World Journal of Agricultural Research, 2019, Vol. 7, No. 4, 119-123
Available online at http://pubs.sciepub.com/wjar/7/4/1
Published by Science and Education Publishing
DOI:10.12691/wjar-7-4-1

Carbon, Nitrogen, and Phosphorus Stocks from Fallow of Forage Legumes on Alfisols of Guinea Savanna Nigeria

Malgwi O.D.[1,*], Odunze A.C.[2], Otene I.J.J[1], Oluwagbemi C.O.[3], Muhammed B.[1]

[1]Department of Soil and Environmental Management, Faculty of Agriculture, Kogi State University Anyigba, Nigeria
[2]Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria
[3]Bioresources Development Centre, National Biotechnology Development Agency, Ogbomoso, Oyo State Nigeria
*Corresponding author: mrssmalgwi@gmail.com

Received August 14, 2019; Revised September 19, 2019; Accepted September 27, 2019

Abstract The aim of this study was to assess soil carbon (C), nitrogen (N), and phosphorus (P) stocks from fallow of two forage legumes: *Centrosema pascuorum* (Cp) and *Macrotyloma uniflorum* (Mu) on Alfisols of Guinea Savanna, Nigeria. The study was conducted at the Institute for Agricultural Research (IAR) experimental field Samaru Zaria, Nigeria (2008 to 2009). Treatment consisted of 3 plots (Cp planted, Mu planted, and control - natural vegetation regrowth). Plot size was 5 m * 3 m = 15 m^2 replicated three times for each treatment. Pre-experimental composite soil samples were taken with an auger at 0-15 depth. The soil samples collected were air-dried, grounded, sieved with a 2 mm sieve, and the less than 2 mm fraction was analysed for C, N, and P. The results of the analysis of soil organic C, total N, and available P were 6.1 gkg^{-1}, 0.53 $gkg\text{-}^{1}$, and 8.75 $mgkg\text{-}^{1}$ respectively. Soil pH was 5.9. The plots were left fallow for one year and again soil samples were collected at 0-15 cm depth and analysed. The results showed that Cp significantly improved and had higher soil available P (13.74 $mgkg^{-1}$) after one year followed by Mu (7.68 $mgkg^{-1}$) and control (4.6 $mgkg^{-1}$). On the other hand, the control plots significantly had highest soil organic C (5.9 $gkg\text{-}^{1}$) compared to 5.2 and 3.7 $gkg\text{-}^{1}$ from Cp and Mu. Similarly, higher total N (2.9 $gkg\text{-}^{1}$) was recorded from control plots compared to 1.4 and 0.5 $gkg\text{-}^{1}$ from Mu and Cp respectively. Results from this study indicate that one year fallow of cultivated Cp has potential to improve soil available P compared to Mu and natural vegetation regrowth. In terms of plant nutrient uptake, the N and P content of Mu was the highest (4.28 and 2.65 % respectively). The natural vegetation from the control plots had the lowest (1.95 %) N concentration. There was no significant difference in the P content of the natural vegetation from the control plots and Cp (1.92 and 1.84 % respectively). Fallow periods of more than a year of cultivated *Centrosema pascuorum* and *Macrotyloma uniflorum* or their incorporation into soils are suggested for further studies.

Keywords: *fallow, forage legumes, soil carbon, soil nitrogen, soil phosphorus*

Cite This Article: Malgwi O.D., Odunze A.C., Otene I.J.J, Oluwagbemi C.O., and Muhammed B., "Carbon, Nitrogen, and Phosphorus Stocks from Fallow of Forage Legumes on Alfisols of Guinea Savanna Nigeria." *World Journal of Agricultural Research*, vol. 7, no. 4 (2019): 119-123. doi: 10.12691/wjar-7-4-1.

1. Introduction

The continuous use of inorganic fertilizers especially under intensive agriculture can intensify problem of soil degradation [1,2]. Also, the availability and affordability of inorganic fertilizers to smallholder farmers constitutes major challenge to crop production. Fallow systems involving forage legumes grown or incorporated into soils is a sustainable method of crop production that enhances soil quality. This includes reduction in the reliance of external inputs such as the use of inorganic fertilizers. However, the increase in the demand for land for competing uses arising from increase in population might make fallow systems of land unrealistic. Therefore, the use of short fallow periods with legumes or grasses can be a sustainable soil quality management [3].

