ALVAN JOURNAL OF SOCIAL SCIENCES (AJSS)
FACULTY OF SOCIAL AND MANAGEMENT SCIENCES
ALVAN IKOKU FEDERAL UNIVERSITY OF EDUCATION, OWERRI
https://www-ajsspub-org.b12sites.com https://www.ajsspub2.org
E- ISSN: 3043 – 5463 ISSN: 1595 – 5842 VOULUME 2, ISSUE 2, 2025

RESEARCH ARTICLE

INTEGRATED GRASSLAND MANAGEMENT EFFECTS ON SOIL HEALTH AND MAIZE YIELDS IN THE GUINEA SAVANNA OF NIGERIA

CHUKWUDI NWAOGU

Department of Environmental Management, Federal University of Technology, Owerri, Imo State, Nigeria

ABSTRACT

The study examined how soil and maize yields responded to the grassland management/treatment in the Guinea savanna of Nigeria. It is hypothesized that soil chemical properties are substantially disparitized under different grazing regime but appropriate fertilizer treatments would improve soil health. Data covering 14 management treatments including burning, litter removal, fertilization and mulching under grazed and non-grazed plots were collected and analyzed from the Guinea savanna agro-ecological zone. The result revealed that the grassland management produced significant variations in the plant-available nutrients and soil chemical properties except on pH (H_2O). Maize grain yield showed no significant in early season mulching for the entire experiment. Early season with fertilizer has higher grain yield than late season without fertilizer. Maize grain and biomass production were significantly affected by litter availability. Cultivating maize in soil without the removal of the dead-matter can be an alternative for fertilization.

Keywords: Grassland management, grazing and fertilization, soil nutrients, maize grain and biomass, Savanna

Corresponding Author

Chukwudi Nwaogu
Email Address: cnwaogu@gmail.com Telephone Number: +2348060197582)

Received: 11/6/2025; **Revised:** 27/7/2025; **Accepted:** 29/7/2025; **Published:** 30/7/2025

https://www-ajsspub-org.b12sites.com https://www.ajsspub2.org
E- ISSN: 3043 – 5463 ISSN: 1595 – 5842 VOULUME 2, ISSUE 2, 2025

1.0. INTRODUCTION

In the Sub-Sahara Africa (SSA), the grassland-savanna covered the largest area of agricultural land use (Rutherford and Prowrie, 2011) and is remarkably a sub-region of the world predominated by continuous soil nutrient depletion (Lal, 2004a) due to unsustainable management and complexity of the biophysical factors (Savadogo et al, 2007). Tropical savanna soils typically have a low inherent production potential and are vulnerable to rapid degradation under natural conditions (Lal, 2004b). About 75% of the soils are residues of heavily disintegrated ultisols and oxisols with the characterization of relatively low nutrient reserves, accelerated soil acidity, poor SOC and other plant-nutrient fixation and retention challenges (Rao, 1998).

The soil nutrients depletion rates have been a long time crucial issue even since 1970s when it was reported that NPK depleted between 22kg/ha/yr to 72kg/ha/yr which accounted for the poor yields of the cereal crops (Zingore, 2011). This was complemented by other studies which emphasized that the average annual soil nutrient loss per hectare due to reduction in land abandonment (fallow) from 7 to 2 years has increased (Stoorvogel et al, 1993). Hence, the yearly mean depletion rates have been 22kg N, 2.5kg P, and 15kg K between 1982-1984, and 26kg N, 3kg P and 19kg K in 2000, and was predicted to be at least 0.5% higher than the past values by the end of 2016 (Sanchez, 2002). This has consequently led to crop yield decrease from 11 t/ha to below 2 t/ha for cassava and from 3t/ha to less than 1t/ha for maize in some areas (Sanginga et al, 1995).

Sequel to these issues, this study aimed to address the following research questions: (i) how varied are the effects of grazing, burning, and litter removal on the soil chemical properties? (ii) Does cultivating maize without litter removal increases the grain yield under the grazed and non-grazed areas? (iii) What is the effect of the grassland management and treatments on maize aboveground biomass (AGB) production? (iv) What are the effects of fertilization and mulching on grain and biomass production; and are there seasonal and annual dynamics?

2.0. THE STUDY AREA

The study was conducted at the experimental research field in the Northern Guinea Savanna (NGS) agro-ecological region of Sub-Sahara Africa (SSA) in Nigeria located between longitude 5^0 15' E to 10^0 21' E and latitude 10^0 31' N to 11^0 17' N. NGS is one of the six classified ecoregional benchmark areas representing the six ecoregions of the Ecoregional Program for the Humid and Sub-Humid Tropics of Sub-Sahara Africa (EPHTA) (IITA, 1996). Benchmark belts are strategic location for conservative and robust research making it one of the paramount characteristics of an ecoregional program such as EPHTA. The selection of the area is not only based on the socioeconomic factors but mainly because of the bioecological or geophysical features, promoting research success and successions for flexible hypotheses and predictions of results (Brader, 1998).

