Gombe Journal of Geography and Environmental Studies (GOJGES)

Vol. 2 N0.1 Jun. 2021

e-ISSN: 2714-321X

p-ISSN: 2714-3201

http://www.gojgesjournal.com

Gombe Journal of Geography and Environmental Studies (GOJGES) Vol. 2 N0.1 Jun. 2021, e-ISSN: 2714-321X; p-ISSN: 2714-3201

SOIL ORGANIC MATTER BUILD UP IN FALLOW FIELDS AND ITS IMPLICATION ON SOME SOIL FERTILITY INDICATORS IN KAFIN MADAKI AREA BAUCHI STATE

[1]Faruk A., [2]Olowolafe E.A and [3]M. S. Ibrahim

[1,3]School of General Studies, Abubakar Tatari Ali Polytechnic Bauchi, Nigeria
[2]Department of Geography and Planning, University of Jos, Nigeria

Corresponding Author's Email/Phone:**farukaliyuahmad@gmail.com, 08069255100**

Abstract

Although duration of fallow in West Africa is gradually decreasing due to rapid increase in human population of the region, the rate at which the system improves soil organic matter accumulation in Alfisols and the impacts of land use during fallow on properties of soil fertility indicators is still scarcely discussed in literature. Therefore, this study is aimed to assess impact of fallow length on organic matter accumulation and its implication on some soil fertility variables in Kafin Madaki area Bauchi State. Farm plots placed under fallow for 12, 7 and 3 years were chosen for the study. Surface soil samples (0-10 cm) were randomly taken for laboratory analysis of soil organic matter (SOM), total nitrogen (TN), available phosphorus (AP), exchangeable calcium (Ca), magnesium (Mg) and potassium (K). The data obtained were subjected to mean, correlation and analysis of variance (ANOVA) with SPSS version 18. The results show that the content of SOM in the soils is low even though a slow and gradual increase in its volume most especially from 3 to 7 years of fallows was noticed. The duration of fallow had insignificant impact on SOM (p=0.745), AP (p=0.244), Mg (p=0.296), TN ((p=0.215), K (p=0.594) and Ca (p=0.157). The relationship between fallow period and soil fertility variables were positive, weak to moderate (r=0.12-0.40) and not statistically significant (p=0.08 – 0.58). Similarly, SOM correlate significantly positive with AP (r=0.7, p=0.00), moderately significant with Mg (r=0.4, p=0.05) and weak to moderate with TN, K and Ca (r=0.12-0.36, p=0.26-0.58). Therefore, for improved food sufficiency in the area, an integrated soil fertility management practice is recommended.

Keyword: fallow, SOM, soil fertility, Kafin Madaki

1. Introduction

World over, there is a growing attention toward maximizing food production in an attempt to meet up with increasing demand posed by population growth. In order to achieve productivity in agricultural product however, soil fertility is important for success of the drive. The role of soil organic matter (SOM) and inorganic fertilization was studied (Chaturvedi, 2005), those of biodiversity and soil productivity (Delgado-

Baquerizo et al., 2017), the role of tree foliage of Locust bean and Neem on soil fertility (Eleno, 2002) as well as the impact of composed cattle manure on soil fertility and productivity (Das et al., 2017) were discussed. Consequently, in most of the tropical agricultural system, maintenance of SOM is understood to be a sustainable soil fertility and productivity management scheme (Eleno, 2002) probably due its role in nutrient build up, increased cation exchange capacity and reduced capacity of phosphorus fixation in soils with iron and aluminum oxide (Erika, 2006). It was also mentioned that in West African Alfisol, SOM accounts for 80% of CEC, available P, K, Mg, and Ca (Aweto, 2016).

Concerning the impact of land use on soil properties, Delgado-Baquerizo et al., (2017) studied the relationships between grazing in agricultural setting on soil infiltration rates, air permeability, soil compaction and surface cover dynamic. The effects of burning and grazing on vegetation cover, soil organic carbon, nitrogen content and biological activities were discussed (Yong-Zhong et al., 2005) while those on soil Mg, Na, P and Mn (Neff et al., 2005). Deterioration of some soil physical properties as well as modification and variability of vegetation community, SOM, TN and P as a result of bush fires and indiscriminate grazing of animals were discussed (Zhou et al., 2010; Li et al., 2005). However, investigation on impacts of grazing on soil organic matter build up during fallow in Northern Savanna areas of Nigeria is scantly available in literature hence this research is set to identify the impact of grazing on the accumulation of soil organic matter in fields committed to fallow management system. Specifically, the study sought to describe the trend of soil organic matter build-up during fallows, compare the SOM and some soil fertility indicators during fallows, investigate the relationships between fallow duration and soil properties and find out the relationship between SOM and other soil fertility indicators