Adequate management of planted fallow legumes can significantly improve soil nutrient status of the soil mainly carbon, nitrogen, phosphorus concentration as well as organic matter [3,4,5]. Furthermore, it provides effective cover against erosion, suppress weeds and pests and improve soil physical conditions [6,7]. Enhanced soil N provided by forage legumes have been reported to improve the growth and yield performance of cereals cultivated after them [8,9,10]. The aim of this study was to assess soil carbon, nitrogen, and phosphorus stocks from fallow of two forage legumes: *Centrosema pascuorum* and *Macrotyloma uniflorum* on Alfisols of Guinea Savanna, Nigeria.

2. Materials and Methods

2.1. 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 [11]. The clay is predominantly Kaolinitic [12], and is typically high in iron (Fe) and aluminium (Al) oxides [13] and are of major agricultural importance [14].

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°C –23.17°C and 29.97°C – 38.43°C respectively [15]. 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 [15]. 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.

2.2. 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) - treatment consisted of 3 plots (Cp planted, Mu planted, and control - natural vegetation regrowth). Plot size was 5 m * 3 m = 15 m^2 replicated three times for each treatment in Randomized Complete Block Design (RCBD).

2.3. Soil Analysis

2.3.1. Sampling and Preparation

Pre-experimental and post-cropping composite soil samples were taken with an auger at depths 0-5 and 5-10 cm. The samples collected were air-dried, grounded and sieved with a 2 mm sieve. The less than 2 mm fraction was analysed for some chemical (organic carbon, total nitrogen, available phosphorus, pH) and physical properties (bulky density, total porosity, and hydraulic conductivity).

2.3.2. Determination of Bulk Density

Bulk densities for the soils were obtained by sampling with 5 cm by 5 cm cores as described by Anderson and Ingram [16]. 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:

$$Bulky\ density\ (g\ cm^{-3}) = \frac{Weight\ of\ oven\ dried\ soil\ in\ core - Weight\ of\ core}{Volume\ of\ Core}. \quad (1)$$

2.3.3. Determination of Saturated Hydraulic Conductivity (Ksat)

The saturated hydraulic conductivity was measured by the constant head method, using the 1CW laboratory permeameter (Eijikelkamp Agrisearch No. 09.02).

2.3.4. Determination of pH

The pH of the soil samples were measured in water and in 0.01M $CaCl_2$ solution, using the potentiometric (glass electrode) method [17].

2.3.5. Determination of Organic Carbon (OC)

The organic carbon contents of soil samples were determined using the Walkley-Black wet oxidation method [18].

2.3.6. Determination of Total Nitrogen (TN)

Total nitrogen was determined using the Kjeldahl method described by Bremner and Mulvaney [19].

2.3.7. Determination of Available Phosphorus (P)

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 and Kurtz [20] and Anderson & Ingram [16].

2.4. 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.

2.5. Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using GENSTAT Discovery software. Means were separated using Least significant Difference (LSD) at 5% probability level ($P<0.05$).

3. Results and Discussions

3.1. Effect of Fallow of Forage Legumes on Selected physical properties of Alfisols of Guinea Savanna Nigeria

The effect of fallow of forage legumes on selected physical properties (saturated hydraulic conductivity, bulk density, and total porosity) of Alfisols in Guinea Savanna of Nigeria (2008 – 2009 Field trials) is presented in Table 1. The results revealed no significant difference in the interaction between legumes cultivated and the depth at which soil samples were collected for the physical properties. After one year fallow, treatments did not show significant difference in bulk density. On the other hand, significant difference in the Ksat and total porosity was observed from the treatments applied. The control plots had lowest Ksat and total porosity (0.037 cmsec-1, and 46.48 % respectively) while the forage legumes plots were higher (Centrosema: Ksat = 0.145 cmsec-1, total porosity = 50.69 %; Macrotyloma: Ksat = 0.535 cmsec-1, total porosity = 51.20 %). This could be due to reduced bulk density, increased porosity and aeration caused by roots of the legumes, and increased organic matter from plant biomass as well as microbial activities [3,21,22,23,24]. There was no difference in Ksat and total porosity of Centrosema and Macrotyloma from one year fallow. Results showed higher (50.15 %) total porosity was observed at 5 – 10 cm depth compared to 48.76 % at 0-5 cm after one year fallow. This is in contrast to the results of Malgwi *et al.* [25] that porosity decreases gradually with depth to a value of 30 % or less in the studied area. A factor that might have influenced the total porosity in this study is cropping and/or tillage system - less intensively used soils or mechanically cultivated. To an extent, the cropping and tillage system also have influence on macroporosity of soils [26].

