BINDURA UNIVERSITY OF SCIENCE EDUCATION

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THE EFFECTS OF SELECTED MIOMBO WOODLAND SPECIES ON CARBON AND NITROGEN STORAGE IN HUMID SAVANNAS.

TATIRE BELIEVE (B1438760)

Research Project

Dissertation submitted in the partial fulfilment of the requirements of the Bachelor of Science Honours Degree of Environmental Science honours degree in forestry.

DEDICATION

To my family.

ACKNOWLEDGEMENTS

ABSTRACT

The miombo tree species represent a significant terrestrial carbon sink which can be important in climate change mitigation. The encroaching *Acacia polyacantha* species are also useful in enhancing soil fertility through biological nitrogen fixation. The aim of the study was to asses the impacts of *A.polyacantha* species on miombo woodlands and also to determine the impact of the differences between these woody species and grasslands on Soil Organic Carbon (SOC), Nitrogen(N) and soil respiration. Soil organic carbon , soil nitrogen and soil respiration differences between *A. polyacantha, B. boehmii, J.globiflora* and grasslands were compared in Mashonaland central. SOC, N and soil respiration was significantly high in soils under acacia species while it was lower in miombo species. The grassland sites had generally lower amounts of SOC, N and soil respiration rates as compared to soils under miombo species. The change in seasons proved to have a positive impact on soil respiration rates. The results of this study suggest that encroachment of *A. polyacantha* have a positive impact on soil chemical properties.

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LIST OF ACRONYMS AND ABBREVIATIONS

Soil organic carbon……….. SOC

Organic matter………………OM

Nitrogen……………………….N

CHAPTER 1: INTRODUCTION

1.1 Background of study

The miombo ecosystem is one of the tropical ecosystems covering about 3.6 million km^2. The miombo woodland is the most extensive tropical seasonal woodland and dry forest formation in Africa, covering an estimated 2.7 million km^2 in wet regions that receive mean annual rainfall that is above 700 mm on nutrient poor soils. In Zimbabwe, the miombo woodlands cover approximately 42% of the country. The miombo woodland is a source of fuel, poles, medicine and food in rural areas as well as mitigation of atmospheric emissions through conservation and management (Munishi, et al 2010).

Forests play an important role in biogeochemical cycles such as carbon and nitrogen cycle and are valued globally for the services they provide to society (Yude, et al 2011).Soils and forests are the major sinks of carbon on earth; globally about 19 % of carbon in the earth biosphere is stored in organic compounds in vegetation living biomass and soils contains about 81 % (France et al, 2013). The amount of organic carbon stored in soils worldwide is about 1600 gigators (Gt) compared to 750 Gt in the atmosphere mostly in the form of carbon dioxide (Rustad, et al 2000). Thus,if soil respiration increases slightly such that 10% of the soil carbon pool is converted to carbon dioxide, atmospheric carbon dioxide could increase by one- fifth (Yude, et al 2011).

Although the miombo woodland is of vital importance to the human livelihoods it is under a lot of threat from agricultural activities which have resulted in massive deforestation. Miombo species are harvested for fuelwood in mostly tobacco growing areas. The gaps being left by these species is being occupied by encroaching tree species such as *A polyacantha*. Kindt et al, (2011) reported that *A. polyacantha* is a serious invader of disturbed areas. Whilst literature abounds on the general effects of tree species on the environment, currently there is not much documented information concerning the effects of these encroaching tree species on the carbon and nitrogen balance within the miombo woodlands. This study assist in providing information on how the encroaching species in the miombo woodlands are affecting the soil carbon to nitrogen balance.

1.2 PROBLEM STATEMENT

Climate change and loss of soil fertility are big threats facing mankind today and greenhouse gas emissions of which carbon dioxide is most abundant and land degradation has been identified as some of the major culprits. The miombo woodlands forests in Mashonaland central are highly deforested and are having little to no influence on soil carbon-holding capacity and soil nutrient improvement. The *A. polyacantha, B. boehmii, J.globiflora* and grasslands therefore may have greater carbon sequestration and nutrient improvement potential, making their assessment not only important for restoration strategies but also for climate change mitigation. Data on effects of miombo woodlands on SOC, N and soil respiration is scarce and few studies if any have documented the effects if miombo species on these properties. This research therefore seeks to assess the effects of selected miombo species on soil organic carbon, soil nitrogen and soil respiration.

1.3 JUSTIFICATION

The information from study will go a long way in policy formulation on the management of forests. The information also shed more light on the role of miombo woodland in forests and its contribution in the accumulation of atmospheric carbon, the increase in soil nitrogen and the rates of respiration.

1.4 AIM

To examine the effects of *A. polyacantha* and *B. boehmii, J.globiflora* on Nitrogen, soil organic carbon and soil respiration.

1.5 OBJECTIVES

1. To determine the effects of an encroaching *A. polyacantha* species on soil organic carbon in the miombo woodlands
2. To determine the effects of an encroaching *A. polyacantha* species on soil nitrogen in the miombo woodlands

3. To determine the effects of an encroaching *A. polyacantha* species on soil respiration in the miombo woodlands

1.6 RESEARCH HYPOTHESIS

➢ There is more SOC under *A. polyacantha* soils than soils under miombo tree species.

➢ There is more soil nitrogen under *A. polyacantha* soils compared to soils under miombo tree species.

➢ There is more soil respiration under *A. polyacantha* soils compared to soils under miombo tree species.

CHAPTER 2: LITERATURE REVIEW
2.1 THE EFFECTS OF VEGETATION ON SOIL ORGANIC CARBON

In a portion of land, the quantity of SOC storage is influenced by variables such as soil types, elevation, slope position, soil texture, site characteristics, soil depth, vegetation types and climate (Liao, et al 2006). A review carried by Ashton, et al (2012) on miombo woodlands soils, showed that the soils differed in SOC storage capacity hence the need to apply different management strategies for soils under different species.

