

Soil dynamics, conservation and food supply in the grassland ecological zone of Sub-Sahara Africa: The need for sustainable agroecosystem management for maize (*Zea mays*)

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Abstract

To a large extent vegetation and its management determine soil quality and this consequently influences agricultural production. These factors and the links between them are among the primary bases for socioeconomic and environmental sustainability. Grassland is a key resource which is valuable for humans, animals and the environment in the supply of food, feed and other ecosystem services. The role played by the African savanna-grasslands can never be overemphasized. This paper focuses on agroecosystem management techniques and their effects on soil and on food provision in the Guinea savanna ecological belt of Nigeria. Firstly, the study analyzed reviews on the production trends in maize growing in Sub-Sahara Africa (SSA). Secondly, the authors carried out research which aimed at examining the variations in soil nutrients and crop yields as mediated by anthropogenic grassland management methods in the Northern Guinea savanna of Nigeria. Data were collected from four states (Niger, Kaduna, Bauchi and FCT-Abuja) located in the agro-ecological zone. In each state, four plots were designated as Plots 1, 2, 3 and 4, each representing one of the agro ecological practices of Fallow, Slash & Burn, Extensive Grazing, and Intensive Grazing. Topsoil (0-15cm) samples were collected from each plot and analyzed for their contents. Maize was cultivated and harvested over three growing seasons and the yield from each plot was measured. The results revealed that the extensive grazing plot produced the highest maize yield, while the slash and burn plot had the lowest. The effects of the soil nutrients as mediated by the treatments, significantly influenced the yield. It was recommended that Agricultural Extension Agents be deployed in the region in order to educate the rural farmers about the best management practices for increasing the food supply and achieving sustainable development.

Key words: Agroecosystem management, soil conservation, maize, Guinea savanna-grassland, Africa

Introduction

In many African and other developing countries there has been a rapid growth in population. Optimistically, this has required complementary sustainable increases in food production in order for these countries to attain food security. Unfortunately, at present there are serious threats to agriculture, mainly due to poor and unfavorable agroecosystem management techniques, which have reduced soil fertility and the productivity of agricultural land in these regions (Slaymaker, 2002).

Economic and environmental developments are significantly related to sustainable production, with the focus on the long-lasting agroecological sustainability of natural resources, especially soil, which is a primary source of food in resource-poor regions. In order to achieve global and regional goals in food security and poverty and mortality reduction, strategies are urgently needed to mollify soil degradation activities and restore the land's productive potential. This requires encouragement for the sustainable use of soil, vegetation and other related essential resources. Soil degradation in the grassland belts of Sub-Saharan Africa has strong adverse effects on agricultural production, rural livelihoods and food availability. Agriculturalists are key managers of global and local useable lands and they modify the soil and the vegetation cover (Tilman, 2002). Sustainable practices which help in promoting agroecological and ecosystem services are a priority if we are to meet the demands of improving yields without compromising soil and environmental potential and public health.

However, organic and inorganic fertilizers have significantly contributed to the green revolution by replenishing soil quality (Khan, 2007). But most developing countries import these fertilizers and they are often inadequately supplied; a major constraint for resource-poor farmers. The long-term application of fertilizers also poses a severe threat to the soil (Ahmed, 1995). Therefore, the intensification of agricultural production in these countries requires the introduction of sustainable agricultural practices in forage conservation, soil restoration (Pavlů et al, 2011) and productivity enhancement (Pavlů et al, 2013). This paper is divided into two parts: the review and the original research. The review section examined the trends and trajectories of maize production, particularly in Sub-Sahara Africa (SSA). Furthermore, the review identified some limitations to uniform, stable and increasing production in the region. The second section of the paper included the authors' own research, which consisted of a study of selected grassland management techniques and their impacts on soil nutrients and maize yields. There are many agro-management practices prevalent in the rural communities of Africa, but slash and burn, intensive and extensive grazing, and fallowing are primary practices in the Northern Guinea savannah and were applied in the study.

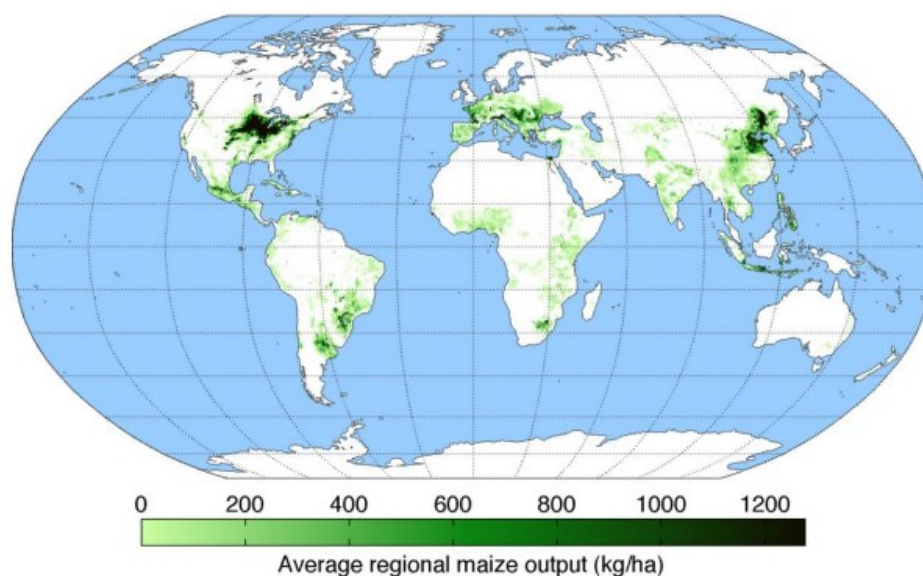
Historical and Global Trends in maize production and distribution

Maize was domesticated in the Tehuacan valley and the Balsas River Valley of Mexico about 9000 years ago. It then spread to Colombia ca. 5600BC. By the 5th century the entire

American continent had the cereal, and it was introduced to Europe through trade in the 6th century. Africa and Asia were among the continents where maize was cultivated in the late 16th and 17th centuries. There have been several varieties of maize, however, hybrid Genetically Modified strains of maize have been introduced and globally make up about 85% of the cereal, with the largest amount coming from the USA. On the African continent, Nigeria and South Africa top the list of maize production, while China dominates in Asia (Fig.1)

The worldwide production of maize is 785 million tons (per annum), with 42% coming from the largest producer, the United States. Africa produces 6.5% and the largest African producer is Nigeria with nearly 8 million tons, followed by South Africa. Africa imports 28% of its required maize from countries outside the continent. Most maize production in Africa is rain fed. Irregular rainfall can trigger famines during occasional droughts (Nwaogu, 2000).