3.2. Soil Carbon, Nitrogen, and Phosphorus Concentrations from Fallow of Cultivated Forage Legumes on Alfisols of Guinea Savanna Nigeria

Soil carbon, nitrogen, and phosphorus concentrations from one year fallow of cultivated forage legumes on Alfisols of Guinea Savanna Nigeria is presented in Table 2. Highest pH (6.0), total nitrogen (2.9 g/kg), and organic carbon (5.9 g/kg) were recorded from the control plots. Highest phosphorus concentration (13.74 mg/kg) were recorded from centrosema plots followed by Macrotyloma (7.68 mg/kg), and control (4.64 mg/kg).

While the control plots had increase in pH from one year fallow period, plots planted to centrosema and macrotyloma had a decrease in pH. The pH of the soils is slightly acidic (5.8 – 6.0). The Nigerian guinea savanna soils are generally slightly acidic, less leached soils derived from precambrian crystalline basement complex rocks, the soils are generally coarse textured consisting of sandy loam or loam over gravelly clay loam [13].

There was an increase in the total nitrogen of the control and macrotyloma plots while centrosema plots had a decrease in total nitrogen from the one year fallow period. Furthermore, one year fallow period resulted in decrease in the carbon content of control and macrotyloma plots but increase in carbon was observed in the cetrosema plots. Also, it was evident that one year fallow period increased the phosphorus concentrations of plots planted to centrosma and Macrotyloma. Conversely, there was a decrease in the phosphorus concentration of the control plots from one year fallow period. The improved soil physical properties (Ksat and total porosity) observed in the centrosema and macrotyloma plots might have contributed to increased concentrations of phosphorus. Although it has been reported that the of fallow legumes can significantly improve soil carbon, nitrogen, phosphorus concentration as well as organic matter [3,4,5], the results from this study only affirms for increase in phosphorus concentrations.

Table 1. Effect of Fallow of Forage Legumes on Selected physical properties of Alfisols of Guinea Savanna Nigeria (2008 – 2009 Field trials)

Treatment	Saturated Hydraulic conductivity - Ksat ($cmsec^{-1}$)		Bulk Density (mgm^{-3})		Total Porosity (%)	
	Initial	After Fallow	Initial	After Fallow	Initial	After Fallow
Legumes (L)						
Control	0.42	0.037b	1.46	1.36	45.09	46.48b
Centro	0.10	0.145ab	1.42	1.32	46.04	50.69a
Macro	0.29	0.535a	1.43	1.34	45.98	51.20a
SE±	0.22	0.14	0.02	0.03	0.75	0.36
Soil Depth (D) (cm)						
0-5	0.32	0.11	1.41	1.36	46.28	48.76b
5-10	0.23	0.37	1.45	1.32	45.12	50.15a
SE±	0.18	0.11	0.024	0.025	0.61	0.29
Interaction (L*D)	NS	NS	NS	NS	NS	NS

Note: Control = Natural vegetative regrowth, Centro = Centrosema pascuorum, Macro = Macrotyloma uniflorum
Means in a column of any set of treatments followed by unlike letters are significantly different at $P \leq 0.05$.

Table 2. Soil carbon, nitrogen, and phosphorus concentrations from fallow of cultivated forage legumes on Alfisols of Guinea Savanna Nigeria

Trt	pH		Total N (gkg^{-1})		Available P ($mgkg^{-1}$)		Organic C (gkg^{-1})	
	Init.	After F.	Init.	After F.	Init.	After F.	Init.	After F.
Control	5.9	6.0a	0.53	2.9a	8.75	4.64c	6.8	5.9a
Centro	6.0	5.9b	0.88	0.5c	8.75	13.74a	4.4	5.2b
Macro	5.9	5.8c	0.53	1.4b	5.25	7.68b	4.2	3.7c
SE±	-	0.02	-	0.14	-	1.83	-	0.11

Note: Trt = Treatment, Total N = Total Nitrogen, Available P = Available Phosphorus, Organic C = Organic Carbon, Init. = Initial, After F. = After Fallow, Control = Natural vegetative regrowth, Centro = Centrosema pascuorum, Macro = Macrotyloma uniflorum
Means in a column of any set of treatments followed by unlike letters are significantly different at $P \leq 0.05$.

