EFFECT OF SELECTED FORAGE LEGUMES ON SOIL QUALITY AND MAIZE YIELD IN THE SAVANNA

BY

Oluwaseun Ola JEKAIYE
(MSC./AGRIC./10965/2007-2008)

MARCH, 2012

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THESIS SUBMITTED TO THE POST GRADUATE SCHOOL AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTERS OF SCIENCE IN SOIL SCIENCE.

DEPARTMENT OF SOIL SCIENCE,
FACULTY OF AGRICULTURE,
AHMADU BELLO UNIVERSITY, ZARIA.

MARCH, 2012

DECLARATION

I declare that this thesis entitled "Effects of Selected Forage Legumes on Soil Quality and Maize Yield in the Savanna" has been performed by me in the Department of Soil Science under the supervision of Prof. A. C. Odunze. Information derived from literature has been duly acknowledged in the text and a list of references provided. No part of the thesis was previously presented for another degree or diploma at any university.

_____ _____

Oluwaseun Ola Jekaiye Date

Declaration confirmed by:

_____ _____

Prof A. C. Odunze Date
Chairman, Supervisor Committee

CERTIFICATION

This thesis entitled "Effects of Selected Forage Legumes on Soil Quality and Maize Yield in the Savanna" by Jekaiye Oluwaseun Ola, meets the regulations governing the award of Masters of Science Degree of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this work to my father and mother, who brought love and sunshine into my life, for their various acts of love, encouragement, assistance and support.

ABSTRACT

Study on the effect of selected forage legume on soil quality and maize yield in the Guinea Savanna was conducted in Ahmadu Bello University Farm, Samaru, Zaria (longitudes 7^{o} 30^{1} and 7^{o} 50^{1} E and latitudes 11^{o} 00^{1} and 11^{o} 10^{1}) Nigeria in the year 2008 to 2009. The study involved planting two forage legumes; Centrosema Pascuorum (Cp) and Macrotyloma uniflorum (Mu) as the main plots. A natural vegetation regrowth was used as control. The treatments consisted of factorial combination of Nitrogen rates (0, 40, 80 and 120 kg ha^{-1}) and Phosphorus rates (0, 13.2 and 26.4 kg ha^{-1}) imposed as sub-plots. Data obtained were evaluated on a split plot design for soil chemical [organic carbon, available phosphorus, total nitrogen, soil carbon fraction, CEC, soil pH, exchangeable bases (Ca, Mg, Na, K) and micro nutrients (Zn, Mn, Fe)] properties measured. Crop phrenology (plant height, leaf number, maize stover yield, maize cob weight and grain yield), soil physical (bulk density, hydraulic conductivity, particle size distribution, dry and wet aggregate stability and total porosity) properties were also measured and soil microbial biomass (carbon, nitrogen, phosphorus and particulate organic matter) were also measured. Results showed that, pre-maize planting soil condition, *Centrosema pascuorum* planted (CPF) fallow significantly improved soil chemical properties {Available phosphorus (10.50 $mgkg^{-1}$), total nitrogen (0.88 g Kg^{-1}), pH (6.0), CEC (6.8 c /mol Kg^{-1}), manganese (9.3 mg Kg^{-1}), Iron (42.2 mg Kg^{-1}), exchangeable calcium (2.80 c /mol Kg^{-1}), exchangeable sodium (0.68 c /mol Kg^{-1}) and mean weight diameter (1.37 g) } compared to all other treatments. This indicates that *Centrosema pascuorum* planted fallow is a better soil amendment than natural vegetation regrowth which gave lower improvement in soil chemical properties {Available phosphorus (8.75 $mgkg^{-1}$), total nitrogen (0.53 g Kg^{-1}), pH (5.9), CEC (5.0 c mol Kg^{-1}), manganese (6.4 mg Kg^{-1}), Iron (31.1 mg Kg^{-1}), exchangeable calcium (2.40 c mol Kg^{-1}), and exchangeable sodium (0.58 c mol Kg^{-1}) }. *Macrotyloma uniflorum* planted fallow (MPF) slightly improved soil chemical properties {Available phosphorus (5.25 mg kg^{-1}), total nitrogen (0.35 g Kg^{-1}), pH (6.0), CEC (6.6 c /mol Kg^{-1}), manganese (7.9 mg Kg^{-1}), Iron (31.1 mg Kg^{-1}), exchangeable calcium (2.40 c /mol Kg^{-1}), and exchangeable sodium (0.48 c /mol Kg^{-1}) }. However, natural vegetation regrowth contributed higher organic carbon (6.1 g Kg^{-1}), exchangeable potassium (0.17 c /mol Kg^{-1}) and soil zinc (10.7 mg Kg^{-1}) to the soil than CPF and MPF under one year fallow management at pre-maize planting. Phosphorus application significantly influence soil properties with 26.4 kg P ha^{-1} producing higher values among other rates, suggesting that 26.4 kg P ha^{-1} was optimal for maize production under the legume short fallow production. This study therefore suggests the application of 80 Kg N ha^{-1} and 26.4 kg P ha^{-1} under the one year *Centrosema pascuorum* planted fallow and one year maize cultivation as being the most beneficial. The practice will ensure sustainable maize production, reduced (less than 120 Kg N ha^{-1}) the use of inorganic fertilizer for maize production and improve soil quality.

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CHAPTER ONE

1.0 INTRODUCTION

Maize (*Zea may L.*) is a very important staple cereal produced both for cash returns and for food in the savanna agro ecologies (Jagtap, 1995). It has a high yield potential and occupies about 40% of the area under agricultural production in the savanna zones. Enhanced maize production therefore has a strong potential for improving the livelihood of small scale farmers in Nigeria. However continuous cropping of maize, a major staple crop in Nigeria, has adversely affected soil quality especially under monocropped system in savanna ecologies. Various attempts have been made to improve soil productivity through the application of inorganic fertilizers and intercropping cereals with legumes (Reijnties *et al.,* 1992, Adepetu, 1997). Studies have shown that continuous use of inorganic fertilizers alone is not helpful under intensive agriculture as it aggravates the problem of soil degradation (Marinari *et al.,* 2000; Ayoola and Makinde, 2007). In the Nigerian savanna, loss of organic matter which consequently results in low soil biological activities (Pascual *et al.,* 1997), increase soil acidity, soil nutrient imbalance, low water uptake and ultimately low crop yield (Giller *et al.,* 1998; Marinari *et al.,* 2000 and Tarawali *et al.,* 2001) has been observed. Reduced cation exchange capacity, exchangeable cations and upset in the cationic balance have also been reported (Agbenin and Goladi, 1997). Soils of the West Africa Savanna dominated by kaolinite clays are inherently poor in fertility, fragile and degrade rapidly under continuous intensive cropping and livestock production systems (Jones and Wild, 1975; Adeoye, 1984; Lombin, 1987; Lal, 1979; Odunze *et al.,* 1992).

Upland soils in the Nigerian savannas are known to be sandy loam at the surface layer, have low water holding capacity, low organic matter level and result in low soil microbial activity and cations exchange capacity (Pascual *et al.,* 1997, Tarawali *et al.,* 2001). Therefore continuous monocropping of maize may lead to rapid decline in soil productivity due to these

soil physical, chemical and biological problems (Lombin *et al.,* 1991). Also the native soil nitrogen level is so low that all cereal crops respond mainly to nitrogen fertilizer, which is one of the significantly prime factors limiting maize yield in the savannas ecologies (Odunze, 2003).

Bush burning, soil erosion, compaction, overgrazing, indiscriminate tree falling, inappropriate cropping systems, and soil mining have resulted in serious degradation of the soils. Consequently, the soil fertility status and water holding capacity are reduced, resulting in decline in crop yields (Balasubramanian and Nnadi, 1980; Ike, 1987; Odunze *et al.,* 1996). Also, inorganic fertilizer sources are becoming increasingly unavailable to small-scale farmers and other fertility sources are needed to supplement inorganic fertilizer needs for sustainable crop production. To ensure sustainable crop production, causes of soil degradation must be checked and other sources of fertility must be provided for crops.

Conservation agricultural practices could however restore the soil quality for sustainable productivity. According to Youngberg *et al.,* (1984), conservation agriculture is a viable environmental and socially sustainable method of production that reduces the reliance on external inputs while increasing their reliance on resource conservation management strategies including crop rotation, organic manure, as well as biological pest control strategies. To improve the soil for sustainable agriculture, one management practice that might ensure sustainability of soils is the use of short fallow systems which involves use of forage legumes grown and incorporated into the soils. Watson and Goldsworthy (1964) and Lal and Okigbo (1990) suggested that properly managed planted fallows and cover crops of mainly leguminous species are more efficient and require less time in restoring soil fertility/productivity than natural fallows. According to Francis (1986), Prinz (1986), and Hullugale (1988), planted fallow of leguminous crops, if properly managed will add

substantial amounts of N and other nutrients and organic matter to the soils, recycle nutrients from the subsoil, provide effective cover against erosion, suppress weeds and pests and improve soil physical conditions. Herbaceous legumes are currently being promoted in the moist savanna of West Africa for use as green manure for soil fertility improvement and weed control (Akobundu, 1987; Versteeg *et al.*, 1998). It is often assumed that they will fix nitrogen freely and therefore not depend solely on available soil nitrogen.

Studies have shown that some forage legumes including *Centrosema pascuorum, C.brasilianum, Lablab purpureus* and *Macrotyloma uniflorum* can be successfully integrated into the cropping system of the guinea savannas (Iwafor and Odunze, 2000, Odunze, 2003). Their nitrogen fixation potential will further enhance Nitrogen (N) status of the soil by the leakage of N from intact roots (Tian *et al.,* 1991) and through mineralization of their nodules and roots left in the soil following decomposition. This enhanced soil N status might result in substantial N-effect of the forage legumes on yield of the cereal in the season of cultivation after forage legumes is incorporated. Nitrogen is an essential element in maize nutrition. Maize crop takes up the element in large quantities. Since majority of Nigerian farmers cannot afford adequate inorganic fertilizer application to cereals, especially maize, it therefore becomes imperative to examine the effect of forage legume incorporations on some selected soil physical and chemical properties and on the yield of maize. This study is aimed at evaluating contribution of forage legumes short fallow using two leguminous forages namely: *Centrosema pascuorum and Macrotyloma uniflorum* mulch were planted in soil for one year as fallow cover crops with maize (test crop) sown on the plots after spraying them. A natural fallow plot was also sown with maize for comparison.

1.1 JUSTIFICATION OF THE RESEARCH

Soil of the savanna zones in Nigeria are low in fertility status and degrade rapidly when cultivated for crop production (Jones and wild, 1975, Sanchez, 1976; Odunze and Kureh, 2006). Short fallow practices however have potentials for influencing physical, chemical and biological properties of the soils (Tarawali *et al.,* 2001; Sanginga *et al.,* 1996; Jones, 1975) and reducing the use of inorganic nitrogen sources for sustainable crop production. Also legumes short fallow practices provide quality fodder for livestock; a resource that is scarce and in high demand in the Nigerian savanna between the months of December and May (Odunze *et al.,* 2004). The study therefore aims at evaluating contribution of two legume crops under one year fallow practice for sustainable soil improvement and enhanced maize production.

1.2 RESEARCH OBJECTIVES

The general objective of this research is to investigate the contributions of two forage legumes to soil quality improvement and yield of maize under a short fallow system.

The study was therefore conducted with the following specific objectives.

- To evaluate the effects of one year fallow involving forage legumes on soil quality (*Centrosema pascuorum* and *Macrotyloma uniflorum*.)
- To determine fertilizer (N & P) requirements for maize crop planted under a year fallow practice.
- To determine the influence of forage legume on the yield of maize

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Soils of the Nigerian Northern Guinea Savanna.

The Nigerian savanna soils are generally slightly acidic, less leached soils derived from pre-cambrian crystalline basement complex rocks (with rain averaging about 1050 mm). The soils are generally coarse textured consisting of sandy loam or loam over gravelly clay loam (Esu & Ojanuga, 1985). They are poorly structured at the plough layer and so the bulk density tends to rise rather rapidly after cultivation thereby impeding root development. The bulk densities range from 1.47-1.63 gcm^{-3} and 1.29-1.81 gcm^{-3} in the surface and subsurface horizons respectively. The soils also have low total porosity values ranging between 39-44% in the surface horizon. Total porosity decreases gradually with depth to a value of 30% or less (Malgwi et al., 2000).

As a result of the dominating Kaolinitic clay mineralogy of the soils, cation and water retention capacities are low. Cation Exchange Capacity (CEC) often falls below 5 cmol/kg. The low CEC is partly attributed to the characteristic low organic matter content of the soils. A greater correlation between the effective CEC and organic matter content (R=0.85) has been established compared to that between the effective CEC and the clay content (R=0.39) (Bationo and Mokwunye 1991). The low level of organic matter content also accounts for the low total nitrogen content and available phosphorus deficiency in these soils. Generally, the soils have low fertility status and farmers in the region have to cope with this in several ways.

2.1.1 Traditional soil management practices on Nigerian savanna soils

Traditionally, farmers in the Nigerian Savanna zones use several farming systems such as Long natural fallow periods (greater than 10years) followed by short cropping periods (3-5years) were possible in the past but practically impossible in recent times due to

demographic conditions. Other traditional farming systems include mixed farming, bush burning, ridge and furrow systems, intercropping etc. in trying to maintain soil fertility. These systems have improved the soil status and have proved effective in reducing and preventing nutrient losses and imbalances while maintaining productivity. Effectiveness of these systems would be attributed to their close adaptation to the specific environments found in the regions: that is, soil properties and land quality (Greenland, 1978). This is the result of accumulated experience of generations of farmers. The most widespread traditional farming system used in the region for soil fertility maintenance was the natural fallow system.

2.2 Soil Organic Matter

The soil organic carbon content is an important source of plant nutrient, especially in subsistence agriculture. The important effect of SOC on productivity and environmental quality is through its role in supplying nutrients, nutrient cycling, improving soil/plant available water reserves, increasing soil buffer capacity and stabilizing the soil structure (Doran *et al.,* 1994). Soils of the world play a critical role in global Carbon circulation not only because of the size of the soil Carbon resource (Eswaran *et al.,* 1993) but because of the dynamic character of the soil organic carbon (SOC) fractions. Although soils can be a net sink for carbon, available data indicates that as a whole, poorly managed soils have historically been a net source of atmospheric CO_2 (Schlesinger and Andrews,2000); contributing more than 20% of annual increase of CO_2 to the atmosphere (Watson *et al.,* 1992). A reduction in the rate of CO_2 accumulation in the atmosphere can be achieved through planting of forage legumes or sequestration in terrestrial biosphere. The interaction of SOC with the soil primary particles and its distribution among the soil structural units are dominant controllers of SOC accumulation or decomposition (Oades, 1984).

One important feature of a soil organic carbon turnover process is the diverse time scale at which they take place. As plant materials are added to the soil, as much as two thirds of the carbon may be lost to the atmosphere as CO_2 in a single season as a result of decomposition. Subsequent decomposition is slowed however, resulting in significant accumulation of stable carbon in the soil. Organic carbon may remain stabilized in the soil for a great length of time resulting to a large fraction at a very old, stable carbon soils. (Yongsheng and Xaimei, 2001).

2.2.1 Soil Organic Matter Fractions

Soil organic matter does not consist of homogeneous material but rather of organic components that range widely in nature and turnover (Woomer and Swift, 1994), and can be physically separated into a number of fractions depending on research purpose and equipment used. Two major fractions that have agronomic and environmental significance are 1. Particulate organic matter (POM), consisting of organic matter fraction >50μm and 2. Amorphous organic matter consisting of organic matter fraction <50um associated with organo-silt and organo-clay materials and referred to as fine organic matter (FOM).

The POM fraction responds to management practices and decompose easily and faster than fine organic matter in clay and silt size fractions (FOM) (Tiessen and Stewart, 1983; Tiessen *et al.,* 1984). The POM fraction contains large and light fractions and is composed partly of decomposed plant residue, which has rapid turnover and low association with soil minerals. Consequently, it has low degree of physical protection and therefore a good indicator of nutrient supply capacity (Chan *et al.,* 2002). The heavy fraction (FOM) consist of more processed materials and has a slower turnover rate (Christensen, 1987) due to better physical protection and also considered to contribute to soil stability (Hassink *et al.,* 1993). The FOM fraction is also seen as a good indicator of soil management induced carbon sequestration, better than the total organic carbon or POM concentrations (Chan, 2001).

In contrast soil organic matter incorporated into micro aggregates (<50μm) and adsorbed on or coated by clay particles has a high degree of physical protection against microbial degradation. Micro-aggregates (<50μm) are considered to be the basic structural units in soils (Tisdall and Oades, 1982) and contain a large proportion of most stable organic matter in soils. The humic fraction of the organic carbon is usually associated with fine silt (2 to 50μm) and clay fraction (<2 μm). Clay fractions generally contain more than 50% of the soil organic carbon (Bonde *et al.,* 1992). Christensen (1995) observed that 48% and 68% of the SOC was in clay, 20 to 43% silt and 2 to 10% in the sand fraction. The proportion of SOC in clay increases with increasing clay content (Balesdent and Balabene, 1992). Experiments conducted in West Africa by Feller *et al.,* (1995) showed a strong correlation of SOC with clay, but SOC in cultivated soils was by 60% greater than that of uncultivated soils.

2.2.2 Soil Organic Matter Aggregation

Soil structure is an important property that mediates many physical and biological processes and controls soil organic matter decomposition (Van Veen and Kuikman, 1990). Soil aggregates are the basic units of soil structure and are composed of primary particles and binding agents that stabilize soil aggregates. Aggregate stability depends on the binding mechanisms such as chemical binding by organic compounds and physical binding of particles by fungal hyphae and plant roots (Angers *et al.,* 1993). Plant C is sequestered in the soil through decomposition and conversion into soil organic carbon in aggregates. As a result of this, additions of carbon or nitrogen from plant residue may improve soil quality before improving microbial activities such as N mineralisation, aggregation and increasing C and N storage in the soil. Aggregation improves water infiltration capacity, root growth in the surface and subsurface soils in agricultural areas where tillage and other cultural practices disturb the land.

2.2.3 Management Effect on Soil Organic Matter

In agricultural systems the amount of turnover of soil organic matter (SOM) can be altered by different management practices (Paustian *et al.,* 1997). Several practices that contribute to SOC depletion in cropped lands include, diminished plant residue input, leaching, respiration and erosion. The enhancement of soil respiration in cultivated soils is often ascribed to changes in soil thermal regime and increases in soil aeration and accessibility of aggregate protected SOC to microbial attack, which depends on its chemical composition, C;N ratio, humification state and physical position within the soil matrix (Gochin *et al.,* 1993).

Tillage residues SOC content in all fractions (Tiessen and Stewart, 1983), relative decrease however varies with particle size and in general more in clay size than sand fractions than in fine silt and coarse clay. Possible reason for tillage induced decline is decrease in aggregation, increased rate of decomposition by micro-organisms and accelerated erosion. Greater cropping diversity and intensity coupled with reduction in tillage have been shown to build up soil C (Cambardelle and Elliott, 1992). Sufficient N fertilizer levels are required to increase vegetative growth and maintain C inputs provided by the residue as well as stabilize soil organic matter (Paul and Clark, 1996). Thus, combining a management practice that provides N and augment soil organic carbon, for example planting forage legumes, coupled with a reduction in residue removal and tillage could have addictive effects on C sequestration.

2.3 PHYSICAL PROPERTIES OF THE NIGERIAN SAVANNA SOILS

2.3.1 Bulk Density

Bulk density is the ratio of mass of dry soil to the bulk volume of soil (Brady and Weil, 1999). The bulk volume includes volume of solids and of pore space. Bulk density is a widely used term; in estimating other soil physical properties such as porosity, void ratio etc. The

property is not an invariant quantity for a given soil (Blake and Hartge, 1986). It varies with structural conditions of the soil, particularly that relate to packing. Hence, it is always used as a measure of the soil structure. In swelling soils, it varies with the water content (Blake, 1965).