Figure 1: World view of Maize production with Nigeria among the top in Sub-Saharan Africa (Source: FAO, 2013; Fischer,et al. 2014)



Sub-Saharan Africa: maize breeding, production and distribution

Sub-Saharan Africa (SSA) produced about 53 million tons (Mt) of maize annually from 2008 to 2010. The continent forms diverse regions which are divided by the Food and Agriculture Organization (FAO) into four sub-regions, with the major maize producing countries shown in Table 1 (Fig. 2). Maize is a staple food for many areas in eastern and southern Africa, and it is starting to be widely consumed in western and middle Africa. In general, maize remains a strategically essential food source for the SSA. A recent report indicated that the maize growing area is increasing in eastern (2.0% p.a.) and middle Africa (1.9% p.a.), is steady in western Africa and is declining in South Africa (–3.4% p.a.) (Ficher et al, 2014).

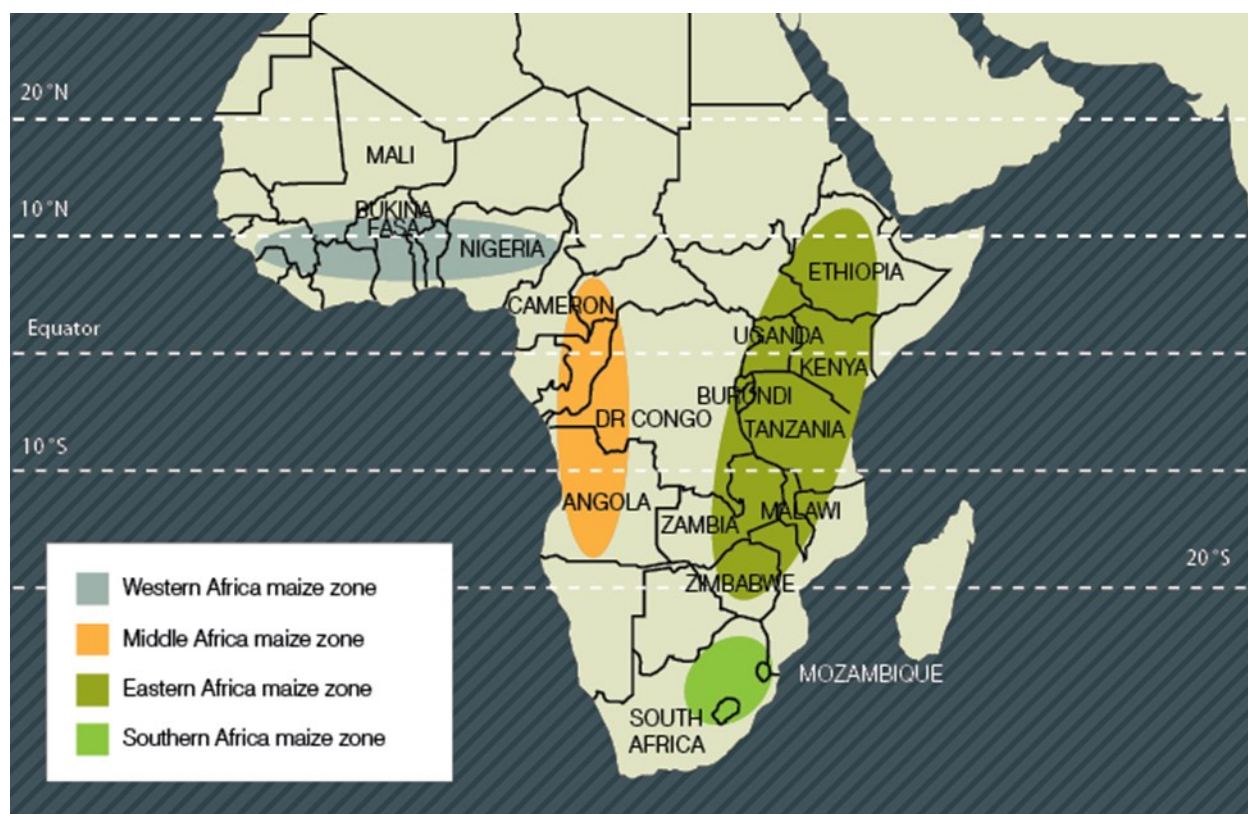
Maize, also called corn, is a cereal crop grown widely throughout the world in a range of agroecological environments. More maize is produced annually than any other grain. About 50 species exist and have various colours, textures, shapes and sizes. White, yellow and red are the most common types. The white and yellow varieties are preferred by most people, depending on which region they are from.

Maize production has a relatively long history in SSA. Maize was introduced to coastal Africa from the Americas in the 1500s and it was swiftly adopted, particularly in southern and eastern Africa. Subsequently, concerted breeding programs were established in some countries, resulting in the 1960 release in Zimbabwe of the world's first commercial single-cross hybrid, known as 'SR52. Thereafter, as development and research continued and the grains improved, two new natural heterotic groups were discovered in Kenya; (i) a local, large, white-grained synthetic cultivar, Kitale II; and (ii) a landrace, Ecuador 573, which was taken from South America to Kenya in 1959. It is important to note that this heterotic trend still forms the foundation of most Kenyan commercial maize breeding programs (Ficher et al, 2014).

Nowadays, maize breeding involved the integration of national research programs, international agricultural research centres and the commercial sector. Remarkably, most of the improved lowland tropical maize germplasm widely dominant in SSA (and suited to MME5 and MME6) originates from IITA (International Institute of Tropical Agriculture) in Nigeria. In Kenya, Zimbabwe and Ethiopia, the CIMMYT (Spanish: Centro Internacional de Mejoramiento de Maíz y Trigo; English: International Maize and Wheat Improvement Centre) continues to carry out breeding programs and generates most of the mid-altitude tropical germplasm suited to MME1–4. It has been reported that hybrids constitute about 95% of all improved maize seed currently on the market (Langyintou, 2010). The cultivation of the F2 hybrid seed (the first progeny of the hybrid seed) by farmers can reach 50% in drought-vulnerable areas. In east Africa, especially Kenya and Malawi, the roles of Multinational and regional seed companies have been substantial.

On the other hand, in West Africa, the private seed sector is still developing rapidly. In this region, except for Nigeria, improved seed is still widely the domain of government parastatals and institutions. Nigeria has experienced a continuous and steady application of the hybrids marketed by private establishments.

According to the reports of Fischer, Byerlee and Edmeades: *“An increasing (and very appropriate) emphasis in breeding led by CIMMYT and IITA—and supported by the Bill and Melinda Gates Foundation—has been to improve the tolerance to drought and low nitrogen of hybrids and OPVs adapted to the broad agroecologies of SSA. Improvement in heat tolerance may also be critically important in the future”* (Ficher et al, 2014).