Vegetation determine the stocks of SOC and their magnitude as well as the composition of SOC in soils and due to that it is regarded as one of vital factors in SOC composition (Helfrich, et al 2006). According to Stockmann et al., (2013) Soil Organic Carbon is stored mainly in the form of humus which is the final result of decomposition of plant residues in the soil over extended periods. There are different vegetation types that make up different types of forests with different levels of SOC concentration. In the well-known forest types, SOC concentrations decreased in the order: Boreal forests > Tropical forests > Temperate forests, the minimum and maximum values being

140 Pg and 340 Pg in temperate and boreal forests, respectively (Ashton, et al 2012).

Forests are referred to as carbon sinks when they take in more carbon than they release through respiration. Decomposition releases carbon dioxide more slowly than the rate it was assimilated. The Net Ecosystem Production which is the net carbon balance of the forest as a whole which also give the difference between carbon uptake by assimilation, losses through plant and soil respiration was found to be positive (Luyssaert, et al 2008) giving proof that forests are carbon sinks. A thorough research on the content and distribution of the soil organic carbon in a country or a given area enhances the ability to make a forecast of its amount and subsequently mitigate the negative consequences of climate change (Smith et al., 2015)

The increase in SOC in grasslands after woody plants encroachment can also be used as an insights into the effects of vegetation on the levels of SOC regardless of the type. For example in the subtropical Rio Grande Plains of southern Texas in northern Mexico, change in land cover resulted in soil carbon accumulation (McCulley, et al 2004). Although these studies does not directly refer to miombo woodlands, they show differences of woody species and grasses. In a study carried out by Mureva & Ward (2017) in South Africa, semi-arid regions had higher soil carbon in shrub-encroached sites than to open grasslands.

Vegetation change has a marked effect on soil carbon amount and can result in SOC chemical compositional shifts as a result of the interactions between organic inputs and subsequent input transformation by soil microbes (Breulmann, et al 2012). The changes in vegetation can be from native forest to a plantation, or colonisation of grasslands by woody species. These changes can affect and alter soil aggregates, thereby influencing SOC chemical composition (Grandy & Neff 2008). According to Guo et al (2016) variations in SOC chemical composition associated with vegetation change might be attributed to the different patterns of mineralization of plant derived microbial carbohydrate inputs.

Soil organic carbon plays an important part in soil fertility maintenance and is also simultaneously a source and sink for nutrients. A soil with relatively high content of SOC has relatively higher fertility and improved physical properties. While this fact continues to be the case, a different dimension (the climate change regulation dimension of SOC) has of recent come into focus (Smith, et al 2010) . The carbon dioxide that is converted into organic carbon in growing trees is trapped

in the wood biomass until it is released into the atmosphere again during decomposition as carbon dioxide. Cellular respiration and decomposition of litter dropped by trees also release most of the sequestered carbon.

The importance of Soil organic carbon (SOC) is mainly seen through its support of several functions. It is a significant part of soil organic matter (SOM). Soil organic carbon plays a vital role in determining soil physical and chemical properties, it is a major proxy for soil biological activity and also useful in determining of soil productivity (Batjes & Sombroek 1997, Reeves 1997) .These important functions of Soil organic carbon makes it imperative that Land use management strategies that enhance soil carbon levels be put in place for farmers and land use planners (Walker & Desanker 2004). This is needed particularly in areas where soil degradation and desertification are severe, for example ,semiarid and sub-humid Africa where these factors are leading to never ending food shortages (Lal & Singh 2005). In Zimbabwe however there is utter disregard of the importance of SOC as well under protection of forests.

2.2 THE EFFECTS OF VEGETATION ON SOIL NITROGEN

The biggest source of nitrogen in soils is soil organic matter (Ohyama 2010). Most of the organic matter in forests comes from plant litter. The more the plant litter the bigger the stock of nitrogen. This therefore mean that density of vegetation, type of species and distribution of the vegetation can affect soil nitrogen. Amongst the species, there are also those that are capable fixing nitrogen which are mainly leguminous species and also those that cannot fix nitrogen. These two different species affect soil nitrogen differently.

Although nitrogen gas is abundant in the air, plants are not capable of utilising it without a symbiotic relationship with bacteria such as rhizobia or diazotrophic endophytes. Most leguminous species are capable of fixing nitrogen biologically. According to (P Frost) Senescent leaves of miombo species that cannot fix nitrogen contain 0.6–1.8 % of nitrogen and nitrogen fixing miombo species senescent leaves contain 1.9–4.7 % nitrogen. This shows that there is a big difference in the way in which the litter from the fixing and non nitrogen fixing species affect nitrogen stocks in the soil.

(Macedo, et al 2008) found that use of nitrogen fixing species for the improvement of tropical forests raised soil carbon and nitrogen stocks by 1.73 and 0.13 Mg ha^{-1} year^{-1} respectively. An

example of a nitrogen fixing specie is *A. polyacantha*. Due to the notable positive impact of *A. polyacantha* on soil nitrogen, it has been used to improve and reclaim degraded lands. Boreal forests constitute an estimated 30% of the forested areas in the whole world (Burton, et al 2003) The deciduous component found in this forest type have been receiving support for its preservation due to its faster turnover of nutrients than coniferous forests and also the negative impact on nutrient availability if a deciduous forest is turned to a coniferous forest (Zasada, et al 1997) On nitrogen availability specifically, Jerabkova, et al (2006) found out that the deciduous forest had more nitrogen and microbial nitrogen on the forest floor than coniferous forest which he attributed to differences in vegetation. This shows the different effects on soil nutrients by different species even in the same biome hence supporting the need to asses the effects of major Miombo species as well as A. polyacantha species on total nitrogen.