Bulk density almost invariably increases with soil depth. Manrigue and Jones (1991) attributed this property to the high organic matter content in surface layer and to tillage practices that relatively impart loose structure on the surface and cause compaction in the subsoil. The overall difference in bulk density among soils could primarily be attributed to differences in particle size distribution. Several procedures have been developed to predict bulk density based on soil texture components (Huntington *et al.,* 1989).

Wide variations have been recorded for bulk density within the Northern Guinea Savanna of Nigeria. Malgwi *et al.,* (2000) reported bulk density values ranging from 1.47 – 1.63 g/cm³ and between 1.29 g/cm³ and 1.81 g/cm³ in surface and subsurface horizons respectively. This, they attributed to the differences in mineralogy, clay content and structural development. Jones and Wild (1975) attributed the high density values in the subsurface horizon to soil compaction following cultivation or decrease in clay content. Esu and Ojanuga (1985) described the bulk density of Alfisols in Kaduna State based on landuse pattern. They reported a bulk density range of 1.68 to 1.84 g/cm³ for mechanically cultivated soils, while less intensively worked soil was reported to have average bulk density values between 1.7 and 1.8 g/cm³ for sandy soils and between 1.45 and 1.65 g/cm³ for clay soil, which have been shown to inhibit root elongation and growth. (Maurya and Lal, 1979).

2.3.2 Porosity

Total porosity and apparent bulk density has been used to assess soil structure (Lal, 1979). Agboola (1981) related soil management technique to total porosity. Pore size distribution in

relation to available water and root growth in some soils in Nigeria has been reported by Babalola and Lal (1977). Some tropical soils are naturally compacted and have low total porosity (Parthasarty *et al.,* 1976), due to the differences in values of total porosity and macro porosity between the mechanically cultivated soils and less intensively used soils. Ojanuga (1987) suggested use of minimum or zero tillage in the Kaduna area.

In Samaru, the porosity values of soils have a range between 39-44% in the surface horizon which favours good aerations, root penetration and free water movement in the soil. Porosity decreases gradually with depth to a value of 30% or less (Malgwi *et al.,* 2000). However, contrary to Esu and Ojanuga (1985), Coote and Malcom (1989) reported a decrease in both saturated and drainable porosity under no tillage farming.

2.3.3 Soil Texture

Soil texture refers primarily to the relative proportion of particles of sand, silt and clay, as well as other skeletal materials in the soil body (Lal, 1979). The particle size analysis is a measurement of the size distribution of individual particles in soil sample had observed predominantly sandy loam to loamy sand on the surface horizon of soils in wet tropics. The texture of Alfisols in the Northern Guinea Savanna consists of sandy loam or loam over gravelly clay-loam (Esu and Ojanuga, 1985). The soils are dominated by fine sand (between 19 & 65%) and sandy silt of less than 2mm (between 21 & 54%). This is in line with earlier research carried out (Kowal, 1968; Ojanuga, 1979). The soils are characterized by clay deficient surface horizons (less than 10%) but increasing with depth to 36% in the subsurface region (Sanchez *et al.,* 1989). This was attributed to biological activities in the soil, clay migration, erosion by runoff or a combination of these (Ojanuga, 1975).

2.3.4 Saturated hydraulic conductivity

The hydraulic conductivity of a soil is a measure of its ability to transmit water (Fares *et al.,* 2000). Hydraulic conductivity and water retention characteristics determine the response of a soil water system to improve boundary conditions (Klute and Dirksen, 1986). Soil hydraulic conductivity among other physical proportion is affected by soil compaction (Adeoye, 1982; Ogunwole *et al.,* (2000) reported a decrease in the saturated hydraulic conductivity with increase in compaction. Also saturated hydraulic conductivity increased with moisture content up to 0.22 cm^3 but decline at moisture content greater than 0.22 cm^3 in Samaru (Ogunwole *et al.,* 2000).

Hydraulic conductivity under conservation tillage can be significantly affected by macro pores formed by earthworms, soil insects or roots (Ehler, 1975). Coote and Malcom-McGovern (1989) found that saturated hydraulic conductivity was great under no-tillage farming than mechanized and intensive cropping. This was attributed to increase in soil organic matter and reduced bulk density (Packer *et al.,* 1984).

Some researchers also found that saturated hydraulic conductivity of soils they studied was neither affected by tillage nor by non-tillage (Obi and Nnabude, 1988), while others (Pikul *et al.,* 1990) reported a reduction in saturated hydraulic conductivity of non-tilled soils. The disparity in results by different researchers was attributed to the inherent heterogeneity in pore geometry both vertically in the soil profile and spatially in the landscape (Hamblin, 1985).

2.4 PRODUCTIVITY LEVEL IN THE NORTHERN SAVANNA ZONE OF NIGERIA

The Nigerian Savanna is currently witnessing increasing intensities of crop and livestock production (Odunze *et al.,* 2004) activities that are resulting in increasing soil erosion, de-vegetation of the land area and desert encroachment especially during the dry season. The

productivity level of soils of Northern Guinea Savanna has remained low and unstable owing to climatic and soil related constraints (Swindle, 1982). The climate related constraints includes short rainy season, variability in timing and amount of rainfall, high intensity rains resulting in high run-off (Kampen, 1980). Alfisols are fertile and productive soils have the severe soil physical limitation of crusting, compaction; both surface and subsoil compaction, erosion, shallow to medium rooting depth and drought stress (Kowal and Kassam, 1978)

Most soils of the region have physical characteristics that are easily affected by adverse seasonal conditions. For example, the low resistance of saturated soil to erosion leads to surface sealing under rainfall impact. Slumping of surface roughness and high soil erodibility by water, high sand or gravel content reduces plant available water capacity. Argillic horizon in the shallow subsoil acts as a throttle to water movement. Weathered parent material restrict root proliferation and soil strength often increases markedly as soil dries (Mullins *et al.,* 1990) which restricts tillage effects, seedling emergence and root system development (El-Swaily *et al.,* 1984). Smaling (1993) identified soil nutrient depletion as one of the root causes which under lie productivity gain-gap in Africa. Soil nutrient depletion is not a simple parameter that can be rapidly evaluated and corrected but rather a syndrome, where diminished availability of underutilized land, continuous soil erosion and nutrient removal results in spiral decay in produce capacity and diminished resilience of soil system to produce suitable medium for crop growth (Woomer and Muchena, 1993).

Accelerated soil erosion (by water and wind) is also a serious problem of agricultural land in Nigeria (Smith, 1982). Soil erosion is a serious problem on land under intensive and or mechanised farming (Lal, 1986; Milner and Douglas, 1989). Erosion results in the degradation of soil physical characteristics such as infiltration rates, soil structure and crusting. It also decreases fertilizer use efficiency by increasing nutrient losses (Lal, 1986).

Lal (1995) reported a yield reduction of 9% due to erosion and projected a reduction in yield of about 16.5% in 2020.

2.5 RESTORING PRODUCTIVITY IN THE NIGERIAN SAVANNA ALFISOLS

2.5.1 Importance of Soil Physical Properties

Physical properties of the soil often limit both agricultural and engineering use of soils. Since physical properties are much harder to alter than chemical properties, it is the physical properties which largely determine soil use, depth of soil, particle size distribution, and drainage, stability of soil crumb, bulk density and water holding capacity are among the common physical properties affecting cultivation of soil (Raymond, 1975). These are also the properties which are considered in soil survey and land capability surveys, when soils are rated for crop production (Raymond, 1975).Recently, sustaining productivity has become a primary focus and the maintenance of productive soil in a particular region is being highlighted (Lal and Sanchez, 1992). Practices for attaining high yield, while maintaining long-term productivity and proper soil structure are often crop, region or site specific and must be adopted for each situation (Bathke *et al.,* 1992).

For sustainable agriculture in the tropics of West Africa, it is necessary that physical conditions of the soil be maintained and the chemical nutrient replenished by inexpensive means while erosion is controlled by methods that are effective and do not involve heavy capital investment (Greenland, 1975). For sustainable crop production, researchers in the tropics have focused on the role of planted fallows in improving soil physical conditions in many decades (Salako, 2002). In some studies carried out in Nigeria, physical properties measured were water content by gravimetric and volumetric methods, bulk density by core method, aggregate stability by wet-sieving and drop method, penetrometer resistance, water infiltration rates were measured using doubles ring infiltrometer (Salako, 2002; Klute, 1986; Carter, 1993).

Soil productivity restoration must focus on increasing infiltration on site which in turn will reduce erosion hazards (Bruce *et al.,* 1995). Earlier studies have shown that the maintenance of crop residue on the soil surface as a decomposing mulch (straw) is effective in the control of erosion, improvement in soil moisture storage, reduction in soil water evaporation and provides ingredients for persistent biological activities (Adeoye, 1984; Ike, 1987; Bruce *et al.,* 1995). However, in the Northern Guinea Savanna Zone of Nigeria, the acquisition of enough straw mulch (6 tons/ha) material is difficult because they that are used for fencing, fed to livestock and used as fuel wood they are therefore not available for mulching (Adeoye, 1984; Ike, 1986). Green manure cover crops-based system has been used to minimize soil degradation in many African countries. They protect the soil surface from direct impact of rain drop; reducing soil splashing and surface runoff. Green manure also increases soil nutrient and soil moisture content (Rice and Smith, 1982).

2.5.2 Concepts of Soil Quality Degradation and Sustainability

Soil quality was defined as the capacity of a specific soil to function within natural or managed ecosystem boundaries to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation (Brady & Weil, 1999). Thus, soil quality assessment reflects biological, chemical and physical properties, processes and their interactions within each resource unit. Soil quality is depleted as the soil is degraded through individual or combined processes of soil degradation which in the savanna region is mainly by continuous cultivation, soil erosion and compaction (Lal, 2001). When a soil is degraded, its capacity to produce biomass is reduced. Recovery of the soil through efforts to rehabilitate it depends on inherent capacity of the soil and the level of degradation reached before rehabilitation efforts and soil resilience.

Soils of the savanna region are physically fragile because the topsoil contains a large proportion of sand, causing weak aggregation; given the low level of organic matter in this layer (Lombin, 1987). The physical constraints are further compounded in gravelly soils or soils with shallow depth overlying plinthic or hardpan layers (Mohammed Saleem and Okigbo, 1986).

Erosion of the 0-15cm layer of soil surface will lead to exposure of more gravel which will make working of the soil difficult. It is therefore imperative that appropriate soil management options for sustainable crop production and improved soil and environmental quality be found for the tropics.

2.6.0 SOIL MANAGEMENT

2.6.1.0 Fallows

2.6.1.1 Natural fallow

Traditional, fallow system is classified into three major groups (Ruthenberg, 1980): shifting cultivation (the years of fallow are at least twice the years of cultivation), bush fallow (the years of fallow are as long as the years of cultivation), and continuous cropping system (the year of fallow are less than that of cultivation). The most important aspect of this practice is that land is taken out of production and allowed to regenerate (Muller-Samann and Johannes Kotschi, 1994). Natural fallow involves the use of species in the local vegetation in the restoration of soil fertility for a long period (Van veen *et al.,* 1990). The following benefits to agricultural production are expected from a piece of land left to naturally fallow for a long period:

i. build-up of surface soil organic matter
ii. improvement in soil physical properties and fertility
iii. recycling of soil nutrients
iv. weed suppression

v. Suppression of soil-borne pests and diseases.

2.6.1.2 Improved fallow (planted fallow)

A fallow is improved over natural fallow only if the plant species used are more efficient than the species in the local vegetation at least in improving the chemical and physical properties of the soil (Van veen *et al.,* 1990). A good fallow plant must have several of the following characteristics (Mulunguy *et al.,* 1985):

1. Growth is quick, closing the canopy quickly to suppress weeds and control erosion.
2. It yields much biomass of good quality that can decompose fast and yield fertilizer.
3. Easy to establish.
4. Nodulate effectively with indigenous rhizobia.
5. They should not increase pest and disease incidence.
6. Should be easy to eradicate by inexpensive means.
7. Should not be poisonous to animal and man

Various forage legumes possess a number of these attributes. A few species were tested for insitu mulching on Alfisols at IITA, Ibadan (Okigbo, 1977; Akobundu and Okigbo, 1984) Nigeria from 1922-1951 and showed that Mucuna species improved soil properties but its effects were not long lasting.

2.6.1.3 Green Manure

Green manure crops are plants grown primarily for soil improvement by incorporating them into the soil while green (Donahue *et al.,* 1990). Green manures can be managed to disrupt plant disease cycles or to suppress nematodes. Generally they grow very quickly, are very herbaceous, decompose rapidly, and release nutrients quickly. Green manure usually performs multiple functions that include soil improvement and soil protection:

- Leguminous green manures such as clover and vetch contain nitrogen-fixing symbiotic bacteria in root nodules that fix atmospheric nitrogen in a form that plants can use.
- Green manure increases the percentage of organic matter (biomass) in the soil, thereby improving water retention, aeration, and other soil characteristics.
- Common cover crop functions of weed suppression and prevention of soil erosion and compaction are often taken into account when selecting and using green manures.
- The root systems of some varieties of green manure grow deep in the soil and cause unavailability of nutrient resources shallower-rooted crops.

Considerable building of soil nitrogen can be achieved by cultivating annual legumes whose biomass is returned to the soil as green manure (Brady & .Weil, 1999).

2.6.2.0 Cover Crop

Broadly defined, a cover crop is any annual, biennial, or perennial plant grown as a monoculture or polyculture, to improve any number of conditions associated with sustainable agriculture. Cover crops are fundamental sustainable tools used to manage soil fertility, soil quality, water, weeds, pests, diseases and diversity and wildlife, in agro ecosystems (Lu *et al.,* 2000). Cover crops are planted to protect the soil surface especially during the winter and are harvested before or intermixed into the soil prior to planting the next crop. (Donahue *et al.,* 1997). One crop may serve both purposes of green manure and cover crop. Both legume and non legume crops have been known to serve the purpose of green manuring and cover cropping. Researchers have however shown that the potentials of legumes to biologically fix nitrogen and the ability of their extensive root system contribute more organic matter to the soil is more beneficial than no-legumes. Researchers have hypothesized that ecological benefits associated with longer fallows would be obtained from planted herbaceous legume

fallow crops with rapid growth and high dry matter productivity (Tian *et al.,* 1991). Odunze *et al.,* (2002) stated that herbaceous legumes could be assets in carbon sequestration.

2.6.2.1 Soil Quality Management

Cover crops can improve soil quality by increasing soil organic matter levels through the input of cover crop biomass over time. Increased soil organic matter enhances soil structure, as well as the water and nutrient holding and buffering capacity of soil. It can also leads to increased soil carbon sequestration, which has been promoted as a mitigation strategy to help offset the rise in atmospheric carbon dioxide levels (Sainju *et al.,* 2002; Lal, 2003).

Although cover crop can perform multiple functions in an agro ecosystem simultaneously, they are often grown for the sole purpose of preventing soil erosion. Soil erosion is a process that can irreparably reduce the productive capacity of an agro ecosystem. Dense cover crop stands physically slows down the velocity of rainfall before it contacts the soil surface, preventing soil splashing and erosive surface runoff. Additionally, vast cover crop root network help anchor the soil in place and increase soil porosity, creating suitable habitat networks for soil macro fauna. Soil quality is managed to produce optimum circumstances for crops to flourish. The principal factors of soil quality are soil salination, pH, microorganisms' balances and the prevention of soil contamination.

2.6.2.2 Water Management

By reducing soil erosion, cover crops often also reduce both the rate and quantity of water that drains off the field that would normally pose environmental risks to water ways and ecosystems downstream. Cover crop biomass acts as physical barrier between rainfall and the soil surface, allowing raindrops to steadily trickle down through the soil profile. Also, cover crop rooting network results in the formation of soil pores, which in addition to enhancing soil macro fauna habitat, provides pathways for water to filter through the soil profile rather

than draining off the field as surface flows. With increased water infiltration, the potential for soil water storage and the recharging of aquifers can be improved.

Just before cover crops are destroyed (by such practices including mowing, tilling, discing, rolling, herbicide application), they contain large amount of moisture. When the cover crop are incorporated into the soil, or left on the soil surface, it often increases soil moisture. In agro ecosystem where water for crop production is in short supply, cover crops can be used as a mulch to conserve water by shading and cooling the soil surface (Adeoye, 1984). This reduces evaporation of soil moisture. In other situations farmers try to dry the soil out as quickly as possible before going into the planting season.

Other benefits include soil fertility managements: are used to manage a range of soil macro nutrients and micronutrients (Vanlauwe *et al.,* 2000); weed management. Thick cover crop stands often compete well with weeds during the cover crop growth period, and can prevent most germinated weeds seeds from completing their life cycle and reproducing. Diseases management: in the same way that allelopathic properties of cover crops can suppress weeds, they can also break disease cycles and reduce population of bacterial and fungal diseases and parasitic nematodes; Pest management: some cover crops are used as so-called ‘’trap-crop’’ to attract pest away from the crop of value and toward what the pest sees as a more favourable habitat, and diversity and wildlife management: they improve farm habitat for wildlife and adds at least one or more dimensions of plant diversity to a cash crop rotation.

2.7 LEGUMINOUS COVER CROPS AND SOIL PHYSICAL PROPERTIES

Badaruddin and Meyer (1989) reported that leguminous covers import soil properties. The superior crop yield in rotation with Stylosanthes pastures were attributed to among other things, improve physical properties such as bulk density infiltration rates and field moisture capacity (Mohammed-Saleem and Okigbo, 1986). Odunze (1997) reported an improvement

in the bulk density, soil moisture, and total and macro porosity of Samaru soils planted to leguminous crops (*Mucuna, Lablab and Macrotyloma). Stylosanthes hamata* also improved bulk density, soil moisture, total and macro porosity (Odunze *et al.,* 1992).

Legume cover crops can also sustain crop production on erodible land (Bruce *et al.,* 1987). A legume lay (Akobundu, 1982; McCown, 1987) might improve soil structure due to the effects of roots. Cover cropping with herbaceous legume (improved fallow) is one of several possible strategies that can be employed to improve or maintain the soil resource base for sustainable agriculture. However, the result of the practice depends on location and was found to be the case in the tropics (Young, 1976). In deciding whether such techniques are suitable, the natural site thus plays a vital role. Other conditions are also important namely: the labour resources of the farm, its technical capacity and experience and interest of the farmers (Manyong, *et al.,*1996; Muller *et al.,* 1994). All these aspects must be taken into account as well as land tenure factors and economic viability (Muller *et al.,* 1994) before employing this technology.

2.8 *Centrosema pascuorum Mart. ex Benth*

Family: Leguminosae. *Centrosema pascuorum* is an annual, twining herb that can root from the nodes of trailing stems under moist conditions. Stems are cylindrical, extending up to 2 m from the crown. Leaves are trifoliate. Flowers are predominantly self- pollinated. *Centrosema pascuorum* is adapted to a wide range of soils, from sand to heavy clay. It can adapt to tropical areas with pronounced dry seasons of up to 8 months; 700 – 1,500 mm rainfall per year is suitable. *Centrosema pascuorum* is best sown, drilled or broadcast. Best times for sowing are the start of the wet season.

2.9 *Macrotyloma uniflorum (Lam.) Verdc.*

Family: Fabaceae or Leguminosae. They are adapted to a wide range of well-drained soils from sands and gravels to clay loams and heavy clays. African collections originate from areas with annual rainfall from 450-750 mm. Best growth is produced during hot moist weather, with temperatures between about 35 and 25 °C, the growth rate declining markedly at temperature below 20 °C. Normally drilled or broadcast into a well-prepared seedbed, but can establish with little ground disturbance. Sometimes sown with maize (Zea mays), so they mature together, the legume improving the quality of the maize residue.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Site Location and Description

The study was conducted at the Institute for Agricultural Research (IAR) experimental field Samaru Zaria. Samaru is located on longitude 7° 38' E and latitude 11° 11' N. It is characterised by a tropical continent type of climate with alternating wet and dry seasons, which vary markedly in intensity and duration with attendant effects on agricultural productivity. The soils are formed from loess materials overlying basement complex, covering an area of 43,000 km (Klinkenberg and Higgins, 1968). The clay is predominantly Kaolinitic (Ojanuga, 1979), and is typically high in iron (Fe) and aluminium (Al) oxides (Esu and Ojanuga, 1985) and are of major agricultural importance (Agbenin and Goladi, 1997).