2. Study area

The study was carried out in Kafin Madaki area Bauchi State, located between Latitude $10^0$31’ N and $10^0$11’ E. The dominant inhabitants are peasant farmers who produce crops such as sorghum, millet, beans, maize, groundnut and sesame mainly for family consumption, though some of the farms produce are taken to market in order to meet up with pressing domestic needs. Majority of the farmlands were acquired through inheritance and purchase from the original owners. The climate in the area is typical tropical dry and wet type with annual rainfall amount of up to 1031 mm and occurs in 5 – 6 months (May – October). Rainfall in the area is generally characterized by an average of two weeks dry spell occurring either from the beginning or toward the end of the rainy season. The temperature condition ranges from warm to hot (27^0c – 35^0c) throughout the year though a slight decline occurs (20^0c – 25^0c) in December – February of every year. The geological formation of the area remains a Precambrian basement complex of the north central Nigeria which constitutes gneiss and granite. The gently undulating nature of the terrain is intercepted with pockets of isolated rock outcrops with height ranging from 400 – 600 meters above mean sea level. The soil is poorly leached ferruginous type that is classified as Alfisols

or Ultisols (USDA, 1999) while the tropical Sudan Savanna consisting of Seyal onogeissus , Acacia albida. Afzella Africana and Adansonia digitata remained the dominant vegetation of the area (BSADP, 1983)

3. Materials and Methods

The farm plots which are placed under different lengths of fallow duration were identified during reconnaissance survey out of which those of 12, 7 and 3 years were considered for this study. The soil characteristics in selected fallow plots were ranked and compared, however, due to lack of available mature secondary vegetation community in the area that is greater than 12 years, a control site for assessing the extent of soil organic matter accumulation was not included. Consequently, the parent materials, climate, gradient of the slope and land use type on the fallow soils were similar, and any changes in soil properties noticed can be related to fallow duration only.

In order to track the impact of grazing and field burning during fallow, sampling was done at the peak of dry season (before the onset of rainfall). Each farm plot chosen for the study was divided into 6 grids, within each grid, a total of six sampling sites were chosen randomly by throwing a white colored stone up six times. A sample was taken at a point where the white colored stone landed. The six surface samples (0-10cm) taken from one grid were then thoroughly mixed to form a composite sample out of which a sizeable content was taken. The same procedure was followed in the other five grids of a farm plot. This therefore means that in each farm plot a total of 6 soil samples were taken making the total of 18 composite samples in the whole 3 farm plots. The samples were air dried, crushed, sieved through 2 mm sieve meshS, packaged, labelled on the polythene bag and then analyzed for the following soil properties: organic matter, total nitrogen, available phosphorus, calcium, magnesium, and potassium. For soil organic matter, Black (1965) procedure was followed in organic matter determination. The total nitrogen was determined by Kjeldahl method. Firstly, solution of the nitrogen in the soil was converted to ammonium sulphate by reacting the solution with H_2SO_4 and hydrogen peroxide. The resultant ammonium was titrated with standard acid to yield the nitrogen. Available phosphorus was determined by Bray and Kurtz, (1945) method which involved the use of diluted dihydrochloric acid to extract phosphorus. The exchangeable calcium, magnesium and potassium were determined by the neutral ammonium acetate procedure.

Data obtained were subjected to mean statistics, relationship between fallow duration and soil fertility indicators as well as those between soil organic matter and other soil fertility variables were obtained using Spearman's correlation while comparison of the soil properties across follow periods was done using analysis of variance (ANOVA).

4. Results and Discussion

4.1 Pattern of soil organic matter accumulation

Mean value and significant level of some soil fertility variables under different fallow period were presented in Table 1. The table reveals that contents of SOM in soils under 3, 7, and 12 years fallow were rated as low. The mean SOM levels during 3, 7, and 12 years fallow period were 1.2186%, 1.5900% and 1.4388% respectively. Concerning the patterns of SOM changes in the soils during fallow period, there was a slow and gradual increase of the variable with further increase in the duration of fallow length. In soils under fallow for 3 years, a slight accumulation was noticed. Thereafter, the peak development occurred in soils under 7th years of fallow, after which a slight decline in SOM build up was noticed in soils placed under fallow for 12 years (Table 1).