2.3 EFFECTS OF VEGETATION ON SOIL RESPIRATION

Soil respiration refers to the effluxion of carbon dioxide from soil (Bond-Lamberty & Thomson 2010) . Respiration is the main process by which carbon dioxide returns to the atmosphere after being sequestered by land plants (Schlesinger & Andrews 2000). The rates of soil respiration differ significantly between major forest biomes and the vegetation in these forest biomes impact on soil respiration through influencing soil structure, the quantity and quantity of litter dropped to the soil as well as the rate of root respiration(Raich & Tufekciogul 2000)

Within a forest ecosystem, soil respiration mean rates vary greatly between major biomes according to James W Raich (1992). The tundra and deserts have the lowest rates of respiration whilst the highest rates occur in tropical moist forests.   Soil respiration mainly is a result of the integration of root and soil organic matter and litter respiration processes. Also globally, rates of forests litter fall and above ground productivity in grasslands correlated positively with rates of soil respiration (J W Raich & Tufekciogul 2000). These determinants of soil respiration are mainly dependent on the biomass and activity of plants and soil microbes (McGroddy & Silver 2000). Furthermore, soil respiration rate is also influenced by factors like soil temperature, soil water content and soil airation. Knohl, et al (2008) added that soil respiration is influenced by stand aboveground species composition and structure.

Understanding the differences in soil respiration rates and factors like vegetation that affect its rates is vital for reducing errors in evaluation and scaling up of soil carbon flux (Grace, et al 2006). In a study carried out by Merbold et al (2011) in Zambia the highest daily mean fluxes (around 12 μmol CO_2 m−2 5−1) were in the protected forest in the wet season and lowest daily mean fluxes (around1 μmol CO_2 m−2 5−1) in the disturbed grassland area during the dry season. Also in another study carried out by Mureva & Ward (2017) South Africa concluded that Soil microbial biomass and basal respiration was higher in shrub-encroached grassland across the precipitation gradient. The results of these studies give a clear picture of the influence that vegetation exert on the rates of respiration.

Sotta, et al (2004) added that the soil water contents might be a limiting factor of long-term variation in soil respiration rates in central Amazonian tropical forests with a severe dry season. also other measurements of soil respiration have been done in numerous varieties of ecosystems forest in other continents, but there is a paucity in similar studies from tropical ecosystems particularly in Africa (Nouvellon, et al 2008). Also, as pointed out by Grace, et al (2006) there are very few studies that where done to determine miombo woodlands impact on co^2 efflux despite it being the most extensive semi-arid to sub humid woodland formation in Africa.

However, in studies done on miombo woodlands there was no direct comparison on how grasslands, encroaching *A. polyacantha* species and fully grown miombo species affect soil respiration, which is necessary if we are to fully understand the long term impact differences in soil total respiration in Zimbabwe as well as in Africa as a whole.

CHAPTER 3 METHODOLOGY
3.1 STUDY AREA

The study was carried out in Mashonaland central province of Zimbabwe adjacent to Chihuri farm. The area is about 10 km south of Bindura town. Terrain of the area is irregular with gentle and steep slopes. The soils red clay soils derived from dolerite (Kamusoko, et al 2014). The altitude of the area varies from 1000 m to 1740 m above sea level. The temperature of the area usually reaches its peak in the second half of October or early November with an average maximum temperature

range of 26 °C to 35 °C. The study area receives a mean annual rainfall ranging from 700 mm to 1000 mm and is distributed from mid-October to April (Kamusoko, et al 2014).

Figure 3.1 location of Chihuri farm (Mashonaland central)

3.2 DATA COLLECTION

Soil samples were collected from sites where there was *A. polyacantha* and the two dominant miombo species (*Julbernadia globiflora* and *Brachystegia boehmii)*. Three trees were randomly selected for each specie and three samples were collected at each tree, one sample 20cm from the stem since soils very close to the bole would have been influenced by the plant longer than soils under the mid canopy. The other sample was taken under the mid canopy, 200cm from the stem and the third one was from the control site outside the canopy. A soil pit measuring 0,5 m length * 0,5 width * 30cm depth were opened and soil samples were collected at depth ranges of 0 - 5cm, 10 - 15 cm and 20 - 25 cm totalling 3 samples per pit. Nine samples were collected per tree. Thus a total of 27 pits were dug and 81 samples were collected.

For the chemical analysis the soil samples were taken to Bindura University Chemistry Laboratory for analysis. After taking the samples for each site, they were air dried (about 29°C) and sieved to remove coarse living roots and gravel but decaying coarse organic material such as dead roots was crushed and then mixed into the sieved fine earth (< 2 mm) (Nanni & Demattê, 2006).

Random distribution of sampling sites was achieved by laying a dot grid on a map of the study site. Random numbers were computer generated and were used to select the numbered dots on the map grid and where then marked on the map to represent the centre of the site where the species would be selected.

Before analysis all data was tested for normality using a Kolmogorov-Sminorv test and for equality of variances using a Levene's test. In all cases the data were normal and assumed equality of variances therefore a parametric ANOVA was used to test for the effects of site and depth on carbon and nitrogen levels as well as respiration rates in the three species. Carbon and nitrogen levels were used as the dependent variables in their respective models while site, depth and the interaction of site and depth were taken to be the explanatory variables. For respiration rates, site, season and the interaction of site and season were taken to be explanatory variables. Models were run for each species. All data were analysed in SPSS version 21 at 5% level of significance.

3.3 ACACIA POLYACANTHA AND MIOMBO WOODLAND SPECIES EFFECTS ON SOIL CHEMICAL PROPERTIES ANALYSIS

3.4 SOC DETERMINATION

Loss on Ignition (LOI) analysis was used to determine the organic matter (OM) content of a soil sample in this study(Robertson, 2011). LOI calculates organic matter percentage by comparing the weight of a sample before and after the soil has been ignited. The difference in weight before and after ignition represents the amount of the OM that was present in the sample (Robertson, 2011). Soil samples were weighed and placed in the oven and heated for 24hrs at 105ºC to account for moisture. After heated in the oven they were placed in a desiccator to cool for 30min then weighed.