3.2 Climatic Condition

The area has a uni-modal pattern of rainfall annually, beginning in April and ending in October. Rainfall records show that the month of August recorded the highest rainfall amounts. The area is also characterised by high average monthly maximum temperatures and low minimum temperatures within the year with temperatures peak normally attained in March/April. The maximum and minimum temperatures during the rainy season range from 14.12 ^{o}C –23.17 ^{o}C and 29.97 ^{o}C – 38.43 ^{o}C respectively (Anosike, 1999). The hamattan periods of December to February are mostly associated with lower temperature. Samaru has a very wide range of mean monthly relative humidity (11-85%) compared with locations at lower latitudes within Nigeria (Anosike, 1999). The length of raining season however has been on the decline in recent years. The normal raining season had been from the month of February with steady rise through the months of August when it attains its highest peak and begins to decline gradually terminating in October. In 2008 however, the rainfall began in April. There was an increase in amount in the middle of July with the effective rainfall

terminating virtually in October (Table 1a). In 2009, the rainfall began in April, amount from the month of May to July was below the 2008 value and rainfall coincides with the actual planting period in this area (Table 1b). The length of the raining season is between Aprils to October. Monthly weather data for each year was collected at IAR Meteorological unit.

Table 1a: Samaru Mean Monthly Weather 2008

Months	Relative Humidity (%)	Temperature (^{o}C) Max	Min	Rainfall (mm)
January	15.1	29.0	13.6	0
February	9.4	32.0	15.7	0
March	13.8	38.60	19.9	0
April	23.9	57.2	29.1	72.60
May	46.2	35.0	21.9	95.0
June	55.1	33.1	20.9	111.70
July	68.0	30.5	20.0	201.30
August	73.2	29.7	19.5	352.60
September	66.0	31.4	25.5	217.50
October	51.8	33.2	18.2	89.00
November	23.1	33.8	12.8	0
December	17.8	32.1	14.6	0
Total	463.4	415.6	231.7	1140.0
Mean	38.6	34.6	19.3	95.0

Source: Meteorological Unit, Institute for Agriculture Research Ahmadu Bello University, Zaria. Nigeria.

Table 1b: Samaru Mean Monthly Weather 2009

Months	Relative Humidity (%)	Temperature (°C) Max	Min	Rainfall (mm)
January	14.84	33.81	14.12	0
February	9.43	36.29	16.86	0
March	10.03	38.00	19.65	0
April	48.67	38.43	23.17	52.40
May	60.87	35.48	22.23	92.90
June	71.23	33.20	21.00	158.30
July	73.39	31.29	20.00	216.80
August	80.61	29.97	20.42	313.40
September	75.50	31.87	20.03	211.20
October	71.03	32.77	20.25	82.30
November	37.47	32.37	14.80	0
December	16.52	33.45	13.26	0
Total	569.59	406.93	225.79	1127.3
Mean	47.47	33.91	18.82	94.0

Source: Meteorological Unit, Institute for Agriculture Research Ahmadu Bello University, Zaria. Nigeria.

3.3 Soil Sampling and Preparation

Pre-experimental composite soil samples were taken with an auger at depths 0-15 and 15-30 cm. The sample collected were air-dried, grounded and sieved with a 2 mm sieve. The less than 2 mm fraction was analysed for some physical, chemical and biological analysis. The second set was collected with a core sampler at depth 0-5 and 5-10 cm for the determination of selected soil physical properties- bulky density, total porosity and hydraulic conductivity which were taken a week before sowing maize crop, 8 weeks after sowing and 11 weeks after sowing. At harvest soil samples were again taken at depth 0-15 cm for physical, chemical and biological analysis.

3.4 Treatments and Experimental Design

The experimental field under natural fallow for a year was divided into three (3) main plots. Two (2) of these plots were cultivated with forage legumes for a year while the third plot continued as natural fallow (control plot). The first plot was cultivated with *Centrosema pascuorum* and the second plot with *Macrotyloma uniflorum*. The field was then cropped with test crop- maize. The forage legumes were then sprayed with systemic herbicides to eradicate them and the natural fallow as they were not cut or weeded.

The main plots for this experiment were *Centrosema pascuorum, Macrotyloma uniflorum* and Natural fallow. The sub-plot treatments were factorial combination of four nitrogen levels (0, 40, 80 and 120 kg N ha^{-1}) and three levels of P (0, 13.2 and 26.4 kg P ha^{-1}). The field was laid out in split plot arrangement with three replicates. Gross plot size was (5 m x 3 m) = 15 m^2, while net plot size was (1.5 m x 5 m) = 7.5 m^2**.** Extra early maize variety (SAMMAZ 11) was used as test crop.

3.5 Cultural Practices

The experimental field was properly laid out and the maize seed were planted in the uncultivated fallow at 25 cm along the row 4th week in June, 2009. The field was then sprayed with systemic herbicides to eradicate the forage legume and natural vegetative regrowth. Thinning and hand pulling of unwanted grasses was done two weeks after planting. Single super phosphate fertilizer was applied at 4 cm away from the planted maize seeds. Nitrogen in form of urea (46%N) fertilizer was applied in two split doses at 2 and 7 weeks after planting.

3.6 Plant Analysis

Biomass produced for the three fallow systems were estimated using the quadrant method of 1m by 1m. Forage legumes biomass were harvested, separated from the roots, weighed as wet weight then was oven dried for 48 hours and later reweighed for dry weight. Samples of these dried shoot were taken, ground, sieved and analysed for N and P.

3.7 Laboratory Analysis

3.7.1 Particle Size Determination

Particle size analysis of samples was conducted to determine percentage of sand, silt and clay in the soil samples. These percentages were used to determine textural classes of the soil samples. The analysis was done using the hydrometer method (Gee & Bauder, 1986; Bouyoucous, 1951)

Fifty grams (50 g) of the 2 mm sieved soil was weighed and transferred into a 250 ml plastic beaker. One hundred millilitres (100 ml) of Calgon (Sodium hexametaphosphate) was added to the beaker and the solution was stirred. Then 100 ml of distilled water was added and again stirred after which the solution was mechanically shaken for 30 minutes. The sample was transferred into a 1000 cm^3 measuring cylinder. Care was taken to wash out the contents completely into the cylinder. The cylinder was filled to mark with water. The solution in the

measuring cylinder was vigorously mixed with the plunger, and then the hydrometer was gently lowered into the measuring cylinder. Hydrometer readings were taken for 40 seconds and two hours, to calculate the settling velocities of silt and clay fractions respectively. A blank hydrometer reading was also obtained by lowering the hydrometer gently into a 1000 cm^3 measuring cylinder filled to mark with water, but without soil sample. The hydrometer readings were then corrected by subtracting the blank reading, and by adding 0.36 g/L for every degree above 20 °C.

I.e. $C = R - RL + (0.36T)$

Where C = Corrected Hydrometer Reading

R = Hydrometer Reading in Soil Suspension

RL = Blank Hydrometer Reading.

T = Room Temperature minus 20°C

$$\%Clay = \frac{C_2hrs \times 100}{\text{Soil Wt taken}}$$

$$\%Silt = \frac{C_4osec \times 100}{\text{Soil Wt taken}} - \%\ clay$$

$$\%Sand = 100 - (\%\ Clay + \%\ Silt)$$

3.7.2 Bulk Density Determination

Bulk densities for the soils were obtained by sampling with 5 cm by 5 cm cores as described by Anderson & Ingram (1993). The core samples were oven dried at 105 °C-110 °C over 24 hours to constant weight, after which they were removed and their weights taken. The bulk densities were computed using the formula.

$$\text{Bulky density } (g\ cm^{-3}) = \frac{\text{Weight of oven dried soil in core- Weight of core}}{\text{Volume of Core}}$$

3.7.3 Aggregate Size Stability

3.7.3.1 Wet sieving

One hundred and fifty gram of 2 mm sieved soil was sieved in a bucket ¾ filled with water using a 250 µm (0.25 mm) diameter sieve for 60 seconds at an average of 12 strokes. The filtrate was sieved again using a 53 µm (0.53 mm) diameter sieve for seconds at an average of 5 strokes. The soils retained in the sieves were labelled > 0.25 mm and > 0.025 mm respectively and were transferred into cans. The filtrate was allowed to settle and decanted. The soil collected was labelled < 0.053 mm and was transferred into can. The samples in the cans were oven dried at 50 °C for 24 hrs after which the temperature was raised to 105 °C for 24 hrs until the samples were dried. Weights of samples were calculated as follows:

Weight of aggregate = weight of can + aggregate – weight of empty can.

Aggregate size distribution was calculated as proportion of soil retained in each sieve i.e.

$$\frac{\text{Weight of soil retained in sieve}}{\text{Total weight of soil taken}}$$

The mean weight diameter (MWD) was calculated using the formula

$$MWD = \sum Pidi$$

Where Pi = proportion of soil aggregate in the sieve

di = diameter of sieves (Van Bavel, 1949).

3.7.3.2 Dry Sieving

One hundred and fifty gram (150g) of bulk soil was weighed and transferred into the nest of sieves consisting sieves of diameters 2 mm, 500 µm, 250 µm, 106 µm and 53 µm. The nest of sieves was placed on a mechanical shaken for 60 seconds after which the weight of soil retained in each sieve was taken.

Aggregate size distribution was calculated as proportion of soil retained in each sieve i.e

$$\frac{\text{Weight of soil retained in sieve}}{\text{Total weight of soil taken}}$$

The mean weight diameter (MWD) was calculated using the formula

$MWD = \sum Pidi$

Where Pi = proportion of soil in the sieve

di = diameter of sieves (Van Bavel, 1949).

3.7.4 Saturated Hydraulic Conductivity

The saturated hydraulic conductivity was measured by the constant head method, using the 1CW laboratory permeameter (Eijikelkamp Agrisearch No. 09.02). The equipment operates on the principle that water is cause to flow through a saturated soil column by pressure difference on both sides of a well saturated soil sample.

The caps from the ring were removed and samples were saturated over-night in a basin of water. This was done by first of all covering the blunt end of the ring with a piece of nylon cloth, held in place by means of a rubber band to disallow soil loss.

A measure container was used to hold the ring which was in turn placed inside a plastic container and inserted into the permeameter after establishing a constant head. A tube already filled with water was used as a junction, connecting the inside of the ring holder and the water in the permeameter to ensure flow of water into the burette. Depending on the ease with which water flows through the sample, the time at which a conveniently chosen volume is attained in the burette is taken using a stop watch. The height of water inside the ring holder and outside was measured and saturated hydraulic conductivity (Ks) was calculated from the formula.

$$K(s) = \frac{V.L.}{AT(H)}$$

Where

V = Volume of water collected (cm3)

L = Length of soil column (cm)

A = Cross-section area of the sample (equivalent to area of core ring) cm2

T = time in seconds

H = Hydraulic head difference (cm).

3.7.5 pH Determination

The pH of the soil samples were measured in water and in 0.01M $CaCl_2$ solution, using the potentiometric (glass electrode) method (Rhoades, 1982). The pH was determined in soil solution ratio of 1:2.5 thus: 10 g of the 2 mm sieved air-dried soil was weighed and added into a beaker and 25 mls of distilled water was added. The suspension was stirred for 30 minutes. The pH meter was then calibrated using buffer solution of pH 4 and pH 9. Electrode was then immersed into the soil solution, but without allowing it to touch the bottom of the beaker. The pH was read after 30 seconds. The procedure above was then repeated for soil samples dissolved in 0.01M $CaCl_2$.

3.7.6 Organic Carbon Determination

The organic carbon contents of soil samples were determined using the Walkley-Black wet oxidation method (Nelson & Sommers, 1982). This procedure uses potassium dichromate to oxidize organic matter in the soil samples, at a high temperature of about 120 ^{o}C generated by the addition of concentrated sulphuric acid.

For this purpose 1 g of the soil samples was weighed and added into a 250 ml Erlenmeyer flask and a pipette was used to add 5 mls of $K_2Cr_2O_7$, after which the flask was swirled gently to disperse the soil. Ten millilitres (10mls) of concentrated H_2SO_4 was then added rapidly from a measuring cylinder and the flask was again swirled gently for about a minute. The suspension was then allowed to cool and 100 mls of distilled water was added.

Five drops of indicator (0.025 M O-Phenanthrolein Ferrous Sulphate indicators) was added to the suspension in the flask. The suspension was then titrated with ferrous ammonium sulphate

solution, until a blue to green to a dark green and finally a red colour change was observed. A blank determination was made in the same manner as outlined above, but without soil sample. The percentage organic carbon was then calculated as follows:

$$\text{Organic carbon (\%)} = \frac{(\text{blank titre} - \text{actual titre}) \times 0.3 \times M \times F}{\text{Soil Weight taken}}$$

Where M = Concentration of ferrous ammonium sulphate

F = Correction factor =1.33

3.7.7 Total Nitrogen Determination

This was determined using the Kjeldahl method described by (Bremner & Mulvaney, 1982). The procedure involves two basic stages:

- Digestion of soil sample to convert nitrogen to ammonium. During this step, 1 g of the soil was weighed into a digestion tube. About 5 g of Kjeldhl catalyst mixture was added and 10 mls of concentrated H_2SO_4 was then added. The tube was heated on a digested block for about 3 hours. Afterwards, the tube was cooled and water was added with care to wash contents carefully into 100 ml volumetric flask. This was allowed to cool and made up to mark with distilled water. Ten millilitres 10 mls of the digest was then transferred into a distillation flask using a pipette.
- Titration for determination of ammonium in digested solution. In this step, 10 mls of 2 % Boric acid was measured and added into 50 ml conical flask and was introduced to the bottom of the distillation condenser. Ten millilitres (10 mls) of 10 N NaOH was added into the digest in the distillation flask. This was then transferred immediately into the distillating unit to distil the digest. When about 25 ml of distillate was collected in the conical flask at the base of the distillating condenser, it was removed and titrated with 0.025N H_2SO_4 until a purple end point was obtained. The titre value

was then recorded. A blank titration was also carried out without soil sample and recorded. The total N contant was calculated using the formula.

$$\text{Total Nitrogen \%} = \frac{0.014 \times (T-B) \times NA \times \text{Vol. Of digest} \times 100}{\text{Weight of soil} \times \text{Aliquot distilled}}$$

Where T = Actual Titre; B = Blank Titre; NA = Normality of the acid.

3.7.8 Available Phosphorus Determination

Two major steps were involved in the determination of the available soil P. The Bray 1 Method was employed for extraction and Ascorbic acid in the presence of ammonium molybdate and antimony tartarate was used for colorimetric quantitative determination of the available P as described by Bray & Kurtz (1945) and Anderson & Ingram (1993).

To 1 g of soil sample in a 50 ml centrifuge tube was added 7 mls of Bray 1 extractant (1N NH_4F + 0.5N HCl). The mixture was shaked for 15 minutes and centrifuged for about 5 minutes. Two millilitres (2 mls) aliquot was taken from the obtained supernatant into 25 ml plastic vial before 18mls of distilled water and 4 mls of colour developer (Ascorbic acid in the presence of conc. H_2SO_4, ammonium Molybdate and antimony tartarate) was added. This was allowed to stand for about 15 minutes for the blue colour to develop before colour intensity related to available P concentration was read on a spectrometer. The available P was calculated from the formula

$$\text{Available P } (mgKg^{-3}) = \frac{R \times G \times VE \times DF}{\text{Weight of soil} \times \text{Aliquot taken}}$$

Where R = Spectrometer absorbance reading of sample

G = Slope gradient

VE = Volume of extractant

DF = Dilution factor

3.7.9 Exchangeable Acidity Determination

Exchangeable acidity was determined using the method of extraction with 1N KCl (as the exchange of acidic cations is pH dependent, and they are hence extracted with unbuffered KCl solution) and quantitative determination of ions in the extract by titration (Black 1965). For this purpose, 10g of soil samples was weighed and added into a funnel fitted with a filter paper and the sample was leached with 100 mls of 1N KCl solution for about two hours using small aliquots at a time. The leachate was collected in a 100 mls volumetric flask, made to volume with 1N KCl and mixed well. Fifty millilitres of the leachate was collected and added into a 250 mls beaker using a pipette and 5 drops of phenolphthalein indicator was added. This was then titrated with 0.1N NaOH to a permanent pink end-point. The amount of NaOH used was recorded being equivalent to the exchangeable acidity (Al^{3+} + H^{+}) of soil samples. The exchangeable acidity was calculated using the formula.

$$\text{Exchangeable Acidity} = \frac{(T-B) \times NB \times \text{Vol. Of extract} \times 100}{\text{Weight of soil} \times \text{Aliquot taken}} \quad (CmolKg^{-3})$$

Where T = Actual Titre

B = Blank Titre

NB = Normality of the Base

3.7.10 Exchangeable Bases/Base Saturation Determination

The exchangeable bases (Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+}) were determination using the ammonium acetate (NH_4OAC) saturation method (Schollenberger & Simon, 1945) for extraction from soil sample. For this purpose, 1g of soil sample was weighed and added into stopper bottle and 25 mls of NH_4OAC was added before shaking mechanically for about 15 minutes. The suspension was then centrifuged for about 5 minutes before decanting and preserving clear supernatant for quantitative determination of exchangeable bases. The extracted monovalent

cations (Na^+, K^+) were then quantitatively determined by a flame photometer while the divalent (Ca^{2+}, Mg^{2+}) were determined using Atomic Absorption Spectrometer.

3.3.11 Cation Exchange Capacity (CEC) Determination

The CEC was determined by summation of exchangeable acidity (EA) and exchangeable bases (SEB) as described by Coleman & Thomas (1967). The below formula was used for the calculation.

$CEC\ (cmolKg^{-3}) = EA + SEB = EA + (Na^+ + K^+ + Ca^{2+} + Mg^{2+})$

3.7.12 Base Saturation Percentage Determination

Base saturation is the percentage of soil cation exchange capacity saturated by basic cations (exchangeable bases). The base saturation was calculated using the formula

$$\text{Base Saturation \%} = \frac{SEB}{CEC} \times 100$$

Where SEB = sum of exchangeable base, CEC = Cation exchangeable capacity

3.8 Soil Biological Properties

Microbial biomass nitrogen

The soil microbial biomass nitrogen (SMBN) was estimated using the chloroform, incubation method of Jenkinson and Powlson (1976). Fifteen grams of soil sample were weighed into 50 ml beaker and fumigated with 25 ml chloroform ($CHCl_3$) in desiccators for 2 hrs. The soils were incubated for 3 days. The SMBN was determined by extracting the fumigated soil with 0.5 M K_2SO_4 by shaking for 30 minutes. The soil extracted was then filtered with whatman filter paper, No. 42, after which 10 ml of the extract was analysed for NH_4-N by the Kjeldahl method. (Bremner & Mulvaney, 1982). 15 g of same soil sample was extracted with 0.5 M K_2SO_4 without fumigation and the NH_4-N determined. The SMBN was determined using the formula.

SMBN = (NH_4-N) fumigated – (NH_4-N) unfumigated/Kn

Where Kn = 0.41 (Carter and Rennie, 1982)

Kn represents the fraction of microbial biomass N mineralised on the 3rd day of incubation period.

Microbial biomass phosphorus (MBP)

Microbial biomass P was determined by the method described by Hedley and Stewart (1982) except that there was no removal of resin extractable P prior to $CHCl_3$ fumigation because of low amounts of resin P in soils (Agbenin and Goladi, 1997).

Two (2 g) grams of moist soil were put into centrifuge tubes and 2 ml of alcohol free HCL_3 added. The suspension was shaken vigorously for 2 hrs in a reciprocating mechanical shaker after which the centrifuge tubes were opened and transferred to a fume hood to evacuate the chloroform. Thirty millilitres of 0.5 M $NaHCO_3$ were added to the fumigated soil and extracted for 16 hrs in a mechanical shaker. The soil suspension was centrifuged and the extract filtered through a Whatman No 1 filter paper. Phosphorous in the extract was digested with 1.8 N H_2SO_4 and hydrogen persulfate. Phosphorus in the digest was determined colorimetrically using the method of Murphy and Riley (1962). The soil microbial biomass P was calculated using the following formula.

