present in soil organic phosphorus. Near distances from the eucalyptus tree recorded the lowest phosphorus presence across the stand and the control season (0.13% and 0.15%). An increase in distance progressively increased the amount of organic P in the soil. There was no marked deference for the yield of organic Phosphorus between the distances of 40-60 against control.

Acacia adjacent pastures had the highest amount of organic Phosphorus across all stands in near distances (0.17% and 0.21%) for a distance of 1m away in dry and wet seasons. Seasons had significant effects on the amount of Phosphorus yielded during the period. Adjacent pastures next to cypress recorded higher organic Phosphorus than eucalyptus but lower than Acacia. Closer distances to the tree stand recorded a lower amount of Phosphorus than the other stand (0.15% dry and 0.16% wet seasons). There was an increase in the amount of phosphorus yield in different seasons. No marked difference in organic phosphorus amount was recorded after 40-60m away against control.

Table 4.9

Effects of Canopy/Shade levels on Soil Organic Phosphorus

	Distance From the Shade	Dry Season Soil Organic Phosphorus Percentage	Wet Season Percentage
Eucalyptus	1	0.13%	**0.15%**
	1-10m	0.17%	**0.22%**
	10-20m	0.20%	**0.25%**
	20-30m	0.21%	**0.27%**
	30-40m	0.24%	**0.30%**
	40-60m	0.28%	**0.33%**
Acacia	1m	0.17%	**0.21%**
	1-10m	0.18%	**0.25%**
	10-20m	0.15%	**0.28%**
	20-30m	0.16%	**0.28%**
	30-40m	0.28%	**0.32%**
	40-60m	0.27%	**0.33%**
Cypress	1m	0.15%	**0.16%**
	1-10m	0.19%	**0.23%**
	10-20m	0.20%	**0.25%**
	20-30m	0.22%	**0.28%**
	30-40m	0.26%	**0.30%**
	40-60m	0.28%	**0.33%**
Control		**0.29%**	**0.33%**

4.1.13 Effect of the Canopy on Stomata Conductance of the Adjacent Pastures

Stomata conductance was measure using quantum sensor for Photosynthetic Photon Flux Density (PPFD).The main aim was to compare light irradiance in canopy areas and open field without canopy (Table 4.10). The study results shows that effect of the shade had a higher stomata conductance during the morning hours than in the afternoon. Eucalyptus recorded 0.033-0.031µmol m^{-2} s^{-1} in the morning and 0.029-0.028 031µmol m^{-2} s^{-1}during the afternoon. Acacia recorded 0.033 µmol m^{-2} s^{-1}-0.031 µmol m^{-2} s^{-1}, 031µmol m^{-2} $s^{-1}$and 0.037 µmol m^{-2} s^{-1}- 0.028031µmol m^{-2} s^{-1}. In the afternoon Cypress recorded 0.034 µmol m^{-2} s^{-1}- 0.031 µmol m^{-2} s^{-1} 031µmol m^{-2} $s^{-1}$and 0.031 µmol m^{-2} s^{-1} – 0.028 µmol m^{-2} s^{-1} 031µmol m^{-2} s^{-1}in the afternoon. The result indicated that morning hours had more stomata light conductance than in the afternoon. The stomata light conductance was lower in control than shade at a distance of 1 m away from the tree stand. The stomata conductance was higher in rainy seasons than in dry season. Morning hours in the rainy seasons showed higher stomatal conductance than in the afternoon. Stomata conductance was not significant in the control and distance of 1m away. This means that stomata conductance did not respond to full light in the control than the shade. The findings concur with the work of Timling et al. (2010) that low light levels casted by dense canopy stands have often been known to affect stomata conductance.

Table 4.10

Effect of Shade on Adjacent Pastures Stomata Conductance (μmol m−2 s−1)

	Distance From the Shade	Dry Season		Wet Season	
		Stomatal Conductance (μmol m^{-2} s^{-1})			
		8-11pm	**12-3pm**	**8-11pm**	**12-3pm**
Eucalyptus	1	0.033	0.029	0.041	0.035
	1-10m	0.036	0.031	0.045	0.039
	10-20m	0.038	0.034	0.048	0.042
	20-30m	0.041	0.038	0.052	0.048
	30-40m	0.042	0.031	0.043	0.038
	40-60m	0.031	0.029	0.038	0.036
Acacia	1m	0.033	0.037	0.044	0.042
	1-10m	0.039	0.039	0.049	0.046
	10-20m	0.042	0.041	0.051	0.049
	20-30m	0.048	0.044	0.056	0.053
	30-40m	0.031	0.028	0.038	0.036
	40-60m	0.031	0.027	0.038	0.036
Cypress	1m	0.034	0.031	0.043	0.037
	1-10m	0.037	0.033	0.048	0.041
	10-20m	0.039	0.037	0.051	0.046
	20-30m	0.043	0.039	0.055	0.052
	30-40m	0.031	0.028	0.038	0.036
	40-60m	0.031	0.028	0.037	0.035
Control		0.031	0.028	0.038	0.036

4.1.14 Effects of Canopy's photosynthetic Active Radiation (PAR) on Grass Biomass - An allometry analysis was conducted to establish the inter-relationship among canopy, active photosynthetic radiation, and grass biomass. The results of the study (Table 4.11) indicate that there was a linear progressive increase in grass biomass as distances from the tree shade increased. Lesser light across all the tree stands was recorded during the wet season due to vegetative tree growth that blocks the light radiation. The Eucalyptus tree stand had the lowest photosynthetic active radiation at a distance of 1m away from the tree. The grass biomass was significantly affected and recorded as the lowest across the entire stand and the control. The effect of season was significant since lesser light was recorded reaching the adjacent grass. This consequently affected the biomass of the grass. There was no significant difference in the shade on the grass biomass yield after a distance of 40-60m from the tree stand against the control. Acacia had the highest photosynthetic active radiation reaching the native grass. The small leaf area prevented the acacia tree from blocking the light and, therefore, higher photosynthetic active radiation (PAR) reaching the native grass pastures. The season affected the Acacia adjacent grass biomass, with the wet season recording lower photosynthetic active radiation due to the vegetative growth of the tree blocking the light. As the distance increases from the tree, the biomass progressively increases. However, no significant difference in grass biomass was recorded after the distance of 30-40m and 40-50m away from shade against control. Cypress adjacent pasture had a closer relationship with the PAR reaching the native grass like eucalyptus. Their difference was that adjacent nature grass pastures received more light at a closer distance due to the leaf area, which was smaller than eucalyptus. The grass biomass was much higher than adjacent pastures to eucalyptus but lesser than that of acacia and control. The effect of shade affected the adjacent pastures up to a distance of 30m. Further distances between 30-40m and 40-60m did not significantly affect native grass biomass production. The finding of the study was in line with those Stoll et al. (2001) observed that *light quality, both color, and intensity is a key component of determining the biomass of understory plants.*

Table 4.11

Allometry analysis of Canopy's Photosynthetic Active Radiation (PAR) and Grass Biomass

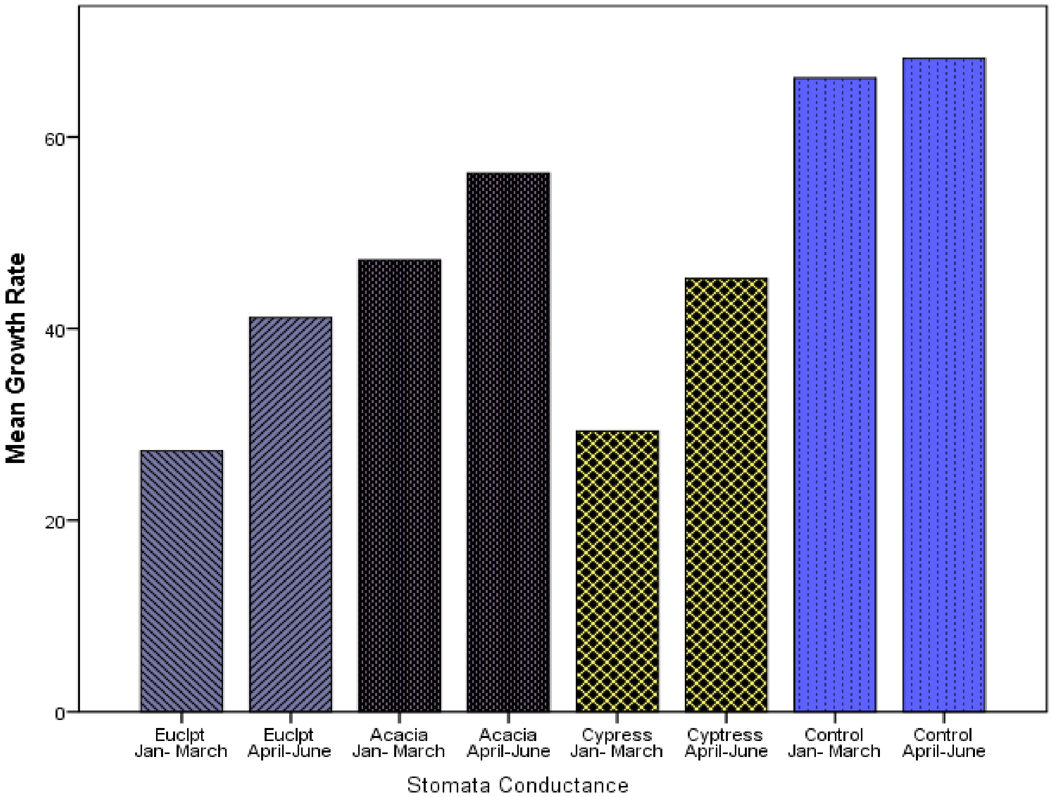
		Dry Season		Wet Season	
	Distance From the Shade	Light interception			
		Light µmol m^{-2} s^{-1}	**Biomass**	**Light µmol m^{-2} s^{-1}**	**Biomass**
Eucalyptus	1	299.2	209.1g	266.2	211.3g
	1-10m	356.3	222.4g	333.1	229.1g
	10-20m	489.2	229.3g	444.4	239.1g
	20-30m	980.4	231.1g	977.2	245.4g
	30-40m	1459.2	242.1g	1434.2	252.3g
	40-60m	1490.2	256.1g	1491.1	261.4g
Acacia	1m	349.3	222.2g	333.4	229.2g
	1-10m	389.3	231.1g	359.3	246.1g
	10-20m	543.3	239.3g	534.4	249.1g
	20-30m	1245.3	247.1g	1232.1	250.4g
	30-40m	1477.4	253.2g	1434.4	261.4g
	40-60m	1490.0	255.2g	1490.2	261.2g
Cypress	1m	301.1	211.3g	282.2	217.3g
	1-10m	366.0	229.2g	360.1	231.3g
	10-20m	496.1	231.1g	491.2	241.2g
	20-30m	1067.3	239.4g	1069.1	249.1g
	30-40m	1467.3	253.4g	1456.0	260.2g
	40-60m	1490.1	254.2g	1492.2	261.1g
Control		1490.2	253.2g	1491.0	261.4g

4.1.15 Effect of Canopy on Leaf Growth Rate

Figure 4.5 Shows effect of canopy on leaf growth rate. The growth rate was observed twice in the duration of the study. Acacia had the highest leaf growth rate of 29cm long against control of 38cm during the dry season. During wet season the growth rate increases to 5cm.This was lower to that of the control by 6cm.Cypress had the second leaf growth rate of 26cm long during dry season and 33cm during wet season. Eucalyptus adjacent pasture was the lowest Total of 25cm long leaf growth rate was recorded during dry season and 30cm during wet season. The result of the study shows that canopy stomata conductance affect leaf growth rate. The study findings were also similar to those of Haque and Rahman (2009) that canopy reduces photosynthetic active radiation that consequently affects developmental qualities in understory plants growth height and photosynthetic allocation of starch

Figure 4.5

Effect of Canopy on Leaf Growth Rate

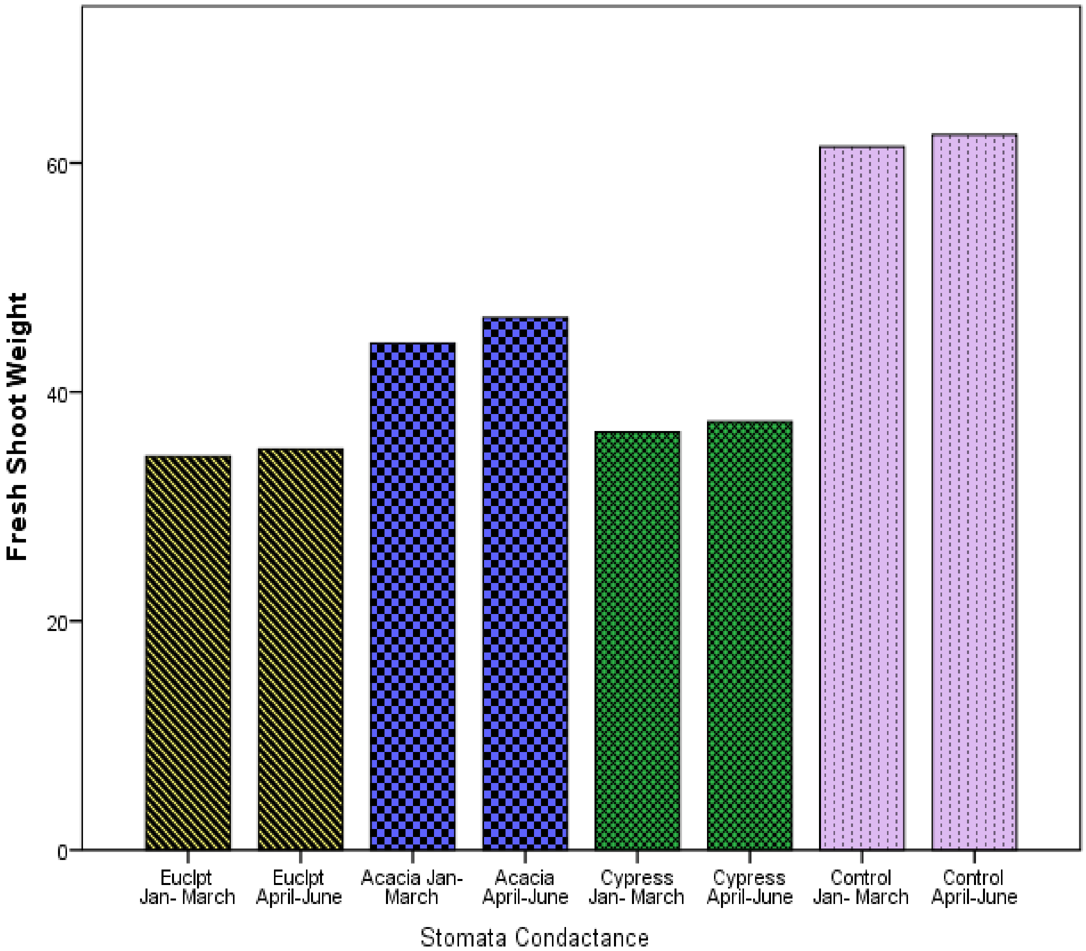


4.1.16 Effect of Canopy on the Grass Shoot weight

The aim of the study was to establish relationship between stomata conductance and its effect on adjacent native grass (Figure 4.6). The highest shoot weight was found in Acacia among the tree stands. Total of 17mg was recorded during dry season and 25 mg during wet season. Cypress adjacent pasture recorded 10 mg of shoot weight during dry season and 12mg during wet season. Eucalyptus was the least with 8 milligrams during dry season and 19 milligrams of shoot weight during wet season. Similar results were also echoed by Baroli et al.(2008) that the play a significant factor in determining shoot weight, biomass distribution and growth height which increase with increase in light intensity

Figure 4.6

Effect of Canopy on the Grass Shoot weight



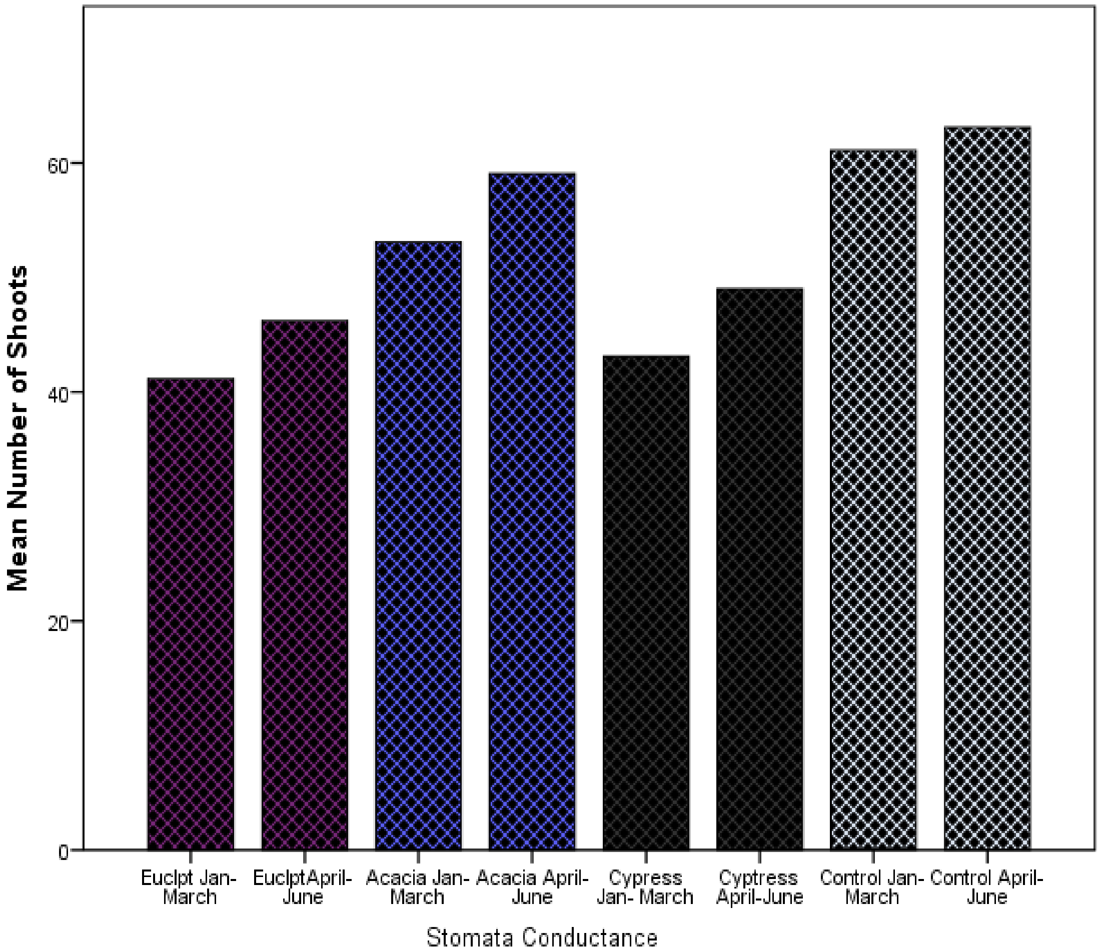
4.1.17 Effect of the tree canopy shade on the Grass Shoot Number

The shoot number was also recorded during experimental period (figure 4.7). Acacia had the highest grass leaf number of 8 shoot during the dry season and 12 shoot during the wet season. During wet season the shoot number increases to 4 shoots.

Cypress had the second shoot numbers with about 5 shoots during dry season and 7 shoots during wet season. Eucalyptus adjacent pasture was the lowest with 3 shoots during dry season and 7 shoots during wet season. The study result shows that canopy is a significant factor in determining the growth rate of adjacent grass shoots Bajad et al. (2017) also echoed the same results that shade causes reduction in overall performance of understory plants in terms of shoot number and total biomass

Figure 4.7

Effect of Canopy on the Grass Shoot Number



4.1.18 Effects of the Canopy on Grass Biomass

The above ground biomass was recorded during wet and dry seasons. The main aim was to find out whether a canopy level has an effect on grass biomass yield. Table 4.10 shows the results. Average biomass yield in grass per $0.25m^2$ transect was evaluated. Across all the stands, lower biomass in dry seasons was observed than in wet seasons. Eucalyptus adjacent pastures recorded the lowest biomass yield in 1m away from the tree stand (209g) against control (253g). There was linear progression increase in biomass yield in grass with increase in distance. Season was significant factor in biomass of the adjacent grass as the record of yields was higher than during the dry season. There was no significance difference in biomass yield found between 40-60m away with the control. Acacia recorded the highest biomass yield across all the other stands in 1m away from the tree stand but lesser than control (222g verses control 253g) in the dry season. Seasonal difference was significant across all distance. There was linear progressive increase in the amount of biomass yield as distance increases. Acacia adjacent grass pasture did not show any significance difference in biomass yield between 30-40m and 40-60m away from three stands against control. Adjacent pastures next to cypress had relatively higher biomass yield than eucalyptus across all distances but lower than the amount recorded in acacia adjacent pastures. Like other adjacent pastures season was significant with progressive increase across all distances. The study result did not find significant different between distance of 30-60m away from tree stand against control. The study results concur with the work of Thompson et al. (2004) that in canopy closed areas some grass species may be able to tolerate low light yielding more biomass than others

Table 4.12

Effects of Canopy/Shade levels on Adjacent Native Grass Biomass

	Distance	Dry Season	Wet Season
Eucalyptus	1	209.1g	211.1g
	1-10m	222.2g	229.0g
	10-20m	229.4g	239.1g
	20-30m	231.4g	245.0g
	30-40m	242.4g	252.2g
	40-60m	254.2g	261.4g
Acacia	1m	222.2g	229.4g
	1-10m	231.2g	246.4g
	10-20m	239.2g	249.2g
	20-30m	247.1g	250.2g
	30-40m	252.1g	263.2g
	40-60m	253.2g	261.4g
Cypress	1m	211.3g	217.3g
	1-10m	229.2g	231.4g
	10-20m	231.2g	241.4g
	20-30m	239.3g	249.3g
	30-40m	253.4g	262.2g
	40-60m	254.1g	261.3g
Control		253.1g	261.2g

4.1.19 Effect of the Canopy Shade on Herbaceous on Species Composition

Figure 4.9a, figure 4.9b, figure 4.9c and figure 4.9d show effects of crown density on species composition. The main aim of the study was to evaluate effect of crown growth structure on species composition and establish connection between them. The study found that the number of species composition was significantly affected by the stand breast height. In Eucalyptus, reduction of canopy breast height resulted to co-existence of species composition. The percentage of species composition did not vary greatly. Relative proportion balance of *Chloris gayana* 18%, *cynbopogon nardus*, 31%, *cynodon dactylon* 20% and *Digitaria scalarum* 31% were observed as compared to Chloris *gayana* 6%, *cynbopogon nardus*,40 %, *cynodon dactylon* 8% and *Digitaria scalarum* 36% in high canopy breast height. Eucalyptus had the highest breast height among the three stands. High breast height casted by eucalyptus tree reduces the number of species composition per unit area as compared to other stands. It was also found to have greater disparities in percentages relative to its size. Cypress had the second largest breast height canopy after Eucalyptus. Just like eucalyptus, significance differences were observed in species composition. Cynbopogon *nardus* had 49 % followed by *Digitaria scalarum* (36%) while *Chloris gayana* and *cynodon dactylon* had 8% and 6% respectively. Lower breast height in cypress significantly increased the relative balance among species composition. Dominance grass species was found to be *cynbopogon nardus* and *Digitaria scalarum.* Acacia had almost balanced species composition with little difference in breast height. Difference in highest and lowest breast height did not go beyond 2 meters. An umbrella shaped canopy was formed. There were no marked differences in species composition but

Digitaria scalarum and *cynbopogon nardus* had 2% higher than the *Chloris gayana* and *cynodon dactylon* grass species. The results show that there were noticeable relationships between canopy cover in different tree stands. However, there were no marked differences was found in acacia tree relative proportion to species composition co-existed against control. A previous study by Timling et al. (2010) observed that low light casted by some canopy stress area has an effect on stomatal conduce and establishment of native grass species composition. This was found to contribute more in ecological selection of valuable species of native grass that only tolerate deep canopy stress

Figure 4.9a

Effects of Eucalyptus Crown Density on Species Composition

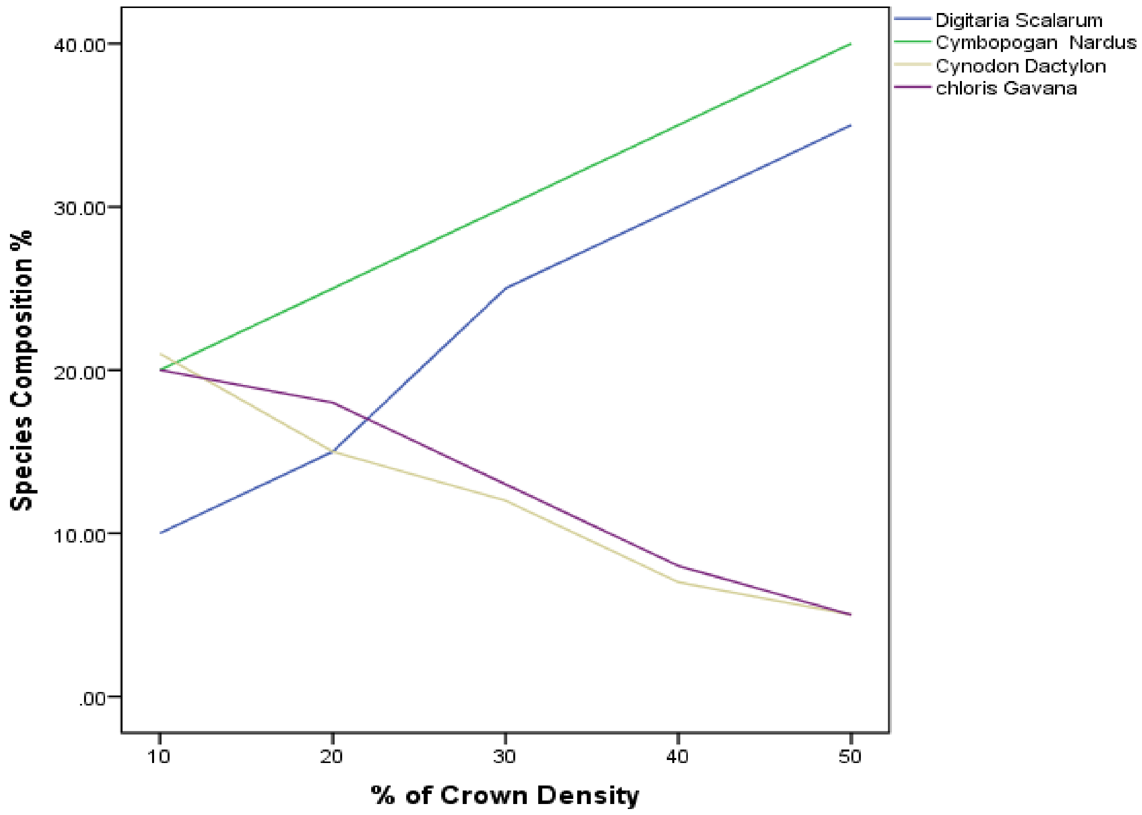


Figure 4.9b

Effects of Cypress Crown Density on Species Composition

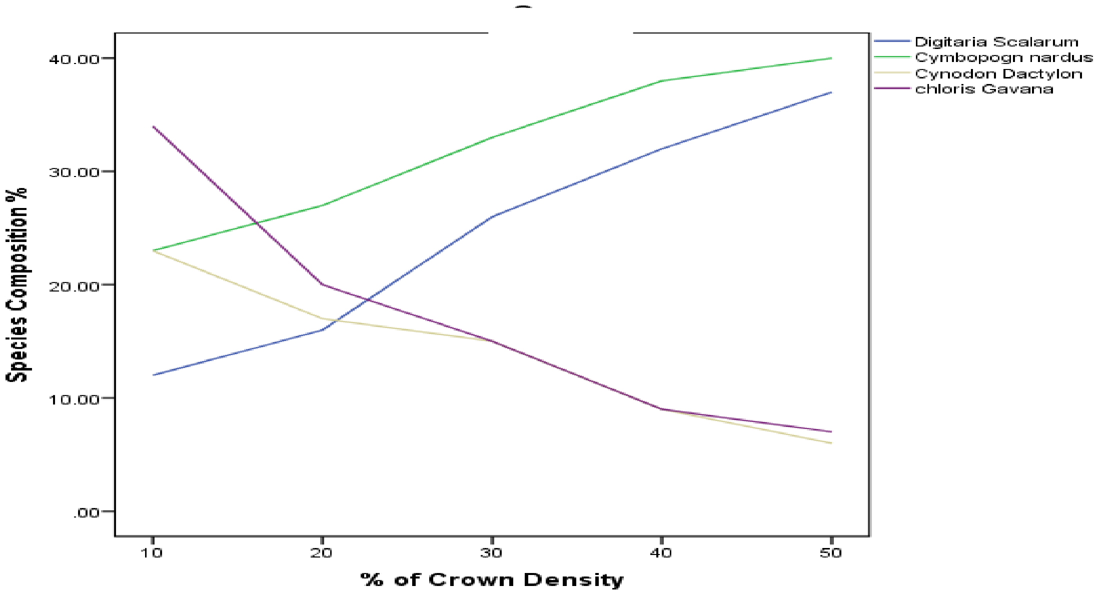


Figure 4.9c

Effects of Acacia Crown Density on Species Composition

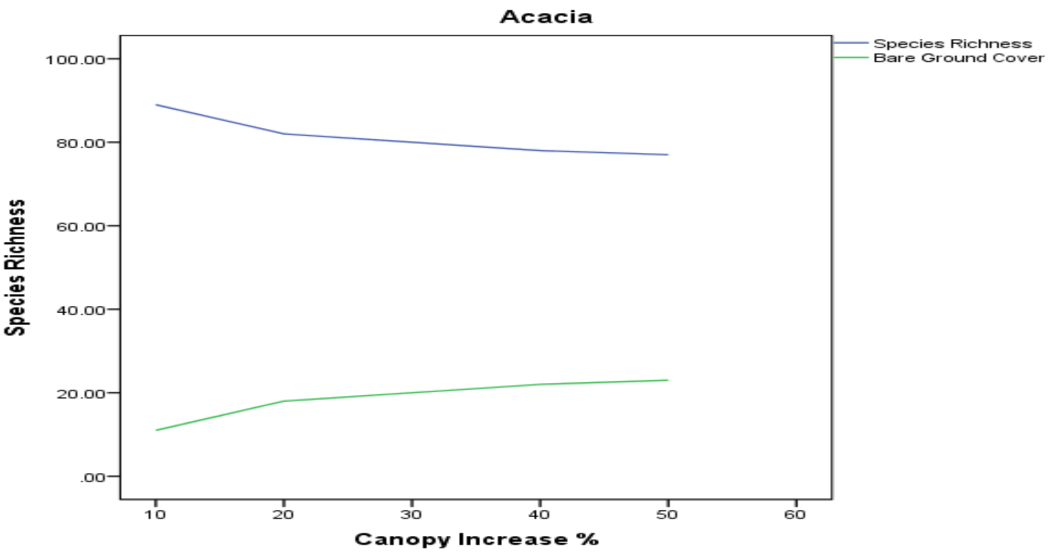
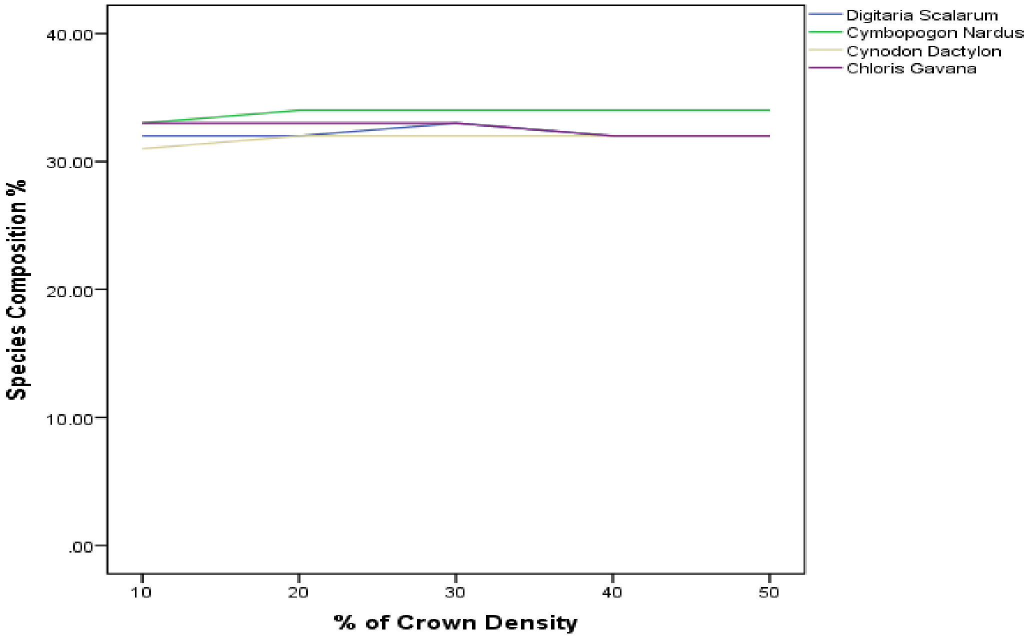