Samples are then taken to the muffle furnace and heated for 24hrs at 550ºC to find the content of OM in the soil sample.

The OM % was calculated using the formulae;

$$\frac{pre\ ignition\ weight\ (g) - post\ ignition\ weight(g)}{pre\ ignition\ weight} \times 100$$

SOC = OM ÷ 1.724

SOIL NITROGEN DETERMINATION

The Kjeldahl method was used for the determination of nitrogen in soil samples (Kjeldahl, 2009). The procedure involves three major steps that includes, digestion, Distillation and Titration. The digestion of soil samples mixed with sulphuric acid concentration with the addition of copper sulphate and potassium sulphate acting as a catalyst is the first stage. The samples are heated for 2 hours for complete dissolution and oxidation. Distillation is the second step. Sodium hydroxide is added to ammonium sulphate produced during the digestion process. The ammonium ion is released in ammonia form and is distilled and received on a boric acid solution. After distillation, then follows Titration. The ammonia is determined by back-titration with a sodium hydroxide solution of a known solution and the results are expressed in percentages

Kjeldahl uses the following formulae for the calculation of nitrogen;

$$\frac{mls\ 0.1NHCL \times extract\ normality\ of\ HCL \times 1.402}{sample\ weight} \times 100$$

where *mls* 0.1*NHCL* = titration figure.

SOIL RESPIRATION

For the determination of respiration i used the soda lime method. The soda lime method involves covering a plot of ground with a chamber and then placing a pre-weighed, open dish of soda lime within it. As the soil organisms release co^2 to the chamber it is quickly absorbed by the soda lime (along with water vapor). After 24 hours, the chamber is removed and the soda lime is dried at 105°C to evaporate the water and is then weighed. The increase in mass of the soda lime is

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attributable to co^2 (Keith & Wong, 2006). The conversion of organic carbon to co^2 by decomposers (mainly bacteria and fungi) is called respiration. Drying the soda lime after the incubation drives off the water that was absorbed and also the water that was produced by CO2 absorption. In order to compensate for this underestimation we multiply by a correction factor (1.69).

The conversions were done as follows:

- ➢ Initial Dry Mass of Soda Lime (g) = Mi
- ➢ Final Dry Mass of Soda Lime (g) = Mf
- ➢ Mass Change of Blank (g) = Mb = Mf(blank) $-$ Mi(blank)
- ➢ Mass Change of Sample (mg) = dM = $(MF - Mi - MB) \times 100$
- ➢ CO2 Absorbed by soda lime (mg CO2) = dM $\times$ 1.69

Soil Respiration (mg CO_2 / m^2 / d) =

CO2 Absorbed/area /days

CHAPTER 4:RESULTS
4.1 EFFECTS OF *A. POLYACANTHA* AND MIOMBO SPECIES ON SOC

The overall differences of SOC between species significantly varied ($F_{2, 54}$ =6.70; p≤0.003;as fig 4.1). Soils under the encroaching species *A. polyacantha* had significantly higher C (98.629 g C/kg soil; Fig 4.1) combined amount of both the bole site and under canopy site than *B. boehmii and J. globiflora* which had 98.63g C/ kg soil, 86gC/kg soil respectively. However there was no significant difference between *B. boehmii* and *J. globiflora* (P>0.05).

In terms of the overall effect of site, significantly higher levels of SOC (P≤0.05) were found in the soils at bole site (93.741 g C/kg soil) while the lowest values were found in the soils at grassland

site (72.222 g C/kg soil). The under canopy soils also had significantly more C than the grassland site. There was no significant difference between the C amount in soils under canopy site and the bole site.

There was a significant difference in the levels of SOC at mid-canopy site at 5cm depth ($F_{2,9}$ = 51.19;$P \leq 0.001$;fig 4.1). As shown in fig 4.1, At 5cm depth, soil under *A. polyacantha* had significantly more SOC(108gC/kg soil) at mid-canopy site than species *B. boehmii* and *J. globiflora* (P=0.001), (P = 0.001) repectively. Also the levels at *B. boehmii* were significantly higher (P= 0.06) than those at *J. globiflora*.
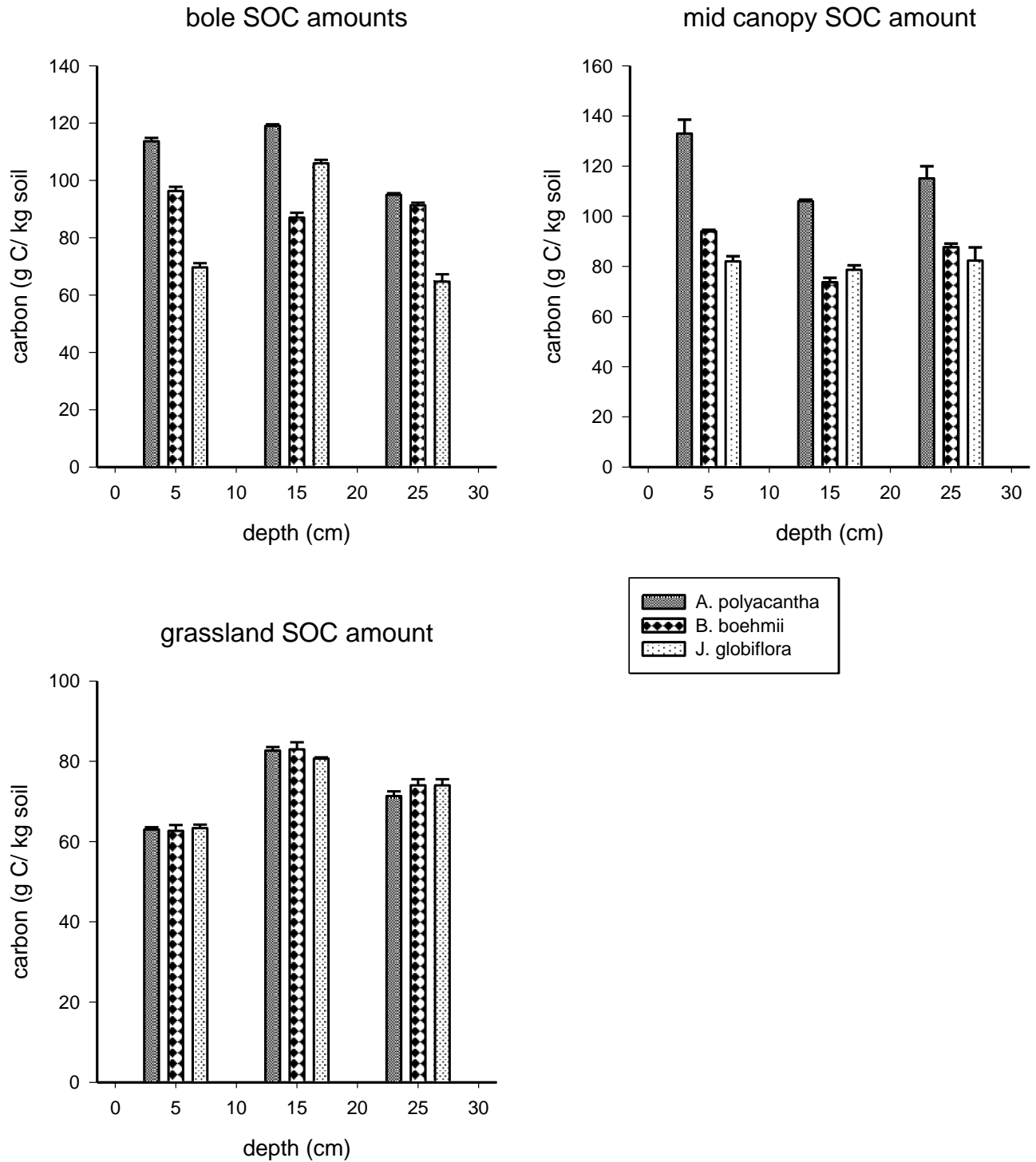
Figure 4.1 shows SOC amounts under A. polyacantha, B. boehmii and J. globiflora on the bole site, mid canopy site and outside canopy site.