SMBP = [$NaHCO_3$-P] fumigated – [$NaHCO_3$-P] unfumigated/Kp

Where Kp = 0.41 (Brooks *et al*., 1985)

Kp refers to the fraction of microbial P extractable with $NaHCO_3$.

Microbial Biomass Carbon (MBC)

Ten (10 g) grams of soil sample (passed through a 2mm sieve) was weighed and put into plastic containers. There were two sets, one of which was to serve as the control. 2ml of water was added to each sample to moisten it and they were covered and left overnight.

To the fumigated set, 5 ml alcohol free chloroform was added in addition to the 2 ml water and left covered overnight. Both set were evacuated for 4hrs after which fresh soil inoculums (5 g) was mixed with each sample and 30 mls 0.5N NaOH was put into a conical flask and put beside each evacuated sample separately in an airtight plastic container and left for 10 days to incubate. The NaOH was to serve as a trap for the CO_2 that would be evolved. Back titration with HCL was used to determine the amount of CO_2 that was evolved.

3.9.0 Observations on Growth Parameters

Four maize plants from each sub-plot were randomly tagged for periodic observation during the crop growth period. The following observations were made at 3, 5, 7, and 11 WAS for harvest parameters.

3.9.1 Plant Height

Plant height of maize was measured from soil level to the base of the flag leaf with metre rule. The measurements were done at two weeks interval beginning from three weeks after germination till tassel.

3.9.2 Number of Leaves

Number of leaves was counted at every two week interval beginning from three weeks after planting. The plant stand of four plants per plot were tagged and used for this observation till tassel.

3.9.3 Shoot Stover Yield

Plants shoot from each plots were cut at soil surface level after maize cob was harvested. The shoot was allowed to sun-dry to constant weight. The stover weight per plot was estimated.

3.9.4 Grain Yield and Yield Components

Grain yield from each net plot was obtained after cobs were threshed winnowed and weighed. The value obtained was extrapolated and expressed in kg ha^{-1}. One thousand (1000)

grains of maize was also counted and weighed. The maize cob weight was determined by weighing the cobs per net plot.

3.10 Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using statistical computer package (SAS 2003). The Duncan's New Multiple Range Test (DNMRT) was used to separate means at 5% probability level ($P<0.05$).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Pre-Experimental Soil Condition

4.1.1 Soil Physical Properties

Saturated Hydraulic Conductivity (Ksat)

Hydraulic Conductivity (Ksat) values of all the treatments are presented in Table 2. There was no significant variation in the initial Ksat value of the study area. They were 0.42, 0.10 and 0.29 cm sec^{-1} for the NVR, CPF and MPF treatment respectively. The Ksat of the subsurface (0.23 cm sec^{-1}) was lower than that of the surface (0.32 cm sec^{-1}) (Table 2). This implies that at the surface there was a better flow of water than at subsurface that could have been compacted from tillage activities.

At 8 weeks, Ksat values of all the treatments varied significantly. The MPF treatment had the highest ksat of 0.24 cm sec^{-1}. This could have been attributed to the increased porosity occasioned by plants/legume root biomass of *Macrotyloma uniflorum* and improved microbial activity. Ehler, (1975) also attributed increase in Ksat to conservative tillage which led to improved pore distribution from the microbial activities. Decrease in Ksat with compaction have been reported by Adeoye (1982), Folorunso and Ohu (1989). Ogunwole *et al*., (2000) also reported a decrease in Ksat with compaction on soils of Samaru. The higher Ksat values recorded for CPF at 5 cm depth (0.18 cm sec^{-1}) and MPF at 10 cm depth (0.20 cm sec^{-1}) could be due to reduced bulk density and increased porosity caused by roots of the legumes, increased organic matter from plant biomass and microbial activities. At the subsurface (5-10 cm) the Ksat had a higher value of 0.15 cm sec^{-1} which implies that there was improved infiltration.

At harvest; MPF gave the highest Ksat value of 0.54 cm sec^{-1} while the control treatment had the least Ksat of 0.04 cm sec^{-1}. This implies that legume treatments increased the organic matter aggregation and pore spaces to enable a high rate of water intake than the control treatment. Subsurface Ksat had higher value of 0.37 cm sec^{-1} than the surface, perhaps because the surface soil contains roots, organic matter and more soil organisms to have improved water conduction at this depth.

Table 2: Effect of forage legumes planted fallow and soil depth on Hydraulic Conductivity.

Treatment	Initial	8 weeks after planting	At harvest
Legumes (L)			
Control	0.42	0.033c	0.037b
Centrosema	0.10	0.095b	0.145ab
Macrotyloma	0.29	0.240a	0.535a
SE±	0.22	0.007	0.14
Soil Depth (cm)			
0-5	0.32	0.09b	0.11
5-10	0.23	0.15a	0.37
SE±	0.18	0.01	0.11
Interaction			
MXD	NS	NS	NS

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.
**- Significant*
NS- Not Significant

Bulk Density

Bulk density (Bd) for the forage legume planted fallow treatments and soil depths are presented in Table 3. The control treatment had the highest bulk density value of 1.46 M g m^{-3}, followed by *Macrotyloma* planted fallow (1.43 M g m^{-3}), while *Centrosema* planted fallow had the least Bd (1.42 M g m^{-3}). These differences were however not statistically significant. The higher Bd of the control treatment (1.46 M g m^{-3}) could be as a result of compaction of the soil. The 10 cm depth had the highest Bd of 1.45 M g m^{-3} than 5 cm, which signifies that Bd increased with increase in depth.

Bulk Density of the treatment varies significantly at 8 WAP. The MPF gave the highest value (1.52 M g m^{-3}) followed by CPF (1.45 M g m^{-3}), while natural vegetative regrowth had the least (1.35 M g m^{-3}). This implies that natural vegetative regrowth matter decompose at a lower rate, leaving more soil organic carbon in soils to have impacted lower bulk density than CPF and MPF. The 10 cm depth also had the highest Bd of 1.47 M g m^{-3}. This implies that as depth increases soil was more compacted. At harvest, bulk densities were not significantly different among the forage legumes. Bulk densities range from 1.32 – 1.36 M g m^{-3} and imply that at harvest, organic matter decomposition equilibrated to have resulted in non-significant difference in bulk density between treatments.

Table 3: Effects of forage legumes planted fallow and soil depth on Bulk density

Treatment	Initial	8 weeks after planting	At harvest
Legumes (L)			
Control	1.46	1.35c	1.36
Centrosema	1.42	1.45b	1.32
Macrotyloma	1.43	1.52a	1.34
SE±	0.02	0.009	0.03
Soil Depth (cm)			
0-5	1.41	1.41b	1.36
5-10	1.45	1.47a	1.32
SE±	0.024	0.007	0.025
Interaction			
MXD	NS	NS	NS

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.
**- Significant*
NS- Not Significant

Total Porosity

Total porosity (TP) for the forage legume planted fallow treatments and soil depths are presented in Table 4. In the pre-maize planting CPF gave the highest value of 46.04 while the surface (5 cm) value was 46.28%. This implies that porosity among depths could be attributed to soil compaction and the low organic matter content of the soils at these depths.

At 8 weeks after planting, TP under the various legume treatments varied significantly. *Macrotyloma uniflorum* Planted fallow had the highest value (49.24 %) followed by CPF (45.16 %) and control treatment (42.51 %). However between depths, subsurface (10 cm) soils had higher TP (46.66 %) than surface soil (44.61). This suggest that perhaps root ramification, bioturbation by macro and micro organisms, organic matter and soil biota activities at 0 – 10 cm depths was optimal for improved TP.

At harvest the TP of legume treatment varied significantly. The MPF treatment had the highest TP value (51.20 %). This was followed by CPF (50.69%). Control treatment had the least value of 46.48 %. The subsurface (10 cm) had a higher porosity of 50.15 % and was significantly higher than surface value of 48.76 %. Contribution of MPF treatment would account for the significant increase of macro pores to influence total porosity increase in the soils than CPF and NVR treatment.

Table 4: Effects of forage legumes planted fallow and soil depth on total porosity

Treatment	Initial	8 weeks after planting	At harvest
Legumes (L)			
Control	45.09	42.51c	46.48b
Centrosema	46.04	45.16b	50.69a
Macrotyloma	45.98	49.24a	51.20a
SE±	0.75	0.36	0.36
Soil Depth (cm)			
0-5	46.28	44.61b	48.76b
5-10	45.12	46.66a	50.15a
SE±	0.61	0.29	0.29
Interaction			
MXD	NS	NS	NS

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.
**- Significant*
NS- Not Significant

4.1.2 Soil Chemical Properties

The soil chemical properties of the sites before the experiment are summarized in Table 5a. pH value of the soils were in the slightly acid (pH 5.9 – 6.0) range. Soil acidity did not decrease beyond pH 5.3 in $CaCl_2$ solution both at surface (0-15 cm) and sub-surface (15-30 cm) depths. This suggests that the soils have no acidity problems and hence, do not require liming for pH remediation.

Soil carbon at the surface layer was 6.1 g kg^{-1} under natural vegetation regrowth (NVR), 5.3 g kg^{-1} under *Centrosema pascuorum* planted fallow (CFL) and 4.0 g kg^{-1} under *Macrotyloma uniflorum* Planted fallow (MFL). This implied that soil carbon credit was better achieved under NVR, followed by CFL at the sub-soil depth (15-30 cm). Organic carbon contribution by NVR was 6.8 g kg^{-1}C, while CFL and MFL contributed 4.4 and 4.2 g kg^{-1}C, respectively. This suggests that plant roots under NVR supported more soil carbon credit at depth 15-30 cm than the planted legume fallows.

The available Phosphorus in the soils following one year fallow treatments (Table 5a) shows that CFL contributed higher available phosphorus (10.50 mg kg^{-1}) in the soils than NVR (8.75 mg kg^{-1}) and MFL (5.25 mg kg^{-1}) at the surface layer (0-15 cm). In the subsoil depth (15-30 cm), both NVR and CFL contributed 8.75 mg kg^{-1} P. These were higher than MFL (5.25 mg kg^{-1}). These suggests that CFL improved soil available P than NVR and MFL.

Total N under CFL treated soils was 0.88 g kg^{-1} and was higher than NVR (0.53 g kg^{-1} N) and MFL (0.35 g kg^{-1} N) at the surface layers. Similar results were obtained at the sub-surface depth (15–30 cm). However higher N was contributed by MFL at the subsoil depth (0.53 g kg^{-1}) than the surface (0.35 g kg^{-1} N). It is inferred therefore, that CFL contributed higher total nitrogen to the soil than NVR and MFL.

Exchangeable cations in the soils decreased in the order Ca>Mg>K>Na at both surface and subsoil depths. This is as observed for agricultural soils and could contribute to the slightly acid soil conditions (pH 5.9 - 6.0 in water) obtained. However, the low Na values (Table 5a) under the treatments as well as the low ESP values indicate that the soils have no sodic problems. Under CFL, higher exchangeable Calcium was obtained (3.0 c mol kg^{-1}) than at the surface layer (2.8 c mol kg^{-1}) and the other treatments (Table 5a). This could be attributed to Ca^{2+} contributions by CFL at this depth being higher than the other treatments. Exchangeable cation contents of the site were low at both depths to confirm that the soils are inherently low in fertility status (Jones and Wild, 1975; Lombin, 1987, Odunze *et al.,* 2004).

Cation Exchange Capacity (CEC) of the soils were very low (<10 c mol kg^{-1}) under the treatments at the two depths. However, CFL treatment improved CEC in the top soils than MFL (6.6 c mol kg^{-1}) and NVR (5.0 c mol kg^{-1}). In terms of Cation and CEC improvements in the soil, CFL could be adjudged a better soil amendment option than NVR and MFL.

Table 5a: Initial physico-chemical properties of soil in 2009.

Properties	0 – 15 cm depth			15 – 30 cm depth		
	Nat	Centro	Macro	Nat	Centro	Macro
pH						
Water	5.9	6.0	6.0	5.9	6.0	5.9
0.01 $CaCl_2$	5.3	5.2	5.3	5.3	5.3	5.2
Organic carbon (gkg^{-1})	6.1	5.3	4.0	6.8	4.4	4.2
Avail. P ($mgkg^{-1}$)	8.75	10.50	5.25	8.75	8.75	5.25
Total N (gkg^{-1})	0.53	0.88	0.35	0.53	0.88	0.53
Exchangeable bases ($cmolkg^{-1}$)						
Ca	2.4	2.8	2.4	1.6	3.0	2.6
Mg	1.0	1.5	1.6	1.1	1.6	1.2
Na	0.58	0.68	0.48	0.60	0.60	0.55
K	0.17	0.15	0.12	0.14	0.15	0.15
CEC	5.0	6.8	6.6	5.5	6.0	5.5
Base Saturation (%)	83	75	69.7	62.6	83.5	81.8
ESP (%)	11.6	10.0	7.2	10.9	10.0	10.0
Micro nutrients ($mgkg^{-1}$)						
Zn	10.7	7.5	10.7	10.7	11.8	8.6
Mn	6.4	9.3	7.9	6.4	10.8	10.9
Fe	31.1	42.2	31.1	31.1	33.3	40.0
Particle size analysis (gkg^{-1})						
Sand	390	390	450	410	390	390
Silt	520	520	460	500	520	520
Clay	90	90	90	90	90	90
Textural class	SILT LOAM			SILTLOAM		

NB: Nat- Natural vegetative regrowth, Centro- Centrosema pascuorum, Macro-Macrotyloma uniflorum, ESP- Exchangeable Sodium Percentage, CEC- Cation Exchange Capacity

4.2 Biomass Production and Nutritional Contribution of the Forage Legumes

i. Biomass Production

At the end of first year, the total above ground biomass production of the cover crops ranged from 94 g/m^2 in the *Centrosema pascuorum* planted fallow to 117 g/m^2 in the natural vegetative regrowth fallow. The total biomass for the *Macrotyloma uniflorum* planted fallow was 113 g/m^2, much of the biomass estimated was grass regrowth in all fallows and did not suggest any trend in the fertility status of the soil. Table 5b

ii. Nutritional Contribution

Macrotyloma uniflorum planted fallow had the highest nitrogen content relative to *Centrosema pascuorum* planted fallow and natural vegetative regrowth fallow. The increase of N over the NVR was 119% for MPF and 75% for CPF. The higher nitrogen and phosphorus contribution of the MPF fallow was noted in the study. Table 5b

Table 5b: Total Biomass Production and Nutritional Content of Forage Legume

Total Biomass (g/m2)				
Treatment	Wet weight (g)	Dry weight (g)	Nitrogen (%)	Phosphorus (%)
CONTROL	164.04a	117.00a	1.95c	1.92b
CENTRO	154.54b	94.45c	3.41b	1.84b
MACRO	165.14a	113.40b	4.28a	2.65a
SE ±	11.33	12.76	0.21	0.17

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.
**- Significant*
NS- Not Significant

4.3. Effect of One Year Forage Legumes Planted Fallow and Fertilizer Rates on Soil Chemical Properties.

4.3.1. Soil Reaction, Total Nitrogen, Available Phosphorus and Soil organic Carbon.

Soil pH values measured in water and $CaCl_2$ for the NVR, CPF and MPF planted fallows varied significantly ($P<0.05$) and are shown in Table 6. Natural vegetative regrowth shows a higher pH in water (5.99) and $CaCl_2$ (5.18) followed by CPF at harvest. This suggests that MPF and CPF were effective in lowering the soil pH both in water and $CaCl_2$ compared to control. Application of N rate at 80 kg N ha^{-1} produced the highest pH in water (5.91) and $CaCl_2$ (5.18), respectively. This implies that with increase in nitrogen fertilization, soil pH also increased though in the acid range. This finding is not in agreement with Caddel et al., (2011) who stated that soil pH usually decrease with time due to nitrogen fertilization, rainfall, leaching, organic matter decay and harvest of crops. Application of 26.4 kg P ha^{-1} produced the highest pH in water (5.90) while 13.2 kg P ha^{-1} gave the highest pH in $CaCl_2$ (5.15). However soil acid reactions did not decrease below pH 5.0 under all the treatments, indicating that the soils had no acid problems.

Total N under NVR was 2.9 g kg^{-1} and was higher than MFL (1.4g kg^{-1}) and CFL (0.5 g kg^{-1}) treatments at harvest. It would be inferred therefore that NVR contributed higher total N to the soil than *Centrosema pascuorum* and *Macrotyloma uniflorum* under one year follow management. Perhaps, this could result from effect of nitrogenising organisms under the Natural vegetative regrowth over a longer period than the planted fallows. Total N was greater 40 kg N ha^{-1}, which implies that 40 kg N ha^{-1} would result in better N contribution than the other rates under this treatment.

One year fallow treatments (Table 6) with CPF (28.92 mg kg^{-1}) contributed higher available P in the soils than MPF (7.68 mg kg^{-1}) and NVR (4.64 mg kg^{-1}). These could suggest that CFL would improve soil available P better than *Macrotyloma uniflorum* planted fallow and

natural vegetative regrowth. Also N rate at 80 kg N ha^{-1} produced the highest available P in soil. This implies that *Centrosema pascuorum* contributed higher P than the other treatments. There were no significant differences among the phosphorus rates.

Soil carbon under NVR was 5.9 g kg^{-1} at harvest, 5.2 g kg^{-1} under CFL and 3.7 g kg^{-1} under MPF. The soil carbon value of these treatments varied significantly ($P \leq 0.05$). This implied that soil carbon credit was better achieved under NVR followed by CPF. The low values under the planted legume fallow treatments were attributed to the low amount of forage legumes and high organic matter mineralization in the soil when compared with NVR (control) treatment. Mulongoy *et al.,* (1993) observed that the level of organic matter in soils depends largely on the quantity of plants material and litter returned to the soil. Soil carbon credit was higher at 80 kg N ha^{-1} and 13.2 kg P ha^{-1} and suggests that at these rates soil carbon credits would be high under planted legume fallow treatment.

Table 6: Effect of forage legumes planted fallow and fertilizer rates on soil pH, total nitrogen, available phosphorus and organic carbon (2009) at harvest.

Treatment	pH-H_20	pH-$CaCl_2$	Total Nitrogen (gkg^{-1})	Available Phosphorus $mgkg^{-1}$	Organic Carbon (gkg^{-1})
Legumes (L)					
Control	5.99a	5.18a	2.9a	4.64c	5.9a
Centrosema	5.87b	5.17a	0.5c	28.92a	5.2b
Macrotyloma	5.78c	5.03b	1.4b	7.68b	3.7c
SE±	0.02	0.02	0.14	1.83	0.11
Nitrogen(N) Kg ha at^{-1}					
0	5.87ab	5.06c	1.0ab	13.48ab	4.9
40	5.85ab	5.13b	2.5a	10.53b	4.9
80	5.91a	5.18a	1.0ab	17.47a	5.0
120	5.89b	5.15ab	2.0b	13.51ab	5.0
SE±	0.02	0.02	0.14	2.12	0.04
Phosphorus (P) Kg ha^{-1}					
0	5.88	5.11	1.8	13.98	4.9
13.2	5.86	5.15	1.4	13.90	5.1
26.4	5.90	5.13	1.6	13.37	4.9
SE±	0.02	0.02	0.12	1.83	0.11
Interaction					
L X N	*	*	*	*	NS
L X P	NS	NS	NS	NS	NS
N X P	*	NS	*	NS	NS
L X N X P	NS	NS	NS	NS	NS

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.