Table 1: The mean and p- value of soil organic matter and other soil fertility indicators under fallow periods

Soil characteristics	3 years fallow	7 years fallow	12 years fallow	*p*
Soil organic matter (SOM)	1.2186	1.5900	1.4388	0.745
Available phosphorus (AP)	7.5000	6.2500	5.3638	0.244
Magnesium (Mg)	1.0000	1.1771	1.3200	0.296
Total nitrogen (TN)	0.0328	0.0801	1.4300	0.215
Potassium (K)	0.3357	0.2743	0.2438	0.594
Calcium (Ca)	3.3814	4.5543	4.1713	0.157

P – Value generated from ANOVA

Low SOM rating of the soils is in conformity to ILACO (1985) and London (1991) who classified SOM content ranging from 1.0% - 2.0% as low. This shows that the buildup of SOM in Alfisols during fallow in Savanna vegetation region is relatively slow, possibly as a result of removal of vegetation resources which are the main sources of SOM by uncontrolled grazing of ruminant animals as well as destruction of organic materials by routine annual bush fires in the fallow field on one hand and a slow growth of the vegetation in the area on the other hand. Other factor for low SOM status in the soils may be attributed to high temperature condition of the area due to tropicality. Similar view was reported by Olowolafe (2008). The buildup of SOM was faster in the south western areas of Nigeria (Aweto, 1981) possibly due to large supply of organic materials by the luxuriant vegetation of the forest biome in the area.

The gradual increase in SOM most especially from the 3rd year to 7th year of fallow may be attributed to the fact that grasses which is the dominant vegetation in the area, as well as shrubs which develops during secondary succession in the fallow fields provide roots, leaves that are converted quickly into SOM during dry spells. Also, such a steady increase may be seen as a signal for development of the secondary vegetation community. The rapid development of soil organic matter during first few years of fallow was reported (Vine, 1968). The slight

decline in build-up of SOM in soils under 12 years of fallow may be attributed to the fact that vegetation colonizers at that level of succession grows and provide a patchy surface cover which hinders direct breakdown of litters which are the main sources of SOM. Mendoza-Vega & Messing (2005) noted that, young fallow significantly impacted CEC and other soil fertility variables than shrubs and tree fallow. Other reason for the decline may be associated more intense grazing and removal of secondary regrowth vegetation for the purpose of domestic uses; such as power generation, fencing and roofing of homes. Conversely, it is still not clear whether the decline in SOM as noticed in the soil under 12 years of fallow will continue to be so since the fallow field which is greater than 12 years is scarcely available in the area, though, according to Aweto (1981) the canopy of the woody plants has a great capacity to shielding soil surface from the direct beam of sunlight the scenario which reduces the oxidation of SOM.

4.2 Comparison of SOM and some soil fertility indicators during fallow

Table 1 presents the mean and p – values of SOM, AP, Mg, TN, K and Ca of soils placed under fallow for 3, 7, and 12 years. Result from ANOVA reveals that the duration of fallow had no significant impact on SOM ($p = 0.745$), AP ($p = 0.244$), Mg ($p = 0.296$), TN ($p = 0.215$), K ($p = 0.594$) and Ca ($p = 0.154$). The trend of changes in soil properties indicated a gradual increase in Mg and TN with increase in fallow duration. K and AP decreased with increase in fallow length while SOM and Ca content firstly increased gradually from 3 years of fallow to the peak in 7 years fallow soils after which a slight decline was recorded in 12 years fallow soils (Table 1).

No significant difference in soil fertility indicators during resting period show that the fallow duration in Alfisols of tropical dry and wet Savanna areas had little impact on SOM accumulation in the area. This was perhaps due to the practice of open grazing and wild fires the farmlands were subjected to during resting period. This finding was supported by Youmg-Zhong (2005) who reported a degrading effect of grazing on the accumulation of organic carbon and nitrogen in tropical savanna regions. This would indicate that, under open grazing and perennial burning in tropical Savanna vegetation area, the duration of fallow plays lesser role in soil fertility recovery.

4.3 Relationships between fallow duration and Soil fertility indicators

The relationship between fallow duration and soil fertility variables such as SOM, AP, TN, exchangeable Ca, Mg and K were studied. The result showed that, there was no significant association between fallow duration and soil fertility indicators measured. A very weak correlation however existed between fallow length, SOM and K while a weak to moderate correlation occurred between fallow length, AP, TN, Mg and Ca (Table 2).