Figure 2: Major maize-growing regions of Sub-Saharan Africa.**Table 1: Annual production, harvested area and farm yield (FY) data for maize in 2008–10 in selected countries of Sub-Saharan Africa, and changes in FY from 1991 to 2010, together with fertilizer applications to cropland (Source: FAOSTAT, 2013; Fischer, et al. 2014).**

Country or Region	Average 2008–10			Farm yield (FY)		Coeff. Of variation (%)	Nutrients Applied ^a (kg/ha/yr)
	Production (M.tons)	Area (Mha)	Average 2008–10 (t/ha)	Gain/Year(1991–2010)			
				(kg/ha)	(% of 2008–10)		
Kenya	2.8	1.9	1.5	ns –9	–0.6	13	27
Malawi	3.2	1.6	2	*47	2.4	23	29
Tanzania	4.5	3.3	1.3	ns –5	–0.4	48	5
Eastern Africa ^b	21.9	14.3	1.5	ns 13	0.8	10	10
Nigeria	7.5	3.8	2	***46	2.3	15	3
Ghana	1.7	0.9	1.8	***16	0.9	8	5
Western Africa ^c	14.7	8.3	1.8	***33	1.9	13	3
Cameroon	1.6	0.8	2	**31	1.6	19	8
DR Congo ^d	1.2	1.5	0.8	nd	nd	nd	1
Middle Africa ^e	4	4	1	***12	1.2	10	3
South Africa ^f	12.5	2.7	4.7	***142	3	23	116

*** $P < 0.01$, ** $0.01 < P < 0.05$, * $0.05 < P < 0.10$, ns = $P > 0.10$

a Ratio of nutrients applied (elemental nitrogen, phosphorus and potassium) to total cultivated area.

b Eastern Africa incorporates Burundi, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Rwanda, Somalia, Uganda, Tanzania, Zambia and Zimbabwe, each grows >0.1 Mt of maize annually.

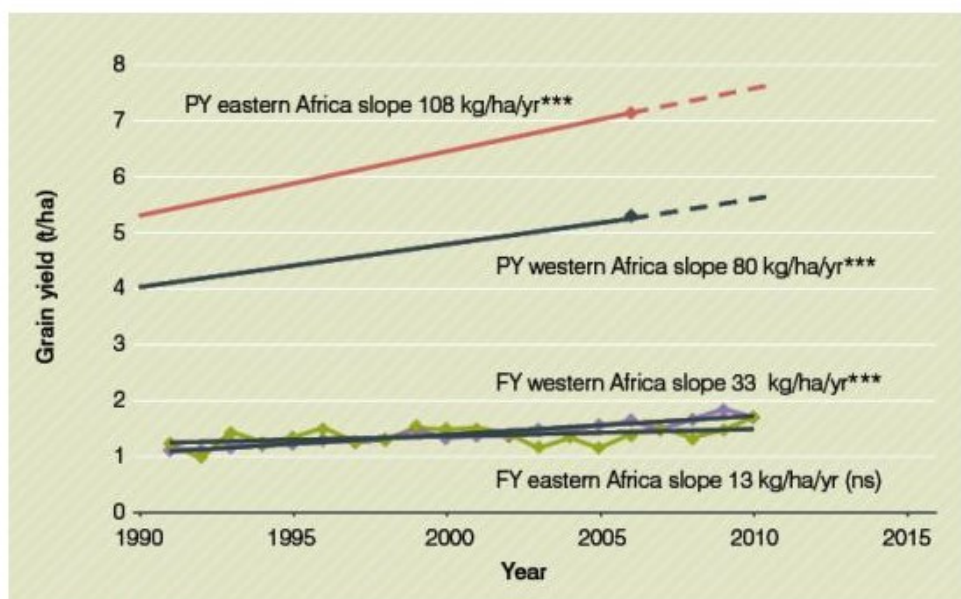
c Western Africa incorporates Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Liberia, Mali, Nigeria, Senegal and Togo, each grows >0.1 Mt of maize annually.

d nd = no reliable long-term data.

e Middle Africa incorporates Angola, Cameroon, Chad, Central African Republic, Democratic Republic of Congo (DR Congo), each grows >0.1 Mt of maize annually.

f South Africa produces 98% of the maize in southern Africa; the other countries in this region are Botswana, Lesotho, Namibia and Swaziland.

Figure 3: Farm yield (FY) for maize in Africa plotted against year, and potential yield (PY) plotted against year of release, from 1991 to 2010. PY progress is based on a 1.5% p.a. increase determined in 2006 vintage hybrids in eastern African mid-altitude zones and western Africa lowland tropics (see text) Source: FY from FAOSTAT (2013).



ns = $P > 0.10$, *** $P < 0.01$

Information from figure 5.4 revealed that there have been inequalities in the production of maize in Sub-Sahara Africa (SSA). However, there have been increased potential yields (PY) in the region but low farm yields (FY) have been recorded in West and East Africa over the past decade. Several biophysical and socioeconomic factors, including management systems, soils, climate, finance, farmers' qualifications and governance have been responsible for these differences. However, agroecological management practices seem to be at the top of the list. A number of the current risk management practices of rural farmers have been reported to effectively decrease maize yields at the farm level. For example, slash and burn and intercropping are popularly practiced in SSA and thus accounted for about 25% of the yield gap between FY and simulated or experimental station yields (Kibaara et al, 2008).

In order to promote, stabilize and increase maize production in all the SSA regions, four salient intervention strategies, including three agronomic and one genetic were introduced. The most important category is soil quality management. For instance, Keating, Carberry, Bindraban, Asseng, Meinke and Dixon describe the soil fertility constraint as ‘overwhelming’ (Keating et al, 2010). Productive use of small amounts of inorganic fertilizer, along with organic sources of nutrients, has the greatest likelihood of success (Tittonel et al, 2008). However, sustainable management techniques are better while genetic improvements is another strategy (Twomlow et al, 2010).

Introduction to the Original Research

The largest proportion of maize production in Nigeria was in the south-western region, but this record of the region with the highest production later shifted to the west due to the discovery of crude-oil in the south (Ogunbodede and Olakojo, 2001). Currently there is a paradigm shift in the production of this vital cereal to the savanna belts, especially the northern Guinea savanna which can now be seen as the “Maize Zone of Nigeria”. Farmers in this belt seem to prefer maize cropping to sorghum or other grains. Several reasons exist, such as the availability of streak resistant varieties for all ecological zones in Nigeria, the availability of high-yield hybrid varieties, an increase in population with the subsequent higher demand for maize, and government policies on the import of many foreign grains, including maize, might be responsible for this. As a sequel to this, local farmers have to produce more in order to supply the needs of people for daily nutrients and the demands of breweries, pharmaceutical companies, livestock owners, cereal industries, as well as the need to increase their own revenues. According to Obi, the middle and northern zones of Nigeria record the highest quantity of maize outputs because of large areas of arable-grassland and a favourable climate (Obi, 1991). These environmental conditions, integrated with highly improved yields and pest-resistant varieties, create conducive conditions for the preservation and cultivation of grains in this belt, yet management practices tend to play the largest role (Obi, 1991). To increase food supply, there is great need to improve crop production by adopting more sustainable agricultural management systems in order to enhance the soil fertility (Yanyineshet and Treydte, 2015) These systems have proved to be efficient in China (Wang et al, 2015). Several studies and efforts have been made to apply agricultural conservative measures in the region to maintain the soil quality but many of these experiments focused on either one practice or on a single locality (Wen et al, 2016). It is rare to find a study which combined the application of up to four different treatments in more than two localities covering the entire region. It follows that our study is significantly unique because it is focused on four major states in the northern-Guinea Savanna.

