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Land degradation and the sustainability of agricultural production in Nigeria: A review

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Human-induced soil degradation that results from erosion, losses of organic matter, plant nutrients and soil compaction are the key factors threatening food security in Nigeria. Food import statistics show that Nigeria is food deficit and starvation stalks the country. The paper examined in some details some factors of soil degradation, their effects on crop yield decline and its impact on the people and the environment. Management options of a combination of agronomic and engineering practices are proposed in order to improve crop yield even in marginal soils. Facts were presented to show that Nigeria needs a paradigm shift in agriculture development from "a green revolution" to an "ecological intensification" approach that will minimize land degradation, improved crop yield and reduce food import in an environmentally sustainable manner.

Key words: Nigeria, land degradation, agricultural sustainability.

INTRODUCTION

Nigeria is blessed with a land mass of about 98 million hectares, out of which 83 million hectares are suitable for cultivation but with only 30 to 34 million hectares presently under cultivation. About 45% of this land area is arable and only about 42% of the arable land is presently cultivated. Nigeria's population is estimated at about 150 million, making Nigeria the most populous country in Africa and the eighth most populous in the world. Approximately one-third of the population lives in urban areas while rural areas account for the remaining two-third. The climate varies northwards from a humid, semi-hot, equatorial climatic region in the south through wet sub-humid regions and dry sub-humid regions to the semi-arid and arid regions in the north (Abbas, 2009; Aina, 2011). Land cover changes in the last 30 years indicate that disturbed forest increased by about 33%, extensive small holder rain fed agriculture by about 13% and flood plain agriculture by 123%. Forest plantations increased by 58% while rainfed arable crop field increased by 3000% (Aina, 2011). All these suggest intensification in southward movement of the grazing zone in the country. In general, the results presented by Abbas (2009) strongly indicate loss of prime arable lands which is in turn leading to the opening up of new virgin land towards the southern part of the country. In the northern and central parts of the country, the Sudan savanna ecology is transiting to Sahel, an indication that desertification intensity is increasing. In a similar manner, the Guinea savanna in the south is giving way to Sudan savanna grassland. Chronic food insecurity in Nigeria

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stems from decades of poor governance. In Nigeria, farming has languished and food systems have stagnated leading to mass poverty and endemic starvation among the poor. These conditions have distorted the macro economy with adverse effects on food security as revealed in the statistics of food imports in Nigeria below. As oil prices went up, interest in agriculture waned resulting in grossly inadequate grain per person in all agro ecological zones of the country. It is important to note that the interaction of poverty, hunger and environmental degradation is adversely prominent in Nigeria where the rate of food importation is high under a diminishing low per-capital income (Ekpu, 2009). Recently, soil condition has also been affected by climate change and an increase in the prevalence of severe weather events (that is, drought and flooding) which has brought Nigeria agriculture into crises (Abiodun et al., 2011). In many parts of Nigeria, poor crop yield per hectare of land have been reported with serious concern. This has been attributed to land degradation (Aina, 2011; Lal, 2010). What then is land degradation? Land degradation is a process in which the value of the biophysical environment is negatively affected by a combination of human induced process acting upon the land (Lal, 2010). It leads to a temporary or permanent decline in the productive capacity of the land. Degradation of land includes soil erosion, salinization, nutrient depletion and desertification. The rate of degradation has increased dramatically with growth in the human population and technology. The continued loss of arable land will jeopardize the survival of agriculture (ISRIC/UNEP, 1991). Many past statements on land degradation, and crop yield decline were based on assertions that were largely unsubstantiated by hard evidence. This knowledge gap was the focus of this review.