3.3. Nutrient (Nitrogen and Phosphorus) Uptake of Forage Legumes in Alfisols of Guinea Savanna, Nigeria

The nutrient uptake (nitrogen and phosphorus) from one year fallow (2008 – 2009) of forage legumes in Alfisols of Guinea Savanna Nigeria is presented in Table 3. The nitrogen and phosphorus content of Macrotyloma was the highest (4.28 and 2.65 % respectively). The natural vegetation from the control plots had the lowest (1.95 %) nitrogen concentration. The nitrogen content from one year fallow period observed in this study was higher compared to the range of 2.0 to 2.19 % reported from two years fallow period in the same region by Odunze *et al.* [27]. There was no significant difference in the phosphorus content of the natural vegetation from the control plots and centrosema (1.92 and 1.84 % respectively). The results indicated that *Macrotyloma uniflorum* had higher nutrient uptake (nutritional quality) compared to *Centrosema pascuorum* and natural vegetation in the studied location. In addition to the nutritional quality that *Macrotyloma uniflorum* can offer to livestock from their fallow period(s), their large groundcover can provide soil quality benefits such as soil aggregate development and soil moisture conservation [27,28].

Table 3. Nutrient (nitrogen and phosphorus) uptake from fallow of forage legumes in Alfisols of Guinea Savanna, Nigeria (2008 – 2009)

Treatment	Nitrogen (%)	Phosphorus (%)
Control	1.95c	1.92b
Centro	3.41b	1.84b
Macro	4.28a	2.65a
SE±	0.21	0.17

Note: Control = Natural vegetative regrowth, Centro = Centrosema pascuorum, Macro = Macrotyloma uniflorum
Means in a column of any set of treatments followed by unlike letters are significantly different at $P \leq 0.05$.

4. Conclusions

This study assessed soil carbon, nitrogen, and phosphorus stocks from fallow of *Centrosema pascuorum*, *Macrotyloma uniflorum*, and natural vegetation regrowth on Alfisols of Guinea Savanna, Nigeria. The results revealed that one year fallow period resulted in decrease in the carbon content of natural vegetation regrowth and macrotyloma. Increase in carbon content was observed in the plots planted to cetrosema. Also, it was evident that one year fallow period increased the phosphorus concentrations of plots planted to centrosma and Macrotyloma. Conversely, there was a decrease in the phosphorus concentration of the control plots from one year fallow period. In terms of plant nutrient uptake, the results indicated that *Macrotyloma uniflorum* had higher nutrient uptake compared to *Centrosema pascuorum* and natural vegetation. Fallow periods of more than a year of cultivated *Centrosema pascuorum* and *Macrotyloma uniflorum* or their incorporation into soils are suggested for further studies.

References

[1] Marinari, S., Masciandaro, G., Ceccanti, B., & Grego, S, Influence of organic and mineral fertilisers on soil biological and physical properties. *Bioresource technology*, 2000, *72*(1), 9-17.

[2] Ayoola, O.T. and Makinde, E.A., Complementary Organic and Inorganic Fertilizer Application: Influence on Growth and Yield of Cassava/maize/melon Intercrop with a Relayed cowpea. *Australian Journal of Basic and Applied Sciences*, 2007, 1(3), 187-192.

[3] Udom, B. E., & Omovbude, S., Soil physical properties and carbon/nitrogen relationships in stable aggregates under legume and grass fallow. *Acta Ecologica Sinica*, 2019, *39*(1), 56-62.

[4] Hubbard, R. Strickland, T.C., and Phatak, S.I., Effects of cover crop systems on soil physical properties and carbon/nitrogen relationships in the coastal plain of southern USA. *Soil Tillage Res.* 2013, 126, 226-283.

[5] Udom, B. E., & Ogunwole, J. O., Soil organic carbon, nitrogen, and phosphorus distribution in stable aggregates of an Ultisol under contrasting land use and management history. *Journal of Plant Nutrition and Soil Science*, 2015, *178*(3), 460-467.

[6] Sanchez, P.A., Improved fallows come of age in the tropics. *Agroforestry Systems*, 1999, 47: 3-12.

[7] Smith, W. N., Grant, B. B., Campbell, C. A., McConkey, B. G., Desjardins, R. L., Kröbel, R., & Malhi, S. S., Crop residue removal effects on soil carbon: Measured and inter-model comparisons. *Agriculture, ecosystems & environment*, 2012, 161, 27-38.

[8] Tian, G., Kolawole, G.O., Kang, B.T., and Kirchhof, G., Nitrogen fertilizer replacement indexes of legume cover crops in the derived savanna of West Africa. *Plant and Soil* 2000, 224, 287-296.

[9] Yusuf, A.A., Abaidoo, R.C., Iwuafor, E.N.O., Olufajo, O.O., and Sanginga, N., Rotation effects of grain legumes and fallow on maize yield, microbial biomass and chemical properties of an Alfisol in the Nigerian savanna. *Agriculture, Ecosystems and Environment* 2009, 129, 325-331.

[10] Nezomba, H., Tauro, T.P., Mtambanengwe, F., and Mapfumo, P., Indigenous legume fallows (indifallows) as an alternative soil fertility resource in smallholder maize cropping systems. *Field Crops Research* 2010, 115, 149-157.