Table 2: Relationship between fallow duration and some soil properties

Fertility variables	r	*p*
Soil organic matter (SOM)	0.14	0.52
Available phosphorus (AP)	0.31	0.16
Magnesium (Mg)	0.40	0.08
Total nitrogen (TN)	0.34	0.13
Potassium (K)	0.12	0.58
Calcium (Ca)	0.30	0.19

P – Value from Spearman's rank correlation

This shows that the increase in fallow duration contributed very little to the increase in soil fertility indicators. Although all indicators increased positively with increase in the duration of fallow, the rate of increase in AP, Mg, TN and Ca with increase in fallow duration was higher than those in SOM and K. Perhaps this was due to type of land use the fallow fields were engaged during resting periods. These which include open grazing of ruminant animals, the vegetation type (savanna), hand removal of secondary vegetation from the fallow fields as well as perennial burning which occur in the area during dry seasons. These results however differ with those observed by Javier et al., (2013) who reported a significant increase in organic carbon, nitrogen, phosphorus and potassium concentration with increase in fallow duration, perhaps due to the decay of abundant above-ground biomass of the forest. Similar view of significant increase in SOC with increase in fallow duration (most especially after 2 or 3 years of fallow) was reported by Tian et al., (2005) while increase in organic matter, total nitrogen and CEC with increase in fallow period were presented by Mendoza, (2005). Therefore, since the biomass of the vegetation which grow and provide litter during fallowing remained the most important source of exchangeable cations, SOM, TN and AP (Manjunatha & Singh, 2020), removal of the vegetation directly by hands or through grazing and fires may greatly negate increase in fertility recovery process during fallowing

4.4 Relationship between SOM and other soil fertility indicators

The data in Table 3 shows simple correlation between SOM and other soil fertility indicators in the top soils during fallows. It can be observed that SOM exerted a very strong effect on available phosphorus, a moderate effect on Mg, while weak to very weak correlation existed with TN, K and Ca. The moderate to weak increase in soil fertility indicators with increase in SOM suggests pattern of build-up in SOM during fallow, as well as nature of the parent material in the area. Aweto (1981) observed higher correlation between SOM and other soil nutrients in Kaolinite parent material. The strong influence between SOM and AP may be attributed to the inorganic fertility (NPK 10-15-15) used by the farmers before commencement of fallow which contain phosphorus. This was evident from the mean value of P in Table 1 which shows high concentration of element in the first 3 years of fallow after which a gradual decline with increase in fallow length was noticed. Olowolafe (2008) noted that the unique immobile characteristic of phosphorus

element may have a residual effect in soil. Therefore, the influence SOM exerts on basic cations and other soil nutrients depend largely on its magnitude in the soil.

Table 3: Relationship between SOM and other soil fertility variables

Fertility variables	Correlation with SOM r	*p*
Available phosphorus (AP)	0.736	0.00
Magnesium (Mg)	0.415	0.05
Total nitrogen (TN)	0.249	0.26
Potassium (K)	0.364	0.09
Calcium (Ca)	0.124	0.58

P – Value from Pearson correlation

5. Conclusion

The study set out to investigate soil organic matter build up in Alfisols during fallow and the implication of its change in some soil fertility indicators. In order to achieve this, the trend of organic matter during fallows, the relationships between fallow duration, organic matter build-up and changes in some soil fertility indicators, examination of the significant difference in SOM and other indicators during fallow periods as well the impact of soil organic matter on other soil fertility indicators were investigated. The main findings of the study suggests that build-up of organic matter during fallow periods in the study area was to some extent low or very low and was characterized by steady increase at the early stage after which the decline occurred in later stage. The amount of soil organic matter and soil fertility indicators increased slightly with increase in duration of fallows, both soil organic matter, total nitrogen, available phosphorus, calcium, magnesium and potassium show no significant changes in amount with increase in fallow duration. A strong and significant relationship was observed between organic matter contents and available phosphorus while a weak to moderate insignificant correlation existed with total nitrogen, calcium, magnesium and potassium. This raised the question on whether replenishment of soil fertility by fallow management system on tropical Savanna Alfisols was sustainable. Therefore, for improved food production in the already rapidly growing population, the integrated soil fertility management practice is recommended. However, this finding may be unique to soil organic matter accumulation during fallows on Alfisols in the tropical Savanna climate of West Africa. A control site was not observed due to lack of its availability in the area. Intensity of grazing and perennial burning was also assumed to be the same in all fallow fields, while it was still not clear whether the decline in amount of soil organic matter at the latter stage of fallow was a continuing one. This therefore shows that, although the study found a slight increase in soil organic matter with increase in fallow duration and that other soil fertility indicators were influenced slightly by changes in soil organic matter in the area. Future study is required to gain better understanding on the role of land use intensity during fallow and its implication on soil organic matter build-up.