MATERIALS AND METHODS

Description of study area

The Nigeria Environment and Land Resources: Nigeria lies roughly between latitudes 4° and 14°N and longitudes 3°and 15°E in West Africa. It covers a land mass of approximately 923,768 km^2 representing about 14% of land area in West Africa. It is bordered by Benin Republic to the west, the Niger Republic to the north, the sub-equatorial Cameroun to the east and the Atlantic Ocean to the south. The country's coastline spans over 853 km. A major feature of Nigeria's coastal and marine environment is the Niger Delta, which covers an area of 70,000 km^2, and that makes it one of the largest wetlands in the world. The mangrove forests of Nigeria rank as the largest in Africa, the third largest in the world. Nigeria is located mainly within the lowland humid tropics and is characterized by high temperatures almost throughout the year. In the far south, mean maximum temperature is 32°C, while in the north it is 41°C. The mean minimum temperature is 21°C in the south and about 13°C in the north, making the north to have a much higher annual range than the south. The mean annual rainfall over the country varies from a high of over 3,500 mm along the coast to a low of less than 600 mm in the Sahel region in the northwest and northeast parts of the country. The annual variation of rainfall, particularly in the north, is large. This often results in climatic hazards, especially floods and droughts, which bring in their wake much suffering with devastating effects on food production and the nation's economy (Ogunkunle, 1986; Abiodun et al., 2011).

Data collection

The data used for this review were collected from Nigeria Federal Ministry of Agriculture, State Ministry of Agriculture, published academic literature, agricultural agencies and books. Information were also obtained from FAO publications on Nigeria.

RESULTS AND DISCUSSION

Food security in Nigeria

To improve crop yield and ensure food security in Nigeria, many studies have suggested the use fertilizer (BADP, 1987). The Ministry of Agriculture and Water Resources disclosed that current use of fertilizer is about 1,000,000 metric tons per annum, while the projected demand estimate is 3.7 million metric tons. While the "average worldwide rate is 93 kg per hectare of NPK, the rate for Nigeria is around 13 kg ha^{-1}" (Bello, 2004; Ekpu, 2009). For example, in a World Bank Project research conducted in Bauchi and Ilorin ADPs, most of the crops grown using different cropping systems, sole and intercropping, have significant response to fertilizer (Tables 1 and 2). This observation is consistence with the reports obtained in many ecological zones of the country (BADP, 1987; Agboola and Aiyelari, 2000; Lal, 2001). The high fertilizer requirements and its unavailability have led to per capital grain yield in Nigeria (Figure 1).

The grain per person ratio observed above in Figure 1 showed the fluctuations in food security in Nigeria. While the grain per capital rose and later declined in the northern zone of the country, it is in decline trend in the southern part. Presently, the nation's economy is feeling the brunt of the rising cost of food items, especially the rise in the prices of staple foods. Significantly, the price of rice has increased by over 100 per cent since 2006. It is instructive to note that Nigeria requires 2.5 million metric tons of rice annually while local rice production is less than half a million metric tons per year. With these figures as released by Minister of Agriculture and Water Resources, Nigeria is short of two million tons of rice, which it has to source from other countries. It is estimated that Nigeria spent a whopping $2billion dollars importing about six million tons of wheat, $750 million on rice $700 million on sugar and $500 million on milk and other dairy products (Ekpu, 2009).

Beyond high prices of staple food items in Nigeria, drought and political situation in Borno state and some other parts of the North-East of the nation are implicated for the food crisis in Nigeria. Also, food scarcity in Nigeria

Table 1. Crop response data by ADP[1] at Bauchi in Bauchi State, Nigeria between 1985 and 1986.

Crops	Yield with Fert.	Yield without	Increase	N, kg ha^{-1}	Response	Significant
			1985			
Maize	1645	718	827	90	3.37	*
Sorghum	465	574	-VE	90	-VE	NS
Sorghum/Maize	294	207	87	120	12	*
Millet	705	280	425	90	2.51	NS
Sorghum/Millet	228	180	48	120	0.45	NS
Cowpea/Sorghum	109	40	69	120	4.5	*
Cowpea/Maize	618	306	312	120	3.18	*
Cowpea	124	66	58	90	4.8	*
			1986			
Groundnut/Sorghum	692	472	220	120	4.89	*
Groundnut	268	269	-VE	90	1.45	NS
Cowpea	247	166	81	90	8.4	*
Millet/Cowpea	520	381	139	120	-VE	NS
Sorghum	76	101	-VE	90	2.21	NS
Maize/Cowpea	1309	772	537	120	4.55	*
Maize	345	128	217	90	1.86	NS

N: applied nitrogen (NPK) per hectare; VE: negative response, *: significant and NS: not significant by Fisher`s LSD test at 5% level of probability.[1]Agricultural Development Programme.

Table 2. Crop response data by ADP[1] at Ilorin, Kwara State, Nigeria between 1985 and 1986.