In West and East Africa, the NGS covers approximately 34 million hactres in area and in Nigeria, the zone is essential in maize production (Manyong et al, 2001). The region is characterized by a growing period ranging from 151 – 180 days with primary soils including Luvisols (PetroFerric) (36%), Vertisols (12.2%), Lithosols (11.3%), Regosols (8.7%) and Ferralsols (8%) (Jagtap, 1995). The altitude is 710m (above sea level) with a mean annual rainfall and air temperature of 1486mm and 26.9^0C respectively.

ALVAN JOURNAL OF SOCIAL SCIENCES (AJSS)
FACULTY OF SOCIAL AND MANAGEMENT SCIENCES
ALVAN IKOKU FEDERAL UNIVERSITY OF EDUCATION, OWERRI
https://www-ajsspub-org.b12sites.com https://www.ajsspub2.org
E- ISSN: 3043 – 5463 ISSN: 1595 – 5842 VOULUME 2, ISSUE 2, 2025

3.0. MATERIALS AND METHODS

3.1. Experimental Design and Treatments

The experiment was established in a completely management randomized block design with three replicates of six management practices and eight treatments (14 experimental plots, each 6m x 6m separated by 0.5m wide buffer zones) as sequentially described with dates.

Table 1: Grassland management and maize plant treatment abbreviations

Abbreviation	*Management* description for grazed and non-grazed plots*
G1	Burn (slash-&-burn) under grazed plot
G2	Litter-removal under grazed plot
G3	Litter abandonment under grazed plot
N1	Burn (slash-&-burn) under non-grazed plot
N2	Litter-removal under non-grazed plot
N3	Litter abandonment under non-grazed plot
	Maize plant growing season and treatment⁺
EoF	Early season with Organic Fertilizer
EiF	Early season with Inorganic Fertilizer
EW	Early season without Fertilizer
EM	Early season with Mulching
LoF	Late season with Organic Fertilizer
LiF	Late season with Inorganic Fertilizer
LW	Late season without Fertilizer
LM	Late season with Mulching

* management = land/soil preparation practices before sowing;
[+] treatment = measure applied to the sowed maize crop in each of the 8 plots to enhance soil fertility and improve yield.

The 14 experimental plots covered the management and treatments: the 6 grassland management (G1, G2, G3, N1, N2, and N3) and 8 crop treatments (EoF, EiF, EW, EM, LoF, LiF, LW, and LM) are explained in Table 1. The grazed and non-grazed plots were separated by a wider buffer zone of 1 meter. Both grazed and non-grazed management were established and sampled as to measure if there are any contrast regarding the herbivores activities, and to determine any change effects on the soil chemical properties and maize yield between the grazed and non-grazed plots.

3.2. Inorganic Fertilizers

The mineral fertilizers (N, P, K) used were urea, calcium superphosphate, and potassium sulfate respectively. A total of 120kg N/ha urea was applied in two splits: two-third (80kg N/ha) as basal fertilizer dressing before planting and the remaining one-third (40kg N/ha) for the second phase as supplemental fertilizer which was applied between 50-55 days week after crop emergence (WAE) in order to support flowering and silking of the maize plant.

3.2. Organic Manures

The organic manures on the other hand were generated from maize/wheat straw and stover, legumes (soyabean, cowpea), cottonseed cake, the green manure (*Crotalaria Juncea*) and animal manure after composting. The organic fertilizers were supplied to the designated treatment plots in equivalent rate with the inorganic fertilizers (NPK). All the basal fertilizers (organic and inorganic) were evenly spread manually onto the top soils which were immediately incorporated (0-15cm) into the soil using hand hoes before sowing.

3.3. Maize Varieties

The maize seeds were of very high yield (VHY) and early maturity varieties with mixture of IITA Hybrid EEWH-21 (Ife Maize hyb -5), IITA Hybrid EEWH – 26 (Ife Maize hyb – 6), and the SAMMAZ 13.

2.3. Soil Chemical Properties

Soil samples were randomly collected from each management main plots (G1 to G3 and N1 to N3) in every experimental year as a mixture of three individual subsamples from the upper 15cm layer of the soil. The soil samples were collected using a graduated auger of 7 cm diameter and taken to the laboratory where they were air-dried and visible biomass residues, roots and other organic debris removed. Finally, the samples were ground in a mortar to pass a 2mm sieve. All chemical analyses were conducted in an accredited laboratory of the Department of Soil and Crop Science. The soil samples were analysed for total organic carbon (Tot. Org C) using the Walkely-Black wet oxidation method (Nelson and Sommers, 1982). pH was determined in a 0.2 mol KCL Solution; Total Nitrogen (Tot N) was measured using micro-Kjeldahl procedure (Bremner and Mulvaney, 1982). Plant-available P and K concentrations were extracted using Mehlich III Solution (Mehlich, 1984) regent and determined using ICP-OES while, Ca and Mg concentrations were performed using Atomic Absorption Spectrometer. The mean of three samples from each experimentally-management plots formed the start analysis.