The objective of the study was to assess the effects of traditional management systems on the soil and on the maize yield in the northern-Guinea grassland region. We hypothesized that *“soil properties and maize grain yields are not affected by Slash and Burn, Grazing (Intensive/Extensive) and Fallow.”*

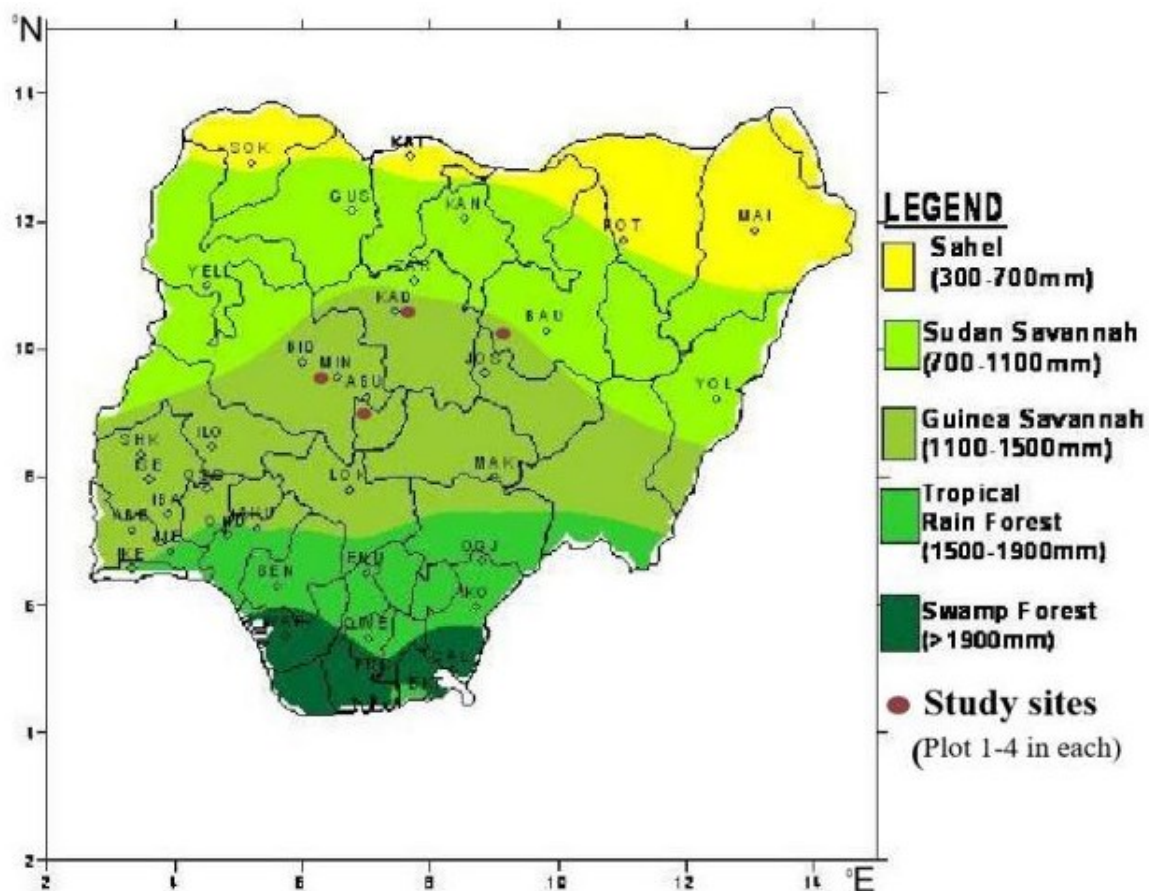
The study attempts to provide answers to the following questions: (i) What is the effect of burning on the soil and on crop yields? (ii) Do soil and yield respond differently under the two different grazing methods? (iii) How does fallowing affect the soil properties and maize grain production?

Materials and Methods

Study area

The northern Guinea Savana eco-regional benchmark area of Nigeria was the study site. It is among 6 benchmark zones representing the six ecoregions of the Ecoregional Program for the Humid and Sub-humid Tropics of sub-Sahara Africa (EPHTA)(IITA, 1996) (Manyong et al, 2001). The choice of this belt was partly because of the recent records in maize output and also because of the agroecological and socioeconomic characteristics of the belt (Manyong et al, 2001). An area of approximately 34,000,000 hectares is covered by the northern Guinea Savanna in West and Central Africa. According to Jagtap, this region is favoured with a long growing season, ranging from (150-180 days, with the following soil characteristics: Luvisols (36%), Vertisols (12.2%), Lithosols (11.3%), Regosols (8.7%), and Ferralsols (8%) (Jagtap, 1995). The region also has a favorable climate that is conducive for the growth of the grains. Four states; Kaduna, Bauchi, Niger and the FCT-Abuja were selected for the study (Fig. 4)

Fig. 4: Agroecological Zones with Study Areas in Guinea Savannah



Experimental Design and Data collection

In the northern Guinea Savanna ecological belt four sampling sites were located across four states namely; Niger, Kaduna, Bauchi and the FCT-Abuja (Fig. 4). In February 2012, four experimental sites were located in each of the four states with the help of the states' ministries of agriculture and the local agriculturists. The sites were protected from any encroachment by humans or animals until 2013 when the area was divided into four portions corresponding to the four introduced agroecosystem management methods (Slash & Burn, Intensive Grazing, Extensive Grazing, and Fallow). Each site was designated as; Plot 1 (Fallow), Plot 2 (Slash & Burn), Plot 3 (Extensive Grazing), and Plot 4 (Intensive Grazing) with an area of 2m x 2m per plot. While activities started in 2013 on the other plots, the fallow plot, which served as the control plot, was not disturbed until early 2014 when the early maize was cultivated. In this control plot the plants were cleared without burning in the preparation of the land for the seedlings. Before tillage, fire was employed to remove the litter on the slash/burn plot, while for the grazing plots the litter was ploughed back into the soil. We made sure that the same quantities of grain and the same varieties were used across all the plots, and the planting was done in the same week. Weeding was done twice during the growing season using traditional/local manual methods. Tillage was done on all the plots but there was no application of fertilizer or pesticides and no mulching or irrigation. The mean data were used from each of the plots (representing each grassland management system). In other words, Plots 1 from FCT-Abuja, Niger, Kaduna and Bauchi State were added together and divided by 4. This was repeated for every other Plot.