[11] Klinkenberg, K and Higgings G.M., An outline of northern Nigeria soil methods of fertilization by maize in the southern Guinea Savanna. 1968.

[12] Ojanuga, A. G., Clay Mineralogy of Soils in the Nigerian Tropical Savanna Regions. *Soil Science Society of America Journal*, 1979, *43*(6), 1237-1242.

[13] Esu, I. E. and Ojanuga, A. G., Morphological physical and chemical Characteristics of Alfisols in the Kaduna Area of Nigeria. *Samaru Journal of Agricultural Research* 1985, 31: 39-49.

[14] Agbenin, J.O. and Goladi, J.T., Carbon, nitrogen and phosphorus dynamics under continuous cultivation as influenced by Farmyard manure and inorganic fertilizers in the Savanna of Northern Nigeria. Agriculture, *Ecosystems and environment*, 1979, 63: 17-24.

[15] Anosike, R.N., Assessment of the main methods for estimating potential evapotranspiration at Samaru in Northern Guinea Savanna Zone Nigeria. Unpublished Ph.D thesis, Ahmadu Bello University Zaria 1999, 189pp.

[16] Anderson J.M. and Ingram I.S., Tropical Soil Biology and Fertility: A Handbook of Methods. 2nd edition. C.A.B International Walling-ford UK. 1993.

[17] Rhoades, J.D., Soluble salts. In: Page, A.L. et al., (ed.). Methods of soil analysis. Part 2. Chemical and microbial methods. 2nd edition. Agronomy Monograph, 9. ASA and SSSA, Madison. WI. 1982.

[18] Nelson, D.W. and Sommers, L.E., Total carbon, organic carbon and organic matter. In: Page, A.L., R.H. Miller and D.R. Keeney (eds.) Methods of soil analysis. Part 2 *American Society of Agronomy, Madison*, 1982, 539-579.

[19] Bremner, J.M. and Mulvaney, C.S., Nitrogen total. In: Page, A.L., Miller, H. and Keeney, D.R. (eds.) Methods of Soil Analysis part 2 chemical and Microbiological Properties. *American society of Agronomy, Madison* W.I., 1982, 595-641.

[20] Bray, K.H. and Kurtz, L.T., Determination of total organic and available forms of phosphorus in soils. *Soil Sci.* 1945, 59, 39-45.

[21] Blair, N., & Crocker, G. J., Crop rotation effects on soil carbon and physical fertility of two Australian soils. *Soil Research*, 2000, *38*(1), 71-84.

[22] Sultani, M. I., Gill, M. A., Anwar, M. M., & Athar, M., Evaluation of soil physical properties as influenced by various green manuring legumes and phosphorus fertilization under rain fed conditions. *International Journal of environmental Science & Technology*, 2007, *4*(1), 109-118.

[23] Schultze-Kraft, R., Rao, I. M., Peters, M., Clements, R. J., Bai, C., & Liu, G., Tropical forage legumes for environmental benefits: An overview. *Tropical Grasslands-Forrajes Tropicales*, 2018, *6*(1), 1-14.

[24] Boddey, R. M., de Carvalho, I. D. N., Rezende, C. D. P., Cantarutti, R. B., Pereira, J. M., Macedo, R., ... & Urquiaga, S.,. The benefit and contribution of legumes and biological N. *Forages in Warm Climates*, 2015, 103.

[25] Malgwi , W. B., Ojanuga, A. O., Chude, C. O., Kparmwang, T., Raji, B. A., Morphological and physical properties of some soils of Samaru, Zaria, Nigeria. *Nigeria Journal of Soil Resource* 2000, 1**,** 58-64.

[26] McKenzie, N. J., Cresswell, H., and Coughlan, K., Soil physical measurement and interpretation for land evaluation: A laboratory handbook. CSIRO Publishing: Melbourne. 2002.

[27] Odunze, A. C., Tarawali, S. A., de Haan, N. C., Akoueguon, E., Amadji, A. F., Schultze-Kraft, R., & Bawa, G. S., Forage legumes for soil productivity enhancement and quality fodder production. *Journal of Food Agriculture and Environment*, 2004, *2*, 201-209.

[28] Maruthi, V., Reddy, P. R., Reddy, K. S., Reddy, B. M. K., & Saroja, D. G. M., Agronomic management of CRIDA-18R-a new variety of horse gram (Macrotyloma uniflorum) for South India matching monsoon patterns of rainfall. *Legume Research: An International Journal*, 2018, *41*(1).