3.4. Yield Measurements

The maize crops were harvested at physiological maturity. Grains and aboveground biomass (AGB) including cobs, straw, stems and leaves were collected from 4m x 4m (16m^2) selected at random from the four center rows of each treatment plot to prevent the border effects. The weight of the samples was determined in the field using a digital scale while subsamples were collected to find grain moisture content. Grain yield was computed on a per hectare basis at 12.5% moisture content. The grains were shelled manually from the cobs using hands and removed from stover. The stover subsamples were oven dried at 75^{0}C till constant mass was reached to convert fresh stover yields determined in the field to dry biomass. The mean of three subsamples per treatment plots was used for start analyses. At the end of every growing season (that is July and November) respectively for early and late seasons, the maize biomass (cobs, straw, stems and leaves) were collected and dried while the concentrations of the chemical nutrients were determined after digestion in aqua regia by inductively coupled plasma optical emission spectrometry (ICP-OES).

ALVAN JOURNAL OF SOCIAL SCIENCES (AJSS)
FACULTY OF SOCIAL AND MANAGEMENT SCIENCES
ALVAN IKOKU FEDERAL UNIVERSITY OF EDUCATION, OWERRI
https://www-ajsspub-org.b12sites.com https://www.ajsspub2.org
E- ISSN: 3043 – 5463 ISSN: 1595 – 5842 VOULUME 2, ISSUE 2, 2025

2.5. Data Analysis

In order to evaluate the effects of grassland management and treatment and their interactions on soil chemical properties, maize grain and aboveground biomass yields, a repeated measure ANOVA and a one-way ANOVA followed by a post hoc comparison using Tukey HSD test were performed. The application of ANOVA was allowed as all the necessary assumptions were reached. The relationships between soil chemical properties and maize biomass, Org C and Tot N, and soil chemical properties concentration and maize grain yield were analyzed by linear regression analysis and Pearson's Correlation respectively. All analyses were done using the IBM SPSS Statistics Version 20 (IBM, 2011) (www.ibm-spss-statistics.soft32.com) and all data were expressed as means of three replicates. A redundancy Analysis (RDA) followed by a Monte Carlo Permutation test with 999 permutations in the Canoco version 5.0 (ter Braak and šmilaner, 2012) was used to evaluate the effect of management and treatment on soil chemical properties.

4.0. PRSENTATION OF RESULTS AND DISCUSSION

4.1. Soil chemical properties

In the grazed plots (G1-burn, G2-litter-removal, G3-Litter-abandonment) effects of the different grassland management on the concentrations of all the plant-available nutrients and soil chemical properties were significant except for pH (H20) (**Table 2**). Remarkably, the mean concentrations of all the monitored soil chemical properties were lowest under the G1 management and highest under G3. The mean concentrations of P ranged from 9.08 mg/kg (G1) to 21.99 mg/kg (G3); Ca mean concentrations ranged from 68.12 mg/kg (G1) to 182 mg/kg (G3); Mg mean concentrations ranged from 46.87 mg/kg to 98.35 mg/kg; K concentrations ranged from 14.46 mg/kg (G1) to 42.43 mg/kg (G3); others were pH (H_2O) which ranged from 4.40 (G1) to 5.44 (G3); and mean Tot N concentrations which ranged from 189.67 mg/kg (G1) to 402.99 mg/kg (G3)

Table 2: Mean soil characteristics under the different management/treatments for the grazed and non-grazed plots in the years of study. *F*-ratio = *F*-statistics for the test of a particular analysis; *p*-value represents corresponding probability value. Numbers represent the average of three replicates; ± standard error of the mean (SE); Significance differences ($p < 0.05$) between management/treatments in accordance with the Tukey's post hoc test are shown by different letters in the row. The management/treatment abbreviations (G1, G2, G3, N1, N2 and N3) are described in Table 1

Treatment		pH(H_2O)	pH(KCL)	P mg/kg	Ca mg/kg
Graze	G1	4.40 ± 0.53	4.13 ± 0.04b	9.08 ± 0.75c	68.12 ± 12.85c
	G2	4.67 ± 0.68	5.61 ± 0.35a	17.15 ± 4.51b	112.27 ± 8.84b
	G3	5.44 ± 0.15	6.13 ± 0.13a	21.99 ± 2.76a	182.00 ± 6.88a
	F-ratio	1.15	23.32	4.47	34.04
	p-value	0.36	< 0.001	0.045	< 0.001
Non-graze	N1	4.11 ± 1.08	2.32 ± 0.31b	20.68 ± 4.33b	63.72 ± 9.51c
	N2	4.61 ± 0.54	5.52 ± 0.47a	18.73 ± 3.88b	161.16 ± 10.1b
	N3	4.71 ± 0.72	5.97 ± 0.67a	47.30 ± 5.75a	210.05 ± 11.0a
	F-ratio	0.159	15.48	18.18	52.22
	p-value	0.855	0.001	0.001	< 0.001