Figure 4.9d

Effects of Control Crown Density on Species Composition



4.1.20 Effect of Canopy Structure on Species Richness

Figure 4.10a, figure 4.10b figure 4.10c and figure 4.10d show effects of crown density on species composition. The objective was to evaluate effect of canopy on species richness and establish connection between them. The study found four dominant grass species across all the stands and the control. The dominancy of the species was related to the adjacent tree stand characteristics of canopy structure. In Acacia, reduced breast height resulted to higher species richness compared to control. Relative proportion balance of *Chloris gayana cynbopogon nardus*, *cynodon dactylon* and *Digitaria scalarum* percentage were closer to that of control. Canopy height of less than 2m breast height in Acacia was found to have 82% compared to control

89%.This mean that other plant characteristics in a reduced canopy did not significantly affect the species richness. A uniform species richness characteristic was observed across canopy breast height. However, wet season was found to increase canopy percentage due to growth of leaves but at the same time the native grass developed time reducing differences in species richness in an enhanced canopy breast height. Cypress had the second highest species richness per quadrat. Effect of canopy breast height significantly affected the percentages of species richness. Other plant growth characteristics were found to affect species richness even in a reduced canopy stress. Eucalyptus had the highest breast height among the three stands. The effect of breast height casted reduced the number of species per quadrat. A greater disparity in percentages of species richness was found against control in a reduced breast height and canopy stress. The result of the study shows that were relationship between species richness and canopy breast height. However, other adjacent canopy stand characteristics may affect species richness even with reduced canopy stress. A related study by Strassburg et al. (2010) on crown closure effects on PAR transmittance found that crown density is associated with relative existence of species composition and richness of the understory vegetation. Some grass species were found to tolerate low light condition while others failed. This affected their number per unit area

Figure 4.10a

Effect of Eucalyptus Canopy on Species Richness

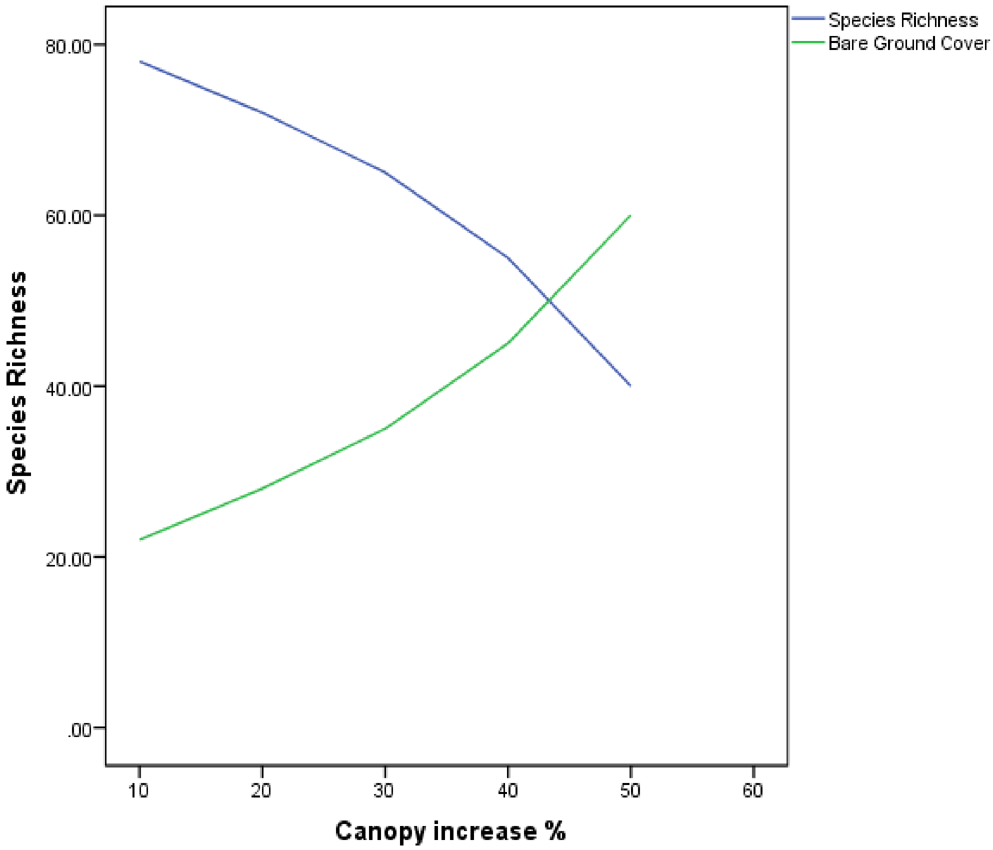


Figure 4.10b

Effect of Cypress Canopy on Species Richness

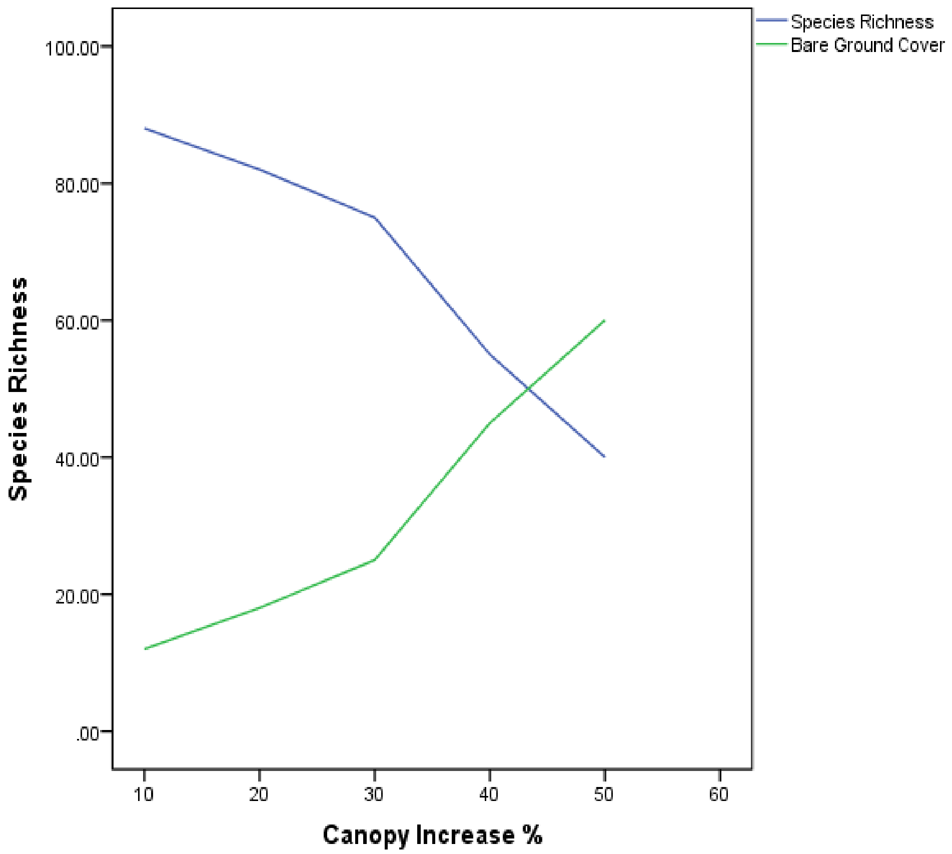


Figure 4.10c

Effect of Acacia Canopy on Species Richness

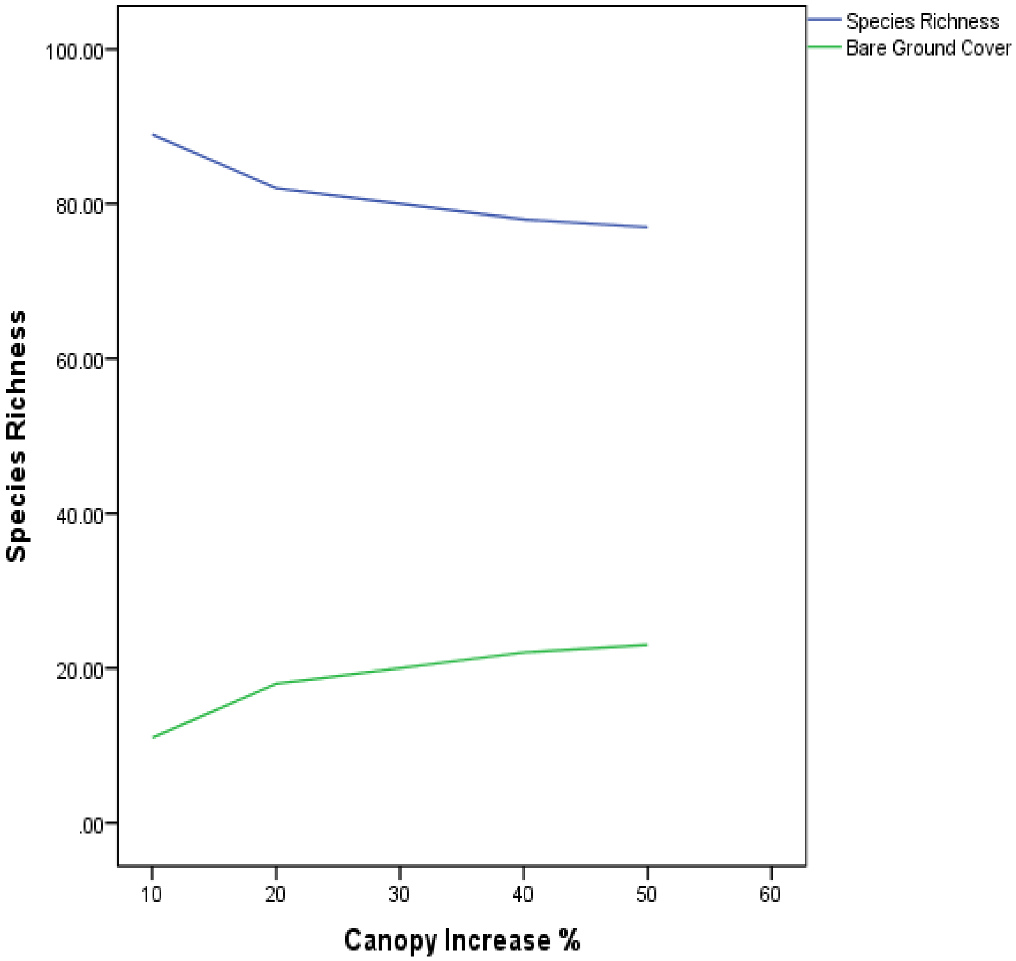
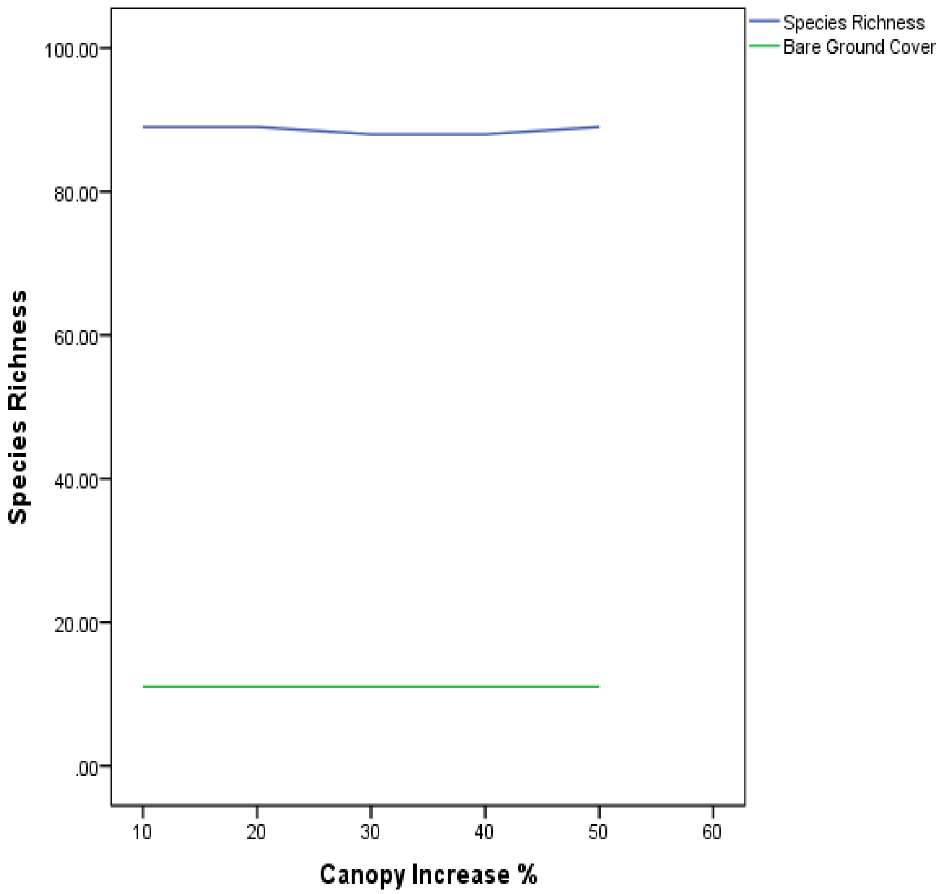


Figure 4.10d

Effect of Control Canopy on Species Richness



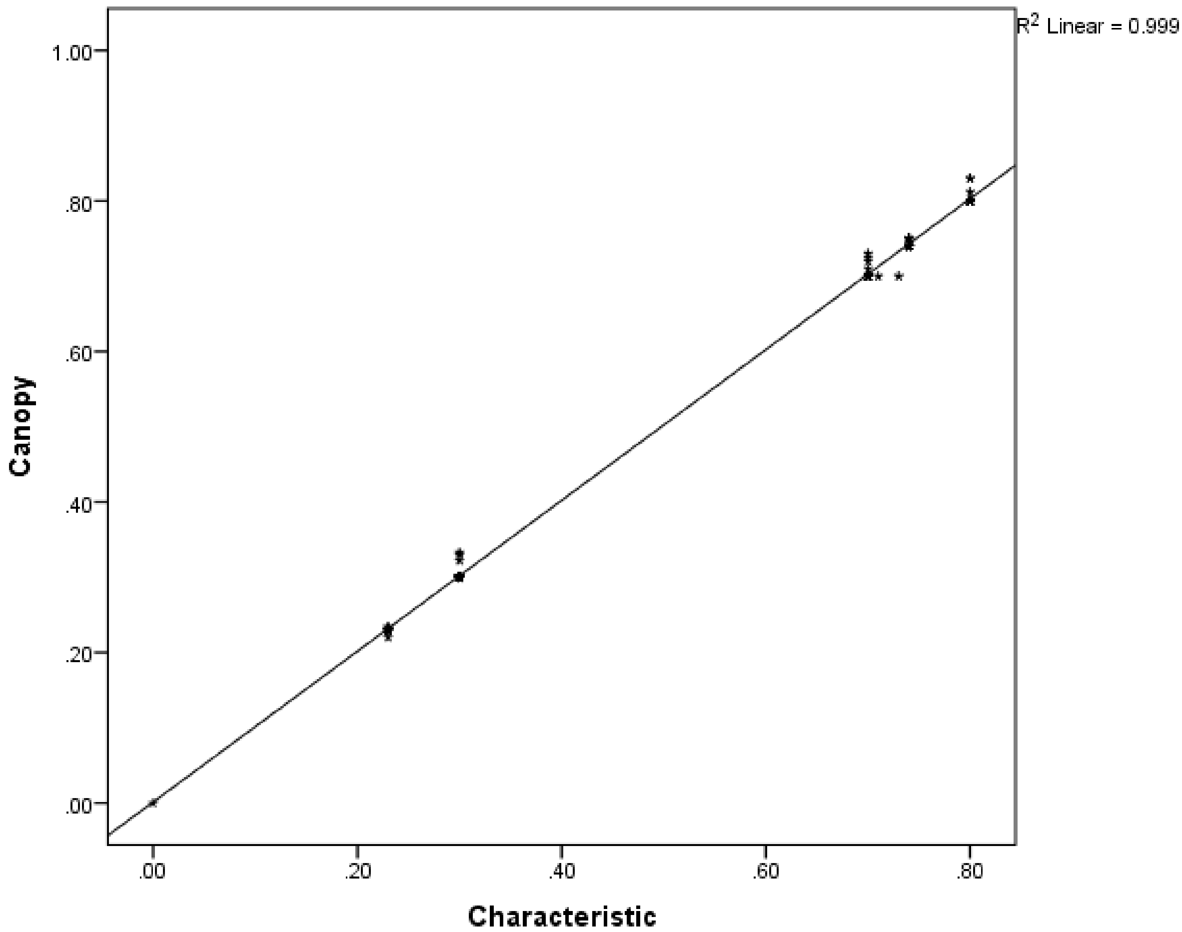
4.1.21 Linear Regression Analysis of Canopy Structure and the Above Ground Grass characteristics.

Species Composition, Species Richness, Species Cover and Grass Biomass were the independent variables.

In the regression analysis (figure 4.11), canopy structure slope (y=24.3x+4) was plotted against above ground grass characteristics (species composition, species richness, species cover and grass biomass as the independent variable).Species composition had weak correlation of $r^2=0.23$ ($p<0.05$) but significant. This suggests that canopy structure did not strongly influence species composition like the other variables. Species richness had a strong correlation of $r^2=0.63$ ($p<0.05$). Another stronger correlations were found with species cover of $r^2=0.73$ ($p<0.05$) while grass biomass had the strongest correlation of $r^2=0.82$ ($p<0.05$). The study results shows that canopy structure influences little to the species composition, moderately affect species richness and species cover while to the most affect the biomass. This was based on the strength of the regression analysis. The study results had similar findings with that of Guo & Sims (2002) that the degree of light significantly affect plants' growth stages and biomass. These different transmissions of light affect physiological and morphological responses of plant species. Gregoriou et al. (2007) also observed that shade causes reduction of photosynthetic active radiation, influences performance and durability of grass surface as well as reduced levels of irradiance. Similar finding were also found by Mahmood et al. (2007) that with increased canopy, grass dry weight, tiller density, leaf area index, degree of coverage and quantity of clipped materials are affected. Based on these findings and the related literature, the null hypothesis which stipulates that there is no significant difference between the canopy structure and the above ground resource influence is rejected.

Figure 4.11

Regression Analysis Model of Canopy Structure as the dependent variable



Species composition r^2=0.23, **Species Richness** r^2=0.63, **Species Cover** r^2=0.73**, Grass Biomass** r^2=0.82

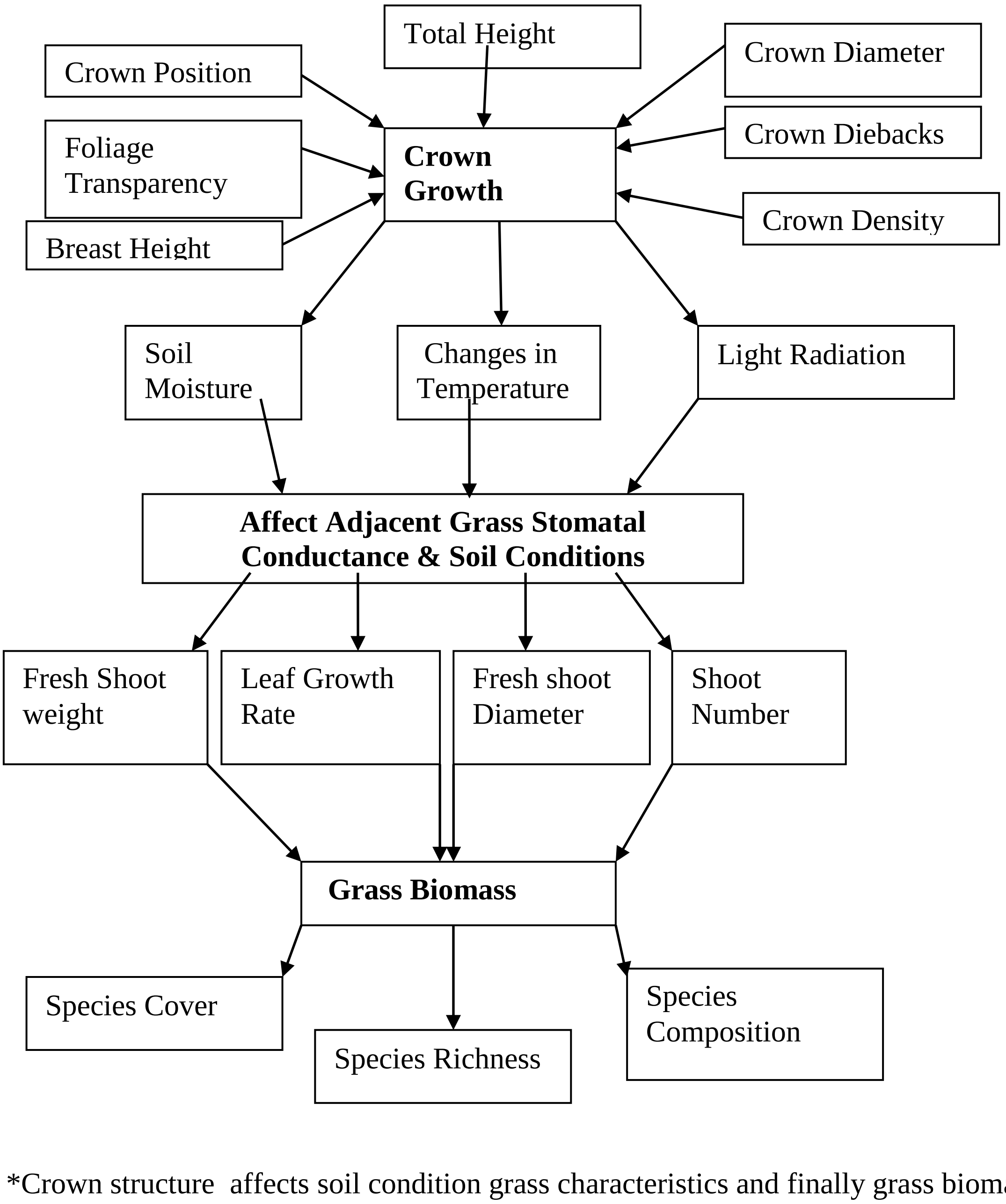
Horizontally, **means are significant ($p<0.05$).

4.1.22 Summary Model Analysis of The Interactions between Tree Crown Structure and Above Ground Processes that affect Adjacent Native Pasture

Figure 4.12 shows model crown growth morphology and their effects on adjacent pasture. Crown growth morphology consists of crown density, total height, breast height, crown position and crown diameter. The nature of the crown affects the light radiation in canopy closed areas. Crown structure such as total height and breast height determined the area of the shadow casted by the tree. Crown position and density control distribution of the light to the ground. Soil temperatures, moistures and light are controlled by the nature of the canopy structure. These factors affect the adjacent native grass pasture stomata conductance which consequently affects their fresh shoot weight, leaf growth rate and number of shoots. Only selected grass species can manage to survive in some canopy closed areas. That adaptive selection creates differences in herbaceous species composition, cover and richness

Figure 4.12

Model Analysis of the Crown Structure and the Above Ground processes that affect the delivery of resources to the adjacent Native pasture



*Crown structure affects soil condition grass characteristics and finally grass biomass in terms of Species richness, composition and cover

4.2 Roots Structure and Below Ground Space Coverage

4.2.1 Analysis of Root Density of the Sampled Tree

Table 4.13, Eucalyptus had highest root density at a distance of 1m away from tree stand (13 $\pm$2.74) in dry season and (13 $\pm$2.68) in wet season. Seasonal changes did not have an effect on root density at a distance of 1m from eucalyptus stand. Further increase in distance caused decrease in the number of roots present per a square grid of 5x5cm.

Cypress tree recorded the second highest root density among the three stands. The amount of root densities was much higher in a distance of 1-10m away from tree stand than far distances. There was linear decrease in density of roots as distance increase. There was no significance difference in root density after a distance of 30m away. Acacia had the lowest root density but significantly higher than cypress in both seasons. Wet season recorded significantly higher root density across all the distances away from tree stand. Like cypress, the record of root density was effective up to a distance of 20m.No significance record of root densities were found after 30m away. The mean root densities across the entire stands were significantly higher in wet season than dry season across all stands

Table 4.13

Analysis of Root Density of the Adjacent Trees

Root density (indiv./cm2) by Distance from the Tree Trunk

Tree type/Dist		**1m**	**10m**	**20m**	**30m**	**40m**	**50m**	**60m**
Eucalyptus	Dry	13±2.74	9±3.77	7±2.35	5±2.21	3±1.37	0	0
	Wet	13±2.68	10±3.56	9±3.38	6±3.27	4±2.37		
Acacia	Dry	10±3.57	9±3.78	5±3.38	0	0	0	0
	Wet	10±3.34	10±2.35	6 ±2.24	0	0	0	0
Cypress	Dry	11±2.28	10±3.45	7 ±2.34	0	0	0	0
	Wet	11±2.33	11±3.22	8 ±3.33	0	0	0	0
Mean	Dry	11±2.83	9±3.67	6±2.56	0	0	0	0
	Wet	11±2.78	10±3.9	8±3.22	0	0	0	0

Note Mean root density ± standard deviation.