Crops	Yield with fertilizer	Yield without fertilizer	Increase in yield	N kg ha^{-1}	Response	Significant
Yam	9259.2	7549.6	1709.6	90	16.84	*
Sorghum	1567.2	777.8	789.4	90	846.7	*
Maize	1272.1	1150.1	123.0	90	1.33	NS
Sorghum/Maize	912.0	844.0	68.0	120	0.61	NS
Yam/Sorghum	1188.0	970.0	218.0	120	1.95	NS

N: applied nitrogen (NPK) per hectare; *: significant and NS: not significant by Fisher`s LSD test at 5% level of probability. [1]Agricultural Development Programme

is partly due to the fact that “Nigeria’s agriculture is mainly rain-fed and she has not taken full advantage of its irrigation potential estimated between two and 2.5 million hectares”. The area under irrigation is officially estimated at about 220,000 ha or less than one percent of the total areas under crops. In contrast, while drought presents a major problem for the affordability and availability of food items, excessive rain has also contributed significantly to the current hike in food prices.

Factors responsible for land degradation in Nigeria

Geology

Nigeria soils suffer from geologically induced and inherently low soil fertility as the bedrock consists of mostly granites and gneiss which accounts for their low fertility because they are characterized by a low proportion of clay, making them easy to work, but also easy to lose (Moorman, 1981; Lal, 1997).

Erosion

Soil erosion has been the single largest threat to soil productivity in Nigeria. This is so because removal of the topsoil by any means has been severally shown to have many deleterious effects on the productive capacity of the soil as well as on ecological well-being (Oyedele and Aina, 1998). A review of the global agronomic impact of soil erosion identifies two severity groups of continents

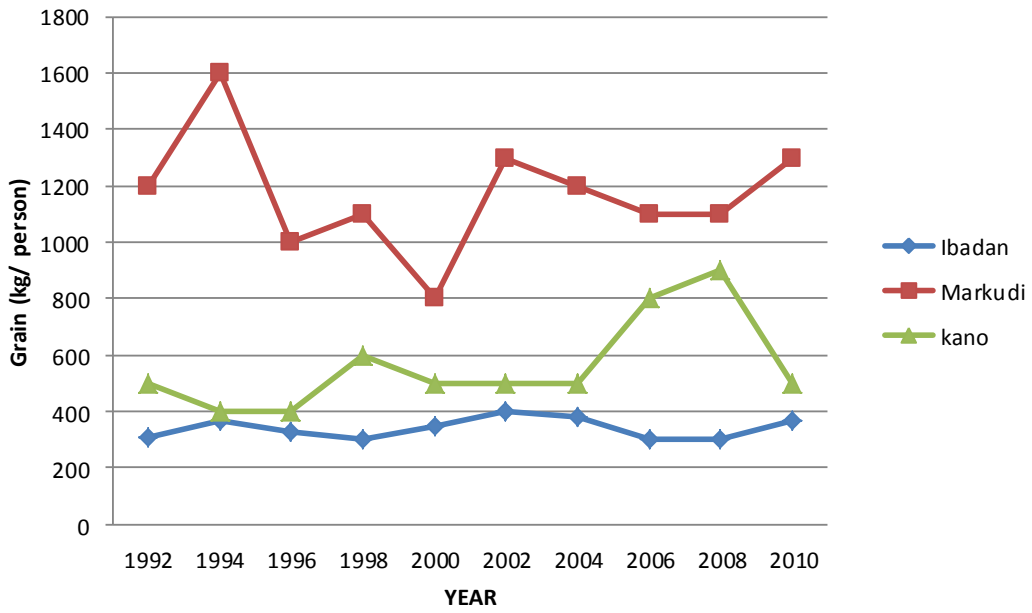

Figure 1. Grain per person in North, Middle-belt and Southern Nigeria. Source: Abbas (2009).

Table 3. Erosion "hot spots" in Africa.

