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Importance of Agricultural Land Use Evaluation in Nigeria: A Review of Literature

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Abstract: The study deals with the importance of agricultural land use evaluation in Nigeria. The study is a desk study which utilised secondary data. The desk study involved the review of published literature, such as books, technical reports and journal articles. The internet was used extensively to search for relevant data to consolidate data that was collected from relevant institutions, organisations. The study finds that agricultural land use evaluation is an important precursor to planning sustainable agricultural programmes. The study has highlighted the importance of sustainable agricultural development to the global community and its relevance to the sustainable development of Nigeria. The use of GIS techniques which makes it possible for the integration and analyses of varied data has become a preferred method and modern trend in agricultural land use evaluation. The study, therefore recommends the encouragement and use of GIS techniques in agricultural land use studies.

Key words: Agriculture, remote sensing, land evaluation, agriculture, sustainability, sustainable agriculture, GIS, Nigeria

INTRODUCTION

Before the 20th century, almost all increases in crop and animal production is said to have occurred as a result of increases in the area cultivated. At the beginning of the 20th century, however the gradual transition from a natural resource based to a science-based system of agricultural production became necessary (Ruttan, 2002). This allowed for a more objective approach in measuring the growth of agriculture and the improvement of several agricultural techniques. According to Rosenberg (2012), farming in the 20th century became highly technological in more developed nations with geographical technologies like Geographic Information System (GIS), Global Positioning System (GPS) and remote sensing while less developed nations continued with practices which are similar to those developed after the first agricultural revolution, thousands of years ago. About 45% of the world's population rely on agriculture for their livelihood. The global population involved in agriculture ranges from about 2% in the United States to about 80% in some parts of Asia and Africa. There are two types of agriculture, subsistence and commercial. Majority of the population is involved in agricultural practice and subsistence agriculture to tend to their need for food (Aliber and Hart, 2009).

Okuneye and Adebayo (2002) described agricultural development in Nigeria as slow in spite of the various agricultural policies over the years. This is because agricultural practice in Nigeria is predominantly subsistent based with gross inadequacy of advanced agricultural technologies. Deliberate actions by the Government of Nigeria towards stimulating development in the agricultural sector can be traced back to the 1970's. The Government of Nigeria has since then formulated a number of programmes and strategies aimed at remedying the decline in agricultural activities which has been consistently blamed on the discovery of oil in the Niger Delta region. The near eclipse of the sector in the era of the oil boom (1972-1975) and inconsistent government policies (Okuneye and Adebayo, 2002; Aregheore, 2005; Ragasa *et al*., 2010; Adebayo *et al*., 2009) have been cited as the main challenges to food security in Nigeria.

Policy programmes and investments did not have significant and visible effects on the development of the agricultural sector in Nigeria due to inadequate commitment from successive governments to ensure sustainability. There are two key sustainable development plans of the present Government of Nigeria. The vision 20:2020 agenda (NPC, 2009) which seeks to put Nigeria among the first 20 developed nations by the year 2020 and the transformation agenda (NPC, 2011) which has short term sector specific strategic goals towards attaining vision 20:2020. These plans show signs of promise for agricultural development with well-articulated sustainability plans. However, they may require firm legislative backing to outlive the present government. Not withstanding, the need to pursue sustainable agricultural development cannot be overemphasized.

The sustainability of agricultural production systems have become a major concern of agricultural researchers and policy makers in both developed and developing countries (Rossiter, 1994; Medugu, 2006; IITA, 2008; Alademerin and Adedeji, 2012). In order to achieve an effective sustainable plan for the development of agriculture, it is important to determine the available potential that exists through land evaluation and land use planning. Land evaluation is the assessment of land performance when used for a specified purpose, involving the execution and interpretation of surveys and studies of landforms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation (FAO, 1976). Land evaluation has received the attention of several scholars in Nigeria (Mbajiorgu and Anyadika, 1997; Akinbol *et al*., 2008; Babalola *et al*., 2011; Uchua and Nduke, 2011; Uchua *et al*., 2012). These studies utilized the mapping capabilities of GIS and Remote Sensing in studying agricultural systems. However, contemporary factors such as climate change, population growth, HIV/AIDS and related diseases, rural-urban migration and availability of hybrid species influence agricultural contributions to economic growth in Nigeria (Anthony, 2010). These factors have not received adequate attention in land evaluation studies in Nigeria.

Internal migration in Nigeria is induced by scarcity of land, impoverished soil, declining crop yields, poor harvests and soil erosion among others. Migration is also known to increase the rate of HIV transmission and may limit access to treatment and care (Habib and Jumare, 2008). The rate of HIV prevalence in Nigeria is 4.1% and Nigeria is the second most burdened country in sub-Saharan Africa (FMHN, 2010). It is, therefore important for agricultural land evaluation studies in to assess these challenges adequately alongside other socioeconomic and biophysical characteristics. This would provide policy makers with more far-reaching recommendations to plan the sustainable development of agriculture. This study intends to utilize relevant literature to demonstrate the importance of agricultural land evaluation towards achieving sustainable agricultural development in contemporary Nigeria.

Study area: Nigeria is the most populous country in Africa with an estimated population of 162, 470, 737 inhabitants (World Bank, 2013a, b). Nigeria's population is divided among 478 different ethnic groups, some numbering fewer than 10,000 people. Of the different ethnic groups, 10 (Hausa, Fulani, Yoruba, Ibo, Kanuri, Tiv, Edo, Nupe, Ibibio and Ijaw) account for nearly 80% of the population. About 25% of the population is in the former Western region (12% area coverage), 21% in the former Eastern region (9% area coverage) and 53% in the former Northern region (79% area coverage).

Data collection: The research methodology consists of desk study and secondary data collection. Desk study involved the review of published literature such as books, technical reports and journal articles. The internet would be used extensively to search for relevant data to consolidate data that was collected from relevant institutions, organisations. Information collected was used in narrative explanations with occasional descriptive statistics in form of tables and graphs.

THEORETICAL FRAMEWORK FOR LAND EVALUATION

The modern era of land evaluation began with the publication of the United Nations Food and Agricultural Organisation (FAO) "Framework for Land Evaluation" in FAO Soils Bulletin 32 (1976) and subsequent guidelines for land evaluation of general kinds of land use (FAO, 1983, 1984, 1985, 1991). The FAO land evaluation approach was first presented at an expert meeting in Wageningen, Netherlands in October, 1972 where it was extensively discussed and further refined. The FAO framework is not a formal methodology but a collection of concepts, principles and procedures on the basis of which local, regional and national evaluation systems can be developed (Verheye *et al*., 2008).

The FAO framework stands as one of the most adequate evaluation methods (Riveira and Maseda, 2006) and has become the main point of reference for land evaluation (George, 1997). It is a flexible system which includes social and economic issues and permits the application of different techniques in order to match land use and units. The FAO framework has provided a basis for the development of various land evaluation techniques, such as the automated land evaluation (Rossiter and Van Wambeke, 1991); quantified land evaluation which depends intrinsically on mathematics and computation (Beek *et al*., 1986; Wagenet and Bouma, 1993); economic land evaluation (Rossiter, 1995; Johnson and Cramb, 1996) and Agro-Ecological Zoning (AEZ) Systam (FAO, 1996). Another post-FAO system is the fertility capability classification (Sanchez *et al*., 2003) which groups soils according to theproblems they pose for agricultural management. Yialouris *et al*. (1997) carried out a suitability evaluation for 5 crops and selection of

optimum crops using the FAO framework and GIS. The study utilised maps of soil, various land uses and climatological information.

Sustainable agriculture: Land is a finite resource (UNEP, 1992). Therefore, the assumption that suitable lands for expansion could always be found when needed is false. Around the world today, there is clear evidence of impending land shortage for various purposes and especially agriculture. Areas in which the combination of land and freshwater resources is moderately or well suited to agriculture are for the most part, already in use. It is therefore, not surprising that the efficient use of agricultural lands is becoming a matter of life or death for the increasing population of mankind (Smyth and Dumanski, 1993).

The United Nations Environment Programme (UNEP, 1992) provoked global political respectability on the concept of sustainable development. The continuing global mismanagement of earthly resources raises questions about the best way to present information on natural resources to land use planners and decision makers and how this knowledge can be put to good use. United Nations (2012a) have continued to advocate for the sustainable use of earthly resources. This is to ensure the livelihood of future generations which is seriously at risk due to projected population growth rate is not endangered by present production choices. Agriculture which is the main source of income for most of the world's population must increase dramatically to meet the food gaps being observed. However, the means of production must be those that can be properly maintained on a sustained basis.

The National Institute of Food and Agriculture (NIFA, 2009) of the United States, Department of Agriculture presented the legal definition of sustainable agriculture as addressed by the United States Congress in the 1990 (Food, Agriculture, Conservation and Trade Act of 1990, public law 101-624, Title XVI, subtitle A, section 1603). According to NIFA (2009), the term sustainable agriculture is defined as an integrated system of plant and animal production practices having a site-specific application that will over the long term satisfy human food and fibre needs enhance environmental quality and the natural resource base upon which the agriculture economy depends; make the most efficient use of nonrenewable resources and on farm resources and integrate where appropriate, natural biological cycles and controls, sustain the economic viability of farm operations and enhance the quality of life for farmers and society as a whole.

According to United Nations (2012b), sustainable agriculture should include crops, livestock, forestry, fisheries and aquaculture that improves food security, eradicates hunger and is economically viable while conserving land, water, plant and animal genetic resources, biodiversity and ecosystems and enhancing resilience to climate change and natural disasters. United Nations (2012b) also recognized the need to maintain natural ecological processes that support food production systems.

Sustainable agriculture is driven through science based approaches. Science based agriculture has led to an improvement in agricultural processes and yields in the 21st century. As Dreyfus (1987) puts it stable agriculture based on a tradition which is transmitted from generation to generation has been gradually replaced by the image of an ultra-modern enterprise whose rapid evolution is propelled by the progress of science and technology. Douthwaite and Ortiz (2001) are of the opinion that science plays a crucial role in helping us avoid the impending catastrophe of food insecurity that is partly of its own making. Perhaps now here is this better demonstrated than in the need for science in developing sustainable agricultural systems. The main role of science in agriculture has been to help us generate novelties that allow us to produce more with less land and less effort and the results have been spectacular. Protacio (2009) defined science based agriculture as the body of evidence-based knowledge passed on to farmers in the form of improved seeds and cropping systems, fertilizers, plant growth regulators, pesticides, tillage and spray and improved post-harvest equipment. It is an empirical body of knowledge, generated by scientific methodology and validated by the worldwide scientific community. Science has made it possible for farmers to attain high yields and to be competitive in the world market. This is important because of heightened concerns over the combined effect of population growth and climate change on global food security (Case, 2012). Sustainable agriculture demands more prudent use of land resources which underscores the importance of land evaluation in order to derive maximum benefits with minimum degradation. It is an applied classification system that assesses the capacity of the soil and land for various uses (Dorronsoro, 2002). Planning for sustainable agriculture in Nigeria requires a good knowledge of the agricultural sector and the current agricultural practices.

Agriculture in Nigeria: Prior to the attainment of independence, agriculture was the most important sector of the Nigerian economy and accounted for >50% of GDP

and >75% of export earnings. Nigerian agricultural holdings are small and scattered and farming is carried out with simple tools. These small farms produce about 80% of the total food. About 30.7 million ha (76 million acres) or 33% of Nigeria's land area are under cultivation (Encyclopedia of the Nations, 2013).

According to Federal Ministry of Agriculture and Rural Development (FMARD, 2010), crop farming is the dominant agricultural activity in Nigeria. The crop sub-sector contributes about 85% to the agricultural Gross Domestic Product (GDP) whereas livestock contributes about 10%, fisheries about 4% and forestry about 1%. Root crops (in particular, cassava and yam) dominate in tonnage, though cereals (maize, guinea corn, rice and millet) are becoming important domestic food items. Root crops account for 9% of GDP whereas cereals account for 8%. Agricultural produce is, however far below their potential yields which are often predicted based on growth under idealized conditions of controlled field trials or maximum yields of comparable agro-ecological zones.

The average annual agricultural sector growth rate from 2001-2008 was about 7%. The current growth of agriculture has nonetheless come from increasing the use of land rather than from gains in productivity. Growth in agricultural output has no doubt been on the rise as farmers are stepping out of the nominal thinking of subsistence agriculture with the support of government and embracing modern civilisation and investing in large scale farming (Ragasa *et al*., 2010).

The most recent policy of government on sustainable agriculture is the Agricultural Transformation Agenda (ATA). The ATA focuses on agriculture as a business as opposed to a developmental project which has been the case in the past. The ATA will help achieve the transformation of the agricultural sector to create jobs, create wealth and ensure food security develop value chains where Nigeria has comparative advantage and it has a sharp focus on youths and women (FMARD, 2011). The ATA, is especially crucial for the development of women because women make important contributions in the agricultural sector. However, they lack access to land for farming and they have limited access to agricultural inputs, such as improved seedlings, agricultural extension services, credit and improved technology. Most of their farming and processing activities are performed using manual labour. This makes farming and food processing very arduous contributing to low output and high wastage (Okojie, 2007).

Agricultural resources in Nigeria are located mainly in rural areas and most of them are under the direct control and management of the rural population who exploit them for their economic activities in such areas as crop production including fishing, livestock and logging. The emphasis on private economic costs and benefits encourages excessive exploitation of the environment. Therefore, monitoring the interaction of rural exploitation and production activities in rural areas is important in national development efforts for sustainable agriculture (Medugu, 2006).

It therefore means that the implementation of sustainable agriculture in Nigeria should consider the sustainable livelihoods framework which places emphases on increasing livelihood assets and improving the capabilities of the rural poor. This approach could lead to improvement in sustainable production through the transfer of agricultural technologies and management practices, improved access to input and commodity markets and contribute to an enabling policy environment (IITA, 2008). Sustainable agriculture requires a value system which enshrines the principle of sustainability over generations and successive governments. According to the Agricultural Research Council of Nigeria (ARCN, 2010), a total of 205 agricultural technologies have been produced mostly by agricultural research institutes. However, proper records are not available to show that the ACRN or the institutes actually monitor the adoption or impact of these technologies. A publication by Ragasa *et al.* (2010) stated that 40% of individual researchers did not have any knowledge about the adoption or impact of new varieties or breeds that they have been produced and 20% did not have information about the adoption or use of new management practices or technologies developed.

Crop farming in Nigeria: According to the World Bank (2013b), there are several crop farming types depending on the type of crops and region. However, crop cultivation takes into consideration water sources necessitating a water based classification. Crop farming is therefore, either rainfed or irrigated. Rainfed agriculture is most significant in sub-Saharan Africa where it accounts for about 96% of the cropland and irrigated farming account for 4% of the total area cropped in Africa. Rainfed agriculture is predominant in Nigeria while large-scale irrigation projects are few and generally restricted in scope (Rilwani and Gbakeji, 2009).

The latest crop production index for Nigeria shows agricultural production for each year relative to the base period 2004-2006. It includes all crops except fodder crops. Regional and income group aggregates for the FAO's production indexes are calculated from the underlying values in international dollars, normalized to the base