4.2.2 Diameter and Branching Pattern of Fine Tree Roots

The basal diameter of the fine root of different stands was measured in relation to their bearing root segment (branching). The result was as shown in the figure 4.13

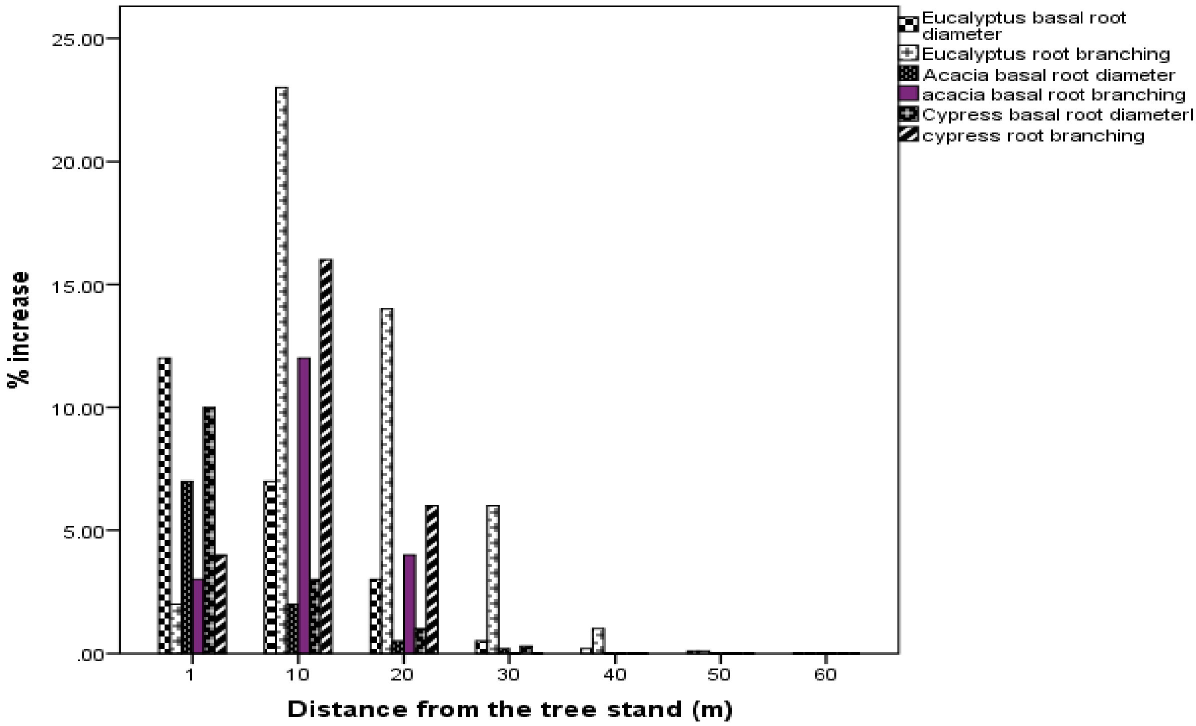
Figure 4.13 indicates that Eucalyptus had the largest basal root diameter. A distance of about 1m from the tree stand had 2.2mm diameter. However, increase in diameter did not correspond with branching capacity. Only three roots were found to branch at near distance from the tree stand. The diameter of the roots significantly reduced as the distance increased. At about 20m from the tree stand, the number of roots branching increases (1.0 mm diameter). At a distance of 30m from the tree stand, the number of roots reduced with a diameter thickness of 0.7mm. At a distance of 40m away, only six branching roots were found within 0.5mm diameter. A distance of 50m away did not have higher number of roots and probably less than 0.1mm in diameter. No roots were found after a distance of 50m away from the tree stand.

Cypress had the second largest diameter of roots at a distance of one meter. A distance of 20m away from the tree stand had 16 branching roots with a diameter of 0.8mm. At a distance of 30m away, the thickness significantly reduced to about 0.5mm but with 16 number of root branches. No roots were found after the distance of 30m away from the tree stand. Acacia tree stand had the lowest number of roots at distance of 1m away. Only 3 branching roots were found on the basal roots with a diameter of 0.7mm. The number of roots significantly decreased as the distance increase. At 20m away, only 12 numbers of branching roots were found with a diameter of 0.2mm. At about 30m away, the diameter of roots significantly reduced to about 0.1mm. Further increase in distance did not have significance differences in number of roots

The result indicates that, the number of roots and their branching diameters depend on tree species type. Exotic two tree had higher number of roots compared to native ones. Significant numbers of branching capacity were also found to increase compared to the native species. As earlier reported by Pal and Mahajan (2017) plant species may differ in their characteristics including production of root’s tissues. They also differ in distribution of roots in terms of depth and chemical composition as well as physical attribute of tissues. Mattana et al. (2010) also observed that roots are heterogeneous. They differ in diameter, physiology, and anatomy.

Figure 4.13

Basal Roots Diameter and the Daughter root Branching



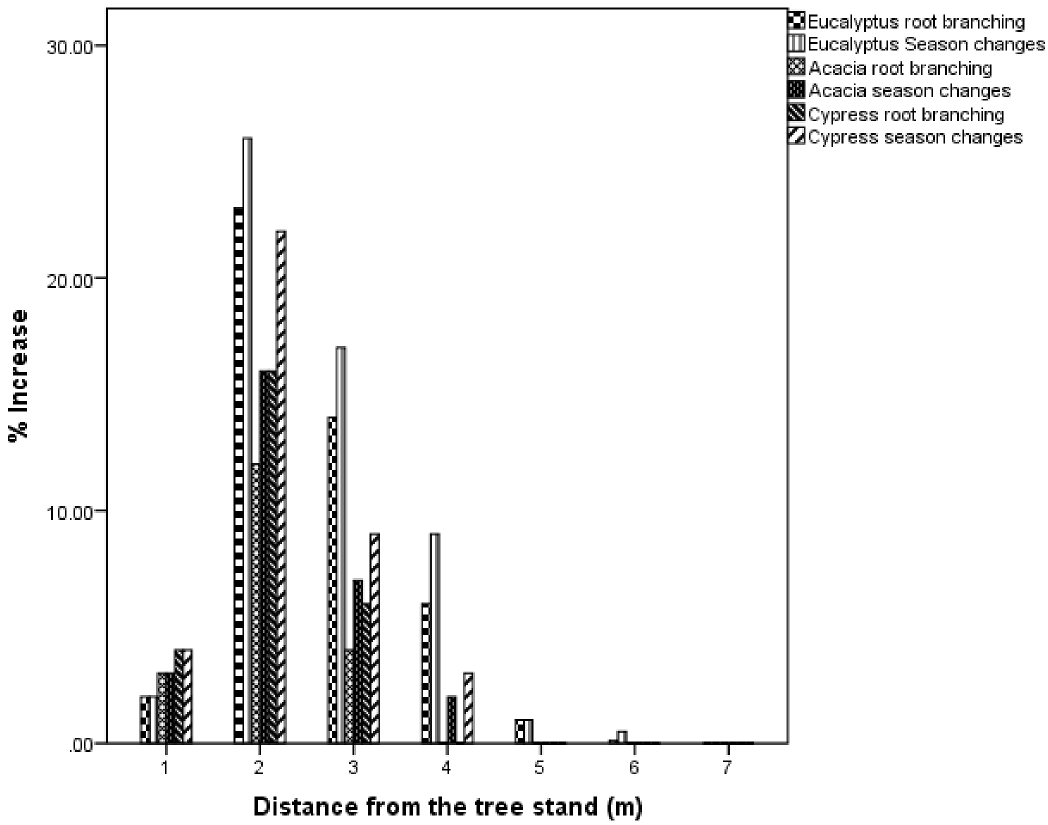
4.2.3 Root Branching in Different Season

Root branching capacity was rated according to season changes (figure 4.14). At a distance of 1m away from the tree stand, Cypress tree stand had the highest number of root branches increase as compared to other stands. There was 4% increase followed by Acacia with 3% while Eucalyptus had 2% increases in branching root changes with season. The number of fine root increased as the distance increases. At about 10m away, Acacia had the highest increase (23%) in wet season followed by Cypress with (12%). Eucalyptus root branching had only 3% increase.

Acacia tree stand also indicated a significant increase in roots branching as compared to others in wet season. At a distance of 20m, there was 14% increase in fine roots whereby cypress had only about 4% increase. Eucalyptus had less than 1% increase. The result indicate that Acacia tree do respond quickly to changes in seasons than the other stands. The report support earlier studies by Hatamian and Salehi (2017) that root distribution and density is closely related to species type and functionality.

Figure 4.14

Effects of Season on Branching

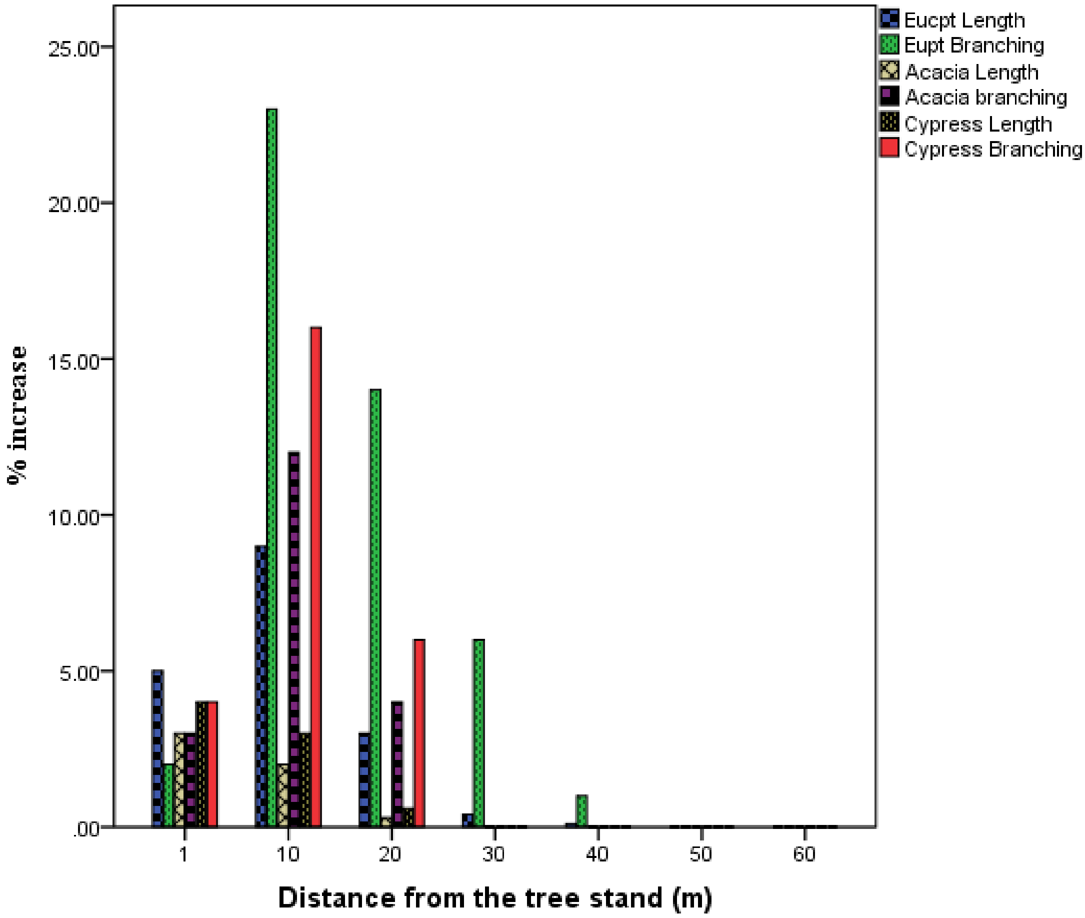


4.2.4 Root Length and Branching of the Sampled Trees

The percentage of root length was rated with root branching. The results were as shown in figure 4.15. From the figure, root branching and root length were significantly lower in a distance of 1m across all stands. Eucalyptus tree shows higher root branching than root length at a distance of 10m away from the tree stand. The surface roots increased in length during wet season. Further increase in distance, increased the branching capacity in relation to increase in root length. Cypress just like Eucalyptus had a higher root branching percentage at a distance of 10m in comparison to their length. No root observed after distance of 30m away from tree stand. Acacia had a significant reduced root length and branching capacity. There was small significant increase in root length and branching capacity at a distance of 10m away but was lower than the other two stands. No root was observed at a distance of 30m away from the tree stand. The findings concur with the study of Sullivan et al. (2007) who observed that roots do not only depend on density or distribution but activities of roots in different species. Aweto et al. (2005) also observed that fine roots differ in their site, season, type and species

Figure 4.15

Comparison of Root Length and Root Branching



4.2.5 Fine Depth Roots of the Sampled Tree

Fine root density was evaluated in vertical depth slices of 15cm, 15-30cm, 30-45cm, 45- 60cm.The results are as shown on Table 4.14 below. From the table 4.14 all the adjacent stands showed significant distribution of roots across all layers in 1m away from tree stand. As the distance increases up to 10m away, only eucalyptus adjacent pastures showed significant distribution of roots to most vertical layers. Acacia and Cypress root distribution was found to a depth of 30-45cm at 10m away from tree stand. No root distribution was found in Acacia and cypress after a distance of 30m cross all horizontal layers. Eucalyptus adjacent tree stand roots distribution decline after 30 meters away from the tree stand. Only a depth of 1-30cm, that the roots were found. A distance of 40m away from the tree stand had no significance difference in roots in Acacia and cypress but was significant in eucalyptus at a vertical depth 0-15cm. There was also sharp reduction of roots on the same vertical depth. No noticeable difference in horizontal and vertical root density across all the stands at a distance of 50m away from the tree stand

Table 4.14

Depth Roots Distributions of the Adjacent Trees

Tree type/Distance		**1m**	**10m**	**20m**	**30m**	**40m**	**50m**	**60m**
Eucalyptus	Dry	13±2.74	9±3.77	7±2.35	5±2.21	3±1.37	0	0
	Wet	13±2.68	10±3.56	9±3.38	6±3.27	4±2.37		
Acacia	Dry	10±3.57	9±3.78	5±3.38	0	0	0	0
	Wet	10±3.34	10±2.35	6 ±2.24	0	0	0	0
Cypress	Dry	11±2.28	10±3.45	7 ±2.34	0	0	0	0
	Wet	11±2.33	11±3.22	8 ±3.33	0	0	0	0
Control	Dry	11±2.83	9±3.67	6±2.56	0	0	0	0
	Wet	11±2.78	10±3.9	8±3.22	0	0	0	0

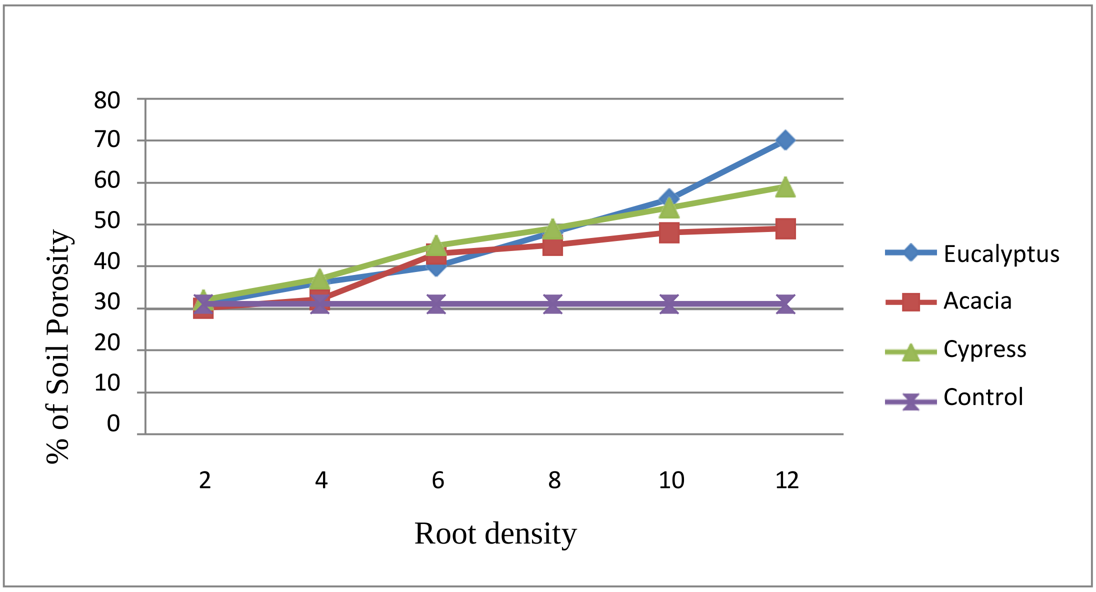
Note Mean root density ± standard deviation

4.2.5 Effect of Roots on Soil Porosity

The study results figure 4.16 below, soil porosity in eucalyptus adjacent pastures increased with the number of root present within the area of influence. Higher root density of 13 ±2.68 recorded the highest (69%) soil porosity in eucalyptus adjacent pastures. Soil porosity in eucalyptus decreases with decrease in root density. Cypress adjacent pastures had also higher soil porosity when the root density is low. The highest was when the root density was 12 ±2.28 (58%).The soil porosity characteristics decrease as the root density decreases just like the eucalyptus adjacent pastures. There was no significance difference in the soil porosity after 2 ±1.37 against control. Acacia had a closer soil porosity relationship with the control though there was an increase of root distribution. This mean that Acacia stand had other characteristics outside root density that reduces high soil porosity at high root density

Figure 4.16

Effect of Roots on Soil porosity



4.2.6 Effects of Roots on Soil Moisture

Soil water content was measured six times during dry and wet seasons. Average volumetric water content was recorded. The results is as shown in figure 4.17 and figure 4.18

The study results figure 4.17 and figure 4.18 indicate that there was a sharp increase in both wet and dry seasonal water content in low root density across all stands. Acacia adjacent pasture recorded highest of all water content with increase of root density. Other plant characteristics such as quality of litter could have led to the retention of water in Acacia in it adjacent pastures with high root density. Eucalyptus adjacent stand was the most affected by water content even in lower root density across all stands and the control. Soil porosity and changes in soil structure could have contributed to this. Cypress had relatively lower water content than Acacia and the control. The decrease in water content decline linearly as the density of the roots increases. The observation agreed with the work of Aweto et al.(2005) that Eucalyptus tree species lower soil tables, reduce water availability, increased hydro-phobicity, high rate of transpiration and biodiversity disruption in associated soils

Figure 4.17

Effect of Root density on Soil Moisture

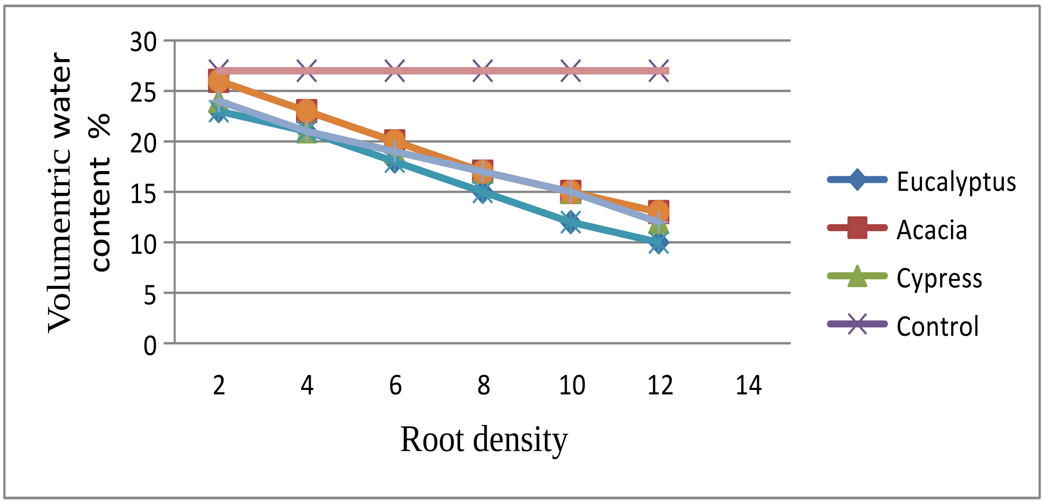
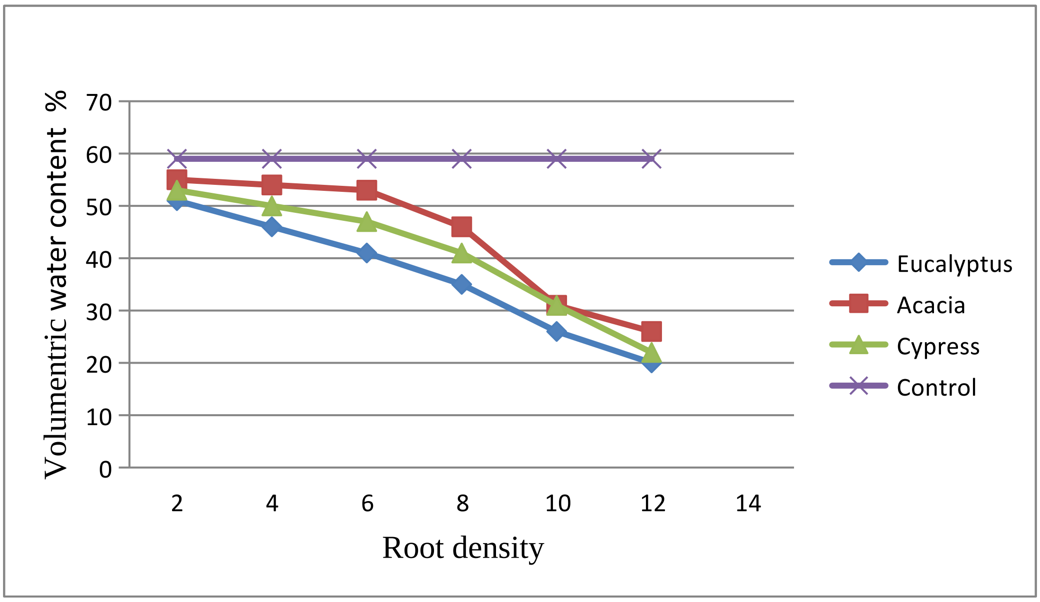


Figure 4.18

Effect of Root density on Soil Moisture



4.2.7 Effects of Tree Roots on Grass Mycorrhizal Associations

The study result table 4.15 shows that the adjacent tree stand mycorrhizal type had no significant effect on grass mycorrhizal type. Ecto- mycorrhizal showed significant increase in mycorrhizal colonization percentage during dry season than in wet season. Arbuscular mycorrhizal (AM) grass associate was positively associated with moisture condition in wet season. Higher moisture condition increased the percentage of Arbuscular mycorrhizal (AM) than in Ecto-mycorrhizal (ECM). Increase in the number of root counts did not affect the percentage increase in mycorrhizal association. No significant relationship was found with influence of the stand on mycorrhizal association in both AM and ECM. The findings concur with the work of Ayres et al. (2009) that ecto-mycorrhizal fungi have the ability to produce more stable nitrogen pool in the soil than Arbuscular mycorrhizal due to their persistence in substrate utilization. Ngoran, et al. (2006) also observed that ecto-mycorrhizal fungi has high substrate utilization efficiency and produces cellular enzymes that enable them to colonize substrate efficiently.

Table 4.15

Effects of Roots on Grass Root Mycorrhizal Associations

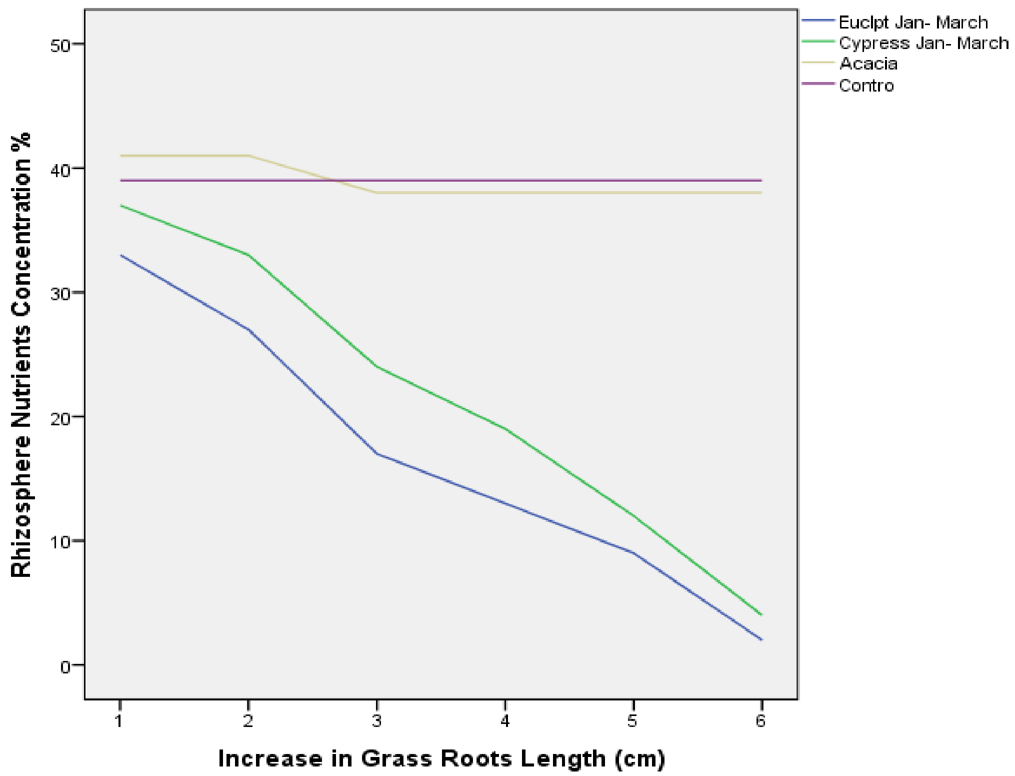
Trees	Adjacent Grass Mycorrhizal Association				
Eucalyptus		**Seasons**	**Counts**	**Colonization %**	**Total root counted**
	ECM	Dry	167	65%	**256**
		Wet	179	63%	**282**
	AM	Dry	111	39%	**278**
		wet	121	48%	**249**
Acacia	ECM	Dry	126	43%	**288**
		Wet	122	41%	**295**
	AM	Dry	172	60%	**287**
		Wet	176	66%	**267**
Cypress	ECM	Dry	142	62%	**223**
		Wet	134	60%	**222**
	AM	Dry	146	50%	**287**
		Wet	132	54%	**243**
Control	ECM	Dry	122	42%	**284**
		Wet	120	40%	**292**
	AM	Dry	171	59%	**284**
		Wet	**173**	**64%**	**266**

4.2.8 Effects of Tree Root Nutrients Concentration Grass Roots Length

Effects of rhizosphere nutrients concentration was plotted against length of the grass roots. The study result is indicated in figure 4.19. From the study significant difference was observed across all stands in root length. Acacia adjacent pastures recorded lowest root length across the entire stand. Nutrients concentration due to high quality litter in close distance from the tree promoted higher and relatively uniform roots length. Slight differences were observed in far distance from the tree. Eucalyptus adjacent stand had the lowest number of grass roots with decreased root length. Due to bulk accumulation of materials and depletion of the available nutrients by eucalyptus roots resulted to the observed characteristic. Cypress had relatively higher fine root length than the Eucalyptus. The decrease in the available mineral contents, root exudates and tree root density discourages growth and length of fine roots

Figure 4.19

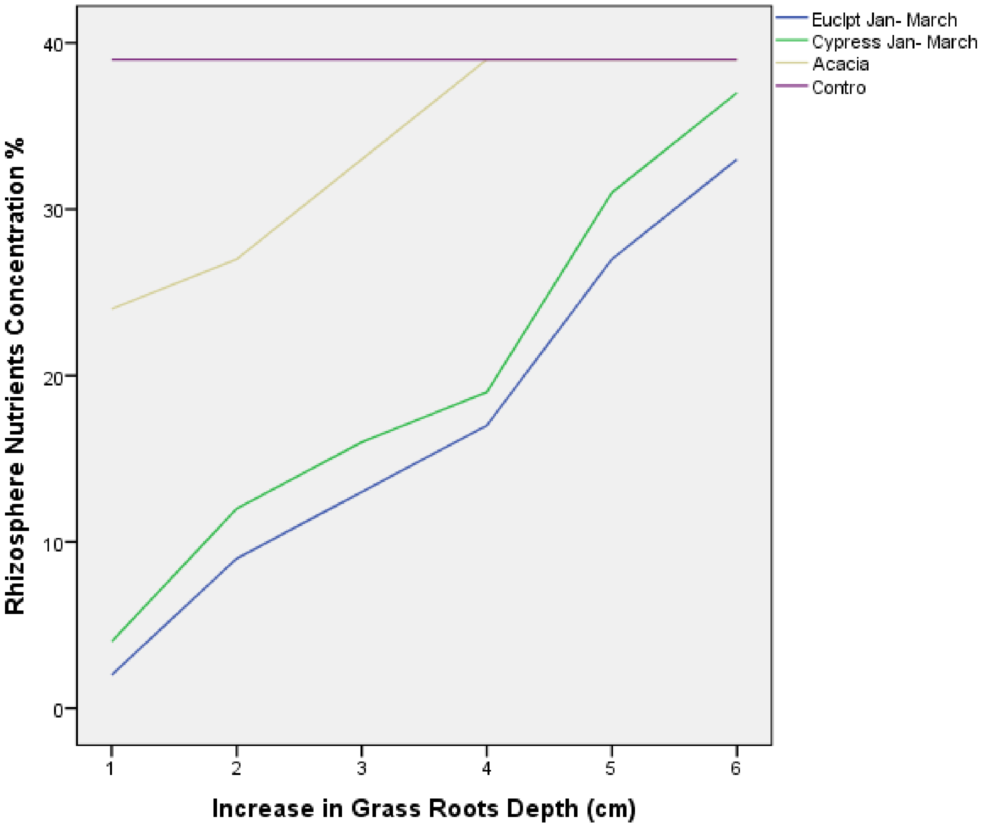
Effects of Rhizosphere Nutrients Concentration Grass Roots Length



4.2.9 Effects of Rhizosphere Nutrients Concentration on Grass Roots Depth

Figure 4.20

Effects of Rhizosphere Nutrients Concentration on Grass Roots Depth

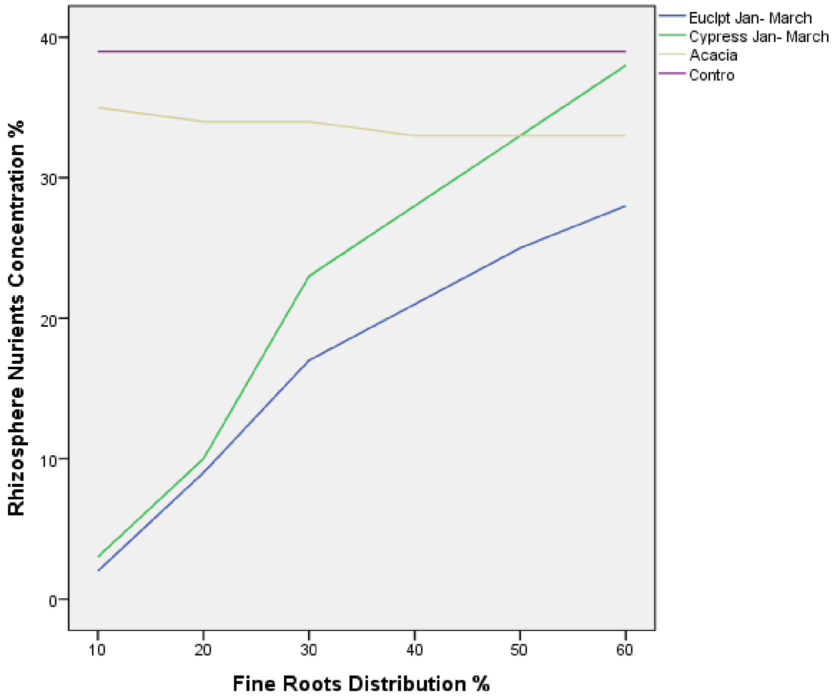


4.2.10 Effect of Rhizosphere Nutrients Concentration on Grass Fine Roots Distribution

Figure 4.21 shows effects of rhizosphere nutrients concentration on grass roots depth. Effects of nutrients were observed in three stand and control of depth of grass roots adjacent to three. From the study, significant difference was observed across all stands in root depth. Acacia adjacent pastures recorded a shallow root depth across the entire stand. Nutrients concentration due to less competitiveness of nutrients in the rhizosphere promoted growth of fine roots in shallow depth. Eucalyptus adjacent stand had the deepest grass roots with increased root depth. This was due to nutrients depletion encouraging fine roots to grow dipper looking for water and mineral. Cypress had relatively lower fine root depth than the Eucalyptus. The study found significant relationship between nutrients concentration and growth of fine roots to dipper layers Grass root density was evaluated in vertical depth slices of 15cm, 15-30cm, 30-45cm, 45- 60cm. From the figure 4.21 significant increases of fine roots was observed as the distance decreases. Eucalyptus and Cypress adjacent pasture had the highest fine roots numbers in near distance. This could have been promoted by available nutrient depletion and water content. Most fine roots were observed during wet season. The effect of fine roots distribution was effective to a distance of 30m away from tree stand against control. Acacia adjacent pasture had slightly higher grass fine roots distribution than the control. The difference was only realized 10m away from the tree stand. The study noted that the availability of nutrient has direct influence fine root production.