Nutrient depletion	Water and wind erosion	Vegetation degradation	Constraints to yield increase
(1)Semiarid croplands of Burkina Faso and Senegal (leading to outmigration). (2) Large areas under transition to short fallow or permanent cropping. (3) Reduction of slit deposits in Nile Delta following construction of Aswan High Dam	(1) Sub-humid SE Nigeria on sandy soils. (2) Wind erosion in Sahel. (3) Mechanization in North Africa causing water and wind erosion. (4) Mechanization with inappropriate plowing techniques (e.g transition zone of West Africa)	(1) Arid and semiarid rangeland devegetation (e.g Ciskei) particularly near water sources. (2) Devegetation due to intensive collection of wood fuel(around cities (3) Devegetation due to overstocking.	(1) Lack of suitable technology for crop grown in areas less than300-m rainfall in North Africa. (2) Unsustainability of annual crops in humid lowlands of West Africa.

Source: Lal (1997).

and reveals that Africa, Nigeria inclusive, belongs to the more vulnerable group (Lal, 1997). Soil erosion by water seems to be the greatest factor limiting soil productivity and impeding agricultural enterprise in the entire humid tropical Africa. Some of the erosion hot spots identified in Africa are shown in Table 3. In Northern Nigeria, the problem is not limited to water and wind erosion prevails mainly in the dry zones. Both forms of erosion can thus aptly define land degradation in the region.

Soil physical and chemical deterioration

Investigation conducted by Agboola and Aiyelari (2000) in Ibadan, southwest Nigeria on two adjacent fields, one that has been under fallow for fifteen years (fallow field) and the other that has been continuously cultivated to maize for the same years shows marked degradation in the soil properties with a steep decline in the fertility status of the continuously cropped field (Tables 4 and 5). Continuous cultivation aided by land degradation factors are largely responsible for the decline in soil quality. Soil chemical deterioration in Nigeria may consist of significant loss in soil nutrients (mainly nitrogen, phosphorus and potassium) which are leached during the intense rainstorms, especially on unprotected land. In addition, they can be depleted by the crops themselves, particularly if the same crops are grown on the same land

Table 4. Soil quality indicators of the fallow sites in Ibadan, southwest Nigeria.

Site	Av. P (mg/kg)	pH	OM (g/kg)	TN %	Exch. Acidity Cmol/kg	Base Sat. %	CEC Cmol/ kg	Texture	Ks cm/hr	BD g/cm^3	MC %
1	21.50	6.52	19.1	1.1	0.45	93	6.40	LS	22.4	1.34	30.28
2	19.15	6.38	17.0	0.9	0.43	95	8.85	LS	22.1	1.35	30.28
3	20.15	6.45	19.3	1.1	0.53	93	7.89	LS	21.9	1.35	30.51
4	22.10	6.55	19.1	1.1	0.43	95	7.83	SL	22.2	1.32	29.83
5	24.15	6.70	24.6	1.4	0.42	95	8.02	SL	22.2	1.32	29.83
6	24.33	6.66	23.9	1.4	0.52	94	8.24	SL	20.4	1.32	9.83
7	24.24	6.66	22.9	1.3	0.53	94	8.29	SL	20.6	1.30	29.71
8	24.30	6.71	25.1	1.5	0.52	94	8.53	SL	22.1	1.30	29.71
9	24.10	6.73	24.9	1.5	0.62	93	12.00	LS	22.1	1.31	30.31
10	23.33	6.69	24.4	1.5	0.62	93	8.33	LS	22.1	1.30	29.90

OM: organic matter; TN: total nitrogen; CEC: cation exchange capacity; Ks: saturated hydraulic conductivity; BD: bulk density; MC: moisture content; LS: loamy sand; SL: sandy loam. Source: Agboola and Aiyelari (2000).

Table 5. Soil Quality indicators of the Continuous Cropping Sites in Ibadan,southwest Nigeria.

Site	Av. P (mg/kg)	pH	OM (g/kg)	TN %	Exch. acidity Cmol/kg	Base Sat. %	CEC Cmol/ kg	Texture	Ks cm/h	BD g/cm^3	MC %
1	9.58	5.75	10.8	0.6	1.22	77	5.34	S	15.08	1.68	24.19
2	5.51	5.20	10.8	0.6	1.85	70	6.18	S	14.20	1.68	24.19
3	5.27	5.65	12.6	0.7	1.33	76	5.59	S	15.10	1.66	23.70
4	5.27	5.55	15.7	0.9	1.45	76	5.92	S	15.01	1.65	23.76
5	5.21	5.55	9.6	0.6	1.45	76	6.04	S	15.03	1.57	22.61
6	3.83	5.50	12.4	0.7	2.16	67	6.57	LS	14.79	1.55	22.01
7	5.51	5.40	16.5	1.0	1.60	74	6.06	S	14.60	1.65	23.76
8	4.31	5.25	8.9	0.5	1.75	72	6.18	S	12.50	1.63	23.15
9	4.43	5.20	17.0	1.0	1.76	71	6.00	LS	14.90	1.65	23.27
10	5.27	5.05	12.6	0.7	1.76	71	6.09	L	12.61	1.66	23.57

OM: organic matter; TN: total nitrogen; CEC: cation exchange capacity; Ks: saturated hydraulic conductivity; BD: bulk density; MC: moisture content; S: sandy; LS: loamy sand; L: loamy. Source: Agboola and Aiyelari (2000).

year after year (Table 4), leading to decline in yield of many crops in Nigeria. Three types of physical deterioration are recognized, they are soil compaction, waterlogging and subsidence. The severity effects of soil erosion on soil physical property deterioration are shown in Table 6. This soil physical deterioration makes tillage more costly and impedes seedling emergence, increase evaporation and make the soils vulnerable to erosion. Million hectares of forest and water movement and gaseous exchange. Also, by restricting water infiltration, they cause faster run-off and water erosion (Eswaran et al., 2001).

Deforestation

Soil degradation caused by deforestation is also a serious threat in Nigeria. Deforestation exposes the soil to high temperatures which break down the organic matter, wood lands in Nigeria are said to be disappearing each year (Ogunkunle, 1986). More serious still is the gradual removal of trees in farms and pastures, which are crucial for protecting productive land from erosion. The rangeland has been changed for the worse, with many of the perennial grasses and riparian zones being replaced by nutritionally poorer annual grasses. This has permanently impaired the rangeland's potential for recovery and decreased its carrying capacity.

Soil management strategies for sustainable increase in crop yield

To reduce the impact of land degradation the FAO and

Table 6. The severity effects of soil erosion on some soil physical properties in Eastern Nigeria).

Severity of erosion	Bulk density (g/cm^3)	Field capacity (%)	Infiltration rate (mm/m)
No erosion	0.79	57.7	10.55
Slight	0.93	52.6	8.74
Moderate	1.04	49.6	5.34
Severe	1.09	46.2	4.45
extreme	1.35	28.0	1.63

Source: Mbagwu and Lal (1985).

the USDA have collated a lot of research findings and came out with the following suggested methods of soil management that can sustainably increase crop yield. These methods are not exhaustive and some of them have been well-researched in Nigerian Universities, Research Institutes and IITA, Ibadan (Lal, 1976, 1979; 1983). While acknowledging the positive functions of all the methods listed, however, given the characteristics of our soils and the acceptability of some of the methods by peasant farmers, the more popular methods such as conservation tillage deserves to be among farmers. The conservation methods are divided into three parts namely: agronomic, appropriate tillage and engineering methods.

Agronomic methods advocated include contour farming, mulching, crop rotation, strip cropping, dry land farming, organic agriculture and low external input and integrated approaches to soil fertility management, the appropriate tillage practices are methods that facilitate soil and water conservation, improve root system development, maintain a favorable level of soil organic matter content, and reverse degradation in the soil's life-support processes (Lal, 1976; Aina, 1979; Mbagwu and Lal, 1988; Freebairn et al., 1993) whereas the engineering methods advocated in this review include the construction of the following structures and land reshaping such as retaining structures, subsurface drainage and terraces.

CONCLUSION AND RECOMMENDATIONS

In Nigeria, majority of the farmers are dependent on low external-input agriculture and directly rely on the inherent quality of soil resources which are now been threatened by land degradation. Because of high-intensity (erosive) rainfall susceptible (erodible) soils, and sensitive ecological balances, the process of soil degradation has impacted on yields loss, food insecurity and large food importation bill. Yields were shown to decline because of soil factors, some associated with erosion, which leads to reduction in effective rooting depth; decrease in available water capacity, decline in soil organic carbon and depletion of other soil nutrients. This review suggests that it makes economic sense to address the problems of land degradation through increased conservation investments in land and water resources for sustainable increased food production.

Conflict of Interest

The authors have not declared any conflict of interest.

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