ALVAN JOURNAL OF SOCIAL SCIENCES (AJSS)
FACULTY OF SOCIAL AND MANAGEMENT SCIENCES
ALVAN IKOKU FEDERAL UNIVERSITY OF EDUCATION, OWERRI
https://www-ajsspub-org.b12sites.com https://www.ajsspub2.org
E- ISSN: 3043 – 5463 ISSN: 1595 – 5842 VOULUME 2, ISSUE 2, 2025

Treatment		Mg mg/kg	K mg/kg	Org C mg/kg	Tot N mg/kg
	G1	46.87 ± 3.10b	14.46 ± 2.84b	2660.83 ± 135.42b	189.67 ± 11.79b
Graze	G2	79.30 ± 6.43a	40.27 ± 5.60a	2961.26 ± 235.93b	278.29 ± 73.71ab
	G3	98.35 ± 6.97a	42.43 ± 3.50a	4742.14 ± 333.41a	402.99 ± 46.60a
	F-ratio	20.43	14.03	20.51	4.45
	p-value	< 0.001	0.002	< 0.001	0.042
Non-graze	N1	58.79 ± 9.49	13.09 ± 2.05b	2683.02 ± 382.83b	202.20 ± 22.40b
	N2	92.85 ± 13.84	47.44 ± 12.9a	3645.68 ± 739.70b	575.57 ± 46.55a
	N3	84.93 ± 4.67	47.41 ± 28.1a	6307.39 ± 247.11a	627.54 ± 43.06a
	F-ratio	3.14	7.83	14.01	35.71
	p-value	0.092	0.011	0.002	< 0.001

In the case of the Non-grazed plots (N1 to N3), the result varied slightly. There was a significant effect of grassland management on the concentrations of pH (KCL), P, Ca, Mg, Org C and Tot N while management revealed no significant effect on the concentrations of pH (H_20) (**Table 2**).

Unlike the result obtained from the grazed plots, the mean concentrations of the soil chemical properties differ across the management (N1 to N3). For example, the mean concentration of P was greater in N1 compared to that of N2, and the mean concentrations of Mg and K were higher in N2 compared to those of N3. However, N1 recorded the lowest mean concentrations for Org C, Tot N, pH (KCL), and Ca while N3 has the highest. The mean concentrations of pH (H_20) ranged from 4.11 (N1) to 4.71 (N3); the mean concentrations of P ranged from 18.73 mg/kg (N2) to 47.30 mg/kg (N3); mean concentrations of Ca ranged from 63.72 mg/kg (N1) to 210.05 mg/kg (N3). Others were mean concentrations of Mg which ranged from 58.79 mg/kg (N1) to 92.85 mg/kg (N2); mean concentrations of K ranging from 13.09 mg/kg (N1) to 47.44 mg/kg (N2), and mean concentrations of Tot N ranging from 202.20 mg/kg (N1) to 627.54 mg/kg (N3).

4.2. Grassland Management, Soil Chemical Properties, and Maize Yields

Maize grain yield was significantly positively correlated with Ca, Org C and Tot N under the grazed and non-grazed plots (**Table 3**).

Table 3: Correlation coefficient Between Soil Chemical Properties and Maize Grain Yield Under Grazed and Non-Grazed Management Plots ($p < 0.05$) *

Soil properties	Yield	
	Grazed Area	Non-Grazed Area
pH (H_2O)	0.025	- 0.018
P mg/kg	- 0.064	0.532*
Ca mg/kg	0.743*	0.764*
Mg mg/kg	0.529*	- 0.042
K mg/kg	0.605*	0.401
Org C mg/kg	0.821*	0.776*
Tot N mg/kg	0.898*	0.781*

ALVAN JOURNAL OF SOCIAL SCIENCES (AJSS)
FACULTY OF SOCIAL AND MANAGEMENT SCIENCES
ALVAN IKOKU FEDERAL UNIVERSITY OF EDUCATION, OWERRI
https://www-ajsspub-org.b12sites.com https://www.ajsspub2.org
E- ISSN: 3043 – 5463 ISSN: 1595 – 5842 VOULUME 2, ISSUE 2, 2025

Potassium concentration was positively correlated with maize grain yield under both grazed and non-grazed management. Mg on the other hand was negatively correlated with maize grain yield under the non-grazed plots but positively and significantly correlated under grazed plots. The non-grazed plots revealed a significant positive relationship between P concentration and maize grain yield whereas a negative association was obtained under the grazed plots. On the contrary, pH (H_20) concentration was weakly correlated with maize grain yield under both management plots.