Figure 4.21

Effect of Rhizosphere Nutrients Concentration on Grass Fine Roots Distribution



4.2.11 Effect of Roots' Density on Species Composition

All grass species were affected by large density exhibited this type of tree stand. At a root density of 40 root/ quadrat, *cymbopogon* grass species has the highest percentage of 8%. *Digitaria* grass species has 7% while *Cynodon* and *Chloris* grass species had 3% and 4% respectively. In lower root density rise in species composition per unit quadrat increased.

Cymbogon had 42% *digitaria* had 32%, *Cynodon* and *Chloris* had 8% and 7% respectively. The result from the study of Eucalyptus shows that some species were unable to tolerate high density branching density. Perennial grasses like *Cynodon* which become unpalatable during maturity stage remain while other grass species are consumed by herbivores. This increases their percentage over the others. Cypress has the second grass species diversity percentages in the composition of grass species. Only grass species such as *Cymbogon* could survive in high branching root density. The relative percentages reveals disparities in term of species composition whereby *Cymbogon* had 49%, *digitaria* 36% while *Cynodon* and *Chloris* had 8% and 7% respectively in low root density.

In high root density, *Cymbogon* had 20%, *Digitaria* had 19% while *Cynodon* and *Chloris* had 9% and 8% respectively. There were decreases in species composition in high branching percentage. Acacia provided a balanced species composition even in high density rooting system. Lower root density, *Cymbopogon* had 42%, digitaria 32% while *Cynodon* and *Chloris* has 27 and 26% respectively. In high density rooting system, differences in percentage of species composition were higher than other adjacent grass species. *Cymbopogon* had 32%, *digitaria* 32% while *cynodon* and *chloris* has 27% and 26% respectively. A sharp decline in species composition in Acacia was notice due to lack of other nutritional factors that are in acacia but not found in open grass (control).

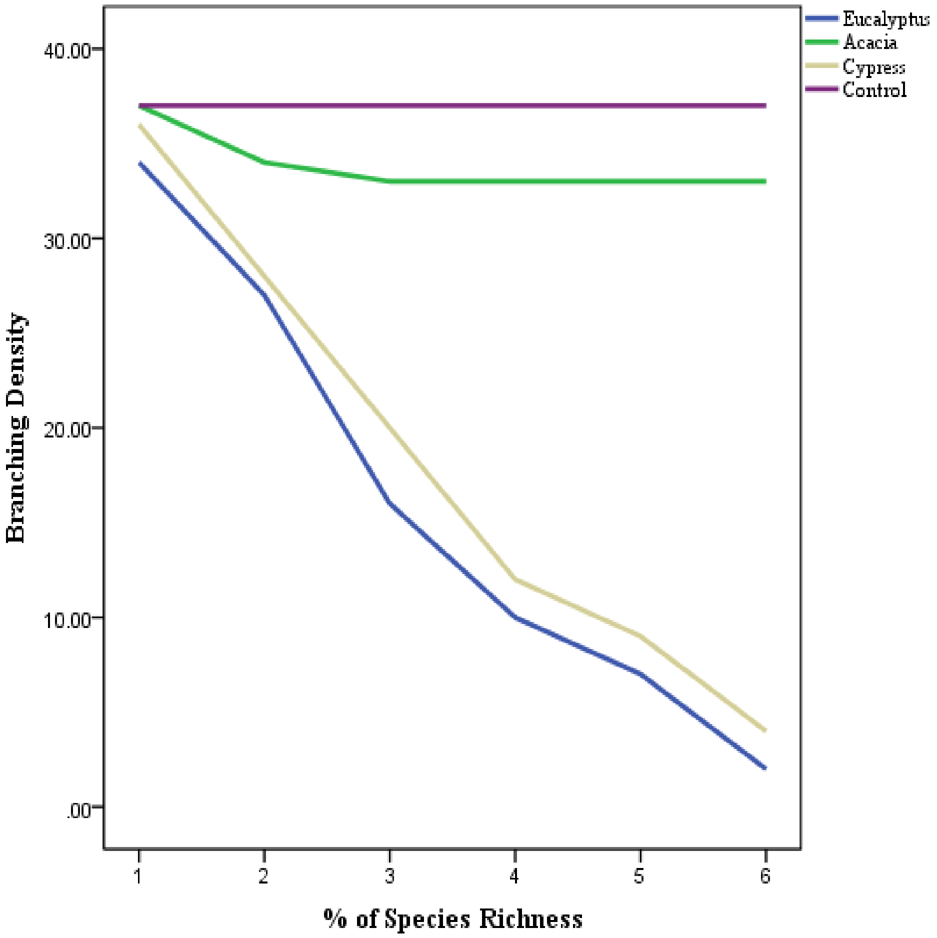
4.2.12 Effect of Roots Density on Species Richness

Figure 4.22 shows mean number of species expressed per unit branching density of the roots. General observable phenomenon shows that there was an effect on species richness and the density of the root. Eucalyptus adjacent pasture mean number of species per unit quadrat of 0.25m^2 was the lowest in high root density. Mean number of species per unit quadrat was 23. In lower root density the average number of species rose to 27 species / 0/25m^2. The result of this study is a clear indication that the numbers of species are significantly affected by the density of the roots. Cypress adjacent pastures had similar characteristics like those that were observed in Eucalyptus. At a higher root density, the mean number of species per 0.25m^2quadrat has an average of 31 grass species. Just like in the Eucalyptus, effect of root density was found to affect the number of species per 0.25m^2quadrat.

Acacia had the highest number of species per 0.25m^2 unit quadrat. Higher density recorded an average of 32 grass species per 0.25m^2 quadrat. This average species number was highest across the entire stands in such a root density. Lower root density also recorded higher number of species across all the stands but slightly lower than that of control. Majority of root branches in Acacia were found to grow vertically, creating less competition pastures hence higher species number per unit quadrat.

Figure 4.22

Effect of Stand Branching Density on Species Richness



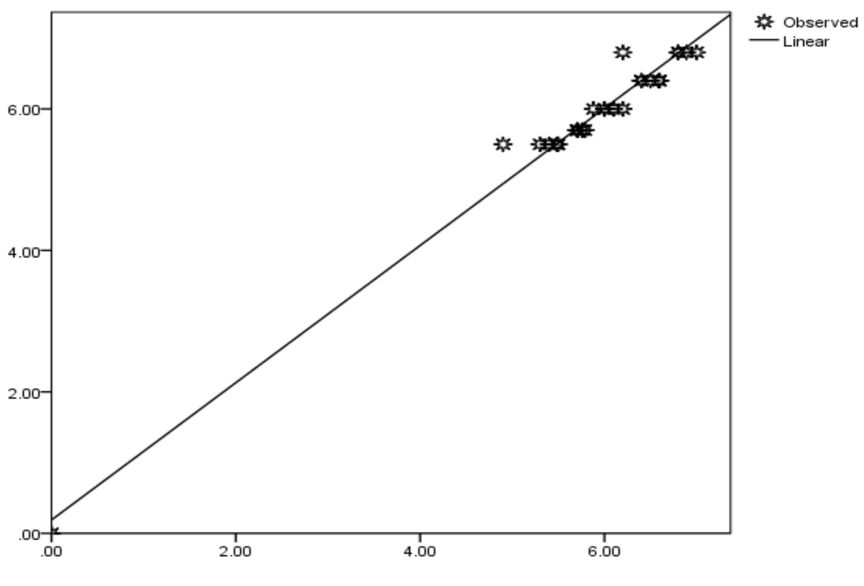
4.23 Effect of Roots Density on Species Cover

The figure shows effect of root density on species cover per unit quadrat ($0.25m^2$). In Eucalyptus adjacent pastures, higher root density significantly reduced the species cover and encouraged bare ground cover. A root density of 20 branches of root per $5cm^2$ grid had 40% species cover and 60% bare ground cover. A lower root branches density of less than 5 root branches / $5cm^2$ grids had 78% species cover and 22 bare - ground cover. Cypress adjacent pasture also had similar characteristic but had a higher species cover. A root density of 20 branches /$5cm^2$ grid were found to have 62% species cover in a square quadrat and 38% bare ground cover. Adjacent pastures to acacia were found to have the highest species cover per unit quadrat but slightly lower than that of the control. The highest root density had 77% species cover and 23% bare ground cover. At a lower root density, 89% were species cover and only 11% was under bare ground cover. The general observation of exotic stands is that root density had considerable significant effect on species cover than the native tree stands. The numbers of root branches were also found to affect the adjacent pasture across all stands against control

4.2.14 Linear Regression Model Analysis of the roots and the below ground Resource influence.

Figure 4.23

Regression analysis Model of Roots Structure and their Effects on Soil Porosity, Soil structure, Soil moisture and Mycorrhizal association



Species composition r^2=0.61, **Species Richness** r^2=0.65, **Species Cover** r^2=0.62**,** **Grass Biomass** r^2=0.68

*Horizontally, **means are significant ($p<0.05$).*

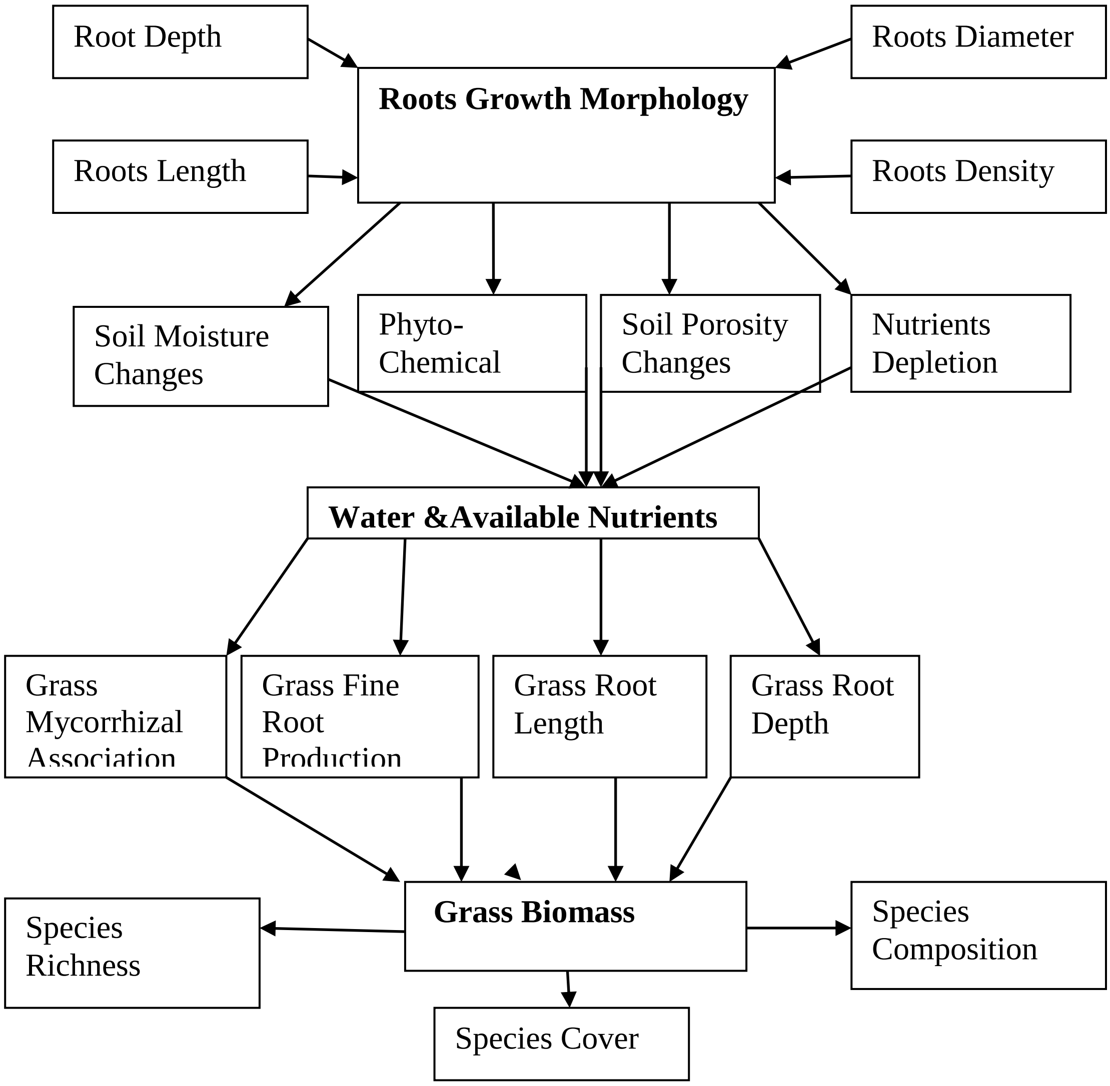
From the regression analysis (*Figure 4.23*), root structure slope (y=34.2x+4) significantly affects the below ground processes. Soil porosity had a strong correlation of r^2=0.61.This suggests that root structure strongly influence below ground resources such as water percolation and aeration which are major components of soil porosity. The root structure in relation to changes in soil structure also had strong correlation of r^2=0.65 while soil moisture had r^2=0.62 and mycorrhizal association with r^2=0.68.This shows that root structure strongly influences below ground resources which affect the above ground native grass characteristics. Based on the evidence provided and other related literature, the null hypothesis which stipulates that there is no significant difference between the root structure and below ground resource influence is rejected.

4.2.15 Summary of Model Analysis of the Effects of Root Structure on Below Ground Plant Resources

Figure 4.24 shows a model of roots structure and the effects on below ground resources. Tree biomass investment to the roots consists of root density, root depth, root diameter and length. The elaborate root structures maximize the absorption of available soil moisture. Some have phyto-chemicals that prevent mineralization of organic compounds and discourage development of grass seedlings. Roots exudates prevent water penetration to the ground and therefore affect soil porosity. Due to dense roots systems, with enlarged diameter, which are deep and long, the available minerals are depleted from the ground. The adjacent grass pasture responds by forming mycorrhizal association to mine the limited resources. Another response is production of fine roots, longer root length and root depth on the surface of the soil to maximize the absorption of the available nutrients and water content. These changes in root rhizosphere due to the available nutrients create differences in above ground grass biomass. Some grass species may not survive in some of these condition hence creating differences in species composition, cover and richness

Figure 4.24

Model Analysis of the Roots Structure and their Influence on Below Ground Resources



*How Root structure affects soil condition grass characteristics and finally grass biomass in terms of Species richness, composition and cover

4.3.1 Litter Chemical Composition

Different chemical analysis was carried out to determine chemical compounds found in the litter. The results are as shown in table 4.16

From the table 4.16 above, Eucalyptus had the highest (37%) in lignin percentages across all the stands. The ratio of lignin to Nitrogen was 1:321 while that of lignin to Phosphorus was 1.645.Under the chemical compound the percentages of litter chemical tannins, polyphenols and cellulose was 86%, 4.7% and 23% respectively. Cypress tree stand was the second with lignin ratio of 29% and lignin N ratio of 1:222 while lignin P ratio was 1:532. The percentages of tannins, polyphenols and cellulose was higher than Acacia with 7.4%, 1.9% and 25% respectively. Acacia had the least in lignin percentages (24%) and had closer lignin N and P ratio of 1:121 and 1:211 respectively. It also had a lower tannins, polyphenols and cellulose of 2.1%, 1.3% and 31% respectively. The study result shows that Eucalyptus litter had highest percentages of chemical compounds followed by cypress leaf litter. These compounds are capable of causing decomposition challenges due to their antibacterial effects. This slow down bacterial activities and hence slow down release of nutrients.The study finding was in line with that of Bohra et al. (2015) that litter decomposition and releasing of soil nutrients depends on the effects of litter substrate quality and physio- chemical mineral association to a particular plant.

Table 4.16

Litter Chemical Composition

Source Variation	Lignin	Lignin N. ratio	Lignin P. ratio	Tannins	Polyphenols	Cellulose
Eucalyptus	37%	1:321	1:645	8.6%	4.7%	23%
Acacia	24%	1:127	1:211	2.1%	1.3%	31%
Cypress	29%	1:222	1:532	7.4%	1.9%	25%
Grass	17%	1.171	1.323	0.6%	0.4%	32%

4.3. 2 Litter C: N Ratio

The C; N ratio of the collected litter was evaluated. The study results (Table 4.17), shows that the C: N ratio of eucalyptus litter was 146:1 in dry season and 136:1 in wet season. This was the highest across all the stands and the control. Wet seasons recorded lower C: N ratio than dry season.

Acacia tree stand recorded higher carbon than cypress but the ratio of carbon to Nitrogen was much smaller than that of cypress making C: N ratio to be 20:1 against cypress 39:1. Season had a observable effect in changes of C:N ratio across all the stand and the control. The study noted that C:N ratio depends on type of litter and it chemical composition. Similar studies was found by Rezai et al. (2018) that a higher leaf litter C/N ratio over 30:1, microbes becomes N limited and therefore the process of immobilization of exogenous sources of inorganic nitrogen starts

Table 4.17

Litter C: N

Tree Species	Distance From the Shade	Dry Season C: N Ratio			Wet Season C:N ratio		
		Carbon	Nitrogen	C:N Ratio	Carbon	Nitrogen	C:N Ratio
Eucalyptus	1	5.1	0.11	146:1	4.6	0.12	136:1
	1-10m	4.5	0.12	137:1	4.3	0.12	135:1
	10-20m	4.2	0.13	132:1	4.2	0.13	131:1
	20-30m	4.1	0.14	131:1	3.9	0.14	127:1
	30-40m	3.9	0.15	127:1	3.7	0.14	126:1
	40-60m	3.9	0.14	126:1	3.4	0.14	124:1
Acacia	1m	4.9	0.24	20:1	4.2	0.21	17:1
	1-10m	4.7	0.21	23:1	4.0	0.21	18:1
	10-20m	4.5	0.19	23:1	3.9	0.18	22:1
	20-30m	4.2	0.17	24:1	3.6	0.15	23:1
	30-40m	3.9	0.16	24:1	3.4	0.14	24:1
	40-60m	3.9	0.16	24:1	3.4	0.14	24:1
Cypress	1m	5.0	0.12	141:1	4.4	0.11	140:1
	1-10m	4.5	0.13	136:1	4.2	0.11	138:1
	10-20m	4.3	0.12	135:1	4.1	0.12	134:1
	20-30m	4.0	0.14	128:1	3.9	0.15	129:1
	30-40m	3.9	0.15	126:1	3.4	0.14	124:1
	40-60m	3.9	0.14	127:1	3.4	0.14	124:1
Control		3.9	0.14	27:1	3.4	0.14	24:1

4.3.3 Litter Bulk and Duff Depth

Average bulk depth, duff depth and total litter depth was measured in centimeters. The main aim was to compare different stands litter depth and the rate at which litter decomposes on the floor of the tree stand. The results are as shown in the table 4.18.

Average Litter Bulk, Duff and Total Litter Depth. From the table 4.19 Eucalyptus had the highest bulk depth (6.8cm) among the three tree stands and the control. The same stand had also the highest duff density and the total litter depth was 13.1cm. Cypress tree stand had the second highest bulk depth of 3.1cm and duff density of 2.9cm. The total litter depth was 6cm.Acacia had the least bulk depth among the three stands but higher than the control. Bulk depth was 2.4cm while the duff density was 2.2cm. The total litter depth was 4.6cm.The results indicate that Eucalyptus litter does not decompose easily and therefore higher total litter depth. The rate at which litter convert into soil was slow, resulting to high bulk and duff depth.

Table 4.18

Average Litter Bulk, Duff and Total Litter Depth

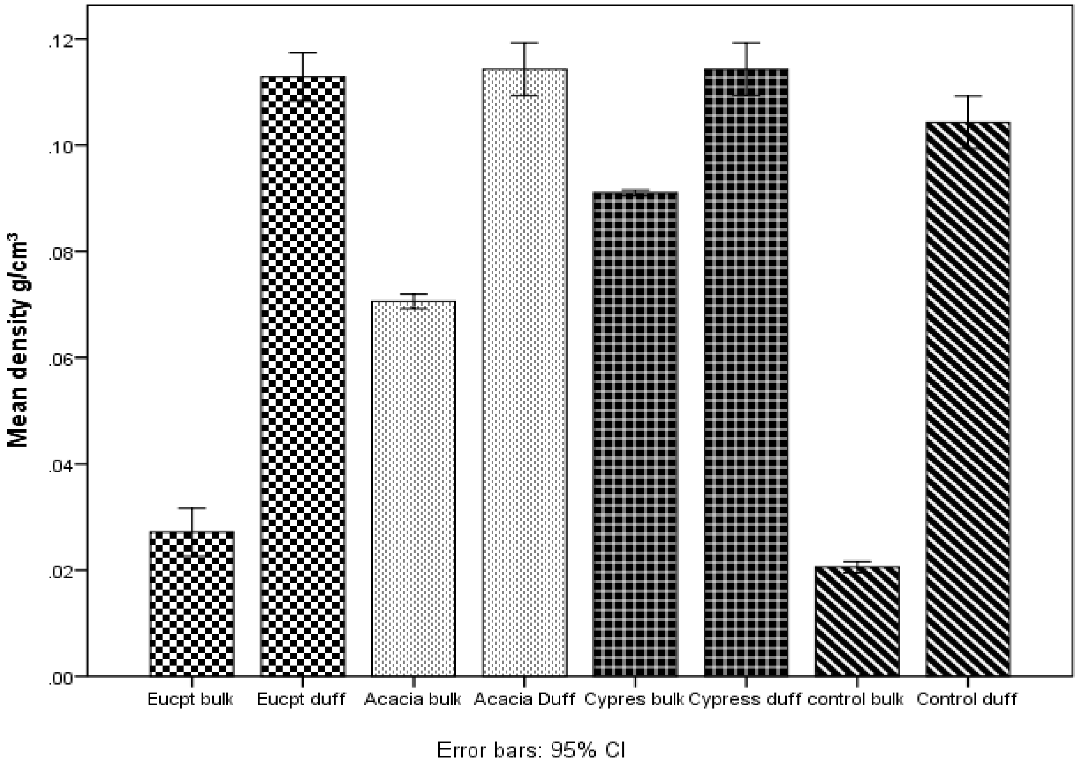
	Bulk depth(cm)	**Duff depth(cm)**	**Total litter depth (cm)**
Eucalyptus	6.8 cm	6.3cm	13.1cm
Acacia	2.4cm	2.2cm	4.6cm
Cypress	3.1cm	2.9cm	6cm
Control	1.9cm	1.3cm	3.2cm

4.3.4 Litter Bulk and Duff density

Figure 4.25 shows comparison of different litter bulk and duff density. The result indicated that Eucalyptus had the least litter bulk density among the three stands. It also had the widest differences between litter bulk density and the duff density (0.3g/cm^3 in bulky density and 0.11 g/cm^3 in duff density).

Cypress tree had the second highest in litter bulk density (0.07g/cm^3). The differences in bulk and duff density were not as high as those of Eucalyptus (0.7 g/cm^3 in bulk density and 0.12g/cm^3 duff density). Acacia tree stand had the highest litter bulk and duff density. Higher decomposition rate in Acacia leaf litter, quickly converted the available litter in to duff and later to mineral soil. This make Acacia tree to have lower bulk and duff depth but higher bulk and duff density.

Figure 4.25



Comparison of Stands litter bulk and duff density

4.3.6 Litter Phosphorus Decomposition Rate

From the table 4.19, Acacia had the highest loss of litter phosphorus through decomposition. 1m away recorded 34% mass loss of 0.11g from the initial recorded amount 0.32g of litter Phosphorus. Increase in moisture content had a significant effect on phosphorus mass loss .A distance of 1m recorded 51% litter phosphorus mass loss. There was progressive decline in litter decomposition rate percentage from the initial recorded amount ranging from 34-26% in dry season and 51% to 34% in wet season (1m-60m away from the tree stand). The decomposition level was only at a distance of 30m away. Any further increase in distance did not affect the adjacent pastures against control.

Adjacent grass pastures next to cypress had the second highest recorded mass loss. The recorded amount of decomposition was inversely proportion to that of Acacia adjacent pastures. Closer distances recorded the lowest litter phosphorus loss whereas in Acacia the highest loss was a distance between 1-10m away. Just like Acacia, seasons had significant effect on the amount of nitrogen loss through decomposition. The amount increased from 6.55 to 18% during the wet season. There was linear progress increase on the amount of litter nitrogen loss as the distance increase from 1m-60m away from the tree stand. The effect of the tree on the adjacent grass pastures was only effective between 1-30m away from the tree stand. Further increase 40-60m did not affect the adjacent grass pastures against control.

Eucalyptus had the lowest mineral phosphorus loss across the entire stand and the control. The effect of the tree was highest in distance of 1-10m away, with lowest record of 7.6% in dry season and 16% in wet season. Effect of season was significant with difference in percentage loss increasing from dry to wet season. Just like cypress tree stand, there was linear increase in the amount of P pools as the distance increase from 1-60m away. The study noted that the effect of eucalyptus tree stands was up to a distance of 50m. Further increase in distance did not have effect in the percentage loss against control. This has also been demonstrated by the work of Berg and Laskowski (2006) that various stages of decomposition can be affected by seasonal variations in temperature and moisture content which is likely alter the soil environment and also influence various biological processes.