Soil samples were collected before and after the treatments. Two topsoil (0-15 cm) samples were collected randomly from each of the 8m x 6m monitored plots using soil augers. The collection was performed at every 5cm, was well mixed and a representation of sub-sample was collected. We removed the biomass residues and roots from the soil samples and air-dried them before taking them to the laboratory, where they were ground in a mortar and passed through a 2mm sieve. All chemical analyses were done in an accredited laboratory of Crop and Soil Sciences in Ahmadu Bello University (ABU), Zaria-Nigeria. The Mehlich III and Kjeldahl methods were among the techniques used for extracting and analyzing the soil samples (Mehlich, 1984). The mean of the two sub-samples from each experimental plot was applied for the statistical analyses. Crop yields: The following season in which the grassland management techniques were adopted, maize grains were planted on each plot with no fertilizers applied. The early rain in that year and the introduction of fast and High-Yielding Varieties (HYVs) meant that cultivation of the crop could occur 3 times in the year; from February-April, May-July, and August-October, representing early, mid and late seasons respectively. At the end of each growing season, the grains are harvested, the quantity is recorded and stored for each plot. The mean outputs were generated for each individual plot. Other laboratory analyses followed the standard procedures as used in the soil nutrient analyses previously conducted in the region (Essiet, 1998).

Data Analyses

To assess the effect of treatment on the soil properties and maize grain yield, repeated measures of one-way ANOVA were used, followed by a post hoc comparison-Tukey HSD test. Where the F-test was significant, a least significant difference (LSD) test was used at $P < 0.05$, if not stated otherwise, to separate the means. In other words, the use of ANOVA was allowed as all the necessary conditions were met. The relationships between yield and Ca, Mg, K, SOM, and Tot N were performed using linear regression. Pearson's correlation was used to analyze the relationship between monitored soil properties, and to measure the association between yields in a season/year under the different treatments. All the analyses were performed using the IBM SPSS statistics version 20 (IBM, 2011).

Results

Soil Nutrients Variations and Grassland Management Techniques

Fallowing slash and burn, intensive and extensive grazing were the primary treatments performed. The results of the study revealed that these grassland management systems have caused significant changes to the soil properties in the selected sites (Table 2).

Table 2: Physical and chemical properties of the soil at the study sites pre-treatment practices

Soil properties	Sites			
	FCT-Abuja	Niger	Kaduna	Bauchi
Sandy(%)	66.2	87	72.1	82.0
Silt(%)	49.3	28.6	48.4	37.7
Clay(%)	35.6	37.5	34.9	33.2
Tot. N(mg/kg)	2.3	3.03	2.47	2.51
SOM(mg/kg)	3.8	2.85	3.14	4.29
pH(H ₂ O)	5.9	5.0	5.7	5.5
CEC(mg/kg)	2.8	3.12	4.03	3.72
Ca(mg/kg)	2.6	2.66	2.97	3.11
Mg(mg/kg)	1.9	1.29	1.98	1.83
K(mg/kg)	1.46	1.69	1.74	1.8
P(mg/kg)	1.21	1.57	1.61	1.93

Table 3: Correlation coefficients among monitored soil properties

	<i>Sandy</i>	<i>Silt</i>	<i>Clay</i>	<i>Tot N</i>	<i>Org M</i>	<i>pH</i>	<i>CEC</i>	<i>Ca</i>	<i>Mg</i>	<i>K</i>	<i>p</i>
Sandy	1										
Silt	-0.993**	1									
Clay	0.071	-0.172*	1								
		0.773*									
Tot N	-0.819*	*	0.467	1							
		0.811*									
Org M	-0.826*	*	-0.267*	0.448*	1						
pH	-0.864	0.837	-0.145	0.551	0.991	1					
CEC	-0.855	0.845*	-0.292	0.473*	0.997	0.988	1				
					0.658*		0.675*				
Ca	-0.909*	0.861*	0.350	0.967*	*	0.744	*	1			
					0.347*		0.375*	0.933*			
Mg	-0.761*	0.716*	0.513*	0.994*	*	0.455	*	**	1		
								0.942*			
K	-0.893*	0.835	0.257*	0.830	0.836*	0.901	0.835*	*	0.765*	1	
				0.931*				0.903*		0.737*	
P	-0.892	0.889	0.144	*	0.484*	0.554	0.530*	*	0.922*	*	1

* $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$

Table 4: Summarized statistics on the relationships between yield under the four management systems for the four sites in 2014 and 2015

Treatment	Plot	2014			2015		
		Early Season	Mid Season	Late Season	Early Season	Mid Season	Late Season
FC	1	0.726*	0.699*	0.684**	0.611	0.631	-0.535*
SB	2	0.614*	0.049*	-0.667*	0.062*	-0.015*	0.007*
EG	3	0.891	0.884*	0.901**	0.735	0.69*	0.594**
IG	4	0.773*	0.607*	-0.631*	0.17	0.094	-0.814**

* $p < 0.05$, ** $p < 0.01$; FC=Fallow/Control; SB=Slash & Burn; EG=Extensive Grazing; IG=Intensive Grazing

The summary of the correlation analyses of the monitored soil properties which were derived during and after the treatments showed that more than 60% of the soil variables were significantly correlated (Table 3). Only the soil's pH was not significantly correlated with any other soil property.

The Cation Exchange Capacity (CEC) has a substantially significant correlation with Ca, Mg, K and P, while sandy was significantly negatively correlated with silt, total N, organic matter, Ca, Mg and K. Silt showed a very strong and significant positive correlation with Total N, organic matter and CEC. On the other hand, clay has a negative significant

correlation with organic matter and a positive significant correlation with Mg and Ca. While organic matter indicated a strong positive correlation with CEC, the relationship was not significant (Table 3).