**- Significant*

NS- Not Significant

4.3.2. Exchangeable Bases and Cation Exchange Capacity 2009 at Harvest

Exchangeable cations in the soils decreased in the order Ca>Mg>K>Na at harvest. This is as observed for agricultural soils and could account for the slightly acidic soil conditions (pH 5.2 to 5.9 in water and 5.3 to 5.9 in $CaCl_2$) obtained. However, the low Na values (Table 7) under the treatments as well as the low ESP values indicate that the soils have no sodic problem if it's to be used for next planting season. Under CPF, higher exchangeable calcium was obtained (2.61 c mol kg^{-1}) than in other treatments. This could be attributed to Ca^{2+} contributions by *Centrosema pascuorum* at harvest being higher than the other treatments. Also with increase in inorganic fertilization, soil sodium decreased and could imply that with increase in nitrogen availability from organic and inorganic sources, exchangeable sodium slowly reduced in soils.

The Cation Exchange Capacity of soils were grouped into three distinct ratings of low, medium and high based on the findings of Adepetu *et al.,* (1979) who reported CEC values of <6, 6-12 and >12 c mol kg^{-1} as low, medium and high respectively. Cation Exchangeable Capacity (CEC) of the soils were very low (<10 c mol kg^{-1}) under the treatments. However, NVR improved CEC of the soils than MPF (5.74 c mol kg^{-1}) and CPF treatment (4.57 c mol kg^{-1}). In term of exchangeable cations and CEC improvements in the soil, CPF treatment was a better soil amendment approach than NVR and MPF. In the aspect of application of nitrogen, 40 kg N ha^{-1} led to production of highest exchangeable cations and CEC except exchangeable potassium that was higher on application of 120 kg N ha^{-1}. The one year forage legume fallow and nitrogen rates showed lower CEC of the soil (Table 7), suggesting that the soils were dominated by low activity clays (Sanchez 1976; Odunze *et al.,* 2003). Application of 13.2 kg P ha^{-1} resulted in high exchangeable K (0.43 c mol kg^{-1}) and Na (0.49 c mol kg^{-1}) while 26.4 kg P ha^{-1} resulted in a high exchangeable Ca (2.55 c mol kg^{-1}), Mg (1.60 c mol kg^{-}

^{1}) and CEC (5.48 c mol kg^{-1}). These suggest that 26.4 kg P ha^{-1} rate would significantly enhance cations released in the soil and improve the soils' potential for cation exchange. The CEC values of 4.57-5.90 c mol kg^{-1} were considered low (Table 7). Application 40 kg N ha^{-1} and 80 kg N ha^{-1} inorganic fertilizer gave the highest 5.90 c mol kg^{-1} and lowest (5.14 c mol kg^{-1}) values respectively.

Table 7: Effect of one year forage legumes planted fallow and rates of inorganic fertilizers on exchangeable bases and cation exchange capacity (2009).

Treatment	Potassium	sodium	Calcium	Magnesium	CEC
	←		(c mol kg^{-1})		→
Legumes (L)					
Control	0.14	0.51b	2.57a	1.50ab	5.90a
Centrosema	0.12	0.29c	2.61b	1.59a	4.57b
Macrotyloma	0.45	0.61a	2.23b	1.36b	5.74a
SE±	0.16	0.02	0.09	0.06	0.12
Nitrogen(N) Kg ha^{-1}					
0	0.16	0.49ab	2.64a	1.63a	5.45ab
40	0.13	0.50a	2.72a	1.69a	5.62a
80	0.14	0.42b	2.32b	1.32b	5.14b
120	0.50	0.48ab	2.21b	1.29b	5.41ab
SE±	0.19	0.02	0.10	0.07	0.14
Phosphorus (P) Kg ha^{-1}					
0	0.14	0.47	2.42	1.42b	5.27
13.2	0.43	0.49	2.45	1.42b	5.47
26.4	0.14	0.46	2.55	1.60a	5.48
SE±	0.16	0.02	0.09	0.06	0.12
Interaction					
L X N	NS	*	*	*	NS
L X P	NS	NS	NS	NS	NS
N X P	NS	NS	*	NS	NS
L X N X P	NS	NS	NS	NS	NS

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.

**- Significant*

NS- Not Significant

4.3.3. Zinc, Iron and Manganese

Micronutrient Zn was 26.85 mg kg^{-1}, 19.05 mg kg^{-1} and 11.34 mg kg^{-1} at harvest with CPF, MPF and NVR respectively (Table 8). This showed that soil extractable Zn was greater under CPF followed by MPF treatment. Application of 120 kg N ha^{-1} had the lowest available Zn (16.63 mg kg^{-1}), while 0 kg N ha^{-1} had the highest (24.44 mg kg^{-1}) Zn content. This indicates a decrease in Zn content as the soil N is increased. Application of 26.4 kg P ha^{-1} had lower Zn content (17.36 mg kg^{-1}) than 13.2 kg P ha^{-1} (21.54 mg kg^{-1}) treatment. This could be attributed to more rigorous root development due to P application, resulting in accumulation of high extractable Zn in the soil. The acidifying effect of P on soil could also contribute to low available Zn levels. This leads to the release of inherent Zn in the soil (Brady & Weil, 1996).

Iron in the soil following one year short fallow treatments (Table 8) shows that NVR (49.69 mg kg^{-1}) contributed higher iron at harvest than MPF (46.27 mg kg^{-1}) and CPF (41.65 mg kg^{-1}). This suggests that Natural vegetative regrowth could result in high soil iron than *Macrotyloma uniflorum* and *Centrosema pascuorum*. Applications of 80 kg N ha^{-1} reduce iron content (49.42 mg kg^{-1}) than other rates. This implies that when N is increased beyond 80 kg N ha^{-1}, iron content could be reduced in the soil. Application of 26.4 kg P ha^{-1} produced the highest (47.63 mg kg^{-1}) iron content compared to 0 kg P ha^{-1} (45.11 mg kg^{-1}).
The CPF treatment resulted in the highest exchangeable Mn (12.01 mg kg^{-1}) compared to NVR (10.35 mg kg^{-1}) and MPF (8.75 mg kg^{-1}). Application of 40 kg N ha^{-1} and 26.4 kg P ha^{-1} resulted in attainment of the highest exchangeable Mn (10.75 and 10.63 mg kg^{-1}, respectively). This implies that *Centrosema pascuorum* planted fallow could contribute higher exchangeable Mn than other treatment. However, the lower extractable iron and Manganese (Table 8) in soils under the planted legume fallow treatments (CPF and MPF)

than the control, suggests that the planted legumes would reduce the rate of redox reaction of Fe and Mn oxides and hydroxides to form Fe hard set nodules and concretions. Therefore planted fallow could hold potentials for improving soil chemical quality better than natural vegetative regrowth.

Table 8: Effect of one year forage legumes planted fallow and fertilizer rates on soil micro-nutrient (2009)

Treatment	Zinc	Iron	Manganese
	<---------- (mgkg^{-1}) ---------->		
Legumes (L)			
Control	11.34b	49.69a	10.35b
Centrosema	26.85a	41.65b	12.01a
Macrotyloma	19.05ab	46.27ab	8.75c
SE±	2.78	1.78	0.38
Nitrogen(N) Kg ha^{-1}			
0	24.44	46.99ab	10.69
40	17.26	45.02ab	10.75
80	17.98	49.42a	10.21
120	16.63	42.04b	9.83
SE±	3.21	2.05	0.44
Phosphorus (P) Kg ha^{-1}			
0	18.33	45.11	10.24
13.2	21.54	44.87	10.24
26.4	17.36	47.63	10.63
SE±	2.78	1.78	0.38
Interaction			
L X N	NS	*	NS
L X P	NS	NS	NS
N X P	NS	NS	*
L X N X P	NS	NS	NS

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.

**- Significant*

NS- Not Significant

4.4 Effects of forage legumes planted fallow on soil microbial-nutrients.

Studies on the effect of forage legume planted fallow on soil microbial biomass nitrogen, shows that CPF contributed the highest (6.7 mg kg^{-1}) microbial biomass nitrogen in the soil (Figure 1). This suggests that *Centrosema pascuorum* planted fallow increased the activities of microbial organism in the soil. *Macrotyloma uniflorum* planted fallow contributed higher (39.5 mg kg^{-1}) microbial biomass carbon in the soil than CPF (38.5 mg kg^{-1}) but was followed by NVR (23.5 mg kg^{-1}). This implies that *Macrotyloma uniflorum* credited carbon in the soil compared other treatments. Furthermore, among the legume planted fallows, CPF (12.72 mg kg^{-1}) to a greater extent enhanced microbial biomass phosphorus (Figure 1) than MPF. This could have been as a result of the nature of *Centrosema pascuorum* and the nutrient composition of root exudates adding more P input to the soil and thereby enhancing microbial activity. The release of organic acid during decomposition could have resulted in the hydrolysis of organic P hence improving P nutrition for plant and micro organisms in the soil. This could be another reason for CPF treatment to have contributed higher biomass P compared to MPF.

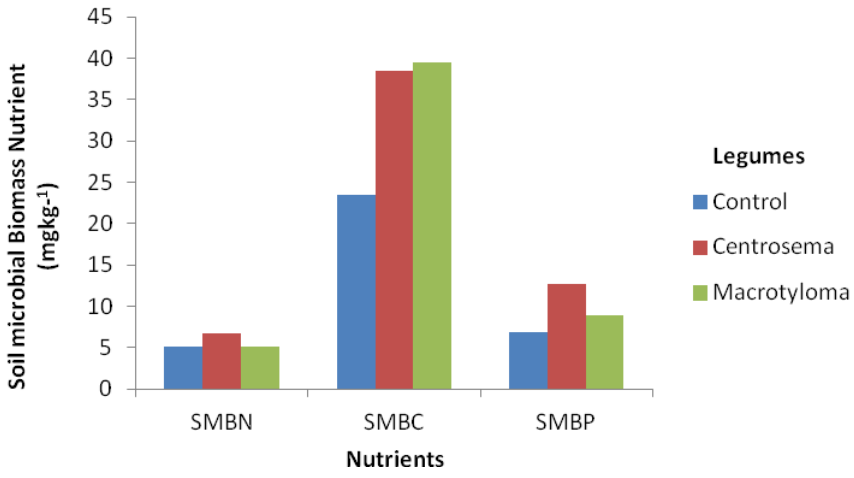


Fig. 1 Effect of Forage Legume planted fallow on Soil Microbial Biomass Nutrients

4.4.1 Effect of Nitrogen rates on soil microbial biomass nutrients

The nitrogen rate applied at 40 kg N ha^{-1} resulted in production of higher microbial biomass nitrogen of (7.4 mg kg^{-1}) in the soil which was statistically at par with the other rates (Figure 2). Beyond this rate (40 Kg N ha^{-1}) capacity of microbial organisms to generate nitrogen will reduce. Application of nitrogen at the rate of 120 kg N ha^{-1} produced the highest (3.6 mg kg^{-1}) microbial biomass carbon though not significant different with other rates. This suggests that increase in N application did not significantly ($P \leq 0.05$) enhance microbial biomass carbon (Figure 2). Application of 80 Kg N ha^{-1} produced (10.84 mg kg^{-1}) a better SMBP which suggests that at 80 Kg N ha^{-1} SMBP is more produced.

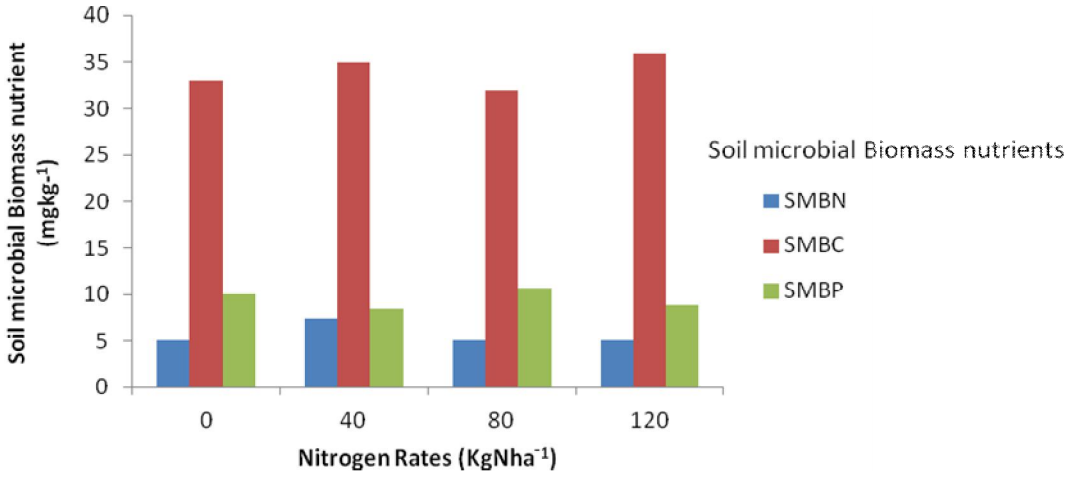


Fig. 2 Effect of Nitrogen on Soil Microbial Biomass Nutrients

4.4.2 Effect of Phosphorus fertilizer rate on Soil Microbial Biomass Nutrients

Application of phosphorus fertilizer rate had no significant difference on soil microbial biomass nitrogen. Application of 0 Kg P ha^{-1} had higher (36 mg kg^{-1}) soil microbial biomass carbon compare to other rates. Application of 26.4 Kg P ha^{-1} had (10.84 mg kg^{-1}) a better SMBP which suggests this rate as optimum phosphorus fertilization rate for legumes. (Fig 3).

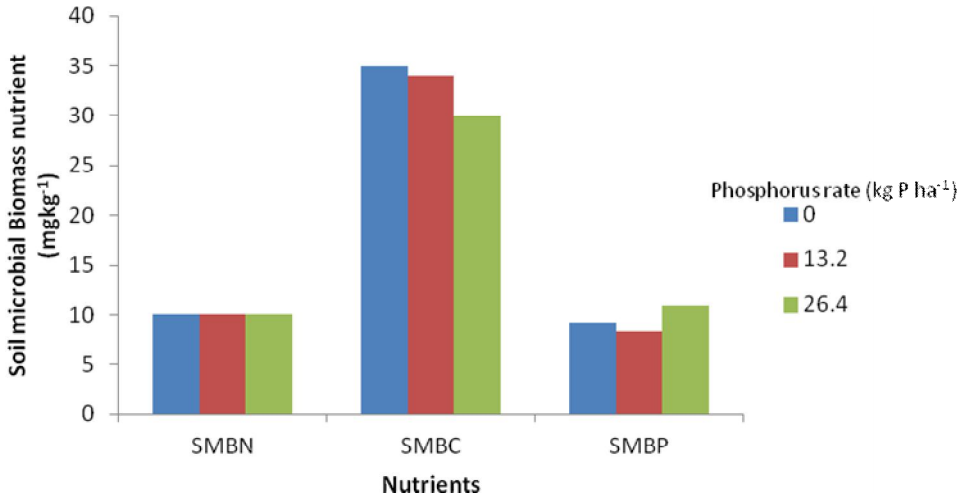
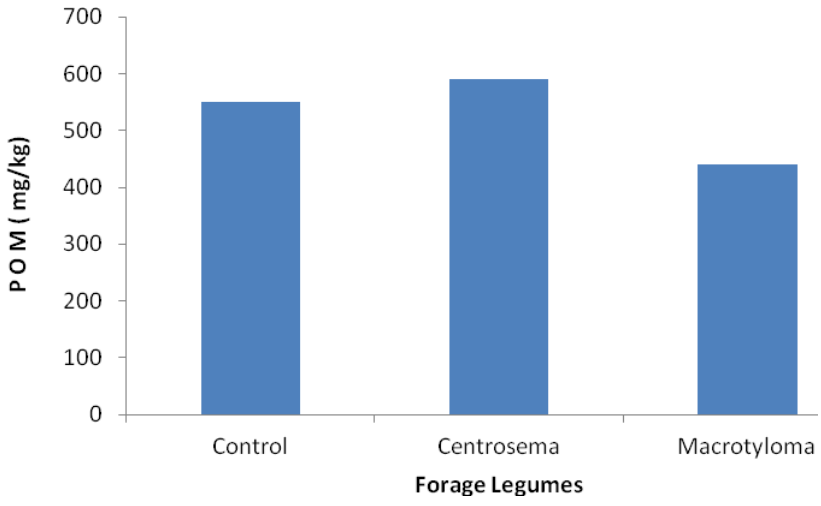


Fig. 3 Effect of Phosphorus on Soil Microbial Biomass Nutrients

4.5. Effect of forage legume planted fallow on particulate organic matter

Centrosema pascuorum planted fallow better enhanced particulate organic matter (590 mg kg^{-1}) (Figure 4), than Natural vegetative regrowth (550 mg kg^{-1}) and *Macrotyloma uniflorum* planted fallow (440 mg kg^{-1}). This suggests that *Centrosema pascuorum* contributed a significantly better organic matter to the soil than other treatments.



Note: CFL = Centrosema planted fallow, MFL =Macrotyloma planted fallow, POM=Particulate Organic Matter

Fig. 4 Effect of Forage Legumes planted fallow on Particulate Organic Matter

4.5.1 Effect of nitrogen rates on particulate organic matter.

Treatment with at 0 kg N ha^{-1} gave a high (540 mg kg^{-1}) POM but was not significantly different from other rates (Figure 5). This suggests that non application of N fertilizer could better enhance POM in the soil than treatments with N-fertilizer application. There was however a significant ($P \leq 0.05$) interaction between the forage legumes and nitrogen rates.

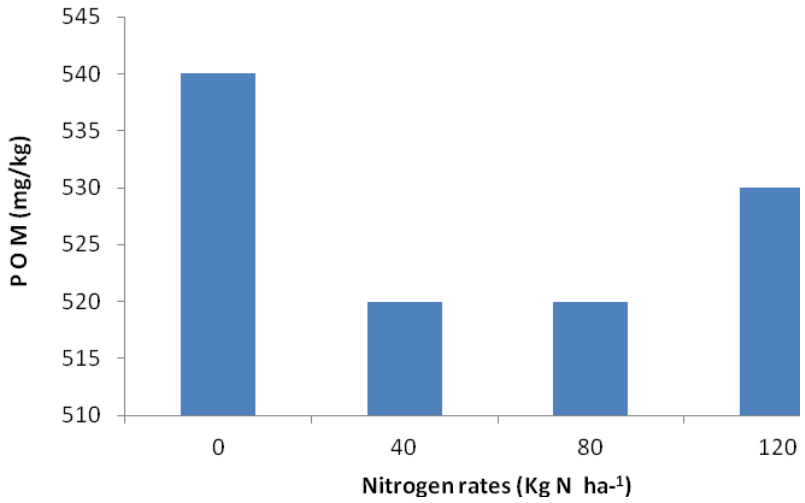


Fig 5: Effect of nitrogen rates on Particulate Organic Matter

4.5.2 Effect of phosphorus rates on particulate organic matter.

Particulate organic matter had the same content on both 13.2 and 26.4 Kg P ha^{-1}, though 0 Kg P ha^{-1} had the least POM. This suggests that for optimum POM production, 13.2 Kg P ha^{-1} should be better applied to reduce the application rate, since it gave the same content, Figure 6.

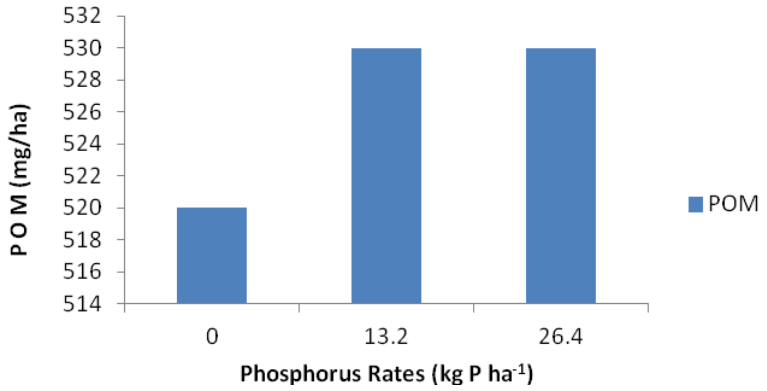


Fig 6: Effect of Phosphorus rates on Particulate organic Matter

4.6 Effect of Forage Legumes on Sequestration of Organic Carbon in aggregate size Fractions.

Centrosema pascuorum planted fallow sequestered more (0.65 g kg^{-1}) carbon than MPF (0.55 g kg^{-1}) in 500 µm soil fraction followed by NVR (0.47 g kg^{-1}) (Figure 7). This implies that 500 µm sized aggregates were more stable under CPF that could resist wind erosion than the other aggregates due to their stabilized state by higher carbon content. *Macrotyloma uniflorum* and natural vegetative regrowth sequestered similar (0.59 g kg^{-1}) carbon content which was statistically the same with CPF (0.57 g kg^{-1}) in 250 µm sized aggregates. (Figure7). These suggest that soil aggregates of 250 µm size were not differently affected by either of the treatment. Considering 50 µm sized aggregates, natural vegetative regrowth contributed the highest carbon (0.80 g kg^{-1}) in the aggregate sized class than the other treatment (figure 7). This implies that 50 µm stable aggregates were bound by organic carbon

better under Natural vegetative regrowth (Fig.7). Regarding the content of OC in <50 µm sized aggregates, the forage legumes were not significantly different, but MPF produced the highest carbon (0.72 g kg^{-1}) in the fraction (Figure 7).