Table 4.19

Decomposition of Litter Phosphorus

Treatments Tree Species	**Distance From the Tree**	**Leaf Litter Characteristics** **Initial** Leaf Litter P g/25g	End of **Dry Season**	Mass Loss of P %	End of **(Wet Season)**	**Mass Loss of P %**
Eucalyptus	1m.	0.132g	0.123g	7.61%	0.112g	**16.1%**
	10m	0.141g	0.131g	11.1%	0.123g	**17.3%**
	20m	0.143g	0.124g	14.3%	0.113g	**21.3%**
	30m	0.171g	0.133g	23.2%	0.123g	**29.2%**
	40m	0.192g	0.145g	26.1%	0.134g	**31.1%**
	50m	0.223g	0.174g	26.4%	0.161g	**34.4%**
	60m	0.234g	0.162g	26.4%	0.162g	**34.2%**
Acacia	1m.	0.322g	0.214g	34.1%	0.133g	**51.2%**
	10m	0.293g	0.231g	31.4%	0.133g	**48.1%**
	20m	0.274g	0.193g	29.3%	0.152g	**44.3%**
	30m	0.251g	0.182g	28.2%	0.161g	**34.4%**
	40m	0.232g	0.182g	26.1%	0.164g	**34.3%**
	50m	0.233g	0.182g	26.1%	0.262g	**34.3%**
	60m	0.233g	0.182g	26.3%	0.264g	**30.1%**
Cypress	1m.	0.161g	0.144g	6.5.3%	0.144g	**18.3%**
	10m	0.164g	0.144g	6.5.2%	0.142g	**18.1%**
	20m	0.194g	0.173g	10.4%	0.153g	**21.3%**
	30m	0.210g	0.191g	10.2%	0.164g	**20.3%**
	40m	0.232g	0.174g	26.1%	0.161g	**34.1%**
	50m	0.231g	0.172g	26.4%	0.162g	**34.4%**
	60m	0.233g	0.173g	26.3%	0.164g	**34.3%**
Control		**0.234g**	**0.171g**	**26%**	**0.163g**	**34.2%**

The results (Table 4.20) indicates that distances and seasons has significance effect on litter P in Eucalyptus and Cypress adjacent pastures with r^2=0.544, r^2= 0.653 respectively but not in their species. However, a negative correlation was found between P mass loss of eucalyptus and Acacia to all their treatment in species, distance and seasons with r^2= - 0.655, r^2= -0.598 r^2= -0.488 respective. There was also negative correlation between cypress and Acacia with all their treatment in species, distance and season of r^2= -0.632 r^2= -0.411, and - r^2= 0.466. The results indicate that the mode of Phosphorus mass loss in the native Acacia tree was different from that of the two exotic species, distance and seasons. In related study by Gregoriou et al. (2007) plant species and litter substrate quality are the linkages that influence microbial response to Phosphorus mineralization and immobilization. Acacia leaf litter enabled higher P mineralization rate at closer distance than the two exotic stands due to litter quality which was easy to decompose. In a similar decomposition of litter in the forest by Chawla (2008) demonstrated that the effects of litter quality and the associated plant exudates have an advance effects on soil stabilization and mineralization process of phosphorus. The findings of this experiment are also in the line with those of Isaac and Nair (2005) who observed that charges in litter quality and quantity in the exotic tree species is a likely mechanism that causes greater P immobilization and reducing P availability. Moisture availability across all stands enabled faster decomposition rate in wet season than in dry season. This was demonstrated by higher P mineralization rate and P mass loss with increase of moisture content. Similar litter decomposition was observed by D’Antonio et al.(1992) in Arctic and Antarctic permafrost soils that microbial community structure are strongly influenced by variation of soil environment and plant litter substrate quality. Distance was also another important factor that affected decomposition and mass loss of litter Phosphorus. Closer distance from the tree stand in exotic trees reduces P mass loss and enhances higher P mass loss in native (Acacia) adjacent stand. In related study by Gaertner et al. (2011) in exotic tree next to crop land found that exotic trees adjacent to crops affect microbial decomposition and are associated with high scarcity of mineral P content. Similar studies was also found by Cortez et al. (2014) that exotic trees adjacent grass vegetation decrease environmental stability by interfering with resource supply and creation of microbial ecosystem disturbance.

Table 4.20

Multiple regression treatments results for Litter P Mass loss

Treatments	Parameters	Correlation	P value
Eucalyptus -Cypress	Species	0.276	**0.061**
	Distance	0.544	**0.013**
	Seasons	0.653	**0.014**
Eucalyptus -Acacia	Species	-0.655	**0.024**
	Distance	-0.598	**0.042**
	Seasons	-0.488	**0.041**
Cypress-Acacia	Species	-0.632	**0.05**
	Distance	-0.411	**0.027**
	Seasons	-0.466	**0.036**
Control	Species	-0.601	**0.053**
	Distance	-0.403	**0.021**
	Seasons	**-0.411**	**0.029**

4.3.7 Litter Nitrogen Decomposition Rate

Litter decomposition characteristics were evaluated in two seasons. The results were recorded after both dry and wet seasons. Samples were taken to the laboratory for N pools analysis for the litter. Table 4.21 shows the results. From the study results, Acacia adjacent pastures had the highest litter Nitrogen loss with 6.5%, to 5.5% during dry season and 12% to 10% in wet season for distances of 1-30m away from tree stand. There was no significance difference in litter nitrogen loss between distances 40 – 60m away from the tree stand against the control.

Cypress adjacent grass pastures had the second highest litter Nitrogen loss. Unlike Acacia, near distance from the tree stand recorded lower litter Nitrogen loss than the control (Mass loss of 0.28g to 0.42g with 3.4% and 4.3% during dry season and 0.25g to 4.0g with 6.9% to 11% in wet season). Seasons had significant effects on litter Nitrogen loss with the wet season recording higher N loss than the dry season. There was progressive significant increase in percentage as the distance increases away from the tree stand. The adjacent pasture next to cypress was affected by the presence of tree stand to a distance of 30m away. No significant difference was found between distances of 40-60m away against control.

Eucalyptus tree stand had the lowest Nitrogen loss in the litter. The amount of Nitrogen loss was lower in near distances than in far distances away from the tree stand. The study also recorded significant increase in the amount of Nitrogen loss in both seasons. Wet season had a higher N loss recorded than dry season. Eucalyptus tree was found to affect the Nitrogen decomposition level to a distance of 50m away from the tree stand. This was 10m significantly higher than the other stands. There was no significant record of mass loss in eucalyptus after a distance of 50m away from tree stand against control.

The observation was in line with those of Cortez et al. (2014) that low decomposition of floor litter under eucalyptus and its recalcitrant litter quality explains the low level of Phosphorus and Nitrogen

Table 4.21

Litter Nitrogen Decomposition Rate

Treatments Tree	Distance	Leaf Litter Characteristics Initial Litter N g/25g	End of (Dry Season)	Mass N%	End of (Wet Season)	Mass Loss of N%
Eucal-yptus	1m.	0.282g	0.272g	3.3%	0.262g	7.12%
	10m	0.273g	0.242g	3.5%	0.252g	7.4%
	20m	0.261g	0.254g	3.8%	0.243g	7.6%
	30m	0.253g	0.232g	3.9%	0.234g	8.0%
	40m	0.444g	0.413g	4.1%	0.394g	11.1%
	50m	0.462g	0.423g	4.3%	0.383g	11.3%
	60m	0.461g	0.422g	4.3%	0.381g	11.4%
Acacia	1m.	0.492g	0.452g	6.5%	0.432g	12.3%
	10m	0.482g	0.444g	6.2%	0.421g	12.3%
	20m	0.461g	0.431g	6.0%	0.402g	11.3%
	30m	0.463g	0.423g	5.5%	0.404g	11.2%
	40m	0.454g	0.422g	4.3%	0.392g	10.1%
	50m	0.454g	0.423g	4.3%	0.394g	10.4%
	60m	0.454g	0.451g	4.3%	0.382g	10.2%
Cypress	1m.	0.292g	0.282g	3.4%	0.254g	6.9%
	10m	0.252g	0.244g	4.0%	0.232g	8.1%
	20m	0.244g	0.231g	4.1%	0.224g	8.3%
	30m	0.232g	0.233g	4.2%	0.224g	8.6%
	40m	0.464g	0.441g	4.3%	0.402g	11.1%
	50m	0.462g	0.423g	4.4%	0.404g	11.2%
	60m	0.462g	0.422g	4.3%	0.402g	11.3%
Control (Average)		0.461g	0.423g	4.4%	0.381g	11.4%

Table 4.22 shows multiple regression treatments results for litter Nitrogen mass loss. A positive correlation of litter Nitrogen mass loss of the Eucalypts and Cypress adjacent pastures in their species, distances and seasons with r^2=0.692, r^2= 0.451 and r^2=0.643 respectively. However a negative correlation was found between litter Nitrogen mass loss of eucalyptus and Acacia in their relation to their distance r^2=-0.432 and seasons r^2= -0.321.Also another negative correlation was found between cypress and Acacia of r^2=--0.346, in their distances and r^2= -0.333 in their differences

in seasons. This could have been as results of difference in their litter Nitrogen mass loss away from tree stand. Acacia adjacent pastures decreased their litter Nitrogen mass loss as the distance increases.

Cypress and eucalyptus adjacent pastures increased their litter Nitrogen mass loss with increase of the distance away from tree stand and in seasons. Low decomposition rate in Eucalyptus resulting to less Nitrogen mass loss in close distances. This could be as a result of leaf characteristics and chemistry. The observation was in the line with those of Berg and Laskowski (2006) that some exotic trees, have leaf chemistry that affects the rate of decomposition of structural Nitrogen. Differences in the decomposition of the two exotic stands and the native (Acacia) tree could also have been contributed by leaf chemistry. This slowed down decomposition rate to release Nitrogen. The observation agreed with the work of Gregoriou et al. (2007) that short term mineralization and releasing of soil nutrients through decomposition depends on the effects of litter quantity and physio- chemical mineral association to a particular plant. Season had significance effects across all adjacent tree stands. Higher decomposition rate was observed in native than exotic adjacent stands

Table 4.22

Multiple regression treatments results for Litter Nitrogen Mass loss

Treatments	Parameter	Correlation	Sig
Eucalyptus -Cypress	Species	0.692	**0.014**
	Distance	0.451	**0.036**
	Seasons	0.643	**0.045**
Eucalyptus -Acacia	Species	0.211	**0.001**
	Distance	-0.432	**0.021**
	Seasons	-0.321	**0.034**
Cypress-Acacia	Species	0.544	**0.022**
	Distance	-0.346	**0.039**
	Seasons	-0.333	**0.042**
Control	Species	0.533	**0.020**
	Distance	-0.301	**0.038**
	Seasons	**-0.322**	**0.040**

4.3.8 Litter Organic Carbon Decomposition Rate

Litter carbon decomposition characteristics were evaluated in two seasons. The results were recorded after both dry and wet seasons. Figure 4.26 and figure 4.27 shows the results. From the figure 4.29 and 4.30, the amount of carbon mass loss percentage across all stands increase with increase in moisture. Acacia tree had the highest organic Carbon mass loss through decomposition. A distance of 1m recorded 36% during dry period and 46% loss during the wet season. The amount recorded in percentage in distance of 1-30m was higher than all the stands and the control.

The decomposition level was in downward trend as distance increases from the tree stand. Acacia tree leaf litter provided higher decomposition level in closer distances. This was due to its litter quality with low C:N ratio that provided fast decomposition. A previous study by Wang et al. (2010) found that the rate of decomposition litters depends on their quality and absent of tough lignin and phenolic compounds with high C/N ratio. The effect of decomposition level from initial to the end of wet season was only effective from a distance of 30m away. Further increase in distance did not affect the adjacent pastures against the control.

Cypress according to the figure 4.26 and 4.27 recorded the second highest amount of carbon mass loss. The amount of carbon mass loss in litter was much less than in Acacia and in the control but higher than that of Eucalyptus adjacent pastures. There was progressive significant increase in percentage as the distance increases away from the tree stand. Just like Acacia, the effect of tree to the adjacent pastures was only effective to a distance of 30m (12.5% - 31% from 1 – 30m away). Further increase in distance did not affect the adjacent pasture against the control.

Eucalyptus had the lowest Carbon pools mass loss across the entire stands and the control. The percentage loss ranged from 8.3%-24% from a distance of 1m-60m away. The effect of the tree was effective up to a distance of 50m away from tree stand. As the distance increased the amount of carbon mass loss increased due to presence of mixed litter. The observation agreed with the work of Cortez et al. (2014) that recalcitrant litter quality explains the low level of carbon mineralization in floor litter under eucalyptus species adjacent to crops. Unlike Acacia and Cypress, season had significant effect on decomposition level of litter Carbon pools ranging from 12%-13% in wet season. The amount in both seasons increase progressively as the distance increase. In a related study by Diaz Pines et al. (2011) in Boreal forest rapid mineralization of soil organic matter is primarily trigged by moisture availability and temperature which increase the rate of microbial activities

Figure 4.26

Litter Substrate Quality on Decomposition (Mass Loss) of Organic Carbon (Dry season)

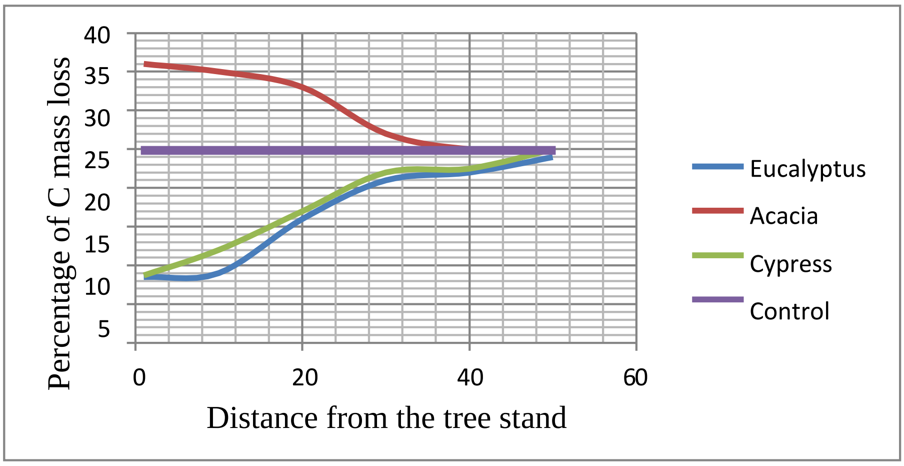


Figure 4.27

Litter Substrate quality on Decomposition Organic Carbon (Wet season)

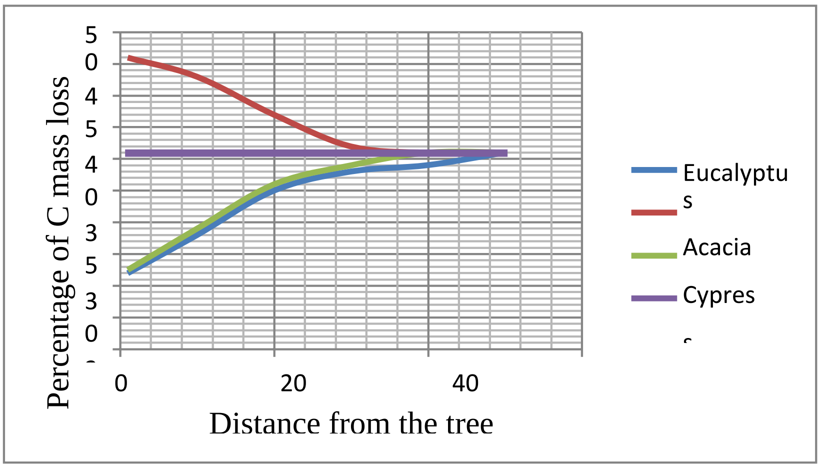


Table 4.23 shows multiple regression treatments results for litter C mass loss. From the study multiple regression results, treatment in species between Eucalyptus and

cypress had r^2=0.322 but was not significance. Distances and seasons has significance effect on litter C mass loss. Eucalyptus and Cypress had correlation of r^2=0.511, r^2= 0.609 respectively. However Eucalyptus and Acacia showed significance negative correlation in their treatment in species, distance and seasons of r^2= -0.699, r^2= -0.498r^2= -0.407respective. There was also negative correlation between Cypress and Acacia with all their treatment in species, distance and season of r^2= -0.467r^2= -0.489, and r^2= -0.404. The results indicate that there were some differences in Carbon decomposition rate between these treatments.

Table 4.23

Multiple Regression Treatments Results for Litter C Mass Loss

Treatments	Parameters	Correlation	Sig
Eucalyptus -Cypress	Species	0.322	**0.063**
	Distance	0.511	**0.023**
	Seasons	0.609	**0.015**
Eucalyptus -Acacia	Species	-0.699	**0.024**
	Distance	-0.498	**0.046**
	Seasons	-0.407	**0.012**
Cypress-Acacia	Species	-0.467	**0.034**
	Distance	-0.489	**0.043**
	Seasons	-0.404	**0.029**
Control	Species	-0.461	**0.031**
	Distance	-0.480	**0.042**
	Seasons	**-0.412**	**0.0233**

4.3.11 Effect of the Litter Substrate Quality Soil pH

From the (Table 4.24) results, soil pH was significantly affected by the seasons across all stands and the control. Eucalyptus had the lowest soil pH recorded. There was a progressive increase in pH level as the distance increases. No significance difference of both soil and litter were found after a distance of 50m against the control. Cypress adjacent pastures recorded the second lowest soil pH levels. A linear progression of pH was observed as the distance increases away from tree stand.

Acacia recorded higher pH level than both eucalyptus and Cypress. There was also a linear progression increase in pH levels as the distance decreases. No remarkable difference of soil pH was observed after a distance of 40m away from tree stand verses the control. The results of the study shows soil pH is strongly influence by the type of litter. Distances from the litter type and seasons have significant effects on soil pH.

Table 4.24

Effect of the Litter substrate quality on Soil pH

Treatments Tree	Distance	Litter and Soil pH in Different Seasons Initial Soil pH	Dry Season Litter pH	Soil pH	Wet Season Litter pH	**Soil pH**
Eucalyptus	1m.	4.50	4.60	4.40	4.20	**4.10**
	10m	4.80	4.90	4.70	4.60	**4.60**
	20m	5.00	5.20	4.80	5.00	**4.70**
	30m	5.50	5.60	5.30	5.20	**5.20**
	40m	6.00	6.20	5.90	6.00	**5.80**
	50m	6.30	6.60	6.10	6.30	**6.00**
	60m	6.30	6.60	6.10	6.30	**6.00**
Acacia	1m.	5.00	5.20	4.90	5.10	**4.80**
	10m	5.50	5.70	5.20	5.50	**5.10**
	20m	5.81	6.10	5.70	6.00	**5.50**
	30m	6.02	6.40	6.00	6.20	**5.80**
	40m	6.30	6.60	6.10	6.30	**6.01**
	50m	6.30	6.60	6.10	6.30	**6.00**
	60m	6.30	6.60	6.10	6.30	**6.00**
Cypress	1m.	4.60	4.70	4.60	4.60	**4.60**
	10m	4.80	4.90	4.80	4.70	**4.80**
	20m	5.00	5.40	5.00	5.30	**5.00**
	30m	5.50	5.90	5.50	5.70	**5.50**
	40m	6.00	6.60	6.10	6.30	**6.00**
	50m	6.32	6.62	6.11	6.31	**6.04**
	60m	6.30	6.60	6.11	6.30	**6.01**
Control		**6.32**	**6.61**	**6.10**	**6.32**	**6.02**

From the Pearson correlation above Table 4.25, a strong correlation of pH levels between eucalyptus litter and the surrounding soil pH $r^{2=}.744$ in dry season and $r^{2=}$ .632 ($\alpha<005$) in wet season. Eucalyptus adjacent pastures also indicated strong correlation pH levels with cypress leaf litter and the surrounding soil pH. The rate of decomposition had a correlation of r^2=.754, r^2=.645at ($\alpha<005$) in dry and wet seasons respectively. A negative correlation pH levels existed between eucalyptus tree stand and Acacia both soil and litter of r^2= -831 and $r^{2=}$-.677

Acacia tree correlated positively, both in litter and soil pH levels of r^2=.944 and r^2=.932 (α<005) in both dry and wet season. There was also positive correlation relationship but not significant with the control of r^2=.455 and r^2=.344 in both dry and wet seasons respectively.

Table 4.25

Pearson Correlation of leaf litter and Soil pH

	Eucpt L.C DS	Eucpt L.C WS	Acacia L.C DS	Acacia L.C Ds	Cypress L.C DS	Cypress L.C WS	Control L.C Ds	Control L.C Ws
Eucpt Soil C, DS	744**							
Eucpt Soil C.WS	632**	833*						
Acacia Soil C, DS	-677*	-766**	944**					
Acacia Soil C, WS	-831**	-822**	911*	944*				
Cypress Soil C, DS	754**	655**	-623**	-786**	903*			
Cypress Soil C, Ws	645**	809**	-712**	-698*	691*	933**		
Control Soil C, DS	455	402	366	307	333	485	977*	
Control Soil C,WS	344	545	388	399	332	432	954*	965*

4.3.12 Effect of Litter Substrate on Soil Moisture

From the above study results, Table 4.26, soil moisture was significantly affected by the seasons across all stands and the control. Eucalyptus had the lowest soil moisture across all adjacent stands. A distance ranging from 1-40m recorded between 16-19% litter moisture content in dry season and 22—27% in litter in wet season. In soils the same distance recorded moisture content ranging from 12-14% in dry season and 22-25% in wet season. There was a progressive increase in moisture content as the distance increases. No significance difference of both soil and litter after a distance of 50m against the control. Adjacent pastures to cypress recorded the second lowest soil and litter moisture. A distance of 1-30m away from tree stand recorded moisture content ranging from 16-19% in litter during dry season and 23-26% in litter during wet season. In soil moisture content, the percentage moisture content was ranging from 14-16% in dry season and 21-25% in wet season.

Acacia recorded the highest soil and litter moisture across all the adjacent stands and the control. A distance of 1-30m recorded 20-19% in dry season and 31-27% in litter during wet season. In soil moisture content, the percentage moisture content was ranging from 17-19% in dry season and 28-25% in wet season. This was unlike other stand soil and litter content. Moisture decreased with increase in distance. Further increase in distance away from tree stand did not affect the moisture content verses the control.

Table 4.26

Effect of Litter Substrate on Soil Moisture

Treatments		**Litter and Soil Moisture in Different Seasons**				
Tree Species	**Distance From the Tree**	Initial	Dry Season		Wet Season	
		Soil Moisture	Litter Moisture	Soil Moisture	Litter Moisture	Soil Moisture
Eucalyptus	1m.	17.2%	16.0%	12.0%	22.0%	20.0%
	10m	17.0%	16.0%	13.0%	23.0%	21.0%
	20m	18.1%	17.1%	13.4%	23.0%	20.0%
	30m	19.0%	17.2%	14.3%	24.1%	20.2%
	40m	20.1%	19.2%	16.2%	27.3%	25.1%
	50m	20.0%	19.1%	16.3%	27.4%	24.2%
	60m	20.2%	19.1%	16.2%	27.2%	25.2%
Acacia	1m.	21.1%	20.3%	17.3%	31.2%	28.1%
	10m	21.3%	20.2%	17.1%	31.4%	28.3%
	20m	19.2%	19.4%	17.4%	30.2%	28.3%
	30m	20.4%	19.4%	16.1%	29.2%	27.1%
	40m	21.2%	19.3%	16.2%	26.4%	25.4%
	50m	20.2%	19.0%	16.1%	27.4%	25.4%
	60m	20.2%	19.1%	16.1%	27.2%	25.1%
Cypress	1m.	17.0%	16.0%	14.1%	23.1%	21.3%
	10m	17.4%	16.1%	14.3%	25.3%	21.3%
	20m	17.3%	16.2%	14.4%	25.3%	23.2%
	30m	18.4%	17.0%	15.3%	26.2%	23.2%
	40m	19.1%	17.1%	16.3%	27.4%	24.2%
	50m	21.0%	18.0%	6.1%	20.2%	26.1%
	60m	20.1%	19.1%	6.2%	27.3%	25.2%
Control		20.0%	19.1%	6.1%	27.1%	25.2%

From the Pearson correlation above Table 4.27, a strong correlation of eucalyptus litter and the surrounding soil. A correlation of r^2 =.766 in dry season and r^2 = 0.877 (α<005) in wet seasons. Eucalyptus adjacent pastures also indicated strong correlation of moisture content with cypress adjacent soils (r2=.734, r^2=.703 (α<005) in dry and wet seasons respectively).

Acacia tree stand showed significant correlation with its adjacent pastures both in litter and soil moisture percentage .A correlation of r^2=.844 and r^2=.899 (α<005) in both dry and wet season. There was also positive correlation relation but not significant with the control of r2=.311 and r^2=.355 in both dry and wet seasons respectively. Adjacent pastures to cypress also indicated strong correlation of its litter to soil moisture percentage. A correlation of r^2=.866 and r^2=.906 (α<005) in wet and dry season respectively was recorded

Table 4.27

Pearson Correlation of litter Substrate and Soil Moisture

Litter Moisture Dry Season	Eucalyptus	Acacia	Cypress	Control
Eucalyptus	.766*	223	.734*	.321
Acacia		.844*	221	.343
Cypress			.866*	.311
Control				.856*
Litter Moisture Wet Season				
	Eucalyptus	**Acacia**	**Cypress**	Control
Eucalyptus	.877*	344	.703*	.377
Acacia		.899*	355	388
Cypress			.906*	.355
Control				.877*

*. Correlation is significant at the 0.05 level (2-tailed

4.3.14 Effect of Litter Substrate on the Soil Temperatures

Soil temperature were taken in the mid-morning (8-11) and afternoon (2-3 pm), this was to establish the effect of temperature on microbial activities. Table 4.28, eucalyptus shade recorded the lowest temperature at a distance of 1 m (29.5°C) and 1-

10m (30.1°C) during 8-11 am in the morning and 12-3 pm in the afternoon. Temperature changes by increasing from 29.5°C to 30.3 °C between 8-11 am and 12-3 pm respectively. There was a significant difference in temperature of the day between seasons. Wet seasons recorded lower temperature than the dry seasons. The temperature between 8-11 am in dry season and 11-9 pm in wet seasons in 3.4°C.The same results was recorded in the afternoon between 2-3 pm with a difference of 3^0C in a distance of 1 m away from tree stand. Distances between 10-40m away from the tree stand, there was significance linear increase in temperature in both seasons but wet seasons recording lower temperature than in dry season? There was no significance difference in temperature between 40-60 m away from the tree stand against control.

Acacia recorded higher temperatures than Eucalyptus adjacent pastures. Higher temperatures were recorded during the day with closer difference of 1°C. The same was recorded between distances of 1-10 m away from tree stands. Increase in temperature during the day could have been brought about by shedding of leaves of Acacia during the dry seasons enabling light to penetrate. There was a remarkable decline in the temperature during the wet season across all distance against control in the adjacent pastures. The distances between 1-10 m away from the tree recorded the lowest temperature than all the other stands in wet seasons. This could have been brought about by increase in vegetative growth during the wet seasons. Cypress adjacent pastures had similar temperature recording like Eucalyptus adjacent pastures. However higher temperature was recorded across all distances but lower than Acacia and the control at distance between 1-30 m away from the tree stand. Seasons had a significance difference in the temperature recorded between distances of 1-30 m away. Closer distance like the other stands recorded lower temperature in wet seasons. No significance difference between 30-60 m away from tree stand was recorded against control.

The results of the study indicate that season variations had a significant effect on soil temperature across the entire stand and the control. Lower soil temperature was found in dense canopy closer to Eucalyptus and Cypress than in Acacia. This might have been brought about by higher transmission of light in Acacia than the other adjacent trees at a closer distance from the tree stand. The finding support earlier studies by Bajad et al. (2017) that remittance of light to the understory depend on depth of the crown which influence sub sequence factors like soil temperatures.

Table 4.28

Effect of Litter Substrate on the Soil Temperatures

		Dry Season		Wet Season	
	Distance	**Soil Temperatures °C**			
		8-11am	**12-3pm**	**8-11pm**	**12-3pm**
Eucalyptus	1	29.5°C	30.3°C	26.1°C	28.3°C
	1-10m	30.1°C	32.3°C	26.4°C	28.7°C
	10-20m	30.6°C	34.4°C	28.2°C	29.2°C
	20-30m	30.9°C	34.7°C	29.4°C	30.3°C
	30-40m	31.2°C	35.1°C	30.2°C	31.6°C
	40-60m	32.5°C	36.0°C	31.5°C	32.6°C
Acacia	1m	30.1°C	31.1°C	25.1°C	27.8°C
	1-10m	30.6°C	33.3°C	25.7°C	27.9°C
	10-20m	30.9°C	34.9°C	27.2°C	28.7°C
	20-30m	31.1°C	35.2°C	30.6°C	31.3°C
	30-40m	32.5°C	36.2°C	31.5°C	31.6°C
	40-60m	32.5°C	36.3°C	31.5°C	32.6°C
Cypress	1m	29.7°C	30.6°C	26.7°C	28.8°C
	1-10m	30.4°C	32.9°C	26.9°C	29.1°C
	10-20m	30.9°C	34.9°C	28.8°C	29.7°C
	20-30m	31.2°C	35.0°C	30.1°C	30.9°C
	30-40m	31.2°C	35.6°C	30.7°C	32.1°C
	40-60m	32.5°C	36.1°C	31.5°C	32.6°C
Control		32.5	36.1°C	31.5°C	32.7°C

4.3.15 Effect of litter Substrate quality on MBN

The percentage microbial biomass Nitrogen was calculated after fumigation with chloroform. The Study results was shown were shown in the figure 4.26 and figure

4.27. From the study results (figure 4.29 and figure 4.30), Acacia adjacent grass pastures recorded the highest MBN of all the other stands and the control. The percentage linearly decreases with distance (43%,41%,40%,39%,39%39% for distance of 1m, 10m, 20m, 30m,40m, 50m,60m respectively). There was no significance difference on percentage increase after the distance of 30m against control.

Cypress adjacent pasture recorded higher MBN than that of Eucalyptus but lower than that of Acacia and the control. The percentage increases with distance unlike that of Acacia. Percentage ranges from 9% to 36% for the distance of 1 – 30m away. Further increase in distance did not affect percentage of MBN against control. Adjacent pastures next to eucalyptus recorded the lowest microbial biomass ranging from 7% to 36% for the distance of 1 – 60m away from the tree stand. Season was a significant effect. Wet season recording percentages ranging from 9% to 41% for the distance of 1 – 60m away from the stand.