4.3. Grassland management, soil chemical properties, and maize aboveground biomass

Significant positive relationships were recorded between soil and maize aboveground biomass concentrations of N (R^2 = 0.69; p < 0.001), P (R^2 = 0.41; *p* = 0.026), K (R^2 = 0.64; *p* = 0.003), Ca (R^2 = 0.49; *p* = 0.011), Mg (R^2 = 0.61; *p* = 0.003) while Total carbon was not significant under the grazed plots (Fig. 1). Similarly, under the non-grazed plots, N (R^2 = 0.62; *p* = 0.004), P (R^2 = 0.55; *p* = 0.006), K (R^2 = 0.43; *p* = 0.020), Ca (R^2 = 0.60; *p* = 0.003), Mg (R^2 = 0.66; *p* < 0.001) and Tot C (R^2 = 0.57; *p* = 0.015) showed significant relationships in their mean concentrations between the soil and maize aboveground biomass (Fig. 2). The relationship between Org C and Tot N in the soil under the different grassland management was revealed to be significantly positive (R^2 = 0.73; *p* <0.001) (Fig. 3).

4.4. Grassland Management, Soil Chemical Properties, and Maize Plant Treatments

As shown by the RDA, both the first and the second ordination axes and all the ordination axes in soil chemical properties and treatments were significant (p < 0.001). The percentage of explained variability by the first ordination axis was 51.3%. Ca, pH (KCL), K, Mg, and Tot N were associated with G3 and N2 while Org C, pH (H_20), and P were related with G2. Greater numbers of the applied treatments were located at the right hand-side of the ordination diagram (**Fig. 4**). The late season treatments (LW, LM, and LIF) tend to relate more with N1 and G1 management.

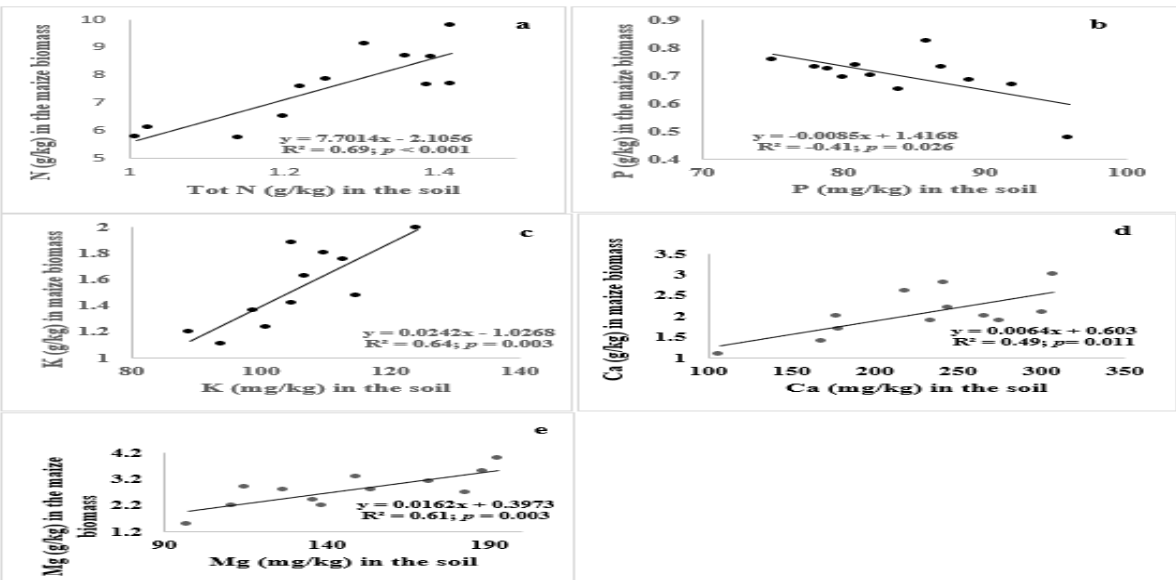

Figure 1: Relationships between (a) N (b) P (c) K (d) Ca (e) Mg concentrations in the soil and in the maize aboveground biomass under the grazed plots