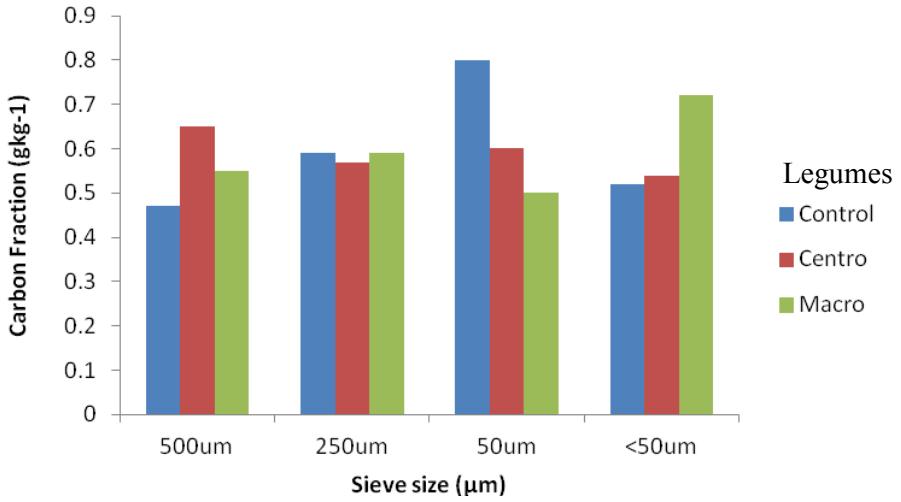


Fig 7: Effect of forage legumes planted fallow on sequestration of organic carbon in aggregate size fraction.

4.6.1 Effect of Nitrogen Rates on Sequestration of organic carbon in aggregate size Fractions

The 0 kg N ha^{-1} contributed a higher (0.90 g kg^{-1}) carbon in the soils than the other rates in 500, 250 and 50 µm sized aggregates, except in <50 µm sized aggregates, (Figure 8). Application of 40 kg N ha^{-1} resulted in sequestration of higher carbon in <50 µm sized aggregates followed by 50 µm, 500 µm and the least in 250 µm sized aggregates. Treatment with application of 80 kg N ha^{-1} sequestered more carbon in 250 µm sized aggregates followed by 500 µm and the least carbon were both in 50 and <50 µm sized aggregates which were statistically equivalent in organic carbon (0.60 g kg^{-1}) as seen in Figure 8. Treatments with application of 120 Kg N ha^{-1} sequestered the same carbon in 250 and <50 µm followed by 500 and 50 µm which had the least. The effect of nitrogen rates on sequestration of

organic carbon suggest that increase in N application rates reduced carbon content in aggregate sized fractions.

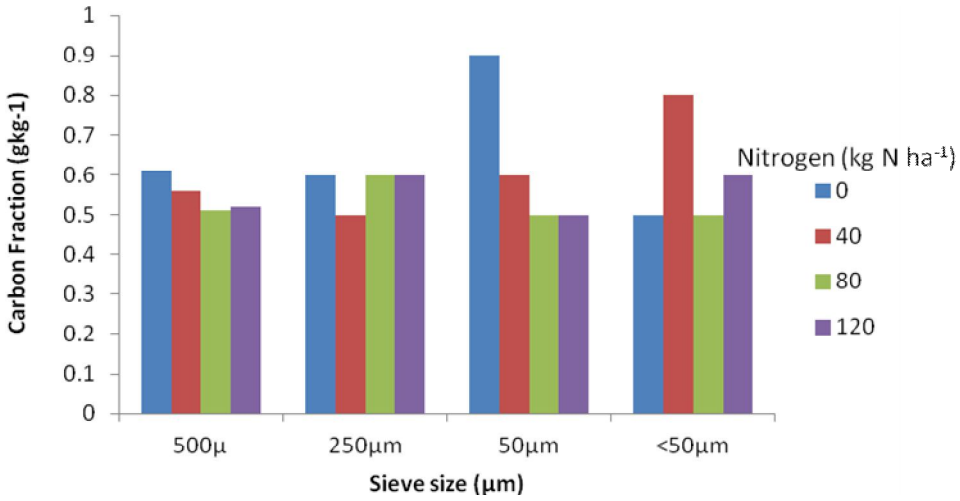


Fig 8: Effect of Nitrogen Rates on sequestration of organic carbon in aggregate fractions.

4.6.2 Effect of Phosphorus rates on sequestrations of organic carbon in Aggregate Fractions.

The application of 0 Kg P ha^{-1} had the highest organic carbon in 250 µm sized aggregates followed by 500 µm while 50 µm and <50 µm sized aggregates both had the same organic carbon. The application of 13.2 Kg P ha^{-1} supported the highest C (0.70 g kg^{-1}) in 50 µm sized aggregates followed by 250 µm than 500 µm and 50 µm sized aggregates that had the least carbon. 26.4 Kg P ha^{-1}, had the highest organic carbon in <50 µm sized aggregates than other rates. All the P rates applied gave statistically similar carbon credit in 250 µm sized aggregates. It is inferred that increase in the rate of P application increase the carbon content in <50 µm sized aggregates fraction. (Figure 9).

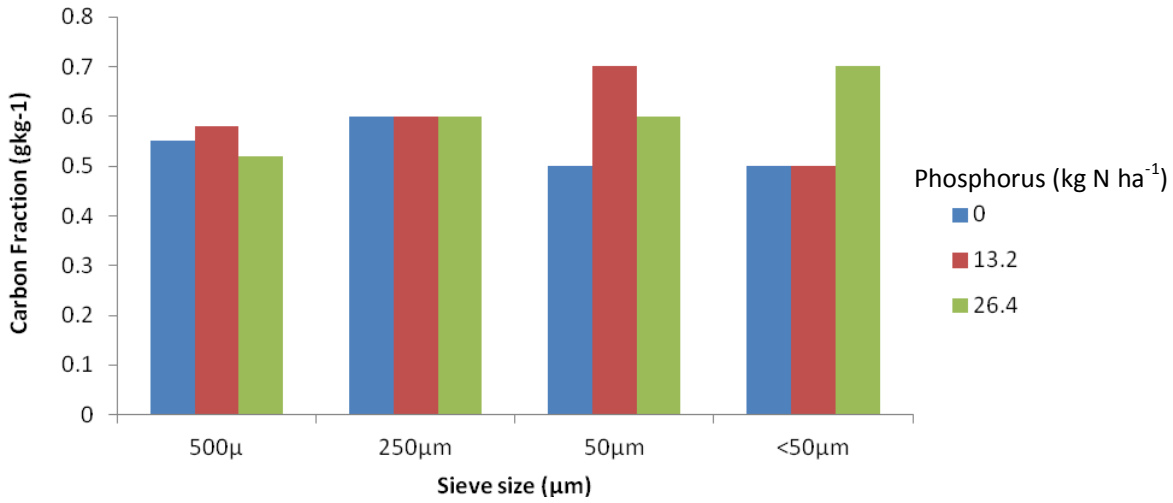


Fig 9: Effect of Phosphorus Rates on sequesteration of Organic Carbon in Aggregate Fraction

4.7 Effect of Forage Legume on Maize Plant Height.

Three weeks old *Centrosema pascuorum* planted fallow and natural vegetative regrowth were statistically similar in maize plant height (Figure 10) (24.81 and 24.71 cm respectively) and was followed by three week old *Macrotyloma uniflorum* planted fallow (23.62 cm) (Fig.10). At 5 WAP CPF and NVR were also statistically similar and MPF had the least maize plant height. At 7WAP, CPF had the tallest maize plant height (103.47 cm) than MPF (83.03 cm) followed by NVR (80.49 cm). This would suggest that the use of CPF could enhance maize performance. CPF had the tallest plant height (147.16 cm) at 9 WAP than MPF (114.93 cm) followed by NVR (111.43 cm). This suggests that CPF could improve plant height than other treatment.

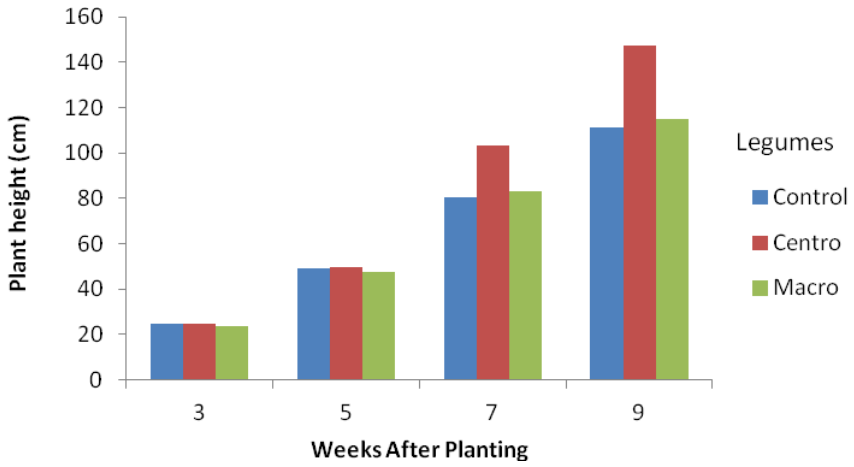


Fig.10 Effect of forage legume on maize plant height.

4.7.1 Effect of Nitrogen on Maize Plant Height

At 3 WAP the application of 120 kg N ha^{-1} produced the tallest plant height (28.77 cm). Followed by 40 and 80 kg N ha^{-1} which were both statistically the same while 0 kg N ha^{-1} had the least maize plant height. This would be inferred to mean that at 3 WAP maize plant needs a large quantity of nitrogen for vegetative growth. Treatment with 80 and 120 kg N ha^{-1} had statistically the same plant height of 49.91 and 50.33 cm respectively, followed by 40 kg N ha^{-1} while 0 kg N ha^{-1} gave the shortest plant height at 5 WAP. Although, at 7 WAP application of 120 kg N ha^{-1} resulted in the production of tall plant height (101.84 cm) Figure 11 followed by 80 kg N ha^{-1} then 40 kg N ha^{-1} and 0 kg N ha^{-1} still have the lowest plant height. This would suggest that increase in nitrogen application would enhance maize growth and performance. At 9 WAP that rate of nitrogen needed begin to reduce, 80 kg N ha^{-1} had the highest plant height (128.83 cm) then 0 kg N ha^{-1} followed by 120 kg N ha^{-1} and 40 kg N ha^{-1} had the least. This suggests that 80 kg N ha^{-1} would result in better crop growth than other treatment.

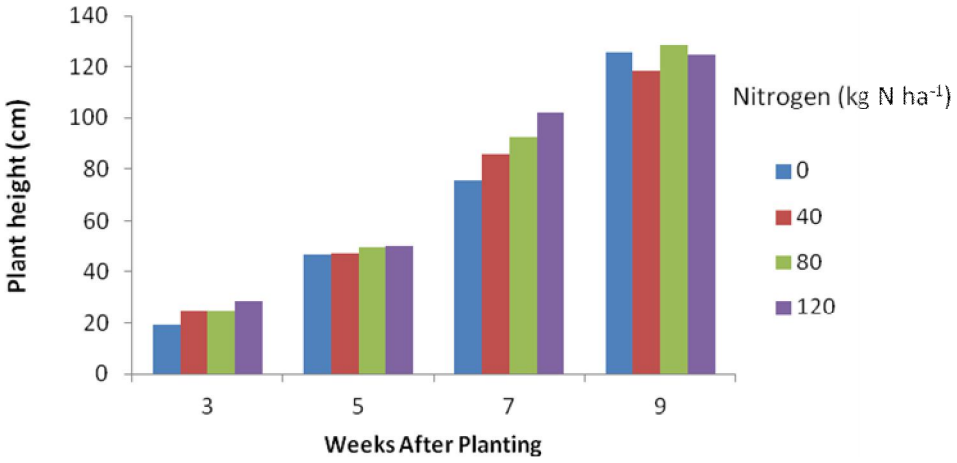


Fig11: Effect of nitrogen rates on maize plant height.

4.7.2 Effect of Phosphorus on Maize Plant Height

Effect of phosphorus on maize plant height shows that application of 26.4 kg P ha^{-1} had the tallest plant height (25.19 cm) followed by 13.2 kg P ha^{-1} and 0 kg P ha^{-1} which are statistically the same at 3 WAP. Application of 26.4 kg P ha^{-1} resulted in the tallest maize plant height followed by 13.2 kg P ha^{-1} while 0 kg P ha^{-1} had the least plant height at 5 WAP. At 7 WAP same result was recorded. At 9 WAP application of 13.2 kg P ha^{-1} had the tallest plant height (figure 12) followed by 0 kg P ha^{-1} and 26.4 kg P ha^{-1} had the least plant height.

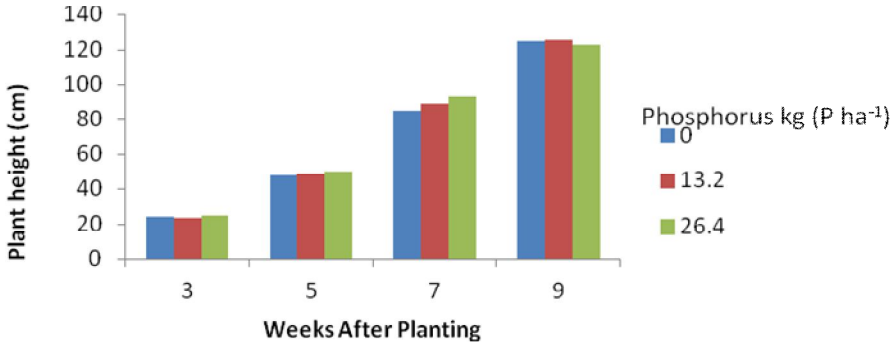


Fig. 12: Effect of phosphorus rates on maize plant height.

4.8 Effect of forage legumes on Maize Number of Leaves.

Figure 13 shows the effect of forage legume on maize number of leaves. Among the forage legumes *Centrosema pascuorum* planted fallow had the highest number of leaves in all the (5.04, 6.59, 10.53 and 12.70 respectively) weeks after planting. This suggests that CPL produced more organic matter that could support better improved soil biological, physical and chemical conditions to facilitate increase in the number of maize plant leaves. MPL had the least leaf number at 3 and 9 WAP and at 5 and 7 WAP it was the second best. NVR had the least number of leaves in the 5WAP and was next to CPL at 3, 7 and 9 WAP. It was inferred that the number of leaves increased as the week increased.

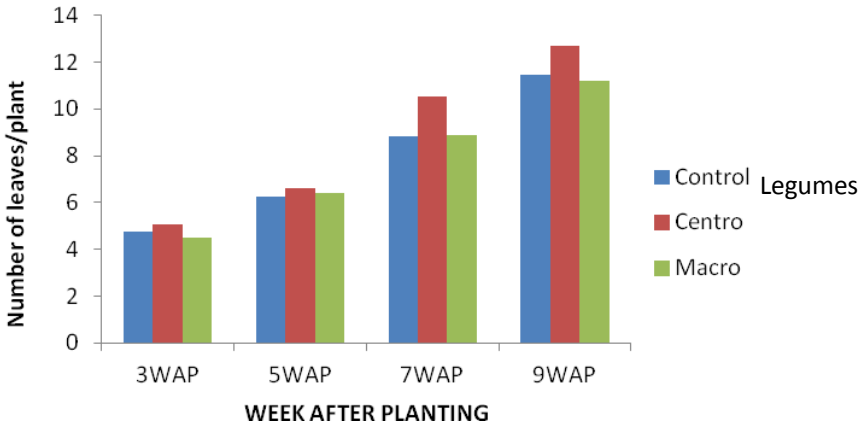


Fig.13 Effect of forage legume on maize number of leaves.

4.8.1 Effect of Nitrogen Fertilizer Rate on Maize Number of Leaves.

There were no significant differences ($P \leq 0.05$) among the N rates applied at 3WAP though 80kgNha^{-1} gave the highest (4.80) number of leaves (Figure 14). At 5WAP, 0 kg N ha^{-1} had the highest number of leaves than other rates. Application of 80 kg N ha^{-1} gave the highest (9.85) number of leaves when compared with other treatments at 7WAP followed by 120 kg N ha^{-1} while 40 kg N ha^{-1} had the least. More so, at 9WAP 80 kg N ha^{-1} resulted in the

highest maize leave number (12.07) although it was not significantly different from the other N-fertilizer rates. It was inferred that maize crops demand high amounts of N for improved yield. Goldworthy (1967) observed that higher doses of N-fertilizers increased maize number of leaves.

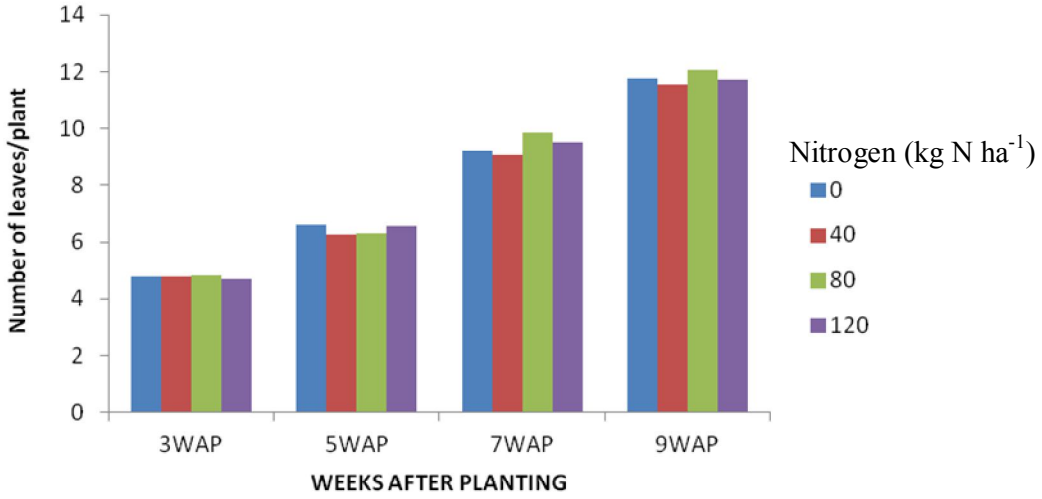


Fig14: Effect of Nitrogen on maize number of leaves.

4.8.2 Effect of Phosphorus Fertilizer rate on Maize Number of Leaves.

There were no significant differences ($P \leq 0.05$) among the P rates applied though 0 Kg P ha^{-1} gave the highest maize number of leaves at 3, 5 and 9 WAP than the other rates. At 7WAP 26.4 Kg P ha^{-1} had the highest maize number though it was statistically the same with 13.2 and 0 Kg P ha^{-1} which had the least number of leaves. (Figure 15).