Figure 4.29

Effect of litter Substrate quality on MBN in Dry Season

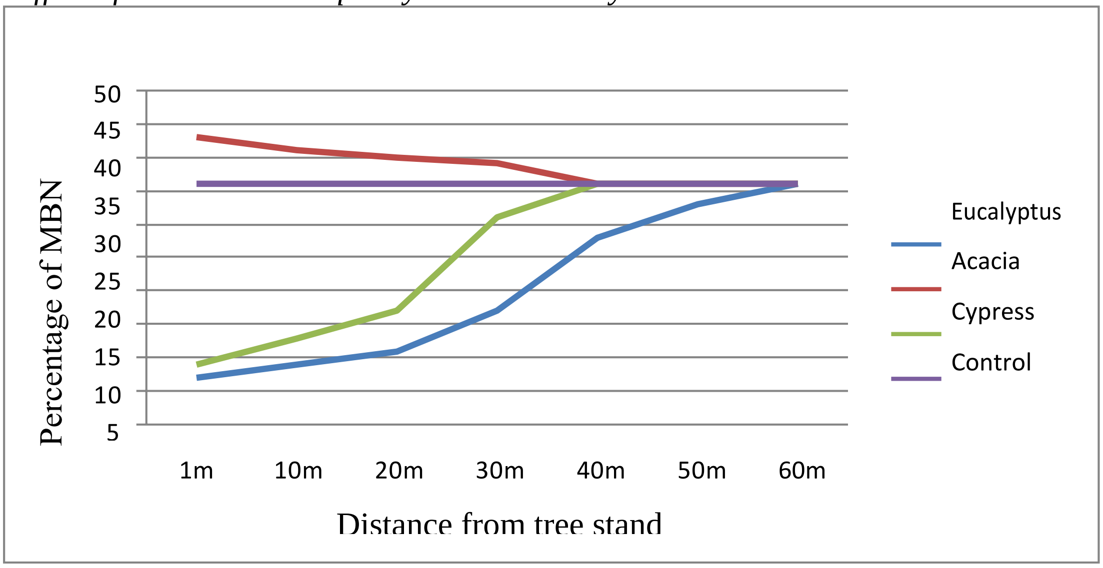
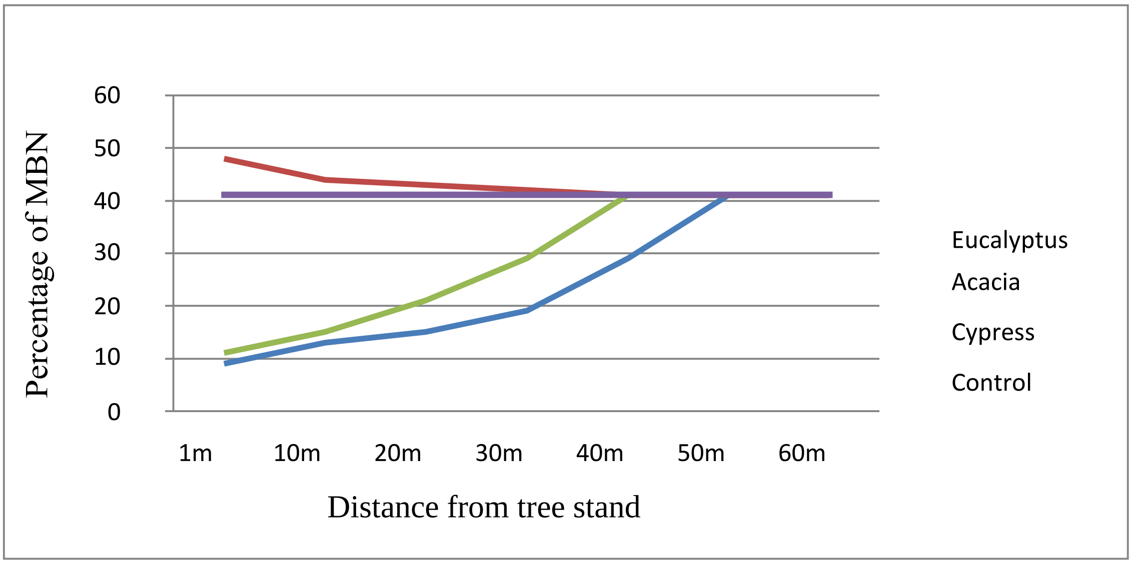


Figure 4.30

Effect of Stand litter Substrate quality on MBN in Wet Season



4.3.16 Effect of Stand Litter Substrate Quality on MBP

The percentage of MBP was calculated after fumigating the inorganic phosphorus obtains the MBP left. Acacia yielded the highest microbial biomass phosphorus among the entire stand and the control. This was effective to a distance of 1 – 30m away from tree stand.MBP decreases as the distance increases from the tree stand. No significance MBP was recorded after a distance of 30m away from tree stand. Season had significance effects with wet season record ranged from 43 – 47% while dry season ranged from 38 – 33% for the distance of 1 – 60m away from tree stand.

Cypress tree stand had the second highest MBP percentage. The amount recorded between 1 – 30m was much lower than Acacia and control but higher than Eucalyptus. Dry season had 7 to 33% and 9 to 37% in wet season. Further increase in distance after 30m away did not significantly affect the microbial biomass phosphorus verses the control.

Eucalyptus adjacent grass pastures had the lowest MBP in all the tree stands and the control. This was for a distance of 1 – 50m. The percentage of MBP ranges from 5% to 37% in dry season and 7 to 37% for wet season. There was no significance different in MBP percentage recorded after 50m away from tree stand against control. The findings was in line with that of Verhoef and Gunadi (2001) who argued that litter quality and phonological characteristics determine P release during decomposition as well as microbial biomass percentage associated with it.

4.3.17 Effect of Stand Litter Substrate Quality on Soil Organic Nitrogen Mass Loss (Decomposition)

Table 4.30 shows effect of litter quality on decomposition rate of litter nitrogen.

Cypress adjacent grass pastures had the second highest organic Nitrogen mass loss. Unlike Acacia, near distance from the tree stand recorded lower soil Nitrogen mass loss. Season had a significant effect on both litter and soil Nitrogen mass loss. Wet season recorded higher N loss than dry season. There was progressive significant increase in percentage of N mass loss as the distance increases away from the tree stand. Cypress affected the adjacent grass to a distance of 30m away

The adjacent pastures to Eucalyptus tree stand had the lowest Nitrogen mass loss both soil and litter. This was effective for a distance 1-40m away. The amount of organic mass loss was lower in near distances than in far distances away from the tree stand. The study also recorded significant increase in the amount of organic mass loss in both seasons. No noticeable difference was found after 50m away from tree stand against control.

Table 4.30

Effect of Stand Litter Substrate Quality on Soil Organic Nitrogen Mass Loss

Treatments		Litter and Soil N. Mass loss in Different Seasons			
Tree Species	Distance From the Tree	Dry Season		Wet Season	
		Litter N% Mass loss	Soil N % Mass loss	Litter N% Mass loss	Soil N%
Eucalyptus	1m.	3.32%	5.30%	7.11%	5.92%
	10m	3.51%	5.62%	7.42%	6.13%
	20m	3.84%	5.63%	7.61%	6.31%
	30m	3.92%	6.21%	8.02%	6.72%
	40m	4.11%	6.43%	11.2%	6.92%
	50m	4.32%	6.62%	11.2%	7.22%
	60m	4.33%	6.61%	11.1%	7.21%
Acacia	1m.	6.51%	9.62%	12.2%	14.1%
	10m	6.20%	9.21%	12.3%	13.2%
	20m	6.01%	9.1%	11.1%	11.1%
	30m	5.50%	8.02%	11.1%	9.01%
	40m	4.32%	6.24%	10.2%	7.21%
	50m	4.30%	6.21%	10.3%	7.22%
	60m	4.3%	6.22%	8.0%	7.24%
Cypress	1m.	3.42%	5.43%	6.92%	5.91%
	10m	4.00%	5.72%	8.02%	6.02%
	20m	4.10%	5.84%	8.31%	6.42%
	30m	4.31%	6.02%	8.61%	6.61%
	40m	4.30%	6.20%	11.2%	6.81%
	50m	4.32%	6.21%	11.1%	7.23%
	60m	4.30%	6.22%	11.0%	7.22%
Control		4.31%	6.21%	11.1%	7.20%

Table 4.31

Pearson Correlation of Litter Substrate and Soil N Mass Loss in Dry and Wet Seasons

	Litter N Eucpt DS	Litter N. Acacia DS	Litter N. Cypress DS	LitterN. Control DS
Soil N Eucpt DS	.877*	-.476	.789*	**.453**
Soil N Acacia DS		.845*	-354	**.566**
Soil N Cyp DS			.755*	**.366**
Soil N contr DS				**.899***
	Litter N Eucpt WS	**Litter N. Acacia WS**	**Litter N. Cypress WS**	**Litter N. Control WS**
Soil N Eucpt WS	.761*	-.379	.822*	**.366**
Soil N Acacia WS		.768*	-298	**.493**
Soil N Cyp WS			.745*	**.388**
Soil N contr WS				**.901***

*. Correlation is significant at the 0.05 level (2-tailed).

Key WS wet Season DS Dry Season

4.3.18 Effect of Stand litter Substrate Quality on Soil Phosphorus Mass loss

Table 4.32 shows effect of litter quality on decomposition rate of litter Phosphorus. The highest litter and soil Nitrogen mass loss was found in Acacia adjacent pastures. There was no significance difference in litter Phosphorus mass loss between distances 40 – 60m away from the tree stands against the control. The amount of Phosphorus mass loss decreases with distance away from the tree stand

The second highest litter phosphorus mass loss was found in the adjacent pastures to Cypress. Unlike Acacia, near distance from the tree stand recorded lower soil phosphorus mass loss. Season had a significant effect on both litter and soil Phosphorus mass loss. Wet season recorded higher P mass loss than dry season. There was progressive significant increase in percentage as the distance increases away from the tree stand. No significant difference was observed after a distances of 40 away against control.

The lowest Phosphorus mass loss in both soil and litter was found in adjacent pastures to Eucalyptus. Near distances recorded lower P mass loss than far distances from tree stand. The study also recorded significant increase in the amount of Phosphorus mass loss in both seasons but higher in wet season. No significant difference was found after 40m in Acacia and Cypress adjacent stands. In Eucalyptus, significance difference was observed from a distance of 50m away from tree stand against control.

Table 4.32

Effect of Stand litter Substrate Quality on Soil Phosphorus Mass loss

Treatments		Litter and Soil P. Mass loss in Different Seasons			
Tree Species	Distance From the Tree	Dry Season		Wet Season	
		Litter P% Mass loss	Soil P % Mass loss	Litter P% Mass loss	Soil P%
Eucalyptus	1m.	7.61%	9.21%	11.1%	13.0%
	10m	11.2%	10.1%	13.2%	15.3%
	20m	14.2%	16.2%	17.3%	19.2%
	30m	23.2%	29.1%	29.4%	33.1%
	40m	26.1%	31.4%	31.4%	35.2%
	50m	26.3%	32.2%	34.2%	39.4%
	60m	26.1%	35.3%	34.2%	39.3%
Acacia	1m.	34.1%	42.2%	51.1%	53.3%
	10m	31.2%	40.3%	48.1%	49.2%
	20m	29.4%	38.2%	44.1%	45.4%
	30m	28.3%	36.4%	34.2%	41.4%
	40m	26.2%	35.2%	34.2%	39.2%
	50m	26.3%	35.1%	34.1%	39.1%
	60m	26.4%	35.0%	30.2%	39.1%
Cypress	1m.	6.53%	35.2%	18.2%	14.5%
	10m	7.52%	11.3%	18.3%	16.0%
	20m	10.1%	13.3%	21.3%	19.1%
	30m	10.3%	17.1%	20.0%	26.1%
	40m	26.4%	30.0%	34.2%	39.0%
	50m	26.2%	35.3%	34.1%	39.1%
	60m	26.4%	35.2%	34.2%	39.2%
Control		26.3%	35.2%	34.3%	39.1%

From the Pearson correlation Table 4.33, a strong correlation between eucalyptus litter and its soil mass loss of $r^{2=}$.877 in dry season and $r^{2=}$ .761 (α<005) in wet season. Eucalyptus adjacent pastures also indicated strong correlation with cypress adjacent pastures decomposition rate of r^2=.822, and r^2=.789 at (α<005) in dry and wet seasons respectively. A weaker correlation also existed between Acacia soil (α<005) r^2= .453 and r^2 .366 with that of the control.

Adjacent pastures to cypress indicated strong correlation of its litter to soil of r^2=.745 and r^2=.755 (α<005) in wet and dry season respectively. Acacia tree stand showed significant correlation with its adjacent pastures both in litter and soil mass loss of r^2=845 and r2=768 (α<005) in both dry and wet season. There was also positive correlation relation but not significant with that of the control of r^2=.566 and r^2=.493 in both dry and wet seasons respectively. A significant negative correlation of r^2=.-354 and r^2=. - 298 with the Cypress adjacent pastures and r^2=.-476 and.-379 with eucalyptus adjacent pastures in both dry and wet seasons respectively. The same findings were also found by Hasanuzzaman et al. (2013) that litter quality significantly promotes mass loss of easily attainable carbon. It may also encourage recalcitrant accumulation of compounds. The leaf litter of Eucalyptus (E. globules) affects the adjacent pastures by slowing down the decomposition rate more than those of Acacia. The rate of decomposition across all the adjacent stands was affected by seasons. Thompson et al. (2004) studies argued that climatic variation is major component of decomposition rate. Organic Carbon, Nitrogen and phosphorus mass loss was highly dependent on the seasons and the type of litter produced. Climatical factor such as temperature, rainfall and humidity had a significant effect on nutrient cycling. The reason may be that climate and litter diversity affects the soil microbial community activity during decomposition process. Strassburg et al. (2010) argued that litter diversity and season, controls decomposition rate and the activity and soil microbial communities.

Table 4.33

Pearson Correlation of Litter Organic P and Soil Organic P

	Litter P Eucpt DS	Litter P Acacia DS	Litter P Cypress DS	Litter P Control DS
Soil N Eucpt DS	.798*	-.289	.729*	.322
Soil N Acacia DS		.744*	-254	.367
Soil N Cyp DS			.745*	.388
Soil N contr DS				.876*
	Litter P EucptWS	**Litter P Acacia WS**	**Litter P Cypress WS**	Litter P Control WS
Soil N Eucpt WS	.711*	-.378	.622*	.321
Soil N Acacia WS		.728*	-271	.277
Soil N Cyp WS			.811*	.315
Soil N contr WS				.895*

*. Correlation is significant at the 0.05 level (2-tailed).

Key: DS Dry Season, WS Wet Season

4.3.19 Influence of Stand Litter on Ecto- mycorrhizal Association

From the Table 4.34, the initial and the final sample analysis of ecto-mycorrhizal (ECM) did not differ so much in seasons. Adjacent pastures next to cypress recorded higher ECM percentage than acacia and Eucalyptus. The percentage progressed positively as the distance increases away from the tree stand. Ecto-mycorrhizal (ECM) was founded to be in high in those regions with the deficiencies in nutrients. The adjacent pastures to cypress recorded higher mycorrhizal association as a compensation factor for mineral nutrient loss. As earlier reported by Fadil et al. (2006) exotic trees have higher associate to ectomycorrhizal than native species due substrate utilization and carbon assimilation efficiencies. This means that there is higher efficiency of mineralizing more carbon per unit substrate than without utilizing ecto-mycorrhizal. The effect of adjacent tree stand did not affect the adjacent pasture more than 30m away. No significance difference in percentage of ECM was found after 30m away the from tree stand. Eucalyptus recorded the second highest ECM after cypress, higher percentage 52 2.12 in dry season and 55 2.11% in wet season. The percentage was higher than acacia and the control at a distance of 1 – 50m away with percentage difference of 53 2.12 to 46 2.11 in dry season and 55 2.12 to 49 2.11 percent in wet season. There were no significant effects in percentages of Ecto-mycorrhizal after a distance of 50m away from the tree stand. Season was significant with higher percentage increase in of ECM.

Acacia adjacent pasture unlike in AM, the trend of ECM changed from high percentage at a closer distance away from the tree stand. The percentage recorded at a distance (1 – 30m) was lower that other stands and the control. The study indicates that number of mycorrhizal was lesser in litter that is easy to decompose and high in litter that does not decompose easily. This was also demonstrated by the work of Bajad et al. (2017) that litter quality affects roots mycorrhizal association. Microbes surrounded by rich rhizopheres, produces signals that enhances plants fitness and growth to a given environment. It is also found to be influence by inter- plant communication in undisturbed environment. It was also observed by Mahmood et al. (2009) that litter quality alters soil properties, microbial structure and function of soil roots. This help to withstand stress and resilience to hatch environmental conditions.

Table 4.34

Effect of stand Litter quality on Ecto- mycorrhizal Association

Treatments		**% of Ect- Mycorrhizal**		
Tree Species	Distance From the Tree	**Initial % of AM**	**% End of Dry season**	**% End of Wet season**
Eucalyptus	1m.	33±2.12%	38±2.92%	39±2.11%
	10m	32±2.19%	37±2.11%	39±2.21%
	20m	37±2.32%	42±2.11%	43±2.13%
	30m	39±2.22%	44±2.14%	46±2.15%
	40m	39 ±3.37%	44 ±3.11%	46 ±3.12%
	50m	40 ±2.41%	45 ±2.41%	47 ±2.43%
	60m	44±2.13%	49±2.11%	49±2.71%
Acacia	1m.	39±3.17%	57±3.17%	63 ±3.11%
	10m	46±3.37%	55±3.11%	57±3.14%
	20m	51±2.34%	54±2.31%	56 ±2.11%
	30m	52 ±2.12%	51 ±2.11%	54 ±2.33%
	40m	53 ±2.18%	49 ±2.12%	51 ±2.14%
	50m	31±2.17%	36±2.17%	38±2.13%
	60m	36±2.37%	41 ±2.37%	43 ±2.37%
Cypress	1m.	34±2.12%	38±2.92%	41±2.11%
	10m	33±2.19%	39±2.11%	42±2.21%
	20m	38±2.32%	45±2.11%	45±2.13%
	30m	39±2.22%	46±2.14%	46±2.15%
	40m	39 ±3.37%	43±2.14%	47±2.13%
	50m	40 ±2.41%	44±2.14%	47 ±2.43%
	60m	44±2.13%	49±2.11%	49±2.71%
Control		33±2.4%	41 ±2.11%	44 ±2.22%

4.3.20 Influence of Stand Litter on Arbuscular mycorrhizal Association

Arbuscular mycorrhizal association was measured in both dry and wet seasons (Table 4.35). Acacia had the highest percentage of Aburscular mycorrhizal (AM) at a closer distance from the tree stand. The percentages range from 57 3.17% to 41 2.37% from a distance of 1 – 60m. A significant downward trend in mycorrhizal association was noted as the distance increases. Seasons had a significant effect on mycorrhizal AM association with higher AM recording higher percentage in wet season.

Cypress adjacent pasture recorded the higher mycorrhizal association than Eucalyptus. The mycorrhizal association was lower in a distance of 1 – 30m away from the tree stand ± with (35 2.22% to 54 ±2.66% in distance of 1 – 30m during the dry season. In high moisture condition (Wet season) the percentage increased from 43 2.21% to 59 2.32% on distance of 1 – 60m away from the tree stand.

The effect of adjacent pasture on mycorrhizal was not significant after the distance of 30m away from the tree stand verses control. Adjacent pastures next to eucalyptus recorded relatively lower percentage than Cypress but were significantly lower to that of Acacia and the control. Unlike the Acacia, Eucalyptus adjacent pastures AM percentages increases with the distance whereas in acacia it decreases with distance. The effect of mycorrhizal on the adjacent stand was only effective at a distance of 40 meters away. Season was significant in mycorrhizal association percentage with high moisture content recording higher percentage than in dry season. No significant AM association against control was recorded after a distance of 50 meters away from the tree stand. The findings on effects of season were also observed by Berg and Laskowski (2006) that various stages of decomposition may also be affected by season variations in temperature. Floor litter is likely to influence various biological processes and finally shift mycorrhizal association according to limited resources needed by plants.

Table 4.35

Effect of Litter on Arbuscular Mycorrhizal Association

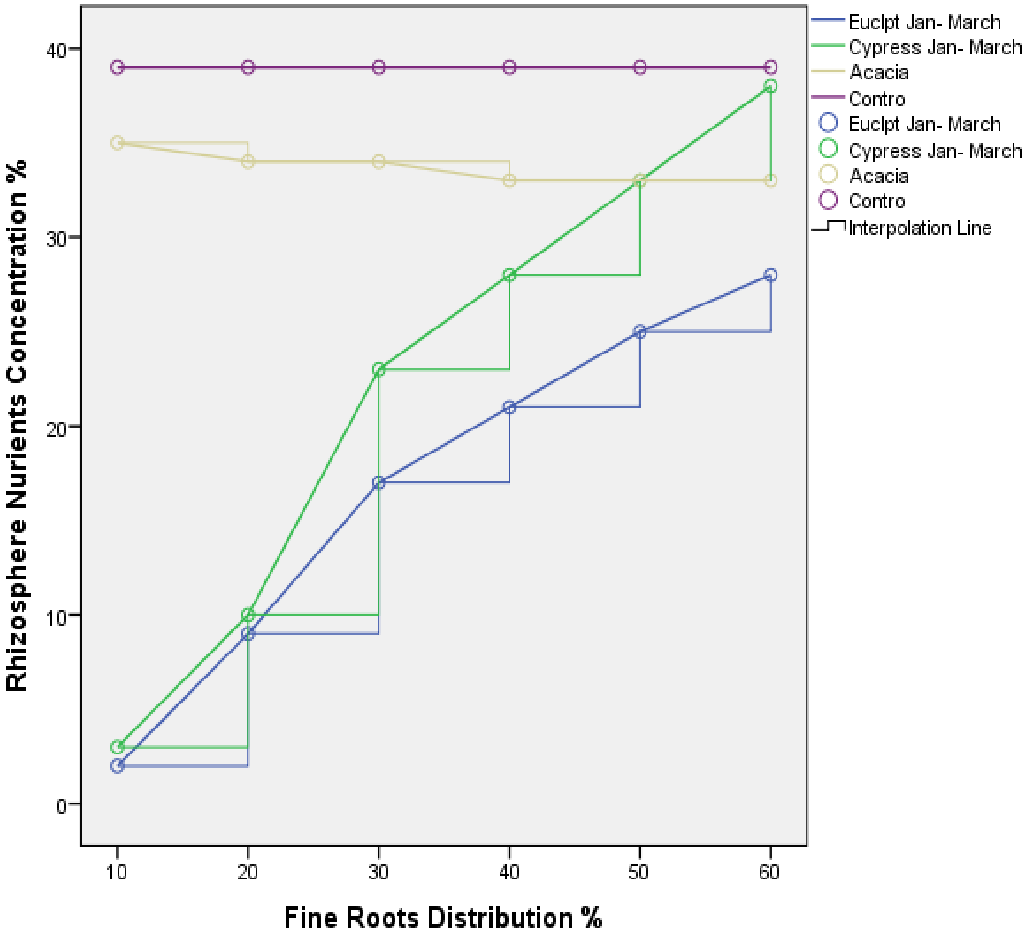
Tree Species	Treatments	% of Arbuscular Mycorrhizal Initial % of AM	% End of Dry season	% End of Wet season
Eucalyptus	1m.	33 ± 2.12%	38 ± 2.92%	**39 ± 2.11%**
	10m	32 ± 2.19%	37 ± 2.11%	**39 ± 2.21%**
	20m	37 ± 2.32%	42 ± 2.11%	**43 ± 2.13%**
	30m	39 ±2.22%	44 ± 2.14%	**46 ±2.15%**
	40m	39 ±3.37%	44 ±3.11%	46 **±3.12%**
	50m	40 ±2.41%	45 ±2.41%	47 **±2.43%**
	60m	44 ± 2.13%	49 ± 2.11%	**49 ±2.71%**
Acacia	1m.	39 ± 3.17%	57 ± 3.17%	63 **±3.11%**
	10m	46 ± 3.37%	55 ± 3.11%	**57 ± 3.14%**
	20m	51 ± 2.34%	54 ± 2.31%	56 **±2.11%**
	30m	52 ±2.12%	51 ±2.11%	54 **±2.33%**
	40m	53 ±2.18%	49 ±2.12%	51 **±2.14%**
	50m	31 ±2.17%	36 ±2.17%	**38 ± 2.13%**
	60m	36 ± 2.37%	41 ±2.37%	43 **±2.37%**
Cypress	1m.	34 ± 2.12%	38 ± 2.92%	**41 ∓ 2.11%**
	10m	33 ± 2.19%	39 ± 2.11%	**42 ± 2.21%**
	20m	38 ± 2.32%	45 ± 2.11%	**45 ± 2.13%**
	30m	39 ±2.22%	46 ± 2.14%	**46 ± 2.15%**
	40m	39 ±3.37%	43 ± 2.14%	**47 ± 2.13%**
	50m	40 ±2.41%	44 ± 2.14%	47 **±2.43%**
	60m	44 ±2.13%	49 ± 2.11%	**49 ± 2.71%**
Control		**33 ± 2.4%**	41 **±2.11%**	44 ±2.22%

4.3.21 Effect s of Litter‘s Substrate Nutrients Concentration on Grass Fine roots Production

Fine roots distribution was evaluated in vertical depth slices of 15cm, 15-30cm, 30-45cm, 45- 60cm. Figure 4.28 shows the results. Eucalyptus had the lowest fine roots production among the three stands. Higher grass fine roots production was found in far distance from the tree stands. Cypress had a similar distribution of fine roots in near distance from the tree stand. The fine roots increases as you go far away from tree stand. Acacia tree had relative evenly distribution of fine roots. Higher fine roots were found in near distance due to nutrients concentration in near distance from the tree. Low concentration of nutrients in near distance from the tree in eucalyptus and Cypress did not favour production of fine roots. The study results show that fine roots production is highly influenced by nutrients concentration). Similar results were also echoed by Gregoriou et al. (2007) that litter decomposition and releasing of soil nutrients depends on the effects of litter substrate quality and physio- chemical mineral association to a particular plant

Figure 4.30

Effect s of Litter's Substrate Nutrients Concentration on Grass Fine roots Production

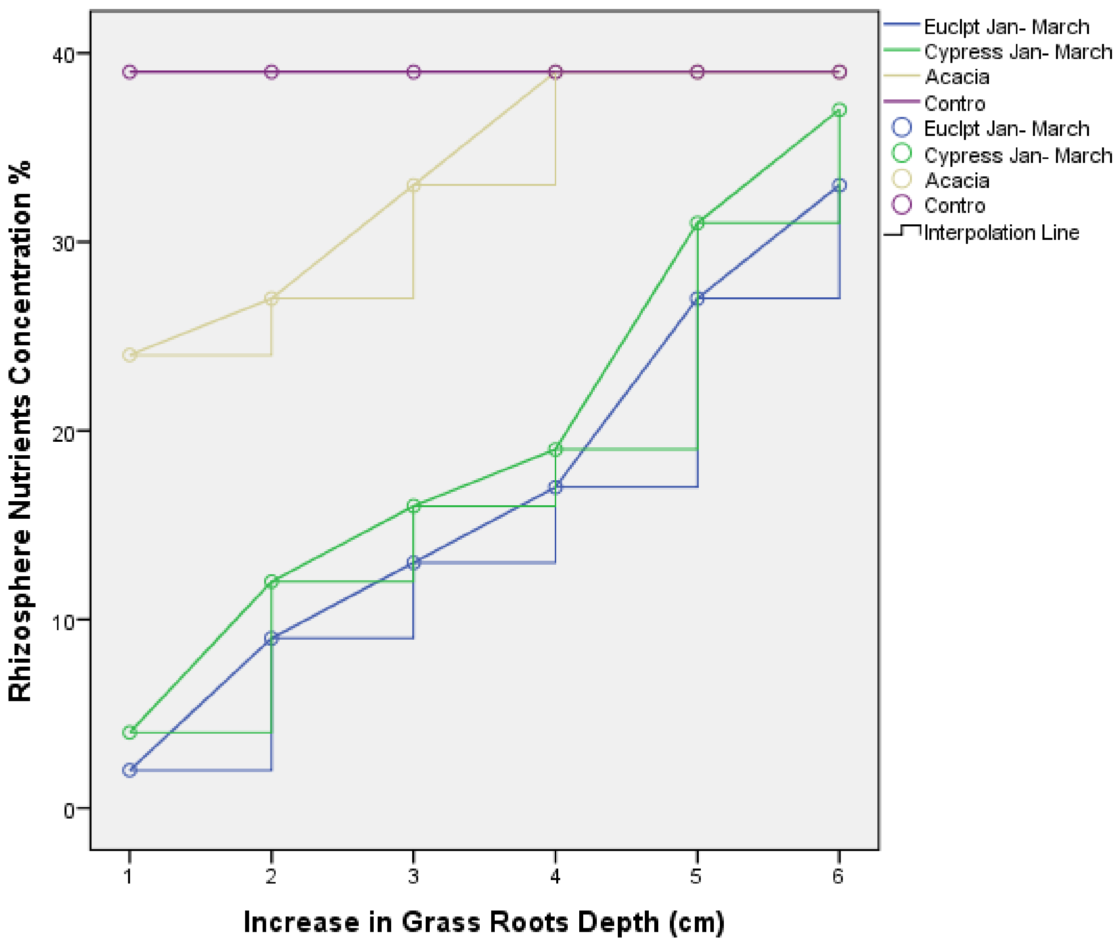


4.3.22 Effects of Litter's Substrate Nutrients Concentration on Grass Root length

Figure 4.29 shows effects of rhizosphere nutrients concentration on grass roots depth. Three tree stands were examined in terms of adjacent grass roots depth. From the study, significant difference was observed across all stands in root depth. Acacia adjacent pastures recorded a shallow root depth across the entire stand. Nutrients concentration due to low nutrients caused by tree roots and high quality litter in close distance from the tree promoted low root depth. Slight differences were observed in far distance from the tree. Eucalyptus adjacent stand had the deepest grass roots with increased root depth. Cypress had relatively lower fine root depth than the Eucalyptus. The results of the study show that nutrients concentrations promote growth of fine roots in deeper layers. Similar study was also found in the work of Hatamian and Salehi (2017) that the growth of fine roots is often associated with nutrient content and moisture availability of the rhizosphere