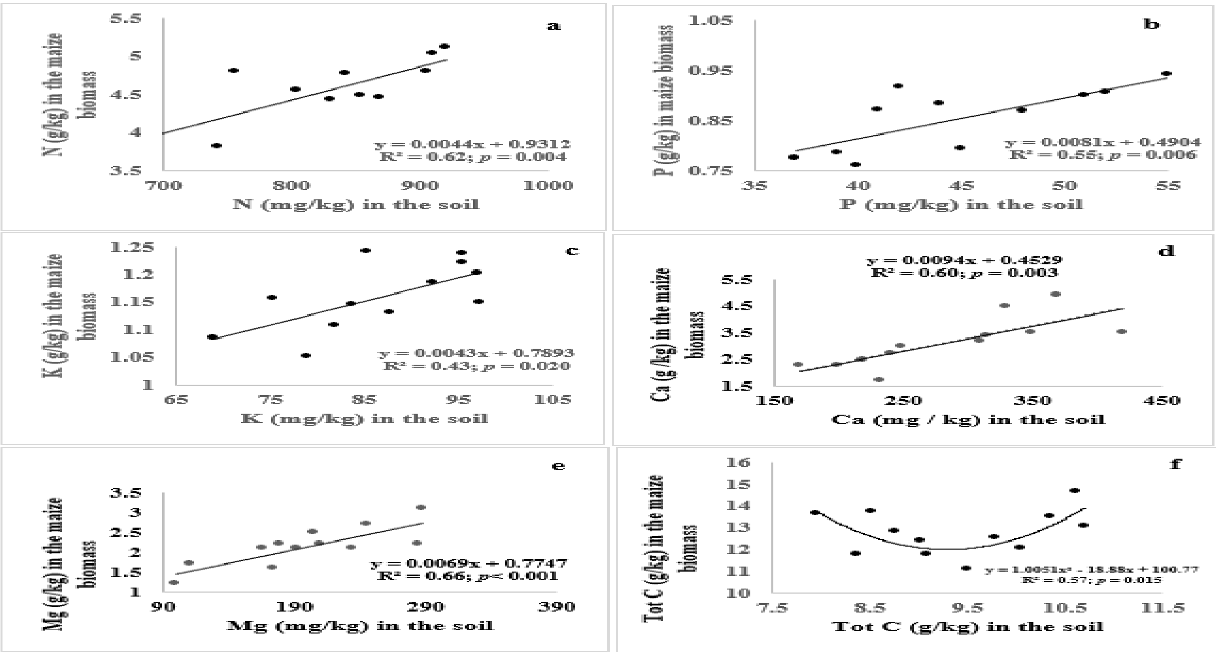

Figure 2: Relationships between (a) N (b) P (c) K (d) Ca (e) Mg (f) Tot C concentrations in the soil and in the maize aboveground biomass under the non-grazed plots

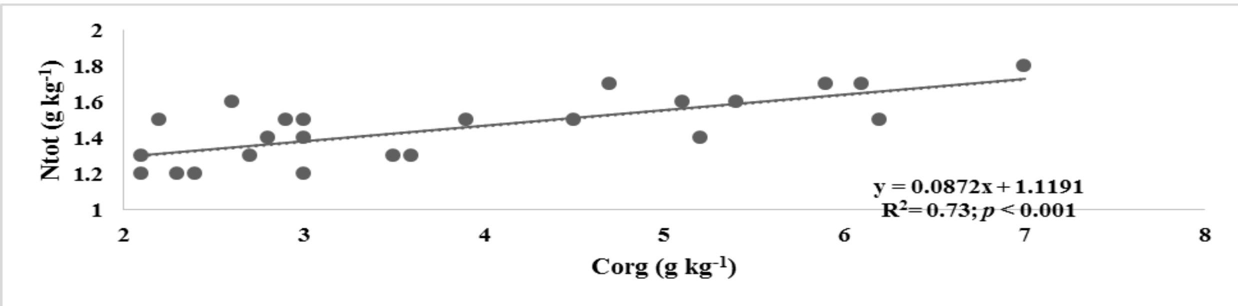

Figure 3: Relationship between Organic C and Total N in the soil under the different treatments

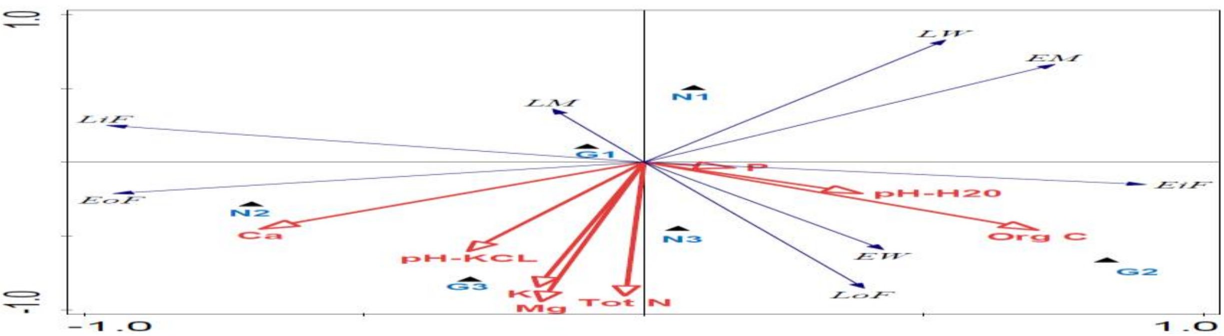

Figure 4: Biplot diagram showing the results from the RDA produced via CanoDraw program indicating the relationships between the soil chemical properties, the treatments and management. For management (GI, G2, G3 and N1, N2, N3) and treatments (EoF, EiF, EW, EM, LoF, LiF, LW, LM) abbreviations see Table 1 and/or Fig. 1.