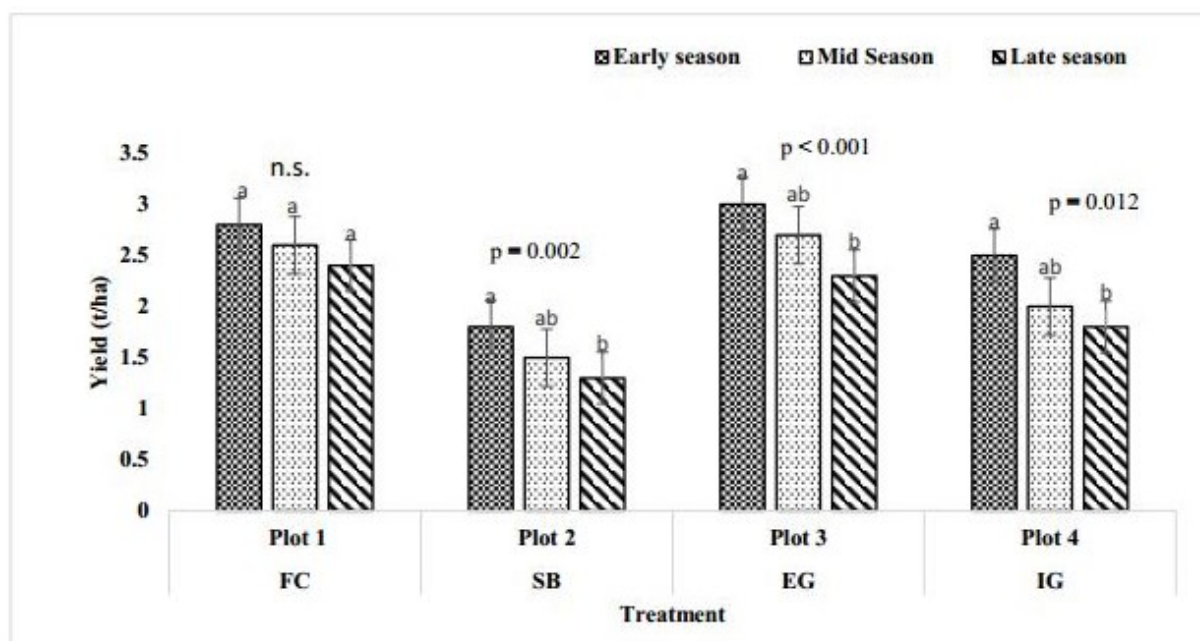
Maize grain seasonal/annual yield and grassland management practices

Generally, the late season cultivation showed strong positive and negative significant correlation in all the treatments (Table 4). Burning indicated significant correlation for all the seasons in the two years of the experiment. The early season yield for 2014 recorded the strongest correlation coefficient among the growing seasons with 0.726 (Fallow), 0.614 (Slash/Burn), 0.891 (Extensive Grazing) and Intensive Grazing (0.773).

In 2014, early season cultivation showed the highest maize yield in all the treatments (Fig.5). The extensive grazing plot favoured the grain yield across the three seasons, while plot-2 where the burning was applied before planting had the lowest grain output. The results further revealed that the significant differences in seasonal yield were recorded in all the adopted management practices except in the fallow/control (plot 1). In terms of seasonal yields, the late season tends to account for the lowest grain production in all the treatments (Fig. 5).

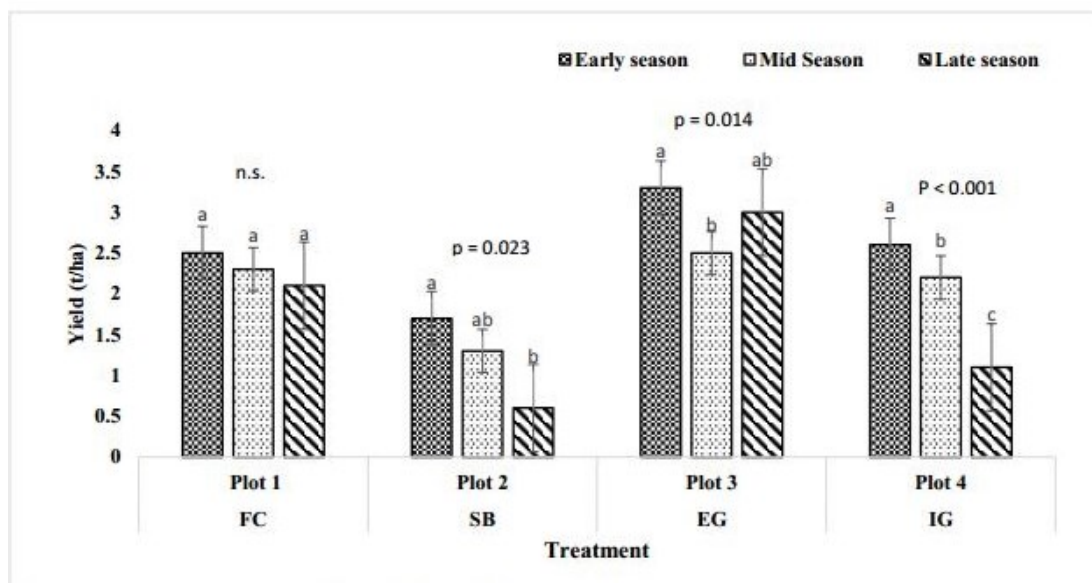
The results from 2015 revealed that extensive grazing and burning treatments have the highest and lowest grain outputs respectively (Fig. 6), corresponding to the 2014 records. The extensive grazing plot produced a contrasting result, where the late season cultivation yielded higher than the mid-season, compared with 2014. Similarly, the control plot with fallow treatment was the management system with no significant difference in the seasonal yields. Intensive grazing showed substantial significant differences ($p < 0.001$).

Fig. 5: Mean maize grain yield under the different treatments in 2014.



Yield values represent the average of two replicates. Bars indicate \pm Standard Error of the mean (SE). Using Tukey's post hoc test, different letters show significant differences between treatment means (least significant difference F-test, $p < 0.05$). n.s. - results of ANOVA analyses were not significant. For Grassland management/treatment abbreviations see table 4.

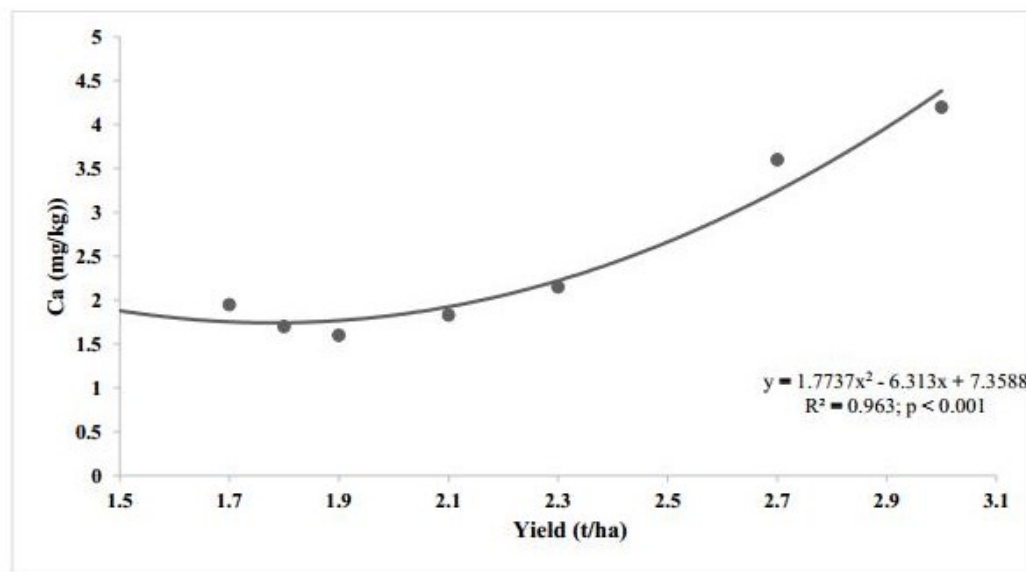
Fig. 6: Mean maize grain yield under the different treatments in 2015.