4.2 EFFECTS OF *A. POLYACANTHA* AND MIOMBO SPECIES ON SOIL NITROGEN

There was overall significant difference between species ($F_{2,54}$ = 5.269;P≤0.008; fig 4.2) (*Acacia polyacantha, Julbernadia globiflora, Brachystegia boehmii*). *A. polyacantha* had the highest nitrogen level mean (0.53%) and the lowest levels were at *J. globiflora* (0.51%). The interaction of species and depth was also significant ($F_{4,54}$ = 8.944;P≤0.001). The total N amounts found in soils under *A. polyacantha* were significantly more than N amounts in soils under *J. globiflora.*

In terms of the overall effect of site, there was a significant difference in the levels of nitrogen with site ($F_{2,54}$=54.816; p≤0.001 ;fig 4.2). The highest levels of nitrogen were found in soils at bole site (0.56% N) while the lowest values were found in the grassland (0.44% N). Both the soils at the bole and mid canopy sites had significantly higher N amounts than the grassland site soil N amounts.

The interaction of site and depth was also significant ($F_{4,54}$=3.782; p≤0.009;fig 4.2). The amounts of N significantly differ in soils at 5cm depth bole site when comparing between all species ($F_{2,6}$ = 36.807;P≤0.001;fig 4.2). There was significant variation P=0.001 between *A. polyacantha* and *j. globiflora* as well as between *B. boehmii* and *J. globiflora* P=0.001. As shown in fig 4.2, the mean differences between species showed that soil under *A. polyacantha* had significantly more nitrogen at 5cm depth (0.64%) and the lowest amounts where at *J. globiflora* (0.37%).

The overall effect of bole site at 15 cm level was significantly different ($F_{2,6}$ = 4.765;P≤0.058 fig 4.2)**.** Nitrogen levels were only significantly different between *A. polyacantha* and *B. boehmii* P=0.021**.** *B. boehmii* had the highest levels of nitrogen (0.66%) and *A. polyacantha* had the lowest with (0.59%)**.**

The three species (*Acacia polyacantha, Julbernadia globiflora, Brachystegia boehmii*) were significantly different ($F_{2,6}$ = 6.447;P≤0.032 fig 4.2) at depth 25cm bole site. The comparisons proved that *Acacia polyacantha* had significantly higher nitrogen amount in soil at its bole site than *J. globiflora* and *b. boehmii* (P=0.05). *J. globiflora* had the lowest nitrogen amounts (0.47%).

Still on the effects of the interaction of sites and depths, there was a significant difference in the levels of Nitrogen at 5cm depth, mid canopy site across all species ($F_{2,9}$ = 51.19;P≤0.035; Fig 4.2).

At depth 5cm mid canopy site , there was significantly more nitrogen at *J. globiflora* (0.54 %) and the lowest amounts were at *A. polyacantha* (0.45%). Levels of nitrogen was significantly different between *B. boehmii* and *A. polyacantha* (P=0.039). *J. globiflora* had significantly higher nitrogen than *A. polyacantha* at mid canopy site p= 0.16.