4.5: Discussion

Our study revealed that the concentrations of all the pant-available nutrients and soil chemical properties (pH (KCL), P, Ca, Mg, K, Org C, and Tot N) monitored were affected by grassland management except pH (H_2O). However, grazing as a management has effects on the concentrations of Mg but non-grazing showed no significant effect. The significant influence of grazing on the soil was expected as this has been previously reported in several studies (Wang et al, 2011). The animal deposited remains in the grazed plots to a large extent affected the soil by enhancing the microbial activities (Sinsabaugh et al, 2013). Contrary to our findings, some experiments have documented cases where herbivores wastes have relatively no effects on the soil properties (Mikola et al, 2009) but the hoofing and trampling activities affect the soils (Ludvikova et al, 2014). However, the studies on the effects of grazing on the soil have been widely reported as either positive (Cui and Holden, 2015), negative (Shi et al, 2009) or no effects (Mikola et al, 2009).

Variations in the quantities of maize grain were obvious prove of significant effects of differences in the soil chemical properties and management practices. In the grazed plots, litter-abandonment(G3) showed the highest mean values of all the monitored nutrients (P, K, Ca, Mg, Org C, Tot N) compared with the plots for burn (G1) and litter-removal (G2). The litter-abandoned plot (G3) has the mean values of available soil chemical properties including org C (4742.14 mg/kg), tot N (402.99 mg/kg), Ca (182 mg/kg), Mg (98.35 mg/kg), and P (21.99 mg/kg) which were more than 80% higher in comparison with the data for the burnt plot (G1) and the litter-removal plot (G2).

Comparatively, under non-grazed plots, the litter-abandoned plot (N3) also recorded higher mean soil chemical properties concentrations of org C (6307.39 mg/kg), Tot N (627.54 mg/kg), Ca (210.05 mg/kg), P (47.30 mg/kg) which were far above the obtained concentration values for N1 and N2. This result was in agreement with a recent finding in the same region where by farmlands with dead plant biomass was documented to have added to soil nutrient enrichment via the increase of SOM content and subsequently contributed to the supply of soil-plant essential nutrients such as N, P, K, Ca, and Mg thus, improved the livelihood of the small-scale farmers (Meppe et al, 2007).

In addition to the grassland management systems, fertilization and mulching treatments were applied to maize plant. The treatments were significantly favorable to the litter-abandonment (G3 and N3) management. Fertilizer applications and mulching have widely been applied as sustainable agricultural and soil nutrient enrichment treatments for improved crop yields in the temperate grasslands (Hejcman et al, 2010).

5.0. CONCLUSION

The differences in maize grain and aboveground biomass production under the grassland management systems were primarily influenced by fertilizer applications than the other treatments. The litter-abandoned treatment regime has higher maize grain and biomass yield because the plants and animal litter, and the inorganic inputs added more nutrients compared to the burnt and/or litter-removed regimes. However, slash-and-burn with zero fertilizer treatments have lowest yields yet, most farmers in the SSA region adopt such agricultural practices due to ignorance, high cost of artificial fertilizers, and inaccessibility of organic manure which are mainly used for livestock feeds, fuel or building materials. A longer-term experiment that will evaluate the influence of climate on soil-plant

ALVAN JOURNAL OF SOCIAL SCIENCES (AJSS)
FACULTY OF SOCIAL AND MANAGEMENT SCIENCES
ALVAN IKOKU FEDERAL UNIVERSITY OF EDUCATION, OWERRI
https://www-ajsspub-org.b12sites,com https://www.ajsspub2.org
E- ISSN: 3043 – 5463 ISSN: 1595 – 5842 VOULUME 2, ISSUE 2, 2025

interaction with combination of organic and inorganic fertilizers would be valuable in understanding soil nutrients and maize yield dynamics in grassland-grazing ecosystem. However, both early and late season produced good maize yields with fertilizer treatment but the former has higher yields than the later due to high risks .of crop failure during the late season because of erratic rainfall (Mutsaers, 1991).t

Conflict of Interest

The author declares that no conflict of interest exist in this manuscript

REFERENCES

Brader, L. (1998). *IITA's Benchmark approach to natural resource endowments and management in West and Central Africa.* A paper presented at the International Centers for participatory research. Washington DC, U.S.A.

Bremner, J.S., Mulvaney, C.S. (1982). Nitrogen-total. In: Page, A.L. (Ed.), *Methods of Soil Analysis* No. 9, Part 2, Chemical and Microbiological Properties. American Society of Agronomy, Madison, WI.

Hejcman, M., Cesková, M., Schellberg, J., Pätzold, S. (2010). The Rengen Grassland Experiment: effect of soil chemical properties on biomass production, plant species composition and species richness. *Folia Geobot. 45,* 125–142.

IBM Corp. (2011). IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp. IBM Corp. www.ibm-spss-statistics.soft32.com.