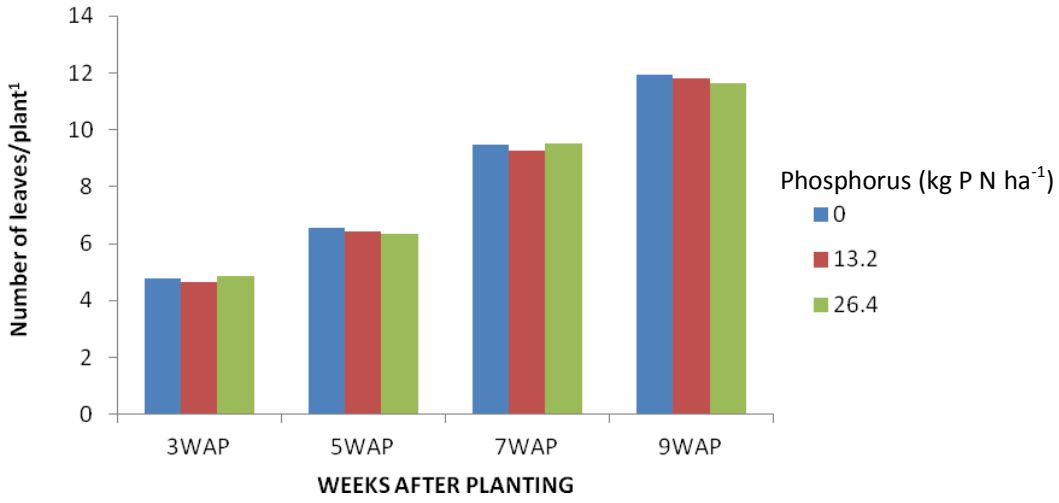


Fig. 15: Effect of phosphorus fertilizer rate on maize number of Leaves.

4.9 Effect of Forage Legumes planted fallow and fertilizer rate on Stability of Dry Aggregate fractions.

4.9.1 Dry 2000 µm-sized Aggregates

Dry 2000 µm-sized soil aggregates (DA) was significantly (P≤0.05) influenced by fallow management practices where *Centrosema pascuorum* planted fallow recorded 3% increase over the control, (Table 9). However, soils under natural vegetative regrowth recorded the lowest values followed by *Macrotyloma uniflorum*, probably because of the nature of the plant materials and contributions to soil aggregation. If control N-fertilizer treatment (0 kg N ha^{-1}) gave the highest value (0.93 g kg^{-1}), this could imply that non-application of N-fertilizer could strongly influence formation of (2000 µm) sized aggregate fraction.

4.9.2 Dry 1000 µm – sized Aggregates

Dry 1000 µm- sized aggregates was significantly (P≤0.05) influenced by forage legume planted fallow. *Centrosema pascuorum* planted fallow produced higher amount of the aggregate fraction (0.25 g kg^{-1}) than natural vegetative regrowth (0.23 g kg^{-1}) followed by

Macrotyloma uniflorum planted fallow (0.20 g kg^{-1}). This suggests that *Centrosema pascuorum* could improve the soil aggregate fractions 1000 µm better than other treatment. The influence of nitrogen and phosphorus rates on this aggregate fraction were also not significant (Table 9), suggesting that N and P application rates had no effects on 1000 µm sized aggregates fraction.

4.9.3 Dry 500 µm- sized Aggregate

The 500 µm- sized DA were significantly influenced by fallow management practices with the highest values recorded under natural vegetative regrowth (0.026 g kg^{-1}) (Table 9). This was followed by *Macrotyloma uniflorum* (0.025 g kg^{-1}) while *Centrosema pascuorum* planted fallow (0.020 g kg^{-1}) plots significantly recorded the least values. The result implies that natural vegetative regrowth plot produced structurally stable 500 µm soil aggregates relative to other treatments.

4.9.4 Dry 250 µm- sized Aggregates

For DA 250 µm – sized fractions, the natural vegetative regrowth recorded the highest values of aggregate fractions with 29% increase over *Centrosema pascuorum* planted fallow that recorded the least value (0.007 g kg^{-1}). This was followed by that of *Macrotyloma uniflorum* (0.013 g kg^{-1}). The result implies that Natural vegetative regrowth could influence the 250 µm aggregates to be stable against wind erosion (Table 9) better than the other treatments.

4.9.5 Dry 50 µm – sized Aggregates

For soil aggregates of 50 µm sized, *Macrotyloma uniflorum* planted fallow plots treatment resulted in the highest value which was 36% higher than control (Table 9). It was observed that *Macrotyloma uniflorum* planted fallow enhanced the development of 50 µm size aggregates. This may result from increased organic matter that bind soil particles and creates organo-mineral complexes while are important for flocculating aggregates (Tisdall and Oades, 1982). There were no significant differences between nitrogen and phosphorus rates

used, suggesting that Nitrogen and phosphorus rates had no direct implication on the 50 µm - sized aggregate fraction.

4.9.6 Dry <50 µm – sized Aggregates

Regarding dry soil aggregates of <50 µm, natural vegetative regrowth treatment recorded the highest values of 50% over the other treatments (Table 9). *Centrosema pascuorum* planted fallow plot recorded the least value that was statistically similar with fallow planted with *Macrotyloma uniflorum*. This suggests that soils under *Centrosema pascuorum* and *Macrotyloma uniflorum* planted fallow would resist wind erosion because of low <50 µm aggregation better than natural vegetation regrowth. Wind dislodges and carries away small soil aggregates leading to erosion (Unger, 1997). Treatments with application of 80 kg N ha^{-1} recorded the highest dry aggregates of <50 µm - sized (0048 g kg^{-1}) and suggests that application of 80 kg N ha^{-1} in the soil might have natural vegetative regrowth plant root biomass that enhanced soil <50 µm aggregation.

Table 9: Effects of forage legumes planted fallow and fertilizer rates on the stability of dry sieved aggregate fractions.

Treatment	2000 µm	1000 µm	500 µm	250 µm	50 µm	<50 µm
Legumes (L)						
Natural	0.91b	0.23b	0.026a	0.018a	0.081b	0.006a
Centrosema	0.99a	0.25a	0.020c	0.007c	0.101a	0.003b
Macrotyloma	0.77c	0.20c	0.025b	0.013b	0.103a	0.003b
SE±	0.02	0.006	0.0015	0.001	0.002	0.0007
Nitrogen(N) kg ha^{-1}						
0	0.93	0.23	0.025a	0.012	0.094	0.0038b
40	0.90	0.23	0.023b	0.013	0.095	0.0044ab
80	0.85	0.22	0.024ab	0.013	0.095	0.0048a
120	0.89	0.22	0.024ab	0.015	0.094	0.0044ab
SE±	0.03	0.007	0.0017	0.001	0.002	0.0008
Phosphorus (P) kg ha^{-1}						
0	0.90	0.22	0.02	0.01	0.093	0.0045
13.2	0.89	0.23	0.02	0.01	0.097	0.0043
26.4	0.89	0.23	0.02	0.02	0.094	0.0044
SE±	0.02	0.006	0.0015	0.001	0.002	0.0007
Interaction						
L X N	NS	NS	*	NS	*	*
L X P	NS	NS	NS	NS	NS	*
N X P	NS	NS	NS	NS	NS	NS
L X N X P	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.
**- Significant*
NS- Not Significant

4.10 Effect of Forage Legumes planted fallow and fertilizer rates on Wet Aggregates Fractions.

4.10.1 Wet 2000 µm – sized Aggregates

The proportion of 2000 µm sized aggregate fraction was significantly (P≤0.05) affected by treatments *Centrosema pascuorum* recorded highest value (0.22 g kg^{-1}) and was followed by fallow planted with *Macrotyloma uniflorum* (Table10). The value for the Natural vegetative regrowth treatments was significantly lower than for the other treatment. Treatments with non - application of nitrogen (0 kg N ha^{-1}), recorded the highest wet 2000 µm aggregates fraction (0.23 g kg^{-1}) though it was statistically similar to 40 and 80 kg N ha^{-1} treatment. This implies that *Centrosema pascuorum, Macrotyloma uniflorum* and N fertilizer rates application enhanced the development of 2000 µm aggregates better than the natural vegetation regrowth treatment.

4.10.2 Wet 1000 µm – sized Aggregate

The proportion of 1000 µm - sized wet aggregates fraction was not significantly (P≤0.05) affected by forage legumes planted fallow. Similarly, Nitrogen and Phosphorus application rates did not significantly (P≤0.05) affect 1000 µm- sized wet aggregates (Table 10).

4.10.3 Wet 500 µm – sized Aggregates

The WA stability of 500 µm - sized fractions was significantly (P≤0.05) influenced by the fallow management practices; with highest values recorded under natural vegetative regrowth (0.020 g kg^{-1}) and 1.41% increase over *Macrotyloma uniflorum* Planted fallow. Lower value was recorded under *Centrosema pascuorum* fallow treatments (Table 10). This implies that natural vegetative regrowth could stabilize the soil aggregates against erosion by water better than the planted legume fallows. However, 0 kg N ha^{-1} produced the highest quantity of 500 µm – sized stable aggregates (0.025 g kg^{-1}). Phosphorus application rates did not significantly (P≤0.05) affect the development of the aggregate fraction.

4.10.4 Wet 250 µm – sized Aggregates

The 250 µm – sized WA fractions, were significantly (P≤0.05) influenced by the fallow management practices. The highest value was recorded under natural vegetative regrowth (0.018 g kg^{-1}) with 13.89% increase over fallow planted with *Macrotyloma uniflorum*. *Centrosema pascuorum* fallow treatment recorded the least value. This suggests that Natural vegetative regrowth increased the 250 µm size aggregates, consequently producing more structurally stable 250 µm size aggregates that would resist erosion by water. Nitrogen and phosphorus application rates did not significantly (P≤0.05) affect the aggregates fraction (Table 10).

4.10.5 Wet 50 µm – sized Aggregates

Among the forage legume planted fallow, *Macrotyloma uniflorum* treatment recorded the highest 50 µm – sized aggregates (0.103 g kg^{-1}) followed by *Centrosema pascuorum* planted fallow and then the (0.101 g kg^{-1}) control. It was observed that *Macrotyloma uniflorum* planted fallow enhanced the formation of 50 µm size aggregates better than the others. There were no significant (P≤0.05) differences between nitrogen and phosphorus rates used (Table 10).

4.10.6 Wet <50 µm - sized Aggregates

With respect to <50 µm – sized WA, there were no significant differences between forage legume planted fallow treatment, although *Macrotyloma uniflorum* produced the highest value (0.026 g kg^{-1}). This was followed by *Centrosema pascuorum* fallow and the control (Table 10). This implies that *Macrotyloma uniflorum* is able to stabilize soil aggregate fractions of <50 µm in diameter. Nitrogen and phosphorus application rates did not significantly (P≤0.05) affect <50 µm WA.

Table10: Effects of forage legumes planted fallow and fertilizer rates on stability of wet aggregate fractions of a savannah Alifisol.

Treatment	2000 µm	1000 µm	500 µm	250 µm	50 µm	<50 µm
Legumes (L)						
Control	0.16b	0.03	0.026a	0.018a	0.081b	0.006
Centrosema	0.22a	0.03	0.020c	0.007c	0.101a	0.003
Macrotyloma	0.20ab	0.02	0.025b	0.013b	0.103a	0.026
SE±	0.015	0.006	0.0015	0.001	0.002	0.014
Nitrogen(N) kg ha^{-1}						
0	0.23a	0.03	0.025a	0.012	0.094	0.0038
40	0.21a	0.02	0.023b	0.013	0.095	0.0044
80	0.15b	0.02	0.024ab	0.013	0.095	0.0048
120	0.20a	0.03	0.024ab	0.014	0.094	0.0357
SE±	0.017	0.006	0.0017	0.001	0.003	0.016
Phosphorus (P) kg ha^{-1}						
0	0.21	0.03	0.02	0.01	0.093	0.004
13.2	0.18	0.02	0.02	0.01	0.097	0.004
26.4	0.20	0.03	0.02	0.02	0.094	0.027
SE±	0.015	0.006	0.0015	0.001	0.002	0.014
Interaction						
L X N	*	NS	*	NS	*	NS
L X P	NS	NS	NS	NS	NS	NS
N X P	NS	NS	NS	NS	NS	NS
L X N X P	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.

**- Significant*

NS- Not Significant

4.11 Effect of Forage Legumes Planted Fallow and Fertilizer Rates on the Wet and Dry Mean Weight Diameter of Soils.

The wet mean weight diameter (MWD) was significantly ($P \leq 0.05$) affected by forage legume planted fallow management practices, with fallow planted with *Macrotyloma uniflorum* having the highest value (0.40 g kg^{-1}), followed by that of *Centrosema pascuorum* (0.37 g kg^{-1}) and then control (0.33 g kg^{-1}) (Table 11). This suggests that the planted forage legumes enhanced soil aggregation better than the control. The high wet MWD value recorded under *Macrotyloma uniflorum* planted fallow could be attributed to the nature of *Macrotyloma uniflorum* to contribute high carbon materials to support more stable aggregates than the other treatments. Treatments with non – application of nitrogen 0 kg N ha^{-1} had significantly ($P \leq 0.05$) higher values of wet MWD. This could be attributed to increase in microbial derived agent produced by soil micro organism as a result of using N-fertilizer as a source of energy.

The dry MWD was also significantly ($P \leq 0.05$) affected by forage legume planted fallow management practices, with *Centrosema pascuorum* planted fallow having the highest value (1.37 g kg^{-1}), and followed by Natural vegetative regrowth (1.26 g kg^{-1}) treatment (Table 11). *Macrotyloma uniflorum* planted fallow had the lowest value (1.12 g kg^{-1}). This implies that fallow grown to *Centrosema pascuorum* stabilize macro aggregate than the other treatments probably through increased organic carbon content. High MWD values indicate resistance of soil to erosion because of high soil aggregate stability that allow for greater water storage and infiltration thereby protecting the soil from being dislodged by wind and water ((Unger,1997). Nitrogen and phosphorus rates did not significantly affect dry MWD, although 0 kg N ha^{-1} and 0 Kg P ha^{-1} treatments gave the highest values.

Table 11: Effects of forage legumes planted fallow and rates of fertilizers on mean weigh Diameter of wet and dry Savannah Alifisol.

Treatment	Wet sieve (g)	Dry sieve (g)
Legumes (L)		
Control	0.33b	1.26b
Centrosema	0.37ab	1.37a
Macrotyloma	0.40a	1.12c
SE±	0.02	0.03
Nitrogen(N) kg ha^{-1}		
0	0.40a	1.30
40	0.37ab	1.25
80	0.31b	1.20
120	0.39a	1.24
SE±	0.02	0.03
Phosphorus (P) kg ha^{-1}		
0	0.36	1.26
13.2	0.34	1.25
26.4	0.40	1.24
SE±	0.02	0.03
Interaction		
L X N	NS	NS
L X P	NS	NS
N X P	*	NS
L X N X P	NS	NS

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.
**- Significant*
NS- Not Significant

4.12 Effect of one year forage legumes planted fallow and fertilizer rates on stover and maize grain yield.

Dry matter of Maize yield following one year short fallow treatments (Table 12) shows that *Centrosema pascuorum* planted fallow treatment produced the highest maize stover yield (2.63 t ha^{-1}) than *Macrotyloma uniflorum* planted fallow (1.43 t ha^{-1}). The Natural vegetative regrowth produced the lowest stover yield (1.43 t ha^{-1}). This suggests that *Centrosema pascuorum* significantly ($P \leq 0.05$) improved maize dry matter better than the other treatments. Application of 80 kg N ha^{-1} gave the highest stover yield and suggests that 80 kg N ha^{-1} was efficiently utilized to produce significantly higher stover yield of maize. A significant ($P \leq 0.05$) interaction was observed in dry matter between legume and Nitrogen as well as Nitrogen and Phosphorus.

Maize cob weight was significantly higher (0.90 t ha^{-1}) with *Centrosema pascuorum* planted fallow than *Macrotyloma uniflorum* planted fallow (0.38 t ha^{-1}) and Natural vegetative regrowth (0.18 t ha^{-1}). This observed increase in maize cob weight could be attributed to enhanced soil conditions under *Centrosema pascuorum* that facilitated root growth and Improved nutrient uptake. The 80 kg N ha^{-1} nitrogen rate applied gave the highest cob weight though it was not significantly different from the other treatments.

Grain yield of maize was significantly higher with *Centrosema pascuorum* planted fallow (0.65 t ha^{-1}) compared to the one planted with *Macrotyloma uniflorum* (0.27 t ha^{-1}) and Natural vegetative regrowth (0.12 t ha^{-1}). This observed increase on grain yield could be attributed to improved soil environment for enhanced biological activity and nutrient cycling under the *Centrosema pascuorum* treatment. The N rate of 80 kg N ha^{-1} still produced the highest grain yield confirming it as the optimum rate that supported higher maize grain yield under *Centrosema pascuorum* one year short fallow.

The result for 1000 seed weight (Table 12) indicates that treatment planted with *Centrosema pascuorum* significantly affected 1000 seed weight. The 1000 seeds weight of crops produced under *Centrosema pascuorum* planted fallow was higher than the one planted with *Macrotyloma uniflorum*. This implies that *Centrosema pascuorum* planted fallow treatment produced better filled maize cob compared to others. The application of 80 kg N ha^{-1} had the highest 1000 seed weight (131.78 K g ha^{-1}).

Table 12: Effect of forage legumes planted fallow and fertilizer rates on dry matter and yield of maize.

	← Kgha^{-1} →			
Treatment	Dry matter	Grain Yield	WMCb	1000WS
Legumes (L)				
Control	889.8c	120.93c	177.09c	113.97c
Centrosema	2625a	648.33a	903.03a	142.33a
Macrotyloma	1432.6b	264.71b	378.59b	125.7b
SE±	130.15	28.86	52.41	5.36
Nitrogen(N) kg ha^{-1}				
0	1577.8b	344.57	503.61	126.32
40	1516.07b	325.68	457.04	130.67
80	1990.13a	399.26	552.73	131.78
120	1512.6b	309.11	431.56	124.55
SE±	150.28	29.86	60.52	6.19
Phosphorus (P) kg ha^{-1}				
0	1738.87	345.65	126.91	496.55
13.2	1607.4	339.72	125.65	473.83
26.4	1601.13	348.59	129.44	488.33
SE±	130.15	28.86	5.36	52.41
Interaction				
L X N	*	NS	NS	NS
L X P	NS	NS	NS	NS
N X P	*	NS	NS	NS
L X N X P	NS	NS	NS	NS

Means in a column of any set of treatments followed by unlike letters are significantly different at P ≤ 0.05 using DMRT.

**- Significant*

NS- Not Significant

1000WS- Weight of Seed, WMCb- Weight of Maize Cob

4.13: Regression of Nitrogen

Figure 16 shows the regression of Nitrogen on maize grain yield. The result obtained shows that maize grain yield increased as the Nitrogen fertilizer increased up to 100 kg N ha^{-1} where it reached its peak and the yield began to drop. This implies that 100 kg N ha^{-1} could be the optimum fertilizer application rate for maize grain yield under this study.

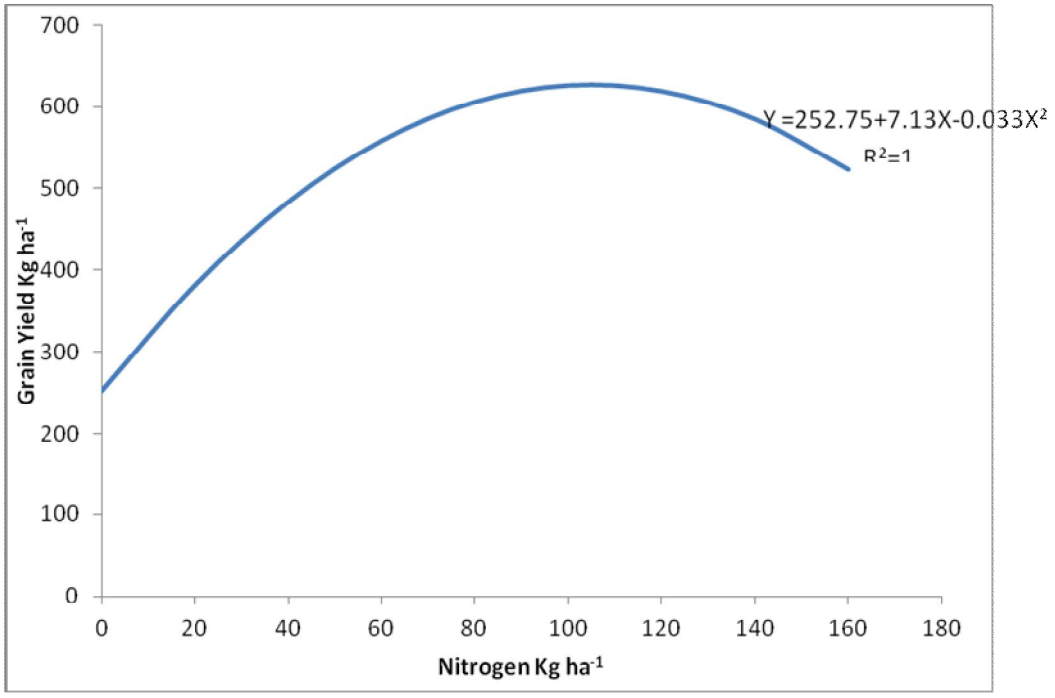


Figure 16: Regression of nitrogen on maize grain yield

4.14: Regression of Phosphorus

Figure17 shows the regression of Phosphorus on maize grain yield. The result showed that increase in Phosphorus Fertilizer rate increased maize grain yield up to 24.6 kg P ha^{-1} after which the grain yield began to drop. This implies that the optimum P fertilizer application rate for this was 24.6 kg P ha^{-1}.