Between species, there was a significant difference in the levels of Nitrogen at mid canopy site at 25cm depth ($F_{2,6}$ = 39. 446;P≤0.001; Fig 4.2). Significant variation (P≤0.05) in nitrogen levels was noted between all three species. The amount of nitrogen at 25cm depth was high in the soils under *A. polyacantha* (0.6%) and lowest at *B. boehmii* (0.39%) at 25cm depth.
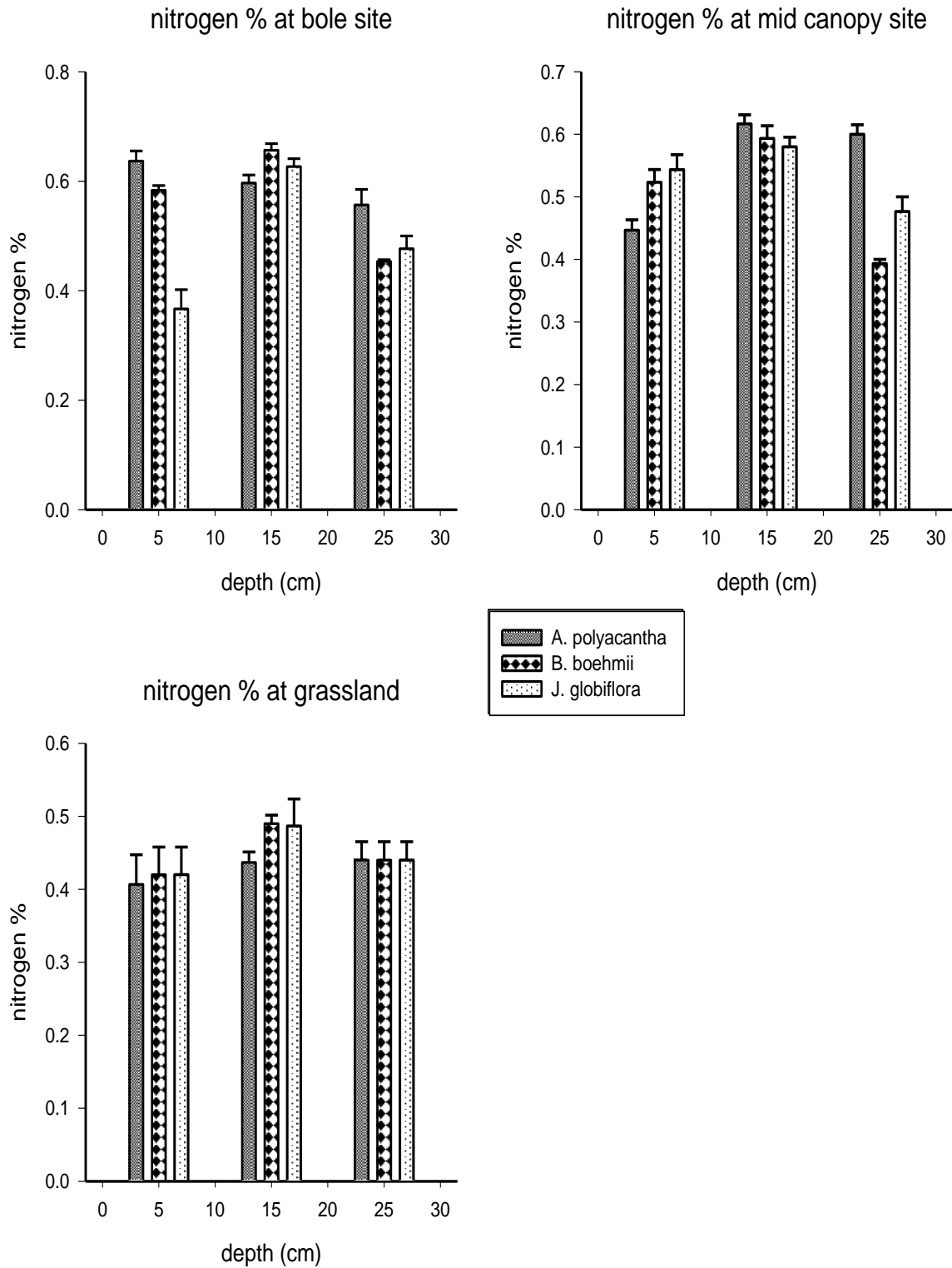
Figure 4.2 shows soil nitrogen amounts under A. polyacantha, B. boehmii and J. globiflora on the bole site, mid canopy and outside canopy site.

4.3 EFFECTS OF *A. POLYACANTHA* AND MIOMBO SPECIES ON SOIL RESPIRATION.

In the dry season, there was significantly high respiration rates at *A. polyacantha* specie (902.222 mg/CO_2/m^2/day; Figure 4.3) than *B. boehmii* and *J. globiflora*. The lowest amounts of soil respiration were found in soils under *J. globiflora* (760.444 mg/CO_2/m^2/day; Figure 4.6).

Significant variation was also recorded between all species (P=0.05) in the wet season. More respiration was at soils under *A. polyacantha* specie (1013.667 mg/CO_2/m^2/day; Figure 4.3) than *B. boehmii* and *J. globiflora*. The lowest amounts of soil respiration were found in soils under *J. globiflora* (900.444 mg/CO_2/m^2/day; Figure 4.3).

The comparison of site differences between species in the dry season proved to be significantly different on the bole site only (p=0.002). The *A. polyacantha* specie had significantly high respiration than *J. globiflora* specie. In the wet season however, rates significantly differ at both the bole site and mid canopy site. There was high respiration rate differences at bole site ($F_{0,6}$ = 1102.053;P≤0.001; Figure 4.*3*)**.** The rates differed significantly from specie to specie (P=0.05) with *A. polyacantha* having the highest rates (1233.333 mg/CO_2/m^2/day) and *J. globiflora* having the lowest (992.333 mg/CO_2/m^2/d).

There respiration rates differed significantly mid canopy site ($F_{0,6}$ = 743.799;P≤0.001; Figure 4.*3*)**.** The differences between species were significant (P=0.001) with *A. polyacantha* having the highest rates (1118.000 mg/CO_2/m^2/d) and *B. boehmii* having the lowest (961.667 mg/CO_2/m^2/d) at the mid canopy site.

When the overall effect of site in the dry season was considered, there was high significant difference in the rates of respiration in soils at the bole site and grassland sites (P=0.05) with more respiration in the soils at the bole site (925.555 mg/CO_2/m^2/d). The lowest amounts on soil respiration where found in the grassland site (656 mg/CO_2/m^2/d). There was no variation between the bole and mid canopy sites (p=0.05). In the wet season, there was notable variation in soil respiration from site to site (Figure 4.*3)*. There was significantly high respiration rates at the bole site (1120.444 mg/CO_2/m^2/d; Figure 4.9) than at mid canopy (1035.332 mg/CO_2/m^2/d) and grassland site (682.444 mg/CO_2/m^2/d). The difference between canopy and grassland site was also significant (P=0.05).

site dry season rates

species dry season rates
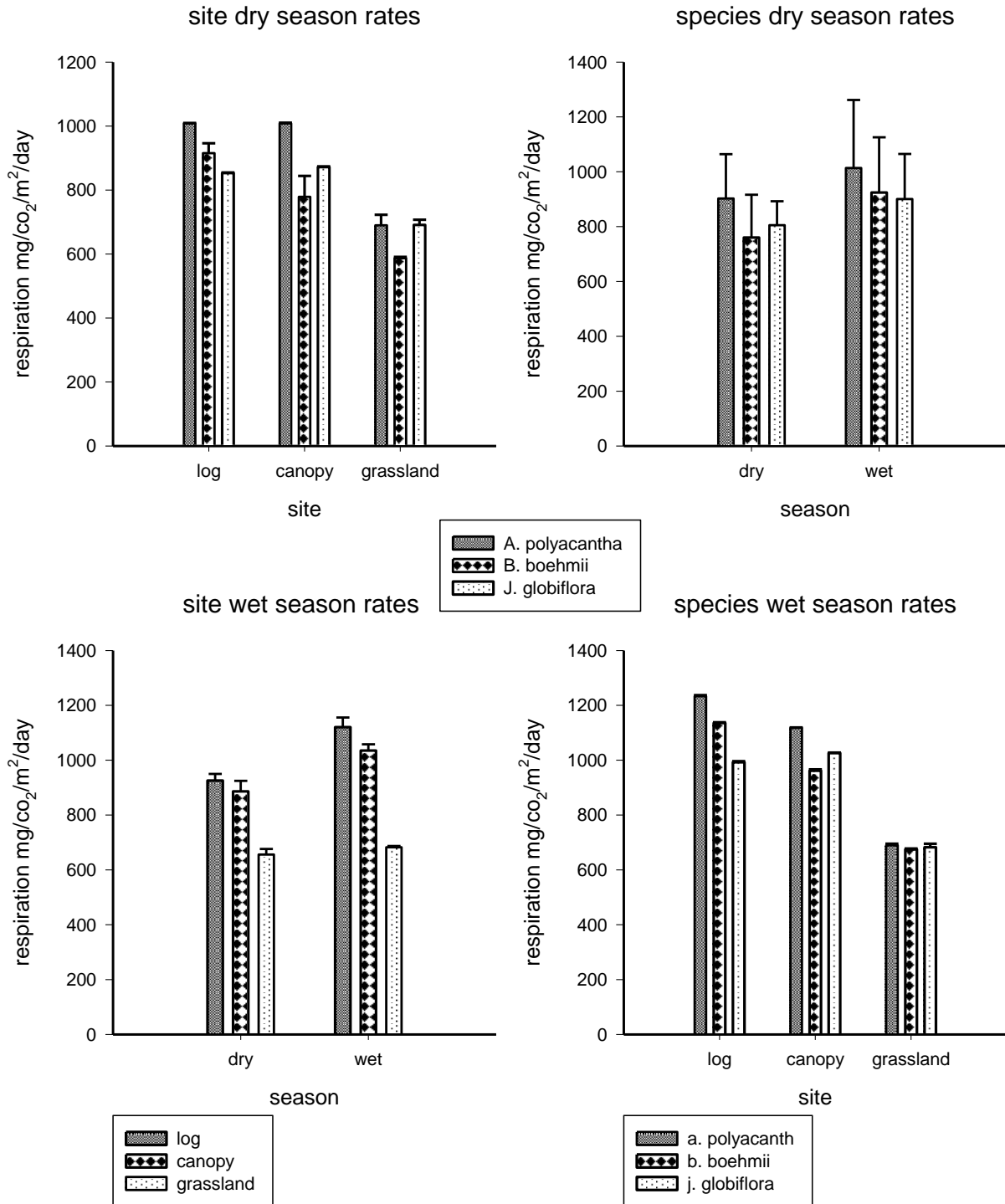
site wet season rates

species wet season rates

Figure 4.3 shows soil respiration rates under A. polyacantha, B. boehmii and J. globiflora on the bole site, mid canopy and outside canopy site as well as season differences.

CHAPTER 5:DISCUSSION
5.1 DIFFERENCES IN SOIL ORGANIC CARBON IN MIOMBO SPECIES WITH DEPTH.

The *A. polyacantha* species had 15.74 g C/kg soil more SOC than *B. boehmii* and 20.78 g C/kg soil more than *J. globiflora.* This is constant with my predictions that soils under *A. polyacantha* species will have more SOC than the miombo species. The high amounts of carbon found in soils under acacia species can be attributed to greater formation of stabilised organic matter under *A. polyacantha* species. The stabilisation process reduces the rate of decomposition resulting in an increase in SOC. Nitrogen enrichment by nitrogen fixing species cause changes in soil microbial activity as the nitrogen could block the formation of enzymes that degrade lignin by fungi causing a slower turnover of organic matter hence the increased amount of SOC at acacia species (binkley 2005).

There was more SOC in soil under *A. polyacantha* and miombo species at all depths than in remnant grassland proving that *A. polyacantha* and miombo species sequester more SOC than grassland. This difference can be attributed to litter inputs, root biomass replacement and exudates (Bolton et al 1993). The higher SOC under tree can also be attributed to the accumulation of decomposition resistant woody debris from trees and roots. The results on SOC support a theory by Scholes (Scholes, 1990) that savanna species act as nutrient pumps. Nutrients drawn from the zone of weathering are transported up the tree and return to the soil as litter fall ,leachates, root litter and as exudates. There' dearth in literature in terms of other research studies that directly link to these findings. However there are studies that are similar to my study that looked at differences in SOC between woody species, shrubs and grasslands which can be related to my study. For example the results of my study are similar to other study by McCulley et al., (2004) conducted in Northern Mexico,and another one by Belsky et al, (1993). There is also another similar study by Traore, et al (2007)that recorded an increase in amounts of SOC in soils under a miombo specie than in open land.

At 5cm depth canopy sites, the amounts of carbon followed the order *A. polyacantha*, *B. boehmii* and *J. globiflora*, with *A. polyacantha* having the highest amount and *J. globiflora* having the

lowest. The lignin content of the A. polyacantha litter that slows the rate of mineralisation can be the reason for differences in carbon amounts (Breman & Kessler, 2012). Also the results show that there was more SOC in the upper layers mostly, decreasing with depth. This result corroborates a study by Becker et al., (2017).

5.2 EFFECTS OF MIOMBO SPECIES ON SOIL NITROGEN

The soils under *A. polyacantha* had more nitrogen amounts than the original miombo species. This result is consistent with predicted results in this study. The total N values reported here of 4% to 6.5% are also within the range reported by Jacobson, (2017). The main mechanism often seen as the reason for the subsequent accumulation of nutrients under *A. polyacantha* is the species' nitrogen fixing capability(Yelenik et al,2004).

The soils that were taken under the *A. polyacantha* and miombo species had more nitrogen than the grassland site(fig 4.5). The difference can be due to the differences in nutrient mining capabilities of grassland and miombo species. The grasses and miombo species have different access to sources of soil nitrogen hence resulting in differences in soil nitrogen amounts. According to Sitters, et al (2013)woody species utilise organic forms of nitrogen more efficiently. The efficient uptake of nitrogen result in more nitrogen in the litter that these species drop. The lack of nitrogen in grasslands was not a surprise since there are other studies that argued that nitrogen is the most limiting nutrient in grassland for example Ludwig, et al (2013).The differences in litter quantity may have also contributed to differences in soil nitrogen amounts since more organic matter is mostly related to more soil nitrogen. The leaf litter quantity measured by Swift et al,(1989) was about one and half times greater than that found in open grasslands. According to Ohyama, (2010) there is about 5% by weight the concentration of N in humus.

The overall effect of site, in soils at both canopy and log site shows that the nitrogen levels where higher at 15 cm for all the three species. This may be due to the fact that the samples were taken towards the end of the dry season where microbial activity will be reduced. For *A. polyacantha*, the dryness of, topsoil horizons at end of the dry season causes a shift in symbiotic N fixation to lower horizons (Vetaas, 1992). The results can also be attributed to leaching and high mobility of nitrogen (Vitousek et al., 1997) since high amounts of nitrogen where expected at the upper layers of the soil.

The log site had more nitrogen as compared to the canopy site and grassland site. The differences in soil N amounts between the log and canopy site can be explained by the differences in impact the tree has had on both sites. The log site, due to stem flow, would have more exudates and moisture for a long time resulting in high microbial activity, thereby increasing the rates of mineralisation. The other reason for the noted differences in soil nitrogen can be emanating from human factors, since the people from the surrounding rural areas cut the grass for thatching.

EFFECTS OF MIOMBO SPECIES ON SOIL RESPIRATION

During the wet and dry season, the *A. polyacantha* had higher rates of respiration than *B. boehmii* and *J. globiflora*. This is in line with the prediction that A. polyacantha species will have more soil respiration than miombo species. In both the seasons also, the rates of respiration where high on the sites under the species than on the grassland site. The results of this study contradicts with Becker et al., (2017) who found an increase in respiration in grassland soils. The reduced C:N ratio of woody plant foliage when contrasted with the C:N ratio of grasses can be the reason behind the differences in respiration rates. The reduced C:N ratio may stimulate soil microbial biomass and activity (McCulley et al., 2004). The higher rates under miombo species than grassland are also in line with another study by Merbold, et al (2011) done in Zambia.

There was high respiration rates in the wet season than in the dry season. The differences can be ascribed to moisture availability. According to (McGroddy & Silver, 2000) carbon amounts and microbial activity is influenced by changes in soil moisture with high moisture leading to water logging causing anaerobiosis and minimal moisture contributing to aerobic respiration. The average rainfall that the site received could have therefore contributed to increased respiration during the wet season. The higher respiration rates in the wet season contradicts other researches that recorded low respiration rates in humid and sub humid areas, for example Mureva et al, (2017)

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSION

The encroachment of *A. polyacantha* increased soil fertility through high quantity litter inputs and quality in the local area under the crown. Fast growth of *A. polyacantha* and the rhizobium symbiosis is the reason why the species had more impact on soil fertility than the miombo species which are leguminous species but are not capable of biological nitrogen fixation. SOC content was high in the upper 5 - 15 cm of all the tree species, the increase was less pronounced in the lower depths of 25 cm. This effect is the result of passive accumulation of N and C from litter fall over time as well as nutrient pumping by the trees. The miombo species and *A. polyacantha*, whether it was a nitrogen fixer or not had the same effects on soil properties, as both had a positive impact as compared to grassland. From the study results it can be concluded that SOC pools and fluxes are related directly to quantity and quality of litter of trees and can be negatively affected by a decrease in tree cover. It is also suffice to say miombo and *A. polyacantha* species affect soil C storage by actively increasing biomass inputs.

6.2 RECOMMENDATIONS

Enhancement of SOC stocks/storage through preservation of *acacia* and miombo species so as to contribute to climate change mitigation when forest/soil management is responsive to existing conditions in the field is recommended.

Land use management strategies that enhance SOC and N levels through tree preservation of acacia and miombo species have to be drafted for farmers and land use planners. This is needed particularly in areas which are like Mashonaland Central where soil degradation and deforestation is most severe.

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