International Institute of Tropical Agriculture (IITA), (1996). Annual Report on Agricultural practices and produce in Sub-Sahara Africa, Ibadan, Nigeria, pp. 2-10.

Lal, R. (2004a). Agricultural activities and the global carbon cycle and nutrients. *Cycles of Agro-ecosystem, 70,* 103–116.

Lal, R. (2004b). Soil carbon sequestration impacts on global climate change and food security. *Sciences, 304,* 1623–1627.

Ludvíková V., Pavlů, V., Gaisler, J., Hejcman, M., Pavlů, L. (2014). Long term defoliation by cattle grazing with and without trampling differently affects soil penetration resistance and plant species composition in *Agrostis capillaris* grassland. *Agric. Ecosyst. Environ. 197,* 204–211.

Manyong, V. M., Mankinde, K.O., Sanginga, N., Vanlauwe, B., Diels, J. (2001). Fertilizer use and definition of farmer domains for impact-oriented research in the Northern Guinea Savanna of Nigeria. *Nutr. Cycl. Agroecosyst. 59,* 129–141.

Mehlich, A. (1984). Mehlich III soil test extractant: a modification of Mehlich 2 extractant. *Commun. Soil Science & Plant Analysis, 15,* 1409–1416.

Meppe, F.1., Bilong, P., Nwaga, D. (2007). Management of improved fallows for soil fertility enhancement in the western highlands of Cameroon, in: Bationo, A., Waswa, B., Kihara, J., Kimetu, J., (Eds.), Advances in integrated soil fertility research in sub-Saharan Africa: Challenges and opportunities. Springer, The Netherlands. pp. 209–229.

Mikola, J., Setälä, H., Virkajärvi, P., Saarijärvi, K., Ilmarinen, K., Voigt, W., Vestberg, M. (2009). Defoliation and patchy nutrient return drive grazing effects on plant and soil properties in a dairy cow pasture. *Ecol. Monogr. 79*, 221–244.

Murungu, F.S., Chiduza, C., Muchaonyerwa, P., Mnkeni, P.N.S. (2011). Mulching effects on soil moisture and Nitrogen, weed growth and irrigated maize productivity in a warm-temperate climate of South Africa. *Soil Tillage Res. 112*, 58–65.

Nelson, D.W., Sommers, L.E. (1982). Total carbon, organic carbon, and organic matter. In: Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties, *2nd ed. Ame. Soc. Agron. 9*, 961-1010.

Rao, I.M. (1998). Root distribution and production in native and introduced pastures in the South American savannas. In: James, E., Box, Jr. (Eds.), Proc. 5th Symposium of the International Society of Root Research, “Root demographics and their efficiencies in sustainable agriculture, grasslands and forest ecosystems”. Kluwer Academic Publishers, Netherlands, pp.19–41.

Rutherford, M.C., Powrie, L.W. (2011). Can heavy grazing on communal land elevate plant species richness levels in the Grassland Biome of South Africa? Plant Ecol. 212, 1407–1418.

Sanchez, P.A. (2002). Soil fertility and hunger in Africa. Sci. 295, 2019–2020.

Sanginga, N., Vanlauwe, B., Danso, S. K. A. (1995). Management of biological N fixation in alley cropping systems: Estimation and contribution to N balance. Plant and Soil 174, 119–141.

Savadogo, P., Sawadogo, L., Tiveau, D. (2007). Effects of grazing intensity and prescribed fire on soil physical and hydrological properties and pasture yield in the savanna woodlands of Burkina Faso. Agric. *Ecosyst. Environ. 118*, 80–92.

Shi, F., Li, Y., Gao, E., Wan, Q., Qin, Y., Ji, X., Liu, L., Wu, Y.Y. (2009). Effects of managements on soil organic carbon of grassland in China. Pratacul. *Sci. 26*, 9–15.

Sinsabaugh, R. L., Manzoni, S., Moorhead, D. L., Richter A. (2013). Carbon use efficiency of microbial communities: Stoichiometry, methodology and modelling. *Ecol. Lett. 16*, 930–939.

ter Braak, C.J.F., Šmilauer, P. (2012). *CANOCO Reference Manual and User’s Guide CanoDraw for Windows: Software for Canonical Community Ordination* (vision 5.0). Microcomputer Power, Ithaca, NY, US.

Wang, S., Wilkes, A., Zhang, Z., Chang, X., Lang, R., Wang, Y., Niu, H. (2011). Management and land use change effects on soil carbon in northern China’s grasslands: a synthesis. *Agric. Ecosyst. Environ. 142*, 329–340.

Zingore, S., Tittonell, P., Corbeels, M., van Wijk, M.T., Giller, K.E. (2011). Managing soil fertility diversity to enhance resource use efficiencies in smallholder farming systems: a case from Murewa District, Zimbabwe. *Nutr. Cycl. Agroecosyst. 90*, 87–103.