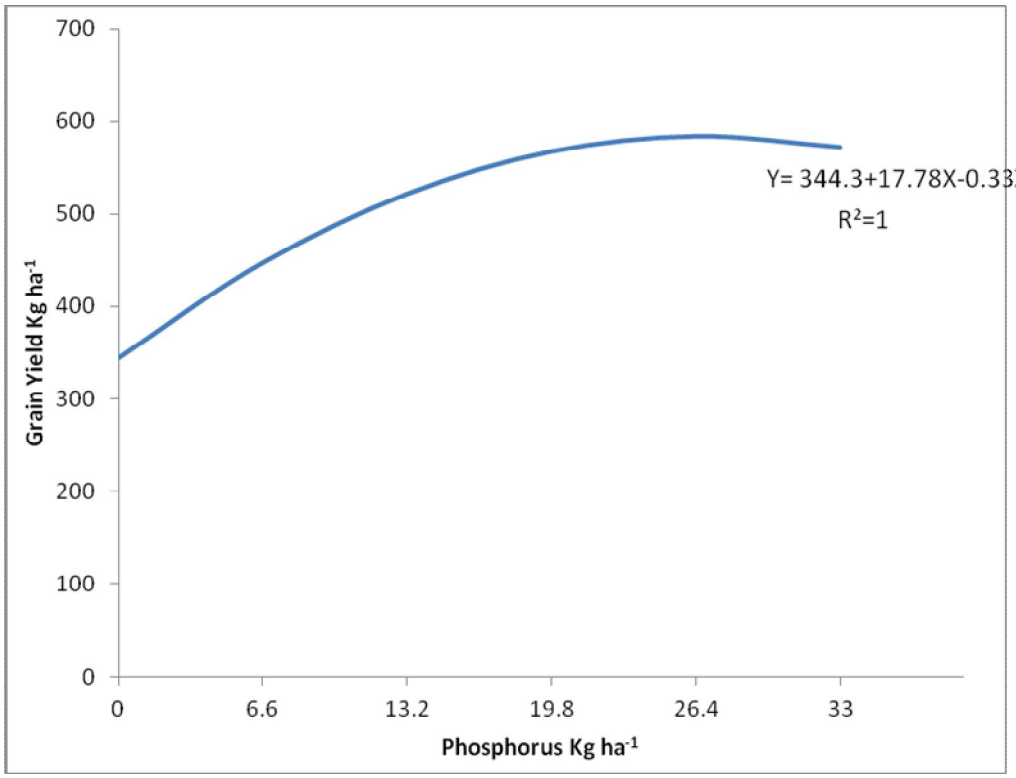


Figure 17: Regression of phosphorus on maize grain yield

4.15 Correlation Studies

The matrix of co-efficient of correlation between the nutrient contents of soil and some plant performance parameters are given in Table 13. The co-efficient of correlation between Nitrogen and all other parameters were negative and significant, except mean weight diameter of wet sieved soil (MWDWS). It is inferred that when N is increased it would lead to an increase in aggregate stability against water erosion. However, a decrease in N will increase the P-level, MBC, MBN, MBP etc. Perhaps, this could be attributed to increased biomass production following increased Nitrogen availability.

The co-efficient of correlation between Phosphorus and other parameters were all positive except SMBN, and carbon fraction at <50 µm. Stover, grain yield, plant height and number of leaves at 9WAS, showed positive and highly significant correlation with P rates. This implies that increase in P content in the soil will also increase the performance of all this above mentioned parameters. For instance increase in P improved the microbial activities thereby increasing MBP in the soil.

The co-efficient of correlation between stover yield and the other parameters were positive except for MBN that was negatively correlated though not significant. The correlation between grain yield, plant height and leave number at 9WAS, MBC, MBP, CF-A and CF-C were highly significant. This implies that an increase in these parameters could improve the performance of stover yield. As stover yield increase, grain yield also increased which suggest that photosynthetic processes of biomass affect the grain yield performance of maize.

Co-efficient of correlation between grain yield and all the parameters show positive correlation. For example, plant heights, number of leaves at 9WAS, MBC, MBP, MWDDS, CF-A, CF-C were highly correlated. This suggests that increase in the grain yield resulted

from increased activities of micro-organism acting on the organic matter to produce C and P needed by the crop.

The co-efficient of correlation between plant height at 9WAS and the other parameters were positive except with MWDWS that was negative. The correlation between Microbial biomass Nitrogen, Microbial biomass Phosphorus, CF-A and CF-C were highly significant. It could be inferred that increase in microbial biomass nitrogen activities greatly influenced the number of leaves at 9WAS.

The relationship between MBN and other parameters were positive, except with MBC and MWDWS that was negative. This suggests that increase in microbial biomass nitrogen could result in a decreased aggregate stability of the soil against water erosion and a reduction in carbon credit increase in Carbon Fraction with 500µm sieve size.

Correlation between microbial biomass carbons with the other parameters were positive and presented in Table 13 except for MWDDS which gave negative correlation. This could imply that increase in Microbial Biomass Carbon would result in increase the carbon fraction present in 500 µm sieve size thereby stabilizing 500 µm sieve size aggregates against wind erosion.

Correlation between microbial biomass phosphorus and the other parameters showed positive correlation, except CF-D that was negative. It would be inferred that increase in the MBP of the soil could decrease carbon credit in aggregates of <50 µm size.

Table 13: Correlation matrix of selected parameters

	N	P	DM	GY	PH	NL	MBN	MBC	MBP	MWDWS	MWDDS	CF-A	CF-C
N	1												
P	-0.23**	1											
DM	-0.27**	0.44**	1										
GY	-0.30**	0.39**	0.88**	1									
PH	-0.31**	0.40**	0.68**	0.70**	1								
NL	-0.24**	0.38**	0.63**	0.59**	0.80**	1							
MBN	-0.05NS	-0.01NS	-0.01NS	0.07NS	0.10NS	0.22**	1						
MBC	-0.09NS	0.13NS	0.30**	0.26**	0.07NS	0.10NS	-0.11NS	1					
MBP	-0.24**	0.39**	0.48**	0.43**	0.35**	0.28**	0.01NS	0.13NS	1				
MWDWS	0.02	0.04NS	0.08NS	0.03NS	-0.03NS	-0.05NS	-0.13NS	0.07NS	0.09NS	1			
MWDDS	-0.14NS	0.15NS	0.14NS	0.25**	0.22*	0.16NS	0.07NS	-0.12NS	0.09NS	-0.03NS	1		
CF-A	-0.19*	0.31**	0.46*s*	0.52**	0.42**	0.40**	0.10NS	0.31**	0.32**	0.01NS	0.30**	1	1
CF-C	-0.30**	0.25**	0.48**	0.46**	0.34**	0.28**	0.05NS	0.17NS	0.33**	0.04NS	0.33**	0.47**	-0.05NS	1

**- Significant*

*NS- Not Significant, **-Highly Significant*

N=Nitrogen, P=Phosphorus, Dm=Dry Matter, GY=Grain Yield, NL=Number of Leaves, PL=Plant Height, MBN= Microbial Biomass Nitrogen, MBC= Microbial Biomass Carbon, MBP= Microbial Biomass Phosphorus, MWDWS=Mean Weight Diameter Wet Sieve, MWDDS= Mean Weight Diameter Dry Sieve, CF-A=Carbon Fraction at 500µm, CF-C=Carbon Fraction at 50µm.

CHAPTER FIVE

5.0 SUMMARY AND CONCLUSION

5.1 Summary

The Northern Guinea Savanna is characterised by soils with inherent low fertility status. Following intensive use of these soils for crop and livestock production, the soils are being degraded by erosion, complete removal of both crop and residues, improper management practices and overgrazing. Natural vegetation regrowth (natural fallow); the traditional method of improving soil fertility and productivity in the Nigerian savanna, is no longer suitable and practicable for most farmers because of rapid population growth that makes arable land unavailable for this practice. Development of alternative management practices to maintain the productive capacity of these soils is paramount.

This study was therefore conducted to assess a short fallow technique using forage legumes (*Centrosema pascuorum* planted fallow and *Macrotyloma uniflorum* planted fallow) in comparison to a natural vegetation regrowth (control) for soil quality improvement and enhanced maize production. The forage legumes were used as live mulch planted for one year and soil samples were taken for analyses at three growth stages of the test-crop (maize). These samples were used to assess the extent to which the forage legumes one year fallow improved or enhanced soil qualities. Also the study determined fertilizer (N and P) requirements of subsequent maize crop planted after a year fallow practice and the influence of forage legume mulch on the yield of maize.

The total N contribution of the treatment were 4.8 g kg^{-1}, out of this 60.42%, 29.17% and 10.42% were contributed by NVR, CPF and MPF respectively. *Centrosema pascuorum* planted fallow mulch contributed significantly highest available phosphorus of about 70.13% compared to control (11.25%). This implies that under NVR and CPF total nitrogen and available phosphorus content of the soils would be increased. Soil carbon under NVR was

39.86% compare to CPF (35.14%) and followed by *Macrotyloma uniflorum* planted fallow (25%).

Exchangeable bases were also observed to increase under *Macrotyloma uniflorum* planted fallow treatment as compared to *Centrosema pascuorum* planted fallow treatment which in turn was higher than the natural vegetation regrowth treatment. Cation exchangeable cation values of 4.57 – 5.90 C mol kg^{-1} were considered low though NVR had 36.62% which is statistically the same with MPF (35.63%) followed by CPF (28.37%). Micronutrient Zn under CPF increased by 27.1% and 13.63% over control (NVR) and MPF respectively while, Fe was higher under NVR.

Centrosema pascuorum planted fallow treatment produced higher soil microbial biomass nitrogen 6.7 mg kg^{-1} while *Macrotyloma uniflorum* planted fallow had the highest soil microbial biomass carbon 38.5 mg kg^{-1} and CPF contributed highest soil microbial biomass phosphorus 12.72 mg kg^{-1}. CPF better enhanced particulate organic matter (590 mg kg^{-1}) with 2.53% increase over NVR and 9.49% increase over MPF. This implies that increase in microbial nutrients could increase the activities of microbial organism which in turn would improve organic matter in the soil. *Macrotyloma uniflorum* planted fallow mulch therefore increased microbial carbon of the soils better than the other treatments.

Centrosema pascuorum planted fallow sequestered more (0.65 g kg^{-1}) carbon than MPF (0.55 g kg^{-1}) in the 500 µm aggregates fraction. This was followed by NVR (0.47 g kg^{-1}). *Macrotyloma uniflorum* and NVR sequestered similar (0.59 g kg^{-1}) carbon content which was statistically the same with CPF (0.57 g kg^{-1}) in the 250 µm size aggregates. Considering 50 µm sized aggregates, NVR contributed the highest carbon (0.80 g kg^{-1}) in the aggregate sized class than the other treatment. With respect to the content of OC in <50 µm sized aggregates,

the forage legumes were not significantly different, However, MPF produced the highest carbon (0.72 g kg^{-1}) in the fraction.

Plant height of maize plants grown in three weeks old *Centrosema pascuorum* planted fallow and natural vegetative regrowth were statistically similar (24.81 and 24.71 cm respectively) Plants grown in three week old *Macrotyloma uniflorum* planted fallow was 23.62 cm. At 5WAP, there were no significant differences in maize plant heights among forage legume planted fallow treatment. AT 7WAP, *Centrosema pascuorum* planted fallow had the tallest plant (103.47 cm) followed by *Macrotyloma uniflorum* (83.08 cm), while natural vegetative regrowth had the least (80.49 cm). *Centrosema pascuorum* planted fallow produce the tallest plants (147.16 cm) at 9WAP, while the Natural vegetative regrowth had the least (111.43 cm).

Centrosema pascuorum planted fallow produced the highest leaf number though there were no significant difference between the treatments at 3, 5, 7 and 9 WAP. This suggests that *Centrosema pascuorum* treatment supported production of higher number of leaves compared to others.

Dry 2000 µm-sized soil aggregates (DA) was significantly ($P \leq 0.05$) influenced by fallow management practices where *Centrosema pascuorum* planted fallow recorded 3% increase over control. However, soils under natural vegetative regrowth recorded the lowest values followed by *Macrotyloma uniflorum*, probably because of the nature of the plant materials and contributions to soil aggregation. Dry 1000 µm- sized aggregates was significantly ($P \leq 0.05$) influenced by forage legume planted fallow. *Centrosema pascuorum* planted fallow produced higher amount of the aggregate fraction (0.25 g kg^{-1}) than natural vegetative regrowth (0.23 g kg^{-1}) followed by *Macrotyloma uniflorum* planted fallow (0.20 g kg^{-1}). The 500 µm- sized DA were significantly influenced by fallow management practices with the

highest values recorded under natural vegetative regrowth (0.026 g kg^{-1}). This was followed by *Macrotyloma uniflorum* (0.025 g kg^{-1}) while *Centrosema pascuorum* planted fallow (0.020 g kg^{-1}) plots significantly recorded the least values. The result implies that natural vegetative regrowth plots produced structurally stable 500 µm soil aggregates relative to other treatments. For DA 250 µm – sized aggregates natural vegetative regrowth recorded the highest values of aggregates with 29% increase over *Centrosema pascuorum* planted fallow that recorded the least value (0.007 g kg^{-1}) and was followed by *Macrotyloma uniflorum* (0.013 g kg^{-1}). For soil aggregates of 50 µm sized, *Macrotyloma uniflorum* planted fallow treatment resulted in the highest value which was 36% higher compared with control. It was observed that *Macrotyloma uniflorum* planted fallow enhanced the development of 50 µm size aggregates. Regarding dry soil aggregates of <50 µm, natural vegetative regrowth treatment recorded the highest values of 50% over the other treatments. *Centrosema pascuorum* planted fallow recorded the least value that was statistically similar with fallow planted with *Macrotyloma uniflorum*. This suggests that soils under *Centrosema pascuorum* and *Macrotyloma uniflorum* planted fallow would resist wind erosion because of low <50 µm aggregation better than natural vegetation regrowth.

Considering wet stable aggregates (WSA), the proportion of 2000 µm sized aggregate fraction was significantly ($P \leq 0.05$) affected by forage legume planted fallow *Centrosema pascuorum* recorded highest value (0.22 g kg^{-1}) and was followed by fallow planted with *Macrotyloma uniflorum* which were statistically similar. The proportion of 1000 µm - sized wet aggregates fraction was not significantly ($P \leq 0.05$) affected by forage legumes planted fallow. The WA 500 µm - sized fractions was significantly ($P \leq 0.05$) influenced by the fallow management practices; with highest values of WA 500 µm – sized WA recorded under

natural vegetative regrowth (0.020 g kg^{-1}) and 1.41% increase over *Macrotyloma uniflorum* planted fallow. Lower values were recorded under *Centrosema pascuorum* fallow treatments. Regarding 250 µm – sized WA fractions, they were significantly ($P \leq 0.05$) influenced by the fallow management practices. The highest values were recorded under natural vegetative regrowth (0.018 g kg^{-1}) with 13.89% increase over fallow planted with *Macrotyloma uniflorum. Centrosema pascuorum* fallow treatment recorded the least value. Among the forage legume planted fallow, *Macrotyloma uniflorum* treatment recorded the highest 50 µm – sized aggregates (0.103 g kg^{-1}) followed by *Centrosema pascuorum* planted fallow and then the (0.101 g kg^{-1}) control. It was observed that *Macrotyloma uniflorum* planted fallow enhanced the formation of 50 µm size aggregates better than the others. With respect to <50 µm – sized WA, there were no significant differences between forage legume planted fallow treatment.

The wet mean weight diameter (MWD) of *Macrotyloma uniflorum* fallow was highest (0.40 g kg^{-1}), followed by that of *Centrosema pascuorum* (0.37 g kg^{-1}) and then controls (0.33 g kg^{-1}). The dry MWD of aggregates under *Centrosema pascuorum* planted fallow was highest (1.37 g kg^{-1}), followed by natural vegetative regrowth (1.26 g kg^{-1}). *Macrotyloma uniflorum* planted fallow had the lowest value (1.12 g kg^{-1}). This implies that fallow grown to *Centrosema pascuorum* could better stabilize macro aggregate than the other treatments probably through increased organic carbon content.

The maize stover following one year short fallow treatments showed that *Centrosema pascuorum* planted fallow treatment resulted in the production of highest maize stover (2.63 t ha^{-1}). Weight of maize cob was also higher (0.90 t ha^{-1}) under *Centrosema pascuorum* planted fallow than *Macrotyloma uniflorum* planted fallow (0.38 t ha^{-1}).

Grain yield of maize under *Centrosema pascuorum* planted fallow was significantly higher (0.65 t ha^{-1}) compared to the maize under *Macrotyloma uniflorum* (0.27 t ha^{-1}). The result for 1000 seed weight was similar.

5.2 Conclusion

In conclusion, the short duration fallow with *Centrosema pascuorum* was more effective at replenishing soil organic matter build-up and a better soil amendment approach than other treatments. In the pre-experiment soil condition about 70% available phosphorus was added to the soil through CPF mulch contribution. 60% total nitrogen contributed by NVR under one year fallow management. From the regression analysis, 26.4 kg P ha^{-1} was suggested to be an optimum phosphorus fertilizer rate for maize growth. The 80 kg N ha^{-1} resulted in significantly higher ($P<0.05$) improved values for all parameters evaluated than the other N rates.

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Appendix I

FIELD LAYOUT

0 kg N ha^{-1}	40 kg N ha^{-1}	80 kg N ha^{-1}	120 kg N ha^{-1}	
P1	P3	P1	P2	Control
P3	P2	P3	P3	
P2	P1	P2	P1	
P3	P1	P2	P3	Centro
P1	P3	P1	P2	
P2	P2	P3	P1	
P3	P1	P2	P3	Macro
P1	P2	P1	P2	
P2	P3	P3	P1	

40 kg N ha^{-1}	120 kg N ha^{-1}	0 kg N ha^{-1}	80 kg N ha^{-1}	
P2	P1	P2	P3	Centro
P3	P3	P3	P2	
P1	P2	P1	P1	
P3	P2	P3	P1	Macro
P2	P1	P2	P3	
P1	P3	P1	P2	
P3	P2	P3	P1	Control
P2	P1	P2	P2	
P1	P3	P1	P3	

80 kg N ha^{-1}	40 kg N ha^{-1}	120 kg N ha^{-1}	0 kg N ha^{-1}	
P1	P1	P3	P2	Macro
P3	P3	P2	P3	
P2	P2	P1	P1	
P3	P2	P1	P3	Control
P1	P1	P3	P2	
P2	P3	P2	P1	
P3	P2	P1	P3	Centro
P1	P1	P2	P2	
P2	P3	P3	P1	

P 1 = 0 kg P ha^{-1} **P 2** = 13.2 kg P ha^{-1} **P 3** = 26.4 kg P ha^{-1}