Figure 4.31

Effects of Litter's Substrate Nutrients Concentration on Grass Root length

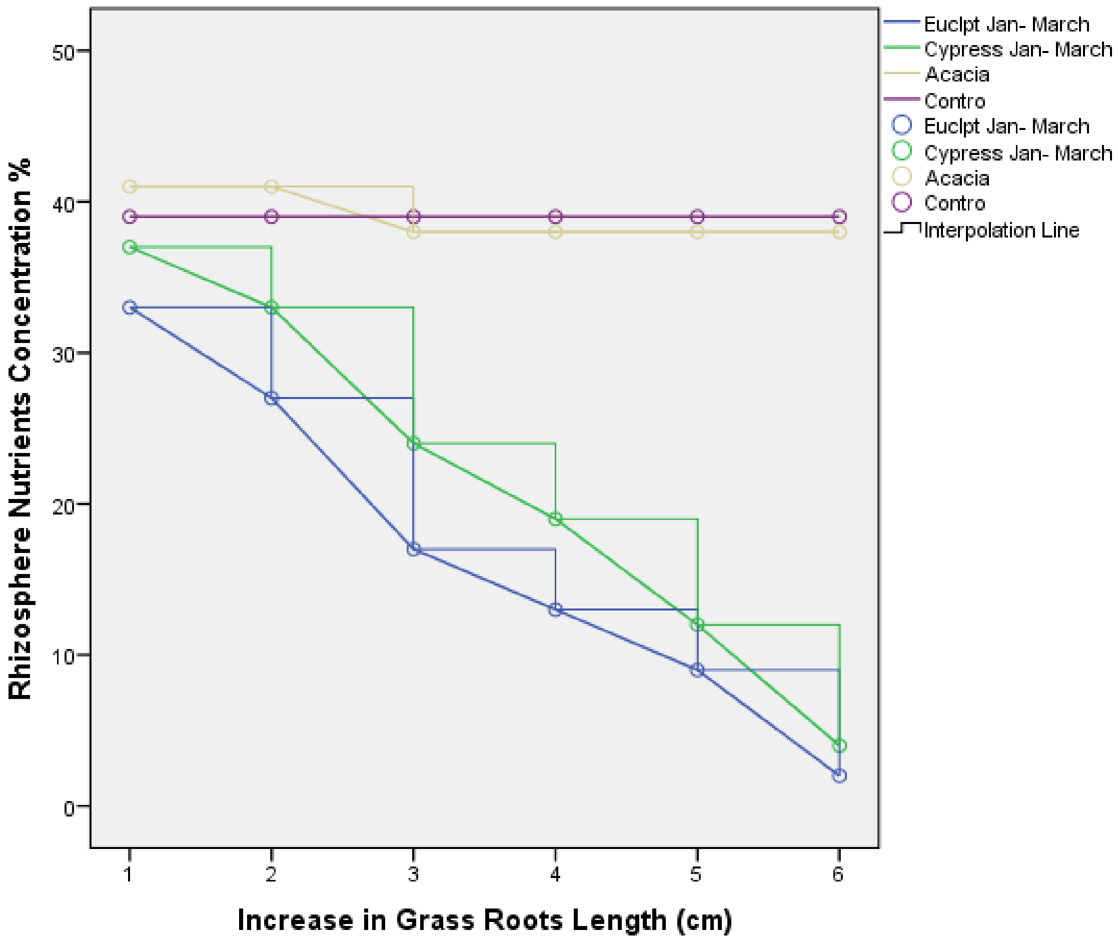


4.3.23 Effects of Litter Substrate Nutrients Concentration on Grass Roots length

Figure 4.30 shows effect of rhizosphere nutrients concentration on grass fine roots length. From the study significant difference was observed across all stands in root length. Acacia adjacent pastures recorded lowest root length across the entire stand. Litter quality with increased nutrients concentration in close distance from the tree promoted higher and relatively uniform roots length. Slight differences were observed in far distance from the tree. Eucalyptus adjacent stand had the lowest number of grass roots with decreased root length. Due to bulk accumulation of materials and depletion of the available nutrients by eucalyptus roots did not favour growth of fine roots and their length. Cypress had relatively higher fine root length than the Eucalyptus. The decrease in the available mineral contents, phyto-chemical and tree root density discourages growth and length of fine roots

Figure 4.32

Effects of Litter Substrate Nutrients Concentration on Grass Roots length



4.3.24 Effects of Litter Substrate Microbial Biomass on Species Composition Richness and Cover

Table 4.36 shows relationship between microbial biomass effect on species composition, richness and cover. In adjacent pastures next to Eucalyptus, species compositions were affected by litter quality. This was because of effect of Microbial Biomass Nitrogen (MBN) present. Litter quality in Eucalyptus adjacent stand failed to release litter Nitrogen hence denying the growing grass species enough Nitrogen. This created relative significant difference in species composition as some of the grass species failed to generate. Changes in season did not significantly affect species composition at (P<0.05) since mineralization of Nitrogen was still being affected by leaf chemistry and quality. The microbial biomass phosphorous did not significantly affect the adjacent pasture species composition at (P<0.05). However microbial biomass carbon (MBC) has an effect on species composition. This might have been possible because of litter carbon mineralization effect. Carbon mineralization in Eucalyptus leaf litter was slow due to its chemical composition. This delayed the release of minerals necessary for the growth of some species. Only grass species that were able to survive in such condition was able to survive. This significant affected the ratio of grass species composition.

In Acacia, microbial biomass Nitrogen did not control species composition at (P<0.05). The species did not differ in composition. Other microbial factor such microbial biomass carbon (MBC), microbial biomass phosphorous (MBP) and MBN: C ratio did not significantly affect species composition at (P<0.05). Season changes in Acacia adjacent pastures also did not affect the relative ratio of species composition.

Cypress adjacent pasture has a significant effect on species composition at (P<0.05). Failure of the leaf litter to release Nitrogen, affected the species composition against control. Only grass species with perennial characteristic and unpalatable such as *cynbopogon nardus* were able to survive in relative to others. Season changes not however had significant effect on species composition at (P<0.05).

Species richness is another component of species abundance in adjacent pastures. Under the eucalyptus adjacent pasture, the amount of MBN production in the leaf litter significantly affected species richness at (P<0.05). The ability of leaf litter to yield Nitrogen, affect the number of species richness per unit quadrat. Other microbial Biomass such MBC, MBP and MBN:C ratio also control the species richness at ($P<0.05$). This was highly affected by the mineralization level of eucalyptus leaf that failed to release nutrient during grass establishment stages. Season however, did not significantly affect the species richness at ($P<0.05$). The decomposition level during wet season was still low delaying the release of the required nutrients to the adjacent soil.

Acacia tree stand had significant effects on adjacent pasture richness. The labile litter in Acacia leaf promoted the growth of species in number. This was significantly higher than the two exotic stands but slight lower than control at ($P<0.05$). Changes in seasons in decomposition of MBN to release litter Nitrogen had a significant effect of species richness. Higher species number was observed during wet season than in dry season. The release of MBC at ($P<0.05$) also affect the number of species since the litter in Acacia leaf was able to decompose quickly enabling the adjacent pastures to acquire required nutrient as a result of carbon mineralization (Table 4.7.12) Other microbial biomass such MBP and MBN:C ration were also significant at ($P<0.05$). The rate of decomposition to release required nutrients affected the number of species more against control.

Cypress just like in Eucalyptus, the MBC, MBN and MBN:C ration had a significant effect at ($P<0.05$). Litter decomposition was slow down, hence affecting the species richness. The number of species per unit $0.25m^2$ quadrat was lower than that of Acacia and control. However, it was much higher than that of Eucalyptus.

Species cover was another component of species abundance. In Eucalyptus species, MBW was observed to affect the species cover at ($P<0.05$) (Figure 4.7.12). MBN had a significant effect in decomposition of litter Nitrogen. This probably affected the release of nutrient hence affected the species cover in relation to bare ground cover. Season had significant effects on species cover obtained during wet season. Other microbial biomass such as MBC, MBN:C also found to control species cover.

In Acacia adjacent pastures, MBN, MBC as well as MBN:C were also found to affect species cover at ($P<0.05$). Cypress just like in Eucalyptus, leaf litter also found to slow down release of Nitrogen, hence controlling microbial biomass such as MBN, MBC and MBN:C ratio at ($P<0.05$) in Table 4.36

Table 4.36

Means treatment for microbial biomass factor on species composition, richness and cover

	Species composition				Species Richness				Species Cover			
	MBN	MBC	MBP	MBN;C	MBN	MBC	MBP	MBN;C	MBN	MBC	MBP	**MBN;C**
Eucalpt	134.2*	436.9*	413.2	321.7*	338.2*	356.9**	423.2**	333.2**	249.2**	326.*	453.2*	**363.2****
Seasons	231.4*	327.5	322.4	453.6	233.5	329.6	341.8	375.9	327.5	353.5*	422.7	**366.7***
Acacia	45.3	42.3	43.7	36.4	39.7**	41.6**	41.8**	47.1*	46.1**	41.3**	44.1**	**43.5****
Season	311.3	422.4	421.8	487.5	437.5	432.7**	433.5	422.6	437.1	462.9*	432.4*	**466.1****
Cypress	39.6**	41.7*	42.8	39.3**	41.7**	42.1*	39.6**	43.2**	41.6**	46.7**	41.9**	**46.3****
Season	222.1*	265.3	277.3	255.6	277.8	271.1**	282.8	277.8	263.2	253.1*	277.3	**288.7**
control	46.3*	43.3	51.3	42.9*	46.4*	43.9	51.1	44.8*	47.4*	46.8	54.3*	**47.4***
Season	**322.1***	**344.5**	**369.1**	**341.7**	**364.1**	**322.6**	**366.7**	**322.7**	**322.7**	**321.8***	**354.2***	**354.2****

Horizontally, ***means are significant (p<0.05).* means are significant at (p<0.01)

4.3.25 Effects of C:N, C:P Ratio On Species Composition, Richness and Cover

Table 4.37 below shows relative ratio of carbon to Nitrogen (C:N) and carbon to phosphorous (C:P) in relation to species composition, richness and cover. In Eucalyptus C:N and C:P ratio was found to affect species composition at ($P<0.05$). Season did not significantly affect the ratio and therefore the species composition was not affected by changes in seasons.

Adjacent pastures next to acacia, C: N and C: P ratio did not significantly affect the species composition at ($P<0.05$). In cypress adjacent pastures, species composition was found to be affected by C:N and C:P ratio of the adjacent pasture against control. The relative changes in species composition were not affected by relative ratio of C: N and C: P during changes in seasons.

Under the species composition, eucalyptus adjacent pasture had higher significance different against control in the number of species per quadrat against control ($P<0.05$). The C: N ratio affected the decomposition and the release of nutrients. Eventually, it affected the number of species per $0.25m^2$ quadrat. Seasons had no significant effect in C:N or C:P ratio in species cover.

Acacia adjacent stand, had not significant effects ($P<0.05$) in species cover. However, during wet season, the labile litter decomposition rates changed. This enhanced the release of nutrients hence changes in species cover.

Cypress adjacent pastures had similar characteristics just like those of eucalyptus. Significant effects on C:N ratio were recorded (Table 4.7.13). Litter decomposition affected the release of nutrient and therefore cover of species per unit $0.25m^2$quadrat was lower than that of the control. Season had a significant effects since more species cover were observed during wet season than in dry season. This means that there was higher species cover per $0.25m^2$ quadrat due to differences in seasons.

Table 4.37

Effect of litter C:N, C:P on Species Composition, Richness and Cover

Source	Species composition		Species Richness		Species Cover	
	C:N	C:P	C:N	C:P	C:N	C:P
Eucalyptus(E)	146.7*	145.7*	1583**	133.4*	144.6**	167.6*
Season(S)	466.3	211.4*	217.4	233.3*	577.5**	233.6
SE±	23.6	78.7	123.1	167.1	34.6	127.7
Acacia(A)	259.4*	288.4**	244.1	322.4	333.2	348.4
Season(S)	234.5	633.2	255.2**	528.5	677.4**	477.4
Cypress(C)	122.5**	169.5	185.4**	156.5	188.7**	199.4
Season(S)	152.6	166.4	1882.**	144.6**	122.5**	144.3
SE±	43.5	42.9	121.8	111.9	35.5	211.6
Control (C)	397.6	866.4	344.4	233.6	566.3	796.4
Season(S)	487.3*	633.8	233.4*	344.6	788.4**	786.4
SE±	23.7	34.8	122.8	172.5	162.1	126.1

Horizontally,***means are significant ($p<0.05$).* means are significant at($p<0.01$)

4.3.26 Effect of Stand litter: P,N,C and NO $^{-3}$ on Species Composition, Richness and Cover

Table 4.38 shows responses of grass species in terms of composition, richness and cover in relation to P, N, C and NO-3 of the adjacent pastures. In eucalyptus, phosphorous (P) did not significantly affect species composition. However, release of Nitrogen (N) to the leaf litter had significant effects (Table 4.7.14). Carbon (C) and Nitrate (NO-3) did not also affect the species composition. Season had no significant effect in phosphorous (P) but had a significant effect on Nitrogen (N) and NO-3. No significant effect was observed in Carbon (C) ($P<0.05$).

In Acacia adjacent pasture, no significant effect was observed at ($P<0.05$) on species composition due to changes in P, N, C and NO-3. The species composition relative ratio remained the same. Cypress adjacent pastures had a significant effect on N and NO-3 release in the leaf litter and therefore affected the adjacent pasture (figure 4.7.3). The chemical composition in the litter, might have affected relative ratio of species composition against control. The findings were also observed by Parton et al. (2009) that some compounds such as polyphenolic substance inhibit the activity of micro-organism. Others may render N inaccessibility to majority of decomposition microorganisms where by N mineralization may occur.

Under the species richness, eucalyptus adjacent pastures were affected on P, N and NO- 3 ratio at ($P<0.05$). Season had significant effects. More species per quadrat were found. In Acacia adjacent pastures, no significant effect in term of P, N and C were found but NO-3 had significant difference. Faster mineralization of Nitrogen might have encouraged more species per unit quadrat.

Cypress adjacent pastures had significant difference in terms of N and NO-3. Higher species numbers were found. However, no significant difference were found to affect species richness in term of Carbon (C) and Phosphorous (P) at ($P<0.05$). Changes in seasons had no significant difference ($P<0.05$).

Under the species cover, eucalyptus adjacent pasture had significance difference in terms of Nitrogen (N) and NO-3 release to the leaf litter at ($P<0.05$). Higher species covers were observed during wet season than in dry season. No significant effects in specific cover in term of Phosphorous (P) and Carbon (C) were found. In Acacia adjacent pastures, significant effects were observed during wet season. This means that season had significant effects on species cover. However, only Nitrogen and NO-3 were observed to have changes in species cover in different seasons.

Cypress has the similar significance difference in term of Nitrogen and NO-3 just like eucalyptus ($P<0.025$). Nitrogen and NO-3 were found to be released but not in Phosphorous (P) and Carbon (C). Season had significant effects. Higher open ground without grass was observed during wet season. Similar findings were also observed by Lugo et al., (1995) that the quality of lignin and phenolic compounds within the litter substrate affects the rate of decomposition of litters. This creates differences in decomposition rate of different leaves in a mixed forest.

4.3.27 Effect of Stand litter: P, N, C and NO $^{-}$on Species Composition, Richness and Cover

Table 4.38

Effect of Stand litter: P, N, C and NO -on Species Composition, Richness and Cover

	Species composition				Species richness				Species cover			
	P	N	C	NO_3^-	P	N	C	NO_3^-	P	N	C	NO_3^-
Eucalyptus	235.1*	344.3**	211..4	324.5*	233.4*	235.5**	733.3	227.6**	349.7	443.3**	367.5	434.5**
Season	433.5*	322.5**	453.5	266.2**	344.2*	463.1**	633.2	644.3**	633.2*	533.3**	356.3	322.4**
Acacia	246.5	324.5	465.5	453.2	456.4*	364.3*	453.4	443.6	423.5	532.4*	644.3	543.4
Season	422.4	645.3**	564.3	433.6	244.5	356.4**	453.4	563.4**	432.4*	453.4**	432.4	534.4**
Cypress	432.3	433.5**	423.4	432.4*	453.3*	432.3**	542.4	643.3**	564.3	653.1**	543.3	463.5*
Season	325.5	456.3**	543.3	453.5**	543.2*	567.3**	345.3	453.6**	453.2	543.2**	564.3	453.2**
Control	342.5	344.2	453.2	456.3	543.5	544.5	432.4	533.3	543.2	636.6	643.1	432.5
Season	544.4	532.4*	533.3	433.3*	432.4*	433.5*	435.3	533.4*	459.9	478.6*	547.7	476.6*

Horizontally, **means are significant ($p<0.05$). * means are significant at ($p<0.01$)

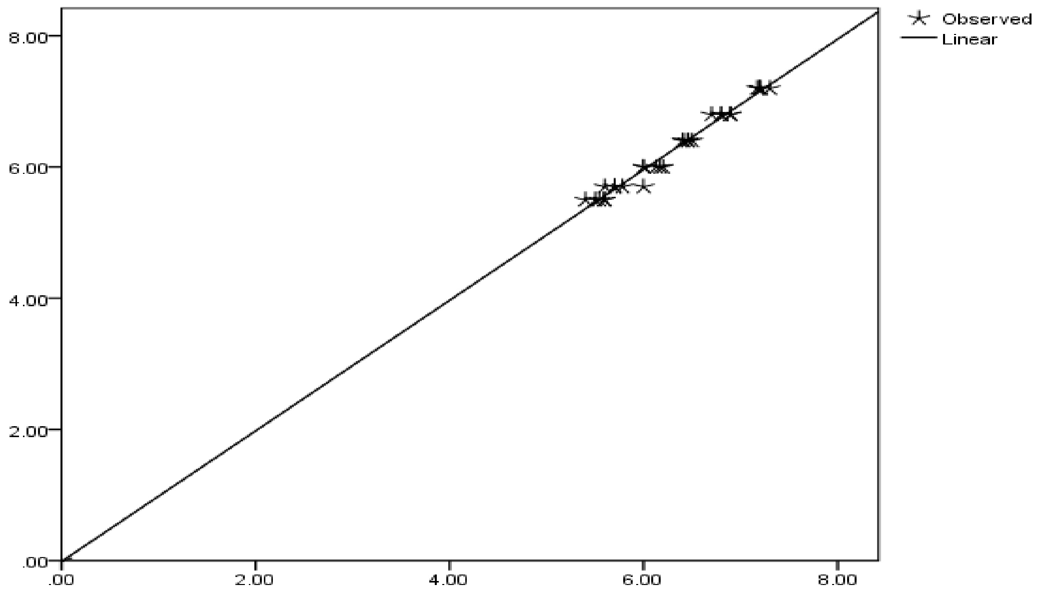
4.3.28 Linear Regression Model Analysis of Litter quality and the below ground

From the regression analysis (figure 4.38) litter quality ($y=4.35x+3$), was plotted against below ground resources influence (Decomposition rates, MBN, MBC, MBP and leaf chemistry) Decomposition rates had a strong positive correlation of $r^2=0.74$ ($p<0.05$).This suggests that litter quality strongly influence below ground resources due to its delay in releasing nutrients. The litter quality in relation to changes in microbial biomass Nitrogen also showed strong correlation of $r^2=0.71$ ($p<0.05$). This mean that nutrients cycling in the soil depend on leaf chemistry (litter quality) which determines immobilization and mineralization processes. Litter quality also had significance positive relationship with microbial biomass carbon (MBC) $r^2=0.66$ at ($p<0.05$).

This indicates that microbial biomass carbon acts as a transfer agent of decomposition of organic matter in the soil. Another significant relationship was also observed with microbial biomass phosphorus (MBP) with a correlation of $r^2=0.57$ at ($p<0.05$)..Leaf chemistry had correlation of $r^2=0.66$ at ($p<0.05$). This shows that Litter quality had strong relationship with below ground resource that influences the above ground understory characteristics. The study results shows that litter quality is a major determinant of below ground resources characteristics. This was also replicated to the above ground understory grass characteristics. Based on results findings and previously related literature, the null hypothesis which stipulates that there is no significant difference between the litter quality and below ground resource influence is rejected.

Figure 4.33

Regression Model of Litter quality (dependent variable) and Decomposition rates, MBN, MBC, MBP and leaf chemistry (Independent variables)



Species composition r^2=0.74, **Species Richness** r^2=0.71, **Species Cover** r^2=0.57**, Grass Biomass** r^2=0.66

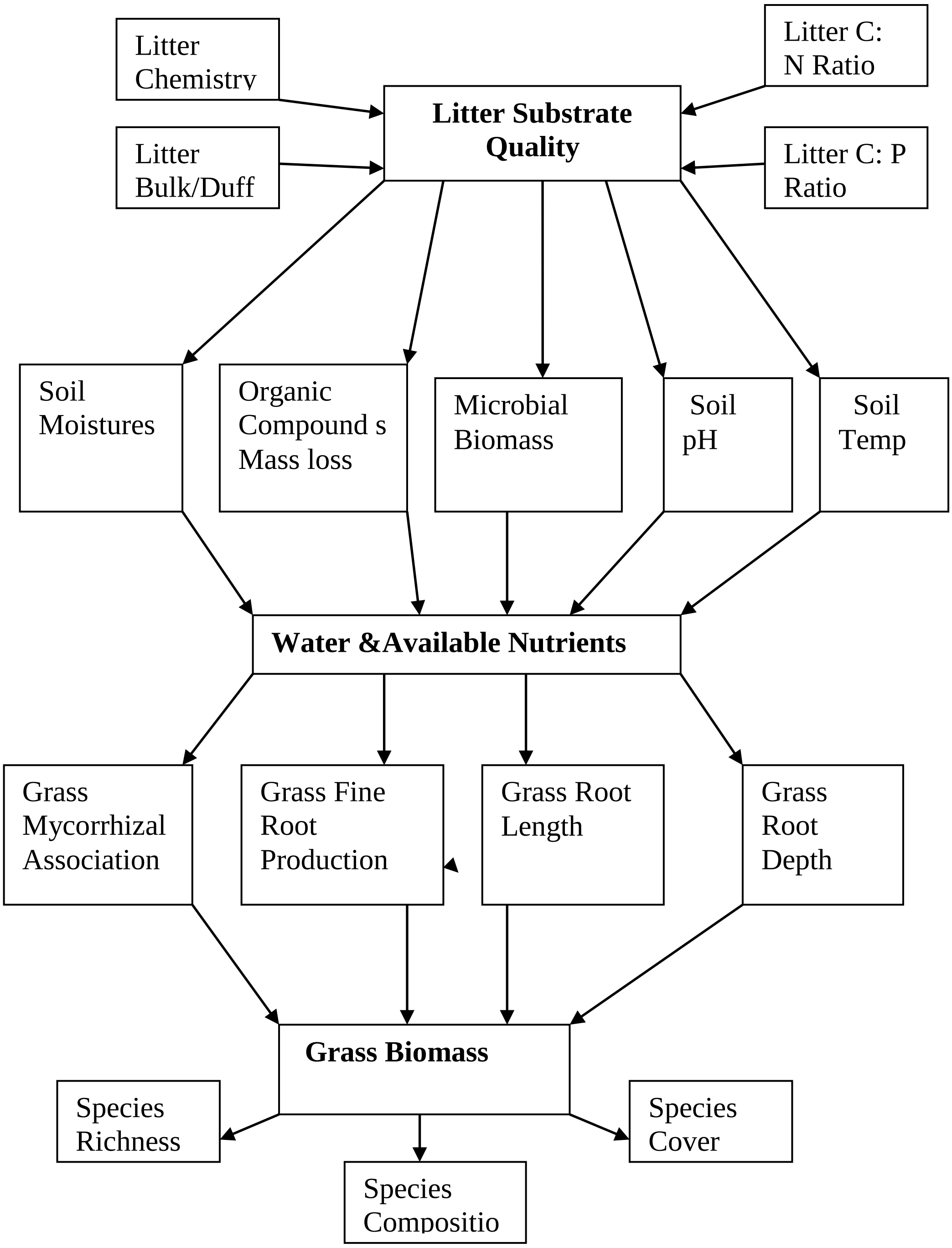
*Horizontally, **means are significant ($p<0.05$).*

4.3.29 Summary Model of Interactions between Litter Substrate Quality and Below

Figure 4.39 shows model analysis of the litter substrate quality and its influence on below ground resources. Litter substrate quality composed of litter chemistry, litter C: N, C: P ratios, pH and bulk and duff depth. These factors create differences in soil temperatures, organic compound mass loss, microbial biomass and soil pH. As results, nutrients cycling are affected. Competition between the tree and adjacent grass for the available nutrients facilitates formation of mycorrhizal association, production of fine roots, increased roots length and depth. These changes in root rhizosphere due to the available nutrients create differences in above ground grass biomass. Some grass species may not survive in some of these condition hence creating differences in species composition, cover and richness

Figure 4.34

Model Analysis of the Litter Substrate Quality and Its Influence on Below Ground Resources



*How litter quality (litter chemistry bulk/duff, C.N and C.P ratio) affects soil condition grass characteristics and finally grass biomass in terms of Species richness, composition and cover

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introductions

This chapter presents the summary, conclusion and recommendation.

5.2 Summary of the Findings

The summary presented here is based on the findings. It is also done per objective of the study

5.2.1 Canopy Structure and the Above Ground Processes

- Crown position and evenness depend on tree type. Acacia had an even crown position distributed all the sides than the two exotic stands. This was demonstrated by different crown position observed
- Photosynthetic active radiation (PAR) in canopy closed areas depend on seasons, leaf surface area and foliage leaf concentration but not crown size. This was demonstrated by higher photosynthetic active radiation (PAR) observed in Acacia (large crown) than the other two stands
- Season variations affect Acacia tree more than the two stands. Acacia tree being a desert tree respond to climatical changes by shedding leaves. These create differences in light passage in different seasons.
- Variation of light passage to adjacent vegetation depends on penetrability and not the size of the canopy**.** Acacia tree had the largest canopy size but higher photosynthetic Active radiation than both Eucalyptus and Cypress.
- Canopy and adjacent grass interaction is perhaps one of the most significant factors in determining native grass community structure in areas of influence. Pattern of species composition, cover and richness are driven by the variations of canopy composition

- Understory light availability appear to be more in Acacia (Shade intolerant) than Eucalyptus and Cypress (Shade tolerant trees). This was demonstrated by different light passage measured in µmol m^{-2} s^{-1} .
- Photosynthetic rate was higher in un-shaded than on the shaded pastures. Higher rate of photosynthesis in un-shaded pastures may explain higher biomass of grass in full sun (control) than shaded areas.
- The grass adjusted itself in shaded region in reaction to light intensity to increase their fitness. Adjacent pasture with shaded region showed no significant difference between transpiration rates apart from during wet season.
- The transpiration rate was higher in areas that were shaded than those that were not shaded during wet seasons in the mid-day. Higher transpiration rate in the morning in the shaded pastures can explain higher stomatal conductance during the morning hours than in the mid-day.

5.2.2 Roots Structure and Below Ground Space Coverage

- The result indicates that, the number of roots and their branching diameter depend on tree species type. Exotic tree had higher number of roots compared to native Acacia. Significant numbers of root branching capacity were also found to increase compared to native species.
- Moisture content is a significant factor in root branching. This was demonstrated by numerous root observed during wet season than in dry season
- There is strong relationship between root length and branching capacity. This was demonstrated by numerous roots observed in different distances across the stands. Eucalyptus has higher branching and root length than the other stands
- There is no relationship between branching of roots and root depth. Roots

concentrated on the surface where it is much easier to get water and mineral salts. Deeper roots did not show higher root depth as compared to surface root and their branching capacity

- Exotic stands have higher root length than Acacia tree stand. This is to enable them survive in different environmental stress.
- Acacia tree stand has higher root depth than the root length. Leave shedding enable it to survive in harsh environment climate than the other two stands
- From the study results, there is clear evidence that distribution of roots mainly depends on root ability to penetrate. In our study, Eucalyptus and Cyprus explored the soil more during wet seasons than in dry season.
- The uptake of water by root and underground percolation enhances soil compatibility. Therefore, soil compatibility was stronger in dry season than in wet season.
- The fine roots distribution observed on the surface soil in Eucalyptus can explain reasons for drying of grass adjacent to it.
- High root density can explain reason for high leaching of minerals to the deep layers in Eucalyptus.
- Due to hydro-phobicity being high in Eucalyptus's soil, the surface run off of the top soil is increased denying areas of influence soil moisture.
- The ability of roots of Eucalyptus tree to spread in areas of influence could also explain reasons for high nutrient uptake in soil solution.

5.2.3 Litter Quality and Decomposition Rates

- The type of litter has significant effects on the type of organic matter formed. Eucalyptus leaf litter poses decomposition challenges to the micro-organism involved in decomposition.

- Decomposition rate of litter in the soil is dynamic. It can be varied through litter mixture or changes in the soil type. The study demonstrate that as the distance increases away from the tree stand, litter changes from purely single leaf litter to a mixture of leaf and grass litter. Since the grass litter decomposes faster than Eucalyptus and cypress litter, decomposition rate increases. At the same time Acacia leaf litter decomposes faster than that of the grass. As the distance increases away from the tree stand, C.N ratio of labile litter in Acacia changes due to litter mixture to where it was buried. This slow down the rate of decomposition of litter hence slow nutrient release pattern
- There is closer relationship between Cyprus and Eucalyptus litter decomposition challenges than Acacia. This was demonstrated by Comparing Nitrogen mass loss in Acacia and other two exotic leaf litter.
- Leaf chemistry is an important factor in decomposition of organic matter. This was demonstrated by comparing chemical composition and decomposition rate. Acacia leaf litter was easier to decompose due to less chemical exudes that allow biogeochemical process involved in decomposition.
- The quality of litter affects the carbon and Nitrogen cycling process. Acacia tree stand recycle carbon more easily than eucalyptus and Cyprus. This is due to substrate quality that is easier to decompose to release nutrients
  - Climatical condition such as temperature, rainfall and micro-organism has significant effects on nutrient cycling process. This was demonstrated by different litter decomposition level in different seasons
  - Association of mycorrhizal is affected by the plant litter quality. Higher AM

were found in Acacia than in Eucalyptus.