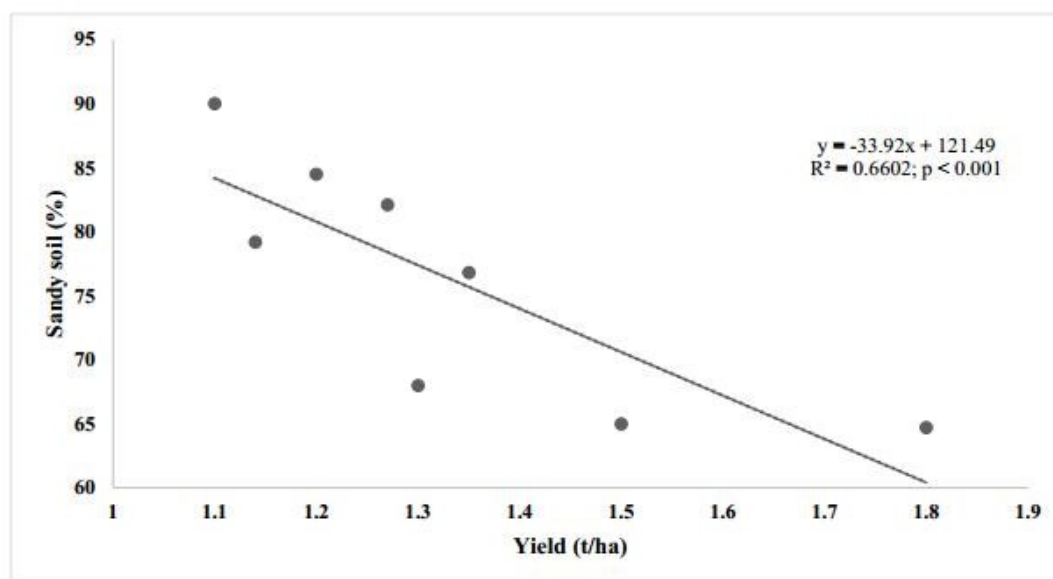
Yield values represent the average of two replicates. Bars indicate \pm Standard Error of the mean (SE). Using Tukey's post hoc test, different letters show significant differences between treatment means (least significant difference F-test, $p < 0.05$). n.s. - results of ANOVA analyses were not significant. For Grassland management/treatment abbreviations see table 4.

Soil properties, grain yield and grassland management

A high positive relationship ($R^2 = 0.963$, $p < 0.001$) was found between Ca concentration and the maize yield under the extensive grazing treatment (Fig. 7). The polynomial-linear regression between Ca and yield was significant, proving that the concentration level of Ca in the extensive grazing farmland was favourable for the maize.

Fig. 7: Relationship between mean Ca concentration and Maize grain yield under Extensive grazing.

Maize grain yield increased with a decrease in sandy soil percentages in the burnt treatment plot (plot 2). However, a strong correlation with a significant relationship was recorded between the yield and the percentage of sandy soil in plot 2 (Fig. 8). A high percentage of sandy soil tends to decrease the silt and essential nutrients by promoting soil erosion, high evaporation and leaching.

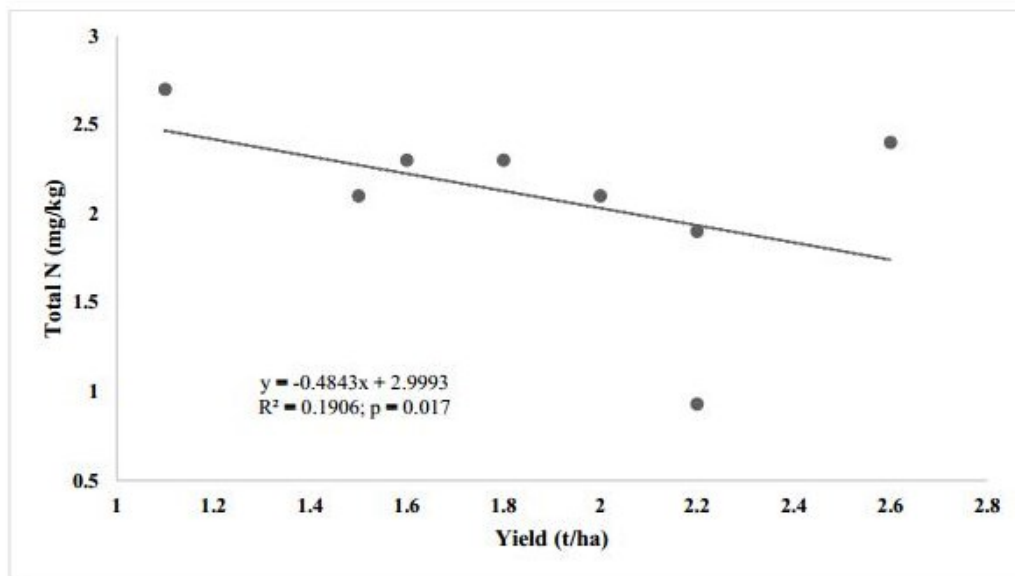
Fig. 8: Relationship between mean Sandy Soil concentration and Maize grain yield under Plot 2 (Slash & Burn).

However, a relationship existed between the mean total N concentration and maize grain yield (Fig. 9) in the intensive grazing treatment plot, but the relationship was negatively

w e a k ($R^2 = 0.1906$) .