References

Aweto, A. O. (1981). Organic matter build-up in fallow soil in a part of South-Western Nigeria and its effects on soil properties. *Journal of Biogeography*, *8*(1), 67–74.

Black, A. A. (1965). *Method of Soil Analysis. Agronomy Service No. 9. American Society of Agronomy. Incorporated. Medison Wisconsin*.

Bray, R. H., and Kurtz, J. (1945). *Determination of total nitrogen and available phosphorus in soil science*. *1*(1), 35–39.

BSADP. (1983). *Bauchi state agricultural development programme: Zonal and development area statistics*.

Chaturvedi, S. (2005). Influence of organic and inorganic fertilization on soil fertility of Soyabeen. *Jounal of Agronomy*, *50*(4), 311–313.

Das, S., Jeong, S. T., Das, S., & Kim, P. J. (2017). Composted cattle manure increases microbial activity and soil fertility more than composted swine manure in a submerged rice paddy. *Frontiers in Microbiology*, *8*(SEP), 1–10. https://doi.org/10.3389/fmicb.2017.01702

Delgado-Baquerizo, M., Powell, J. R., Hamonts, K., Reith, F., Mele, P., Brown, M. V., Dennis, P. G., Ferrari, B. C., Fitzgerald, A., Young, A., Singh, B. K., & Bissett, A. (2017). Circular linkages between soil biodiversity, fertility and plant productivity are limited to topsoil at the continental scale. *New Phytologist*, *215*(3),1186–1196. https://doi.org/10.1111/nph.14634

Eleno, E. U. and K. (2002). Effects of tree foliage of locus been and neem on soil fertility and productivity of maize in a savanna alfisol. *Springer*, *10*(2), 115–122.

Erika, S. (2006). *Contribution of managed fallos to soil fertility recovery. The world bank, Washington, DC, US.*

ILACO, B. V. (1985). *Agricultural Compendium for Rural Development in the Tropics and Subtropics.* Elsevier.

Javier, A.; Peter Motawalli; Caroline, V.; Miguel, A. G. (2013). Impact of cultivation and fallow length on soil carbon and nitrogen availability in the Bolivian region. *Mountain Research and Development*, *33*(4), 391–403.

London. (1991). *Guidline for Rating Soil Fertility Indicators*.

Manjunatha, R. . and, & Singh, N. J. (2020). *Effect of fallow age on soil properties of Jhum fields in West Garo Hills District , Meghalaya*. *9*(2), 591–597.

Mendoza-Vega, J., & Messing, I. (2005). The influence of land use and fallow period on the properties of two calcareous soils in the humid tropics of southern Mexico. *Catena*, *60*(3), 279–292.

https://doi.org/10.1016/j.catena.2004.12.002

Neff, J. C., Reynolds, R. L., Belnap, J., & Lamothe, P. (2005). Multi-decadal impacts of grazing on soil physical and biogeochemical properties in southeast Utah. *Ecological Applications*, *15*(1), 87–95. https://doi.org/10.1890/04-0268

Olowolafe, E. A. (2008). Land use effects on the properties of an alfisol on the Jos Plateau, Nigeria. *Geoderma*, *71*, 83–91.

Tian, G., Kang, B. T., Kolawole, G. O., Idinoba, P., & Salako, F. K. (2005). Long-term effects of fallow systems and lengths on crop production and soil fertility maintenance in West Africa. *Nutrient Cycling in Agroecosystems*, *71*(2), 139–150. https://doi.org/10.1007/s10705-004-1927

USDA. (1999). *Soil taxonomy: A basic system of soil classification for making and interpreting soil survey* (2nd ed.). Soil Management staff.

Vine, H. (1968). *Development in the study of soils and shifting agriculture in tropical Africa. The soil resourses of tropical Africa* (R. P. Moss (ed.); 8th ed.). Cambridge university press.

Yong-Zhong, S., Yu-Lin, L., Jian-Yuan, C., & Wen-Zhi, Z. (2005). Influences of continuous grazing and livestock exclusion on soil properties in a degraded sandy grassland, Inner Mongolia, northern China. *Catena*, *59*(3), 267–278. https://doi.org/10.1016/j.catena.2004.09.001

Zhou, Z. C., Gan, Z. T., Shangguan, Z. P., & Dong, Z. B. (2010). Catena Effects of grazing on soil physical properties and soil erodibility in semiarid grassland of the Northern Loess Plateau (China). *Catena*, *82*(2), 87–91. https://doi.org/10.1016/j.catena.2010.05.005