- Presence of Microbial biomass carbon (MBC) MBN and MBP significantly depend on the type of litter. This is evidenced by higher percentage of microbial biomass MBC) MBN and MBP in Acacia adjacent pastures than the two exotic trees.
- Maintainers of nutrients primary production in adjacent pastures depend on mass loss of the available nutrients. This was demonstrated by different nutrient cycling processes in different adjacent trees
- Decomposition of organic matter mainly depends on soil biota, litter chemistry and climatic condition of the soil. This was demonstrated by different microbial biomass, leaf chemical compositions and variation of seasons
- Litter substrate quality is an important factor that steer the rate of nutrients turn over in the understory vegetation and it's above ground response.
- Senescence leaves in Acacia has better substrate quality litter than the two exotic stands which yield more Nitrogen in near distances from the free stand.
- There was significant interaction of Eucalyptus leave litter and Cyprus leaf litter in respect to nutrient dynamics and pattern of mass loss in litter. This was demonstrated by different C:N ratio and chemical composition observed.

5.3 Conclusion

In the study, both cypress and eucalyptus continued being planted by farmers because of their potential of growing fast, provide materials for construction, fuel and commercial purpose. The study results did not find greater difference in the two exotic trees compared to Acacia in terms of changes in soil pH, bulk and duff density. The rate of decomposition and litter chemistry of the two exotic trees were radically different compared to Acacia. Likewise, the performance of adjacent pasture in terms of species composition, richness and cover also varied greatly. This was probably because of differentiated light quality in terms of photosynthetic Active radiation, soil hydrophobicity and competition for available Nitrogen. In addition, Competition for the available moisture is another higher factor. Dense root network with elaborate high water intake denies grass rhizosphere moisture availability. Hydrophobicity reduces infiltration rate accelerating further problems of moisture availability. Grass mycorrhizal association acted as resilience of ecosystem to changes in nutrient content. Microbial biomass N, C and P determined the rate of decomposition and acted as useful indices for soil fertility.

5.4 Recommendations

- The study recommends regular pruning for exotic trees that are adjacent to crops or grass vegetation, to get rid of established canopy that may affect delivery of resources such as light to the adjacent grass / crops
- It is important to consider species space requirement and evaluation of connected risks and benefits of tree establishment to the adjacent grass/crops
- The study recommends that any establishment of the tree adjacent to crops or pasture, should consider potential spread of roots system and their nutrients uptake
- Recommendations for establishment of exotic tree adjacent to crops or pasture should take into account impact of carbon pools, hydrophobicity and root density which may affect adjacent crops or pastures.
- Replacement of trees from native to exotic should consider contextual dependency relationship between N input pool, variation in litter carbon, litter quality and changes in soil properties

- Establishment of any tree adjacent to crops/pasture should consider capacity of the tree to support nutrient cycling and organic matter stabilization such as soil pH, soil aggregation and polyvalent cations
- In this regard, potential ecosystem and particularly grass pastures, grazing land may be exhausted in future if these aspects of our ecosystem are not addressed. It is therefore important to find species of Eucalyptus / Cypress that require fewer resources through further studies in research. The two exotic trees should be analyze for their economic potentials v/s the effect on soil properties and their co-existence with other crops /grass. The study did not recommend them for small scale farmers whose land is less than 10 ha. of lands. A replacement of a tree like *Acacia Albida* species with high nitrogen content and potential of being economically viable in terms of timber and improvement of ecosystem is recommended.

5.5 Recommendation for Further Research

Herewith a list of potential topics for further research based on the findings of the current study:

i. Effect of shade on understory vegetation under desert vegetation climate
ii. Influence of canopy/shade level on riparian vegetation
iii. Effect of root density on growth and yield of crops under agro-forestry
iv. Effect of spatial distribution of roots on water and nutrients uptake in riparian land
v. Effect of woody debris on decomposition level of native forest floor
vi. Effect of intercropping of eucalyptus and acacia of litter on decomposition Level

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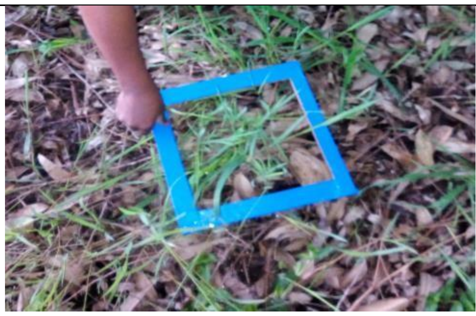
APPENDICES

Appendix 1: Research Sites

	
Source researchers' own collection. Marking plot distance	Source: Researchers' own collection. Assembling the litter Samples
	
Source: Researchers' own collection. Soil Samples from Eucalyptus	Source: Researchers' own collection. Soil Samples from Cypress

	
Source: Researchers' own collection. Eucalyptus adjacent pastures Soil Samples	Source: Researchers' own collection. Eucalyptus adjacent pastures Soil Samples

	
Source: Researchers' own collection. Cypress adjacent pastures Samples from shade	Source: Researchers' own collection. Eucalyptus adjacent pastures Samples from shade
	
Source: Researchers' own collection. Cypress adjacent pastures 1m away from tree stand	Source: Researchers' own collection. Cypress adjacent pastures 1m away from tree stand

	
Source: Researchers' own collection. Eucalyptus Soil samples	Source: Researchers' own collection. Cypress Soil samples

	
Adj.Grass to Cypress	Control Grass(No shade)
	
Grass under cypress' shade	Grass under Eucalyptus' shade
 Source: Researchers' own collection. Litter bag samples burying	 Source: Researchers' own collection. Litter bag samples burying


Source: Researchers' own collection. Sampled Eucalyptus tree


Source: Researchers' own collection. Sampled Acacia tree


Source: Researchers' own collection. Adjacent Cypress tree

Appendix II: Site Summary Data

Table A 1: Eucalyptus Site Summary of the **Photo synthetically Active Radiation** (PAR) Dry **(D)** and Wet **(W)** season

Canopy type	Site ID	Sample Date	**# Sample**	**Light** **$\mu mol\ m^{-2}\ s^{-1}$**
Eucalyptus	**D-EPD1**	27-31/1/2020	10	299 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-EPD2	27-31/1/2020	10	356 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-EPD3	27-31/1/2020	10	489 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-EPD4	27-31/1/2020	10	980 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-EPD5	27-31/1/2020	10	1459 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-EPD6	27-31/1/2020	10	1490 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-EPD1	2-6/5/2020	10	266 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-EPD2	2-6/5/2020	10	333 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-EPD3	2-6/5/2020	10	444 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-EPD4	2-6/5/2020	10	977 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-EPD5	2-6/5/2020	10	1434 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-EPD6	2-6/5/2020	10	1490 **$\mu mol\ m^{-2}\ s^{-1}$**

Table A 2: Acacia Site Summary of the **Photo synthetically Active Radiation** (PAR Dry **(D)** and Wet **(W)** season

Canopy type	Site ID	Sample Date	**# Sample**	**Light** **$\mu mol\ m^{-2}\ s^{-1}$**
Acacia	**D-ACD1**	27-31/1/2020	10	349 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-ACD2	27-31/1/2020	10	389 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-ACD3	27-31/1/2020	10	543 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-ACD4	27-31/1/2020	10	1245 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-ACD5	27-31/1/2020	10	1477 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-ACD6	27-31/1/2020	10	1490 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-ACD1	2-6/5/2020	10	333 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-ACD2	2-6/5/2020	10	359 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-ACD3	2-6/5/2020	10	534 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-ACD4	2-6/5/2020	10	1232 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-ACD5	2-6/5/2020	10	1434 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-ACD6	2-6/5/2020	10	1490 **$\mu mol\ m^{-2}\ s^{-1}$**

Table A 3: Cypress Site Summary of the **Photo synthetically Active Radiation** (PAR Dry **(D)** and Wet **(W)** season

Canopy type	Site ID	Sample Date	**# Sample**	**Light** **$\mu mol\ m^{-2}\ s^{-1}$**
Cypress	**D-CYD1**	27-31/1/2020	10	287 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-CYD2	27-31/1/2020	10	366 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-CYD3	27-31/1/2020	10	496 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-CYD4	27-31/1/2020	10	1067 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-CYD5	27-31/1/2020	10	1467 **$\mu mol\ m^{-2}\ s^{-1}$**
	D-CYD6	27-31/1/2020	10	1490 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-CYD1	2-6/5/2020	10	282 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-CYD2	2-6/5/2020	10	360 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-CYD3	2-6/5/2020	10	491 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-CYD4	2-6/5/2020	10	1069 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-CYD5	2-6/5/2020	10	1456 **$\mu mol\ m^{-2}\ s^{-1}$**
	W-CYD6	2-6/5/2020	10	1490 **$\mu mol\ m^{-2}\ s^{-1}$**

Table A 4: Eucalyptus Site Summary **Soil Temperatures** Dry **(D)** and Wet **(W)** season

Canopy type	Site ID	Sample Date	**# Sample**	**8-11Am**	**12-3pm**
Eucalyptus	**D-EPD1**	27-31/1/2020	10	29.5°C	26.1°C
	D-EPD2	27-31/1/2020	10	30.1°C	26.4°C
	D-EPD3	27-31/1/2020	10	30.6°C	28.2°C
	D-EPD4	27-31/1/2020	10	30.9°C	29.4°C
	D-EPD5	27-31/1/2020	10	31.2°C	30.2°C
	D-EPD6	27-31/1/2020	10	32.5°C	31.5°C
	W-EPD1	2-6/5/2020	10	26.1°C	28.3°C
	W-EPD2	2-6/5/2020	10	26.4°C	28.7°C
	W-EPD3	2-6/5/2020	10	28.2°C	29.2°C
	W-EPD4	2-6/5/2020	10	29.4°C	30.3°C
	W-EPD5	2-6/5/2020	10	30.2°C	31.6°C
	W-EPD6	2-6/5/2020	10	31.5°C	32.6°C

Table A 5: Acacia Site Summary **Soil Temperatures** Dry **(D)** and Wet **(W)** season

Canopy type	Site ID	Sample Date	**# Sample**	**8-11Am**	**12-3pm**
Acacia	**D-ACD1**	27-31/1/2020	10	30.1°C	31.1°C
	D-ACD2	27-31/1/2020	10	30.6°C	33.3°C
	D-ACD3	27-31/1/2020	10	30.9°C	34.9°C
	D-ACD4	27-31/1/2020	10	31.1°C	35.2°C
	D-ACD5	27-31/1/2020	10	32.5°C	36.1°C
	D-ACD6	27-31/1/2020	10	32.5°C	36.1°C
	W-ACD1	2-6/5/2020	10	25.1°C	27.8°C
	W-ACD2	2-6/5/2020	10	25.7°C	27.9°C
	W-ACD3	2-6/5/2020	10	27.2°C	28.7°C
	W-ACD4	2-6/5/2020	10	30.6°C	31.3°C
	W-ACD5	2-6/5/2020	10	31.5°C	32.6°C
	W-ACD6	2-6/5/2020	10	31.5°C	32.6°C

Table A 6: Cypress Site Summary **Soil Temperatures** Dry **(D)** and Wet **(W)** season

Canopy type	Site ID	Sample Date	**# Sample**	**8-11Am**	**12-3pm**
Cypress	**D-CYD1**	27-31/1/2020	10	29.7°C	30.6°C
	D-CYD2	27-31/1/2020	10	30.4°C	32.9°C
	D-CYD3	27-31/1/2020	10	30.9°C	34.9°C
	D-CYD4	27-31/1/2020	10	31.2°C	35.0°C
	D-CYD5	27-31/1/2020	10	31.2°C	35.6°C
	D-CYD6	27-31/1/2020	10	32.5°C	36.1°C
	W-CYD1	2-6/5/2020	10	26.7°C	28.8°C
	W-CYD2	2-6/5/2020	10	26.9°C	29.1°C
	W-CYD3	2-6/5/2020	10	28.8°C	29.7°C
	W-CYD4	2-6/5/2020	10	30.1°C	30.9°C
	W-CYD5	2-6/5/2020	10	30.7°C	32.1°C
	W-CYD6	2-6/5/2020	10	31.5°C	32.6°C

Table A 7: Eucalyptus Site Summary **Stomatal Conductance (μmol m^{-2} s^{-1})** Dry **(D)** and Wet **(W)** season

Canopy type	Site ID	Sample Date	**# Sample**	**8-11Am**	**12-3pm**
Eucalyptus	**D-EPD1**	27-31/1/2020	10	0.033	0.041
	D-EPD2	27-31/1/2020	10	0.036	0.045
	D-EPD3	27-31/1/2020	10	0.038	0.048
	D-EPD4	27-31/1/2020	10	0.041	0.052
	D-EPD5	27-31/1/2020	10	0.042	0.040
	D-EPD6	27-31/1/2020	10	0.031	0.038
	W-EPD1	2-6/5/2020	10	0.029	0.035
	W-EPD2	2-6/5/2020	10	0.031	0.039
	W-EPD3	2-6/5/2020	10	0.034	0.042
	W-EPD4	2-6/5/2020	10	0.038	0.048
	W-EPD5	2-6/5/2020	10	0.031	0.039
	W-EPD6	2-6/5/2020	10	0.028	0.036

Table A 8: Acacia Site Summary **Stomatal Conductance (μmol m^{-2} s^{-1})** Dry **(D)** and Wet **(W)** season

Canopy type	Site ID	Sample Date	**# Sample**	**8-11Am**	**12-3pm**
Acacia	**D-ACD1**	27-31/1/2020	10	0.033	0.044
	D-ACD2	27-31/1/2020	10	0.039	0.049
	D-ACD3	27-31/1/2020	10	0.042	0.051
	D-ACD4	27-31/1/2020	10	0.048	0.056
	D-ACD5	27-31/1/2020	10	0.031	0.038
	D-ACD6	27-31/1/2020	10	0.031	0.038
	W-ACD1	2-6/5/2020	10	0.037	0.042
	W-ACD2	2-6/5/2020	10	0.039	0.046
	W-ACD3	2-6/5/2020	10	0.041	0.049
	W-ACD4	2-6/5/2020	10	0.044	0.053
	W-ACD5	2-6/5/2020	10	0.028	0.036
	W-ACD6	2-6/5/2020	10	0.028	0.036

Table A 9: Cypress Site Summary **Stomatal Conductance (μmol m^{-2} s^{-1})** Dry **(D)** and Wet **(W)** season

Canopy type	Site ID	Sample Date	**# Sample**	**8-11Am**	**12-3pm**
Cypress	**D-CYD1**	27-31/1/2020	10	0.034	0.043
	D-CYD2	27-31/1/2020	10	0.037	0.048
	D-CYD3	27-31/1/2020	10	0.039	0.051
	D-CYD4	27-31/1/2020	10	0.043	0.055
	D-CYD5	27-31/1/2020	10	0.031	0.038
	D-CYD6	27-31/1/2020	10	0.031	0.038
	W-CYD1	2-6/5/2020	10	0.031	0.037
	W-CYD2	2-6/5/2020	10	0.033	0.041
	W-CYD3	2-6/5/2020	10	0.037	0.046
	W-CYD4	2-6/5/2020	10	0.039	0.052
	W-CYD5	2-6/5/2020	10	0.028	0.036
	W-CYD6	2-6/5/2020	10	0.028	0.036

Table A 10: Cypress Site Summary Crown Diameter

Height of tree	Sample Date	**Eucalyptus # Sample**	**Acacia # Sample**	**Cypress # Sample**
1m	27-31/1/2020	0	0	0
4m	27-31/1/2020	0	10.14	0
6m	27-31/1/2020	0	6.00	2.00
8m	27-31/1/2020	4.00	2.00	6.41
10m	27-31/1/2020	8.12	.40	4.00
12m	27-31/1/2020	3.00	.00	2.00
14m	27-31/1/2020	2.00	.00	1.50
16m	27-31/1/2020	1.50	.00	1.00
18m	27-31/1/2020	1.00	.00	.50
20m	27-32/1/2020	.50	.00	.00
22m	27-31/1/2020	.20	.00	.00
24m	27-31/1/2020	.10	.00	.00
28m	27-31/1/2020	.00	.00	.00
Total	27-31/1/2020	13	13	13

Table A 11:Cypress Site Summary on Soil pH Levels

Canopy type	Site ID	Sample Date	**# Sample**	**Average pH**
Cypress	**D-CYD1**	31/1/2020	3	4.4
	D-CYD2	31/1/2020	3	4.4
	D-CYD3	31/1/2020	3	4.6
	D-CYD4	31/1/2020	3	5.0
	D-CYD5	31/1/2020	3	5.7
	D-CYD6	31/1/2020	3	6.1
	W-CYD1	5/5/2020	3	4.1
	W-CYD2	5/5/2020	3	4.2
	W-CYD3	5/5/2020	3	4.4
	W-CYD4	5/5/2020	3	4.8
	W-CYD5	5/5/2020	3	5.6
	W-CYD6	5/5/2020	3	6.0

Table A 12: Eucalyptus Site Summary on Soil pH Levels

Canopy type	Site ID	Sample Date	**# Sample**	**Average pH**
Eucalyptus	**D-EPD1**	31/1/2020	3	4.2
	D-EPD2	31/1/2020	3	4.4
	D-EPD3	31/1/2020	3	4.5
	D-EPD4	31/1/2020	3	4.8
	D-EPD5	31/1/2020	3	5.7
	D-EPD6	31/1/2020	3	6.1
	W-EPD1	5/5/2020	3	4.0
	W-EPD2	5/5/2020	3	4.1
	W-EPD3	5/5/2020	3	4.2
	W-EPD4	5/5/2020	3	4.5
	W-EPD5	5/5/2020	3	5.6
	W-EPD6	5/5/2020	3	6.0

Table A 13: Acacia Site Summary on Soil pH Levels

Canopy type	Site ID	Sample Date	**# Sample**	**Average pH**
Acacia	**D-ACD1**	31/1/2020	3	4.4
	D-ACD2	31/1/2020	3	4.6
	D-ACD3	31/1/2020	3	5.0
	D-ACD4	31/1/2020	3	5.7
	D-ACD5	31/1/2020	3	5.7
	D-ACD6	31/1/2020	3	6.1
	W-ACD1	5/5/2020	3	4.3
	W-ACD2	5/5/2020	3	4.5
	W-ACD3	5/5/2020	3	4.9
	W-ACD4	5/5/2020	3	5.6
	W-ACD5	5/5/2020	3	5.6
	W-ACD6	5/5/2020	3	6.0

Table A 14: Site Summary Soil pH Levels Adjacent Native Grass Biomass

Site ID	Sample Date	**Eucalyptus Sample**	**Acacia Sample**	**Cypress Sample**
D-D1	27-31/1/2020	209g	222g	211g
D-D2	27-31/1/2020	222g	231g	229g
D-D3	27-31/1/2020	229g	239g	231g
D-D4	27-31/1/2020	231g	247g	239g
D-D5	27-31/1/2020	242g	253g	253g
D-D6	27-31/1/2020	253g	253g	253g
W-D1	27-31/1/2020	211g	229g	217g
W-D2	27-31/1/2020	229g	246g	231g
W-D3	27-31/1/2020	239g	249g	241g
W-D4	27-32/1/2020	245g	250g	249g
W-D5	27-31/1/2020	252g	261g	261g
W-D6	27-31/1/2020	261g	261g	261g

Table A 15: Eucalyptus Site Summary Canopy/Shade on C: N Ratio

Site ID	Sample Date	**Carbon Sample**	**Nitrogen Sample**	**C:N Ratio Sample**
D-EPD1	27-31/1/2020	5.1	0.11	46:1
D-EPD2	27-31/1/2020	4.5	0.12	37:1
D-EPD3	27-31/1/2020	4.2	0.13	32:1
D-EPD4	27-31/1/2020	4.1	0.14	31:1
D-EPD5	27-31/1/2020	3.9	0.15	27:1
D-EPD6	27-31/1/2020	3.9	0.14	26:1
W-EPD1	27-31/1/2020	4.6	0.12	36:1
W-EPD2	27-31/1/2020	4.3	0.12	35:1
W-EPD3	27-31/1/2020	4.2	0.13	31:1
W-EPD4	27-32/1/2020	3.9	0.14	27:1
W-EPD5	27-31/1/2020	3.7	0.14	26:1
W-EPD6	27-31/1/2020	3.4	0.14	24:1

Table A 16: Cypress Site Summary Canopy/Shade on C: N Ratio

Site ID	Sample Date	**Carbon Sample**	**Nitrogen Sample**	**C:N Ratio Sample**
D-CYD1	27-31/1/2020	5.0	0.11	41:1
D-CYD2	27-31/1/2020	4.5	0.11	36:1
D-CYD3	27-31/1/2020	4.3	0.12	35:1
D-CYD4	27-31/1/2020	4.0	0.15	28:1
D-CYD5	27-31/1/2020	3.9	0.14	26:1
D-CYD6	27-31/1/2020	3.9	0.14	27:1
W-CYD1	27-31/1/2020	4.4	0.12	40:1
W-CYD2	27-31/1/2020	4.2	0.12	38:1
W-CYD3	27-31/1/2020	4.1	0.13	34:1
W-CYD4	27-32/1/2020	3.9	0.14	29:1
W-CYD5	27-31/1/2020	3.4	0.14	24:1
W-CYD6	27-31/1/2020	3.4	0.14	24:1

Table A 17: Acacia Site Summary Canopy/Shade on C: N Ratio

Site ID	Sample Date	**Carbon Sample**	**Phosphorus Sample**	**C:P Ratio Sample**
D-ACD1	27-31/1/2020	5.1	0.24	20:1
D-ACD2	27-31/1/2020	4.5	0.21	23:1
D-ACD3	27-31/1/2020	4.2	0.19	23:1
D-ACD4	27-31/1/2020	4.1	0.17	24:1
D-ACD5	27-31/1/2020	3.9	0.16	24:1
D-ACD6	27-31/1/2020	3.9	0.16	24:1
W-ACD1	27-31/1/2020	4.6	0.21	17:1
W-ACD2	27-31/1/2020	4.3	0.21	18:1
W-ACD3	27-31/1/2020	4.2	0.18	22:1
W-ACD4	27-32/1/2020	3.9	0.15	24:1
W-ACD5	27-31/1/2020	3.7	0.14	24:1
W-ACD6	27-31/1/2020	3.4	0.14	24:1

Table A 18: Eucalyptus Site Summary Canopy/Shade on C: P Ratio

Site ID	Sample Date	**Carbon Sample**	**Phosphorus Sample**	**C:P Ratio Sample**
D-EPD1	27-31/1/2020	5.1	0.01	460:1
D-EPD2	27-31/1/2020	4.5	0.01	450:1
D-EPD3	27-31/1/2020	4.2	0.04	105:1
D-EPD4	27-31/1/2020	4.1	0.039	105:1
D-EPD5	27-31/1/2020	3.9	0.042	97:1
D-EPD6	27-31/1/2020	3.9	0.041	95:1
W-EPD1	27-31/1/2020	4.6	0.011	440:1
W-EPD2	27-31/1/2020	4.3	0.011	390:1
W-EPD3	27-31/1/2020	4.2	0.02	210:1
W-EPD4	27-32/1/2020	3.9	0.039	114:1
W-EPD5	27-31/1/2020	3.7	0.032	103:1
W-EPD6	27-31/1/2020	3.4	0.037	91:1

Table A 19: Cypress Site Summary Canopy/Shade on C: P Ratio

Site ID	Sample Date	**Carbon Sample**	**Phosphorus Sample**	**C:P RatioSample**
D-CYD1	27-31/1/2020	5.0	0.020	235:1
D-CYD2	27-31/1/2020	4.5	0.020	225:1
D-CYD3	27-31/1/2020	4.3	0.022	195:1
D-CYD4	27-31/1/2020	4.0	0.041	100:1
D-CYD5	27-31/1/2020	3.9	0.04	97:1
D-CYD6	27-31/1/2020	3.9	0.060	95:1
W-CYD1	27-31/1/2020	4.4	0.018	244:1
W-CYD2	27-31/1/2020	4.2	0.021	210:1
W-CYD3	27-31/1/2020	4.1	0.028	146:1
W-CYD4	27-32/1/2020	3.9	0.041	95:1
W-CYD5	27-31/1/2020	3.4	0.037	91:1
W-CYD6	27-31/1/2020	3.4	0.037	91:1

Table A 20: Acacia Site Summary Canopy/Shade on C: P Ratio

Site ID	Sample Date	**Carbon Sample**	**Phosphorus Sample**	**C:P Ratio Sample**
D-ACD1	27-31/1/2020	5.1	0.041	119:1
D-ACD2	27-31/1/2020	4.5	0.046	102:1
D-ACD3	27-31/1/2020	4.2	0.045	100:1
D-ACD4	27-31/1/2020	4.1	0.044	95:1
D-ACD5	27-31/1/2020	3.9	0.060	95:1
D-ACD6	27-31/1/2020	3.9	0.060	95:1
W-ACD1	27-31/1/2020	4.6	0.041	116:1
W-ACD2	27-31/1/2020	4.3	0.036	111:1
W-ACD3	27-31/1/2020	4.2	0.045	97:1
W-ACD4	27-32/1/2020	3.9	0.044	94:1
W-ACD5	27-31/1/2020	3.7	0.037	91:1
W-ACD6	27-31/1/2020	3.4	0.037	91:1

Table A 21: Eucalyptus Site Summary Canopy/Shade on Mycorrhizal association

Site ID	Sample Date	%AM	% ECM
D-EPD1	27-31/1/2020	34 2.37%	44 2.33%
D-EPD2	27-31/1/2020	±36 2.17% ±	46 2.13%
D-EPD3	27-31/1/2020	±38 2.32% ±	49 2.34%
D-EPD4	27-31/1/2020	±39 2.22% ±	52 2.23%
D-EPD5	27-31/1/2020	±49 ±3.36% ±	54 3.31%
D-EPD6	27-31/1/2020	±54 ±2.44% ±	56 2.31%
W-EPD1	27-31/1/2020	±33 4.22% ± ±	44±2.21%
W-EPD2	27-31/1/2020	37 2.14%	46 2.36%
W-EPD3	27-31/1/2020	±38±4.37% ±	49±2.44%
W-EPD4	27-32/1/2020	±39 2.46% ±	52 3.33%
W-EPD5	27-31/1/2020	±43 3.22% ±	54 3.22%
W-EPD6	27-31/1/2020	43 3.44%	56 1.27%

Table A 22: Cypress Site Summary Canopy/Shade on Mycorrhizal association

Site ID	Sample Date	%AM	% ECM
D-CYD1	27-31/1/2020	33 2.37%	43 2.37%
D-CYD2	27-31/1/2020	±35 2.31% ±	47 2.31%
D-CYD3	27-31/1/2020	±36 2.45% ±	49 2.45%
D-CYD4	27-31/1/2020	±40 2.17% ±	52 2.17%
D-CYD5	27-31/1/2020	43 2.31%	53 2.31%
D-CYD6	27-31/1/2020	54 2.37%	56 2.37%
W-CYD1	27-31/1/2020	33 2.36%	43 2.22%
W-CYD2	27-31/1/2020	35 2.44%	47 2.44%
W-CYD3	27-31/1/2020	36 2.49%	49 2.41%
W-CYD4	27-32/1/2020	40 2.23%	52 2.21%
W-CYD5	27-31/1/2020	43 2.22%	53 2.22%
W-CYD6	27-31/1/2020	43 2.44%	56 2.37%

Table A 23: Acacia Site Summary Canopy/Shade on Mycorrhizal association

Site ID	Sample Date	**%AM**	**% ECM**
D-ACD1	27-31/1/2020	36 2.33%	34 2.33%
D-ACD2	27-31/1/2020	±39 3.31% ±	37 2.31%
D-ACD3	27-31/1/2020	±48 3.37% ±	41 3.37%
D-ACD4	27-31/1/2020	±52 2.34% ±	41 2.34%
D-ACD5	27-31/1/2020	54 ±2.32%	56 ±2.32%
D-ACD6	27-31/1/2020	54 ±2.17%	56 ±2.17%
W-ACD1	27-31/1/2020	36 2.43%	37 2.33%
W-ACD2	27-31/1/2020	39 2.30%	39 3.39%
W-ACD3	27-31/1/2020	49 ±3.22%	41 3.22%
W-ACD4	27-32/1/2020	51 2.39%	41 1.39%
W-ACD5	27-31/1/2020	54 ±1.38%	56 ±2.21%
W-ACD6	27-31/1/2020	53 2.37%	56 ±2.17%

APPENDIX IX: RESEARCH AUTHORIZATION

Appendix III: Research Permit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NATIONAL COMMISSION FOR
SCIENCE,TECHNOLOGY & INNOVATION

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Date of Issue: 10/February/2020

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The Ministry of Environment and Forestry

Ref No. RCD/01/2/20

The Station Manager,
South Marmanet Forest,
P.o. Box 8,
Nyahururu 20300.
March 9, 2020

Gichuki P.Mwangi,

P.O. Box 2181,

Nyahururu.

Re: Research Authorization

Following your application for the authority to carry out an academic research titled, ***Effect Of Exotic Tree's Growth Morphology and Litter Quality On Responses of Adjacent Native Grasses***'I am pleased to inform you that your request has been granted for South Marmanet Forest for the period ending 10th February 2021.

Judy Wahome

Forest Station Manager

South Marmanet Forest

FORESTER
SOUTH MARMANET FOREST STATION