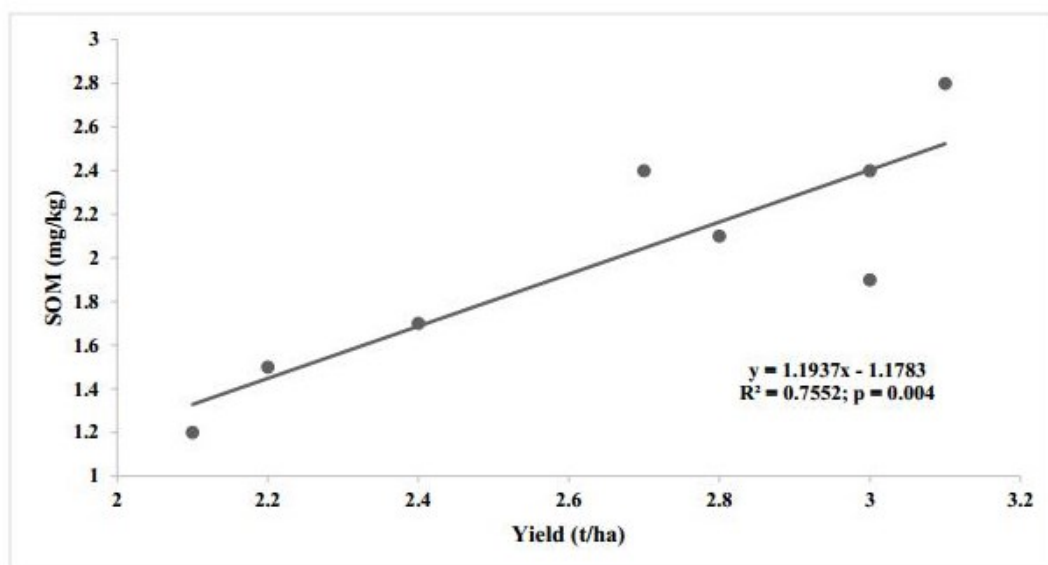
It is remarkable to discover that a decrease in total N has a slight positive effect on the maize grain yield. It is assumed that other factors, including management practices, availability of other soil nutrients and environmental parameters could be responsible.

Fig. 9: Relationship between mean Total N concentration and Maize grain yield under Plot 4 (Intensive Grazing).



The fertility of the soil to a large extent depends on the available soil organic matter (SOM) which consequently has a vital role in crop productivity. The relationship between the mean SOM concentration and maize yield under the fallow treatment was significant ($p = 0.004$) for the two years (Fig. 10). A strong positive relationship ($R^2 = 0.755$) revealed that the optimal concentration of SOM in the fallow plot was substantially conducive for the growth of maize.

Fig. 10: Relationship between mean Soil Org Mat (SOM) concentration and Maize grain yield under Plot 1 (Fallow).



Discussion

Soil properties, grain yield and grassland management

The grassland management system to a large extent influences the quality of soil, which consequently affects yield in an area. The extensive grazing showed that the extensive activities of the herbivores were favorable for the soil. The extensive grazing plot 3 has proved that it has the most required soil nutrients with a higher percentage of silts and organic matter and better CEC. The fallow plot (i.e. control plot) tends to share almost the same soil and yield characteristics as the intensive grazing farmland (Fig. 5). On the other hand, the burnt plot seemed to have suffered from the effects of the heat. This might have led to the loss of essential soil elements such as silt, N, Ca, P, K, Mg and organic matter with the increased sandy percentage leading to a continuous decline in yield (Fig.8). The impacts of the human grassland agroecosystem management methods on the soil nutrients were obvious and this in turn determined the rate of the crop yields. For instance, the relationship between yields and organic matter was significant ($R^2 = 0.755$; $p = 0.004$), which enhanced maize grain yield in the fallow plot. Several studies have been conducted on the significant relationships between crop yields and soil fertility (Pavlu et al, 2013; Marschner, 1995; Hejzman, 2010). The role of base cations, including Ca, on growth and vegetative development was emphasized in the study by Dijkstra in northeastern America (Dijkstra, 2003). In our study, Ca concentration has similarly been revealed as an essential element in maize yield (Fig.7). The study stated that the limitation of any essential soil nutrients poses a great threat to the plants' health.

Grassland Agroecosystem Management Practices and Crop Yields

Four different grassland management methods (Slash and Burn, Intensive grazing, Extensive grazing and Fallowing) were applied in the study on the impacts of soil, eco-anthropogenic management and yield. The results revealed that the sample plot 2, where slash and burn was primarily practiced before cultivation, yielded the lowest maize output (Fig. 5). It was further discovered that plot 3 (involving the Extensive grazing method) produced the highest yield, while the control plot (plot 1), which was allowed to lie fallow before cultivation, also had good yields (Fig.6). Grassland management systems have been highlighted as a core factor in determining the productivity of this biome. A study by Tittonell et al (2008) revealed the unparalleled values of sustainable soil and land resource management in sustaining soil potentials for higher productivity in Sub Sahara Africa. Other past studies have stated that it is better to manage the soil sustainably through the adoption of improved management measures than to rely on inorganic fertilizer application (Chivenge et al, 2011). The study further stressed the dangers of the overuse of fertilizer as regards the soil and crop yields, especially with the recent increased demand on agricultural products. Other studies have reported that proper soil management has a high tendency to boost production (Khan et al, 2007; Slaymaker, 2002; Ahmed, 1995), whereas inappropriate management techniques result in soil degradation and this may

require long-term remediation or the damage could be irreversible (Tilman et al, 2002; Fischer et al, 2014; Tiftonell et al, 2008; Chivenge et al, 2011). However, the findings of our study were in accord with previous research (Bahr et al, 2014; McGrath et al, 2001; Ewel et al, 1981). This is because of the negative impacts of burning, which can be further explained as the killing of the soil microbes and the indirect consequences of rainfall and temperature intensities (Savadogo et al, 2007). On the contrary, several other studies disagree with our results and conclude that the ash materials from the burnt plant material adds substantial nutrients to the soil (Nye and Greenland, 1960; Giardiara et al, 2000; Hamer et al, 2013).

Conclusion

The Guinea Savannah especially the northern belt grassland has the potential for high production of maize and other cereals. Extensive grazing and fallow plots showed higher maize grain productivity than the other grassland agroecosystem management practices. Slash and burn has severe degradable effects on the soil quality. Appropriate soil resource management processes have been demonstrated as catalysts in restoring soil fertility and increasing food productivity in the area. In order to supplement and compensate for the limitations of fertilizers in this region, and the application of improved and sustainable grassland management methods should be a priority. In Nigeria and other SSA, cereal crops, especially maize, are one of the top staple foods and are used as food for African people and feed for their livestock. The grain is also of high economic importance in domestic and international trade and revenue generation. Maize has provided a strong economic boost for sustainable development by increasing and improving people's livelihoods and government sources of foreign exchange. Industrially and socio-culturally, products from maize are of great significance for the chemical, biofuel, medical and food companies. Traditional methods of farm management such as slash and burn should be discouraged among rural farmers. This could be done by educating the agriculturists through the Agricultural Extension Agents. Most of the farmers are novices concerning best management practices. The Nigerian Federal Ministries of Agriculture and Natural Resources, FAO, other international organizations and NGOs should financially, technically and materially support this developmental step.

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