Statistical Evaluation of Sustainability of Selected Crop Production in Nigeria

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Abstract: Sustainable agricultural production is a paramount goal of many developing countries in order to ensure that foods required for the growing population are available in the right quantity and quality. This paper evaluated the extent of sustainability of the Nigerian crop production sector using secondary data from the FAO statistical database. Inferences of sustainability was made with contingency table developed by Monteith (1990) after computing geometric growth rates of land use and crop outputs. Results show that production of majority of the crops was not recently sustainable. Between 1961 and 1980, cereals (4.07%), maize (8.17%), sorghum (5.16%), millet (3.76%), yam (1.08%), kolanut (0.92%), oil palm (0.93%), vegetables and melon (0.82%) and plantain (2.53%) were sustainably cultivated while only cocoa (0.14%) and kolanut (1.82) percent show sustainability between 1981 and 2000. The findings suggest that ensuring sustainability of crop production in Nigeria requires adequate investments in highly productive farm technologies to make up for degradation of soil resources.
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1. Introduction

Agriculture is the most dominant sector in the economies of many sub-Saharan African nations. This is partly because the food it provides is the basis for human existence. However, it is paradoxical to note that as population grows, the food need of nations increases, but the arable land needed to grow the food becomes scarcer. In Nigeria, persistent stagnation in agricultural production is now a matter of serious concern. Although outputs in some crops have recently increased, it had been realized that most of these increases resulted from increase in land areas cultivated (Falusi, 1997). Thus, increasing crop production puts more pressure on the forest, and it is not sure whether this can be sustained as population further increases.

A growing awareness now exists of the fact that attainment of food security has gone beyond availability of improved production technologies, but the natural resource base upon which crop production ultimately depends must be appropriately managed and conserved (Mwale, 1998). In this respect, national governments, international organizations and non-governmental organizations (NGOs) are now actively involved in the development of workable natural resource conservation strategies in order to reverse the negative synergy developing from increased demographic pressure, environmental degradation and food insecurity.

Moreover, it had been realized that the traditional agricultural production system was stable and biologically conducive to soil nutrient replenishment because of the long fallow period (Scherr, 1999). But with increasing demographic pressure in many of the SSA countries, crop production has expanded to marginal lands and fallow periods have drastically reduced. There is now increase in the rates of forest clearing for agricultural production, and degradation of farmlands and decline in yields of crops persists (Pinstrup-Andensen *et al.,* 2001).

Furthermore, the peculiar characteristics of the humid tropical soils which are sandy, highly weathered, low in organic matter, and highly susceptible to soil erosion, nutrient depletion and compaction have worsened the situation (Pinstrup-Andensen and Pandya-Lorch, 2001). The implication of all these on SSA agriculture now poses a great challenge of how to meet the food needs of the ever growing population without irreversibly damaging the fragile land resource base to food policy makers (Pretty, 2001).

In Nigeria, the issues of concern to sustainable agriculture include the problems of soil vis-à-vis human induced soil degradation, bush burning and soil compaction (FAO, 2000). The problem of resource degradation has been identified as the most crucial environmental challenge that faces the nation (World Bank, 1990a). This conclusion was reached based on its great economic significance, the wide area of land that is affected, and the large number of people whose economic activities are directly hampered. Specifically, the problem of land degradation affects about 50 million Nigerians, and an estimated annual cost of US $3 billion is to be borne by the Federal Government. However, this conservative estimate only reflects the cost of food replacement through importation without considering the costs of health hazards that could likely result (World Bank, 1990a). Similarly, natural resource degradation and accelerated rates of population growth have significantly undermined the productive capacity of majority of the Nigerian soils (FAO, 1991; Higgins and Antoine, 1991).

Moreover, the problem of sustaining growth in agricultural production emanates from unplanned land use and inability to give adequate attention to physical, biological and ecological implications of agricultural intensification (Barbier, 2001). Consequently, crop yields on some of the high potential and high input areas of the tropics have now started to decrease, while the reserves of unused lands are decreasing and the resource base of agriculture continues to be degraded (FAO, 1997).

Given the level of agricultural technology development in Nigeria, there are 40-50 million people in excess of the land's supporting capacity at present who are just mining the soil to support themselves (FAO, 2000). In addition, widespread poverty and income inequality also confront the households' decisions for any investment in soil conservation practices (Barbier, 2001). Without being addressed, such economic condition is liable of culminating into serious ecological crises (WCED, 1987). Sustainable development would therefore be compromised under impoverished situation where short-term survival takes precedence over long-term productivity. In some northern states, for instance, just as it is happening in some nations in North Africa, ecology degrading activities by the private and public sectors are in urgent need of remediation. Many irrigation projects have ended up displacing poor farmers and pastoralists from their traditional sources of water and land. Thus, they are forced to move to more fragile lands that are prone to erosion (Barbier and Thompson, 1998; Barbier, 2000).

Conventional wisdom therefore teaches that a central and crucial point in the performance of Nigerian agriculture in the last three decades is the issue of production sustainability. This can be vividly seen from the persistent stagnation in agricultural production resulting from low resource productivity of small-scale farmers that dominate the food production sub-sector. For instance, total cereal production index decreased from 142 in 1996 to 135.6 in 1997, before slightly increasing to 135.9 in 1998. Even between 1990 and 1997, cereal yield per hectare decreased from 1093.11 kg to 1008.44 kg (ECA, 1998).

Sustainable food production as a recent policy objective in Nigeria is far from being realized. Poor agricultural production has led to decline in the level of welfare among the rural and urban households. As food prices increase, poverty and malnutrition problems widen in dimensions. Worse still, 87 percent and 67 percent of the core poor were in agriculture in 1985 and 1992 respectively (FOS, 1999). It has also been found that 77 percent of farmers are poor, while 48 percent are in extreme poverty (FOS, 1999). Because crop yields are low, some farmers cannot even pay for hired labour and land rent at the end of the season. Many who are willing to invest in soil conservation technologies cannot get the means to do so. And because of the fight for survival, continuous cropping and deforestation continue in many ecological zones of the nation.

The importance of agriculture in Nigerian economy cannot be over-emphasized. Specifically, agriculture contributes more than 30 percent of the total annual GDP, employs about 68 percent of the labour force, accounts for over 70 percent of the non-oil exports, and provides over 80 percent of the food needs of the country. However, the small-scale farmers that dominate the sector are facing serious problems in getting good land due to progressive growth in population, land degradation, and inadequate planning in the use of available land (FAO, 1991; Barbier, 2000, 2001). In spite of massive government investment in the sector and related programmes over the years, in the form of input subsidies, the River Basin Development Authorities, Agricultural Development Projects (ADPs), Green Revolution, Operation Feed the Nation, Directorate for Food, Roads and Rural Infrastructure (DFRRI), among others, the sector's performance is still far below expectation.

The Nigerian small-scale farmers largely depend on traditional methods of farming. These farmers are facing various land use constraints, which is one of the major sources of declines in agricultural productivity. Even if rural households choose to stay on degraded land, its declining productivity will be unable to support growing rural populations, not to consider the nation as a whole. Thus, some households are forced to abandon existing agricultural areas in search of new forest land. Where land is scarce, continuous cropping on fragmented pieces of degraded farm plots persists with little or no soil conservation investments, and resource productivity eventually decreases (FAO, 1991).

Low resource productivity of Nigerian agriculture is a reflection of its comparatively low input use (FAO, 2000). Reardon (1998) noted that low use of fertilizer across African countries is a major cause of concern, both from the food production and environmental perspectives. FAO (1998) submitted that shortage of good quality agricultural land for smallholder is a problem in many regions of the world. Payment of compensation in cash or in kind for the use of land no doubt affects land use intensity (Adegboye, 1986). According to Nwosu (1991), the government of Nigeria has been acquiring large tracts of land for agricultural and non-agricultural purposes. Therefore, access to land through ownership or secure tenure is a *sine qua non* for improving agricultural productivity.

In order to therefore address natural resource degradation and food insecurity, the logical and paramount goal that faces Nigerian food policy makers is the development of progress pathways that enhance sustainable natural resource management and increased food production. This is the only way to harmonize population growth with people's increasing food demand so that the nation can steadily achieve its medium term development goal.

Enough evidence abounds on the persistent weakness of the Nigeria's natural resource base to support increasing food demand of the growing population (World Bank, 1990a; 1990b). Food policy makers have now realized the need to integrate environmental matters into the frameworks of agricultural policies, and studies on agriculture-population-environment nexus are now highly demanded at all levels of agricultural development planning. This study then ranks most applicable to current Nigeria's goal of sustainable economic development, because it will provide some important inter-linkages on the issues of environmental degradation and sustainable agricultural production.

Policymakers in developing countries are increasingly frustrated as they try to increase agricultural production, reduce poverty, and sustain their resource base. Their frustration is compounded by lack of information about how to bring about these desired outcomes, and they are unsure about which sustainability targets they should aim for, what the short-term and long-term costs will be, and how to go about reaching these targets (Vosti, 1992). Therefore, economic planners in developing countries are facing serious dilemma on the need to strike a balance between meeting the immediate short-term needs of increasing agricultural production through forest clearing or destruction and the grave long-term cost of reduced agricultural productivity through land degradation. However, this study partially evaluates sustainability of Nigerian crop production sector using the trends of land areas and output. This is vital for addressing future food requirements of the country in relation to persistent degradation of land resources. In the remaining parts of the paper, materials and methods, results and discussions and conclusion have been presented.

2. Materials and methods

The area of study

This study was carried out in Nigeria. Nigeria is one of the Sub-Saharan African (SSA) nations located in the western part of Africa. The nation shares boundary with the Republic of Benin to the west, the Niger Republic to the north, the Republic of Cameroon and the Chad Republic to the east, and the Atlantic Ocean forms a coastline of about 960 Km^2 to the south. The country lies between the Latitudes 40^0 and 140^0 north of the equator. The climate varies from equatorial in the south to tropical in the center to arid in the north. It is equally blessed with a total land area of about 92,377,000 hectares, out of which about 91,077,000 hectares are solid land area. Its terrain consists mainly of southern lowlands, which merge into central hills and plateaus, mountains in the southeast, and plains in the north. Natural resources include petroleum, tin, columbite, iron ore and coal. Soil degradation, deforestation and droughts are the nation's primary environmental concerns.

Sources and limitations of data

The data used in this study were the national aggregates for land areas and output contained in the *Production Yearbook* published by the Food and Agriculture Organization (FAO), FAOSTAT web site (www.fao.org). The study period can be divided into two. First, 1961-1980, which was characterized by low population, low rate of urbanization, agricultural policies that were not too demanding on the environment and little threat from depletion of the ozone layers resulting into climatic vagaries. The second period, 1981-2000 can be described as the period of high population density, high rate of urbanization, increasing threats from climate vagaries, and adoption of agricultural policies like the Green Revolution and the Structural Adjustment Program (SAP) that largely characterized by increased use of agrochemicals. A comparison of the results of the data analysis was therefore made for the two periods.

Methods of data analysis

Standard deviation

The standard deviation is the square root of variance, and it gives us an index of dispersion expressed in the same units as the observations from where it is calculated (Frank and Althoen, 1994). The standard deviation is represented by the symbol *s* and is given by:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}} \qquad 1.$$

Where X_i is the individual observation/score, X is the mean and n is the number of observations.

Test of statistical significant difference

The *t-test* was used to compare some computed means in order to test whether a significant difference exists between them. The formula is given as:

$$t_{cal} = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{S_1^2/n_1 - 1 + S_2^2/n_2 - 1}} \qquad 2.$$

Where:

t_{cal} = student's t distribution value calculated
$\bar{X}_1$ = mean for variable X_1,
$\bar{X}_2$ = mean of for variable X_2,
S_1= standard deviation for variable X_1,
S_2= standard deviation for variable X_2,
n_1= number of observations in variable X_1,
n_2 = number of observation in variable X_2,

Crop production sustainability was inferred from the contingency table developed by Monteith (1990) (table 1). In order to determine the sustainability of crop production, the geometric growth indexes for the land areas harvested and the yields were calculated. These form the basis for conclusion. If the land index is greater than yield index, production is not sustainable, and vice versa.

Table 1: Contingency table for inferring production sustainability based on trends of system inputs and outputs

Output	Input		
	Decreasing	Constant	Increasing
Decreasing	Indeterminate	Unsustainable	Unsustainable
Constant	Sustainable	Sustainable	Unsustainable
Increasing	Sustainable	Sustainable	Indeterminate

Source: Monteith (1990)

The geometric growth (indices of sustainability) were computed from the equation below:

$$I_t = \sqrt[k]{(1+p_1)(1+p_2)..(1+p_k)} \qquad 3$$

Where: I_t =index of output and input used in period t

p_i = percentage growth rate between years t and t-1.

k = n -1 (where n is the number of observations)

3. Results and Discussions

Testing for statistical difference in land areas harvested and yield

In order to analyse the trend in the use agricultural land and crop yields, average land areas cultivated and yields for each crop in the 1961-1980 and 1981-2000 periods were computed, and using the *t-statistics*, statistical differences between them were tested. Table 2 shows that in grain crops the mean differences between land area cultivated to cereal crops, maize, and rice were all statistically significant at 1 percent level. Moreover, the average yields per hectare show statistical difference for cereal, rice, millet and sorghum at 1 percent level. It is worth noting that while maize shows statistical mean difference for land area, yields are not statistically different at 5 percent. This implies that over those periods, maize yields are still at almost the same level. Therefore, it could be inferred that recent increases in maize production in Nigeria have not really come from improvements in the yields, but from expansion in land areas. Falusi (1997) had earlier made this assertion. Millet land areas mean difference is with negative sign, while the yield difference is positive, just as it is recorded in all other cereal crops. This shows that despite the fact that land area cultivated to millet has declined over the years, the yields have increased significantly perhaps due to use of improved seeds, increase in land and fertilizer use that is more prevalent in some Northern States where sorghum is largely grown.

Table 2: Mean difference and t-statistics for some crops land areas and yields during 1961-1980 and 1981-2000

Crop	Cultivated Area		Yield Per Hectare (Kg/Ha)	
	Mean Difference	T-Statistics	Mean Difference	T-Statistics
Cereal	130,003,415	109.592*	473.78	9.7212*
Maize	2,482,200	6.3387*	197.5223	1.3911
Rice	1,099,110	8.1468*	410.230	4.4181*
Millet	-64,700	-0.1753	479.46	7.6181*
Sorghum	383,410	0.9119	368.75	6.0121*
Tuber/Roots	2,055,239.25	1.3976	1,173.77	1.2161
Cassava	1,127,340.4	5.9480*	688.25	2.9043*
Yam	808,600	4.8258*	-458.295	-0.2232
Potatoes	9,333.85	5.6017*	-321.98	7.0686*
Cocoa	23,125	4.1950*	13.555	0.565
Kolanut	-147,500	-2.5047**	69.565	0.2976
Oil-Palm	218,400	2.1636**	123.59	8.1774*
Plantain	18,225	1.6717	1,647.27	7.991*
Vegetables	343,176	6.5469*	791.469	5.4927*

Source: Computed from data from FAO Publications

Note: * Statistically significant at 1% level, ** Statistically significant at 5% level

In the roots and tuber crops, cassava, yam and potatoes all have their mean differences in land area harvested to be statistically significant at 1 percent level. However, it is only cassava and potatoes that show statistical difference for the average yields. It should be noted that the average yield differences in potatoes and yam are with negative sign. This negative sign implies that their production has not been sustainable over those years.

In cash crops, mean difference for cocoa land area shows statistical difference at 1 percent level, but no statistical difference is computed for the yield difference. Mean difference for kola nut land area harvested is with negative sign, and it is statistically significant at 5 percent level. Yield difference for kola nut is however with positive sign, but statistically insignificant at 10 percent level. It is only in oil palm that the land areas mean difference and yield difference are not equal to zero at 5 percent level and 1 percent level respectively.

Finally, in fruits and vegetables, only vegetables and melon have the mean difference land area not equal to zero, being statistically significant at 1 percent level, but both the mean differences of the yields in plantain and vegetables and melons are statistically significant at 1 percent level.

Geometric growth index as a measure of sustainable crop production in Nigeria

This study used the geometric growth index to determine the sustainability index of crop production in Nigeria. This is done in order to overcome the weaknesses of the time trends proposed by Monteith (1990). This weakness is noticed by its not being able to determine the sustainability state when both input and output move in the same direction. Using the geometric proportionate growth index, any production system is concluded sustainable if the proportionate yield growth index is greater than the proportionate land area growth index. However, it should be stressed that the analyses done here have some limitations in the sense that only land is considered as input, and nothing is known about the state of the land in respect of depletion and/or rejuvenation of soil nutrients. Taking all other factors to be constant, this section therefore uses the trend of output and input approach to partly infer production sustainability.

Table 3: Geometric growth index as a measure of sustainable crop production in Nigeria (1961 – 1980)

Crop	Yield Index	Land Index	Sustainability Index	Inference
Cereal	1.0202	0.9795	0.0407	Sustainable
Maize	1.0262	0.9445	0.0817	Sustainable
Rice	1.0429	1.0712	-0.0283	Sustainable
Sorghum	1.0335	0.9819	0.0516	Unsustainable
Millet	1.0169	0.9793	0.0376	Sustainable
Root and tubers	1.0107	1.0118	-0.0011	Unsustainable
Cassava	0.0006	1.0229	-0.0223	Unsustainable
Yam	1.0161	1.0053	0.0108	Sustainable
Potatoes	0.9842	1.0513	-0.0671	Unsustainable
Cocoa	0.9868	1.000	-0.0132	Unsustainable
Kolanut	1.0038	0.9946	0.0092	Sustainable
Oil palm	1.0000	0.9907	0.0093	Sustainable
Vegetable & Melon	1.0110	1.0028	0.0082	Sustainable
Plantain	1.0198	0.9945	0.0253	Sustainable

Source: Computed from data from FAO and Publications

The sustainability indices (table 3) show that out of the crops that were sustainably cultivated, maize has the highest sustainability index of 8.17 percent, while vegetables and melon have the lowest index of 0.82 percent. On a general note, the analysis shows that many of the food and cash crops were sustainably cultivated between 1961-1980. This could be traced to fertility of land. The fallow periods then could be as high as 3 -4 years. The pressure on land during that period was lower because of low population, and farmers readily got the needed fertilizer to add to their crops for increased productivity.

Table 4 shows that during the 1981–2000 period, agricultural production was mostly unsustainable. Only cocoa and kolanut were sustainably cultivated. This shows that land area is growing at higher rate than yield. This could be attributed to possible extension of crop production activities to marginal land and reduction of fallow period.

Cocoa and kolanut that were sustainably cultivated could be attributed to dissolution of the Commodity Boards for the enhancement of cash crop production under the SAP, which made farmers to be able to take better care of their cocoa farms due to better market prices as liberalization policy was fully implemented. As cocoa trees were being cared for, kolanut would not be left out since most farmers intercrop it with cocoa. All these would have contributed to sustainability of cocoa and kolanut production.

Table 4: Geometric growth index as a measure of sustainable crop production in Nigeria (1981 – 2000)

Crop	Yield Index	Land Index	Sustainability Index	Inference
Cereal	1.0057	1.0512	-0.0455	Unsustainable
Maize	1.0025	1.1194	-0.1169	Unsustainable
Rice	0.9853	1.0754	-0.0901	Unsustainable
Sorghum	1.0001	1.0380	-0.0379	Unsustainable
Millet	0.9797	1.0619	-0.0822	Unsustainable
Root and Tubers	0.9995	1.0727	-0.0732	Unsustainable
Cassava	1.0079	1.0518	-0.0439	Unsustainable
Yam	0.9949	1.0932	-0.0983	Unsustainable
Potatoes	0.9881	1.0884	-0.1003	Unsustainable
Cocoa	1.0172	1.0032	0.014	Sustainable
Kolanut	0.9957	0.9775	0.0182	Sustainable
Oil palm	1.0034	1.0215	-0.0181	Unsustainable
Vegetable & Melon	1.0119	1.0437	-0.0318	Unsustainable
Plantain	1.0082	1.0238	-0.0156	Unsustainable

Source: Computed from data from FAO Publications

Table 5 also shows that only cocoa, kolanut and plantain were sustainable cultivated during the period 1961–2000. Sustainable cultivation of plantain could be explained by its ability for natural regeneration and the fact that most farmers use the plant to raise cocoa at the early stage because it provides shade for the tender plants. This implies that increased cocoa production could result into increased plantain production.

Table 5: Geometric growth index as a measure of sustainable crop production in Nigeria (1961 – 2000)

Crop	Yield Index	Land Index	Sustainability Index	Inference
Cereal	1.0126	1.0143	-0.0017	Unsustainable
Maize	1.0139	1.0275	-0.0136	Unsustainable
Rice	1.0133	1.0714	-0.0581	Unsustainable
Sorghum	1.0072	1.0092	-0.0020	Unsustainable
Millet	0.9986	1.0012	-0.0106	Unsustainable
Root and Tubers	1.0027	1.0407	-0.038	Unsustainable
Cassava	1.0011	1.0374	-0.0363	Unsustainable
Yam	1.0053	1.0471	-0.0418	Unsustainable
Potatoes	0.9848	1.0693	-0.0845	Unsustainable
Cocoa	1.0018	1.0016	0.0002	Sustainable
Kolanut	1.0001	0.9845	0.0156	Sustainable
Oil palm	1.0017	1.0022	-0.0005	Unsustainably
Vegetable & Melon	1.0112	1.0224	-0.0112	Unsustainable
Plantain	1.0136	1.0088	0.0048	Sustainable

Source: Computed from data from FAO Publications

4. Conclusion

Sustainability of agricultural system is paramount for ensuring food security of a nation. This objective is however far from being achieved in many developing countries due to rapid degradation of soil resources. The findings from this study have shown that crop production in Nigeria was more sustainable between 1961 and 1980. This study also found that the growth rates of yield are lower than that of land area in most of crops cultivated in Nigeria in recent time. The government needs to redefine research focus and priorities in order to meet the challenges of resource degradation. Many researches in Nigeria are wrongly focused or unclearly defined. Redefining research goals and priorities is imperative. More research is needed on the impact of human cropping activities on the environment especially in the Savannah zone that produces about 80% of grains and 95% of livestock products to satisfy the basic human needs of food. Sustainable agriculture as an integral component of sustainable economic development in Nigeria must be approached by research efforts geared towards broad based holistic goals that can be achieved through multi-disciplinary and system approaches that give due consideration and cognizance to the interactions between man, technology, environmental resources, economic and ecology. Integrating the goal of sustainable and regenerative agriculture is therefore a *sine qua non* for enhancement of resource productivity in the Nigerian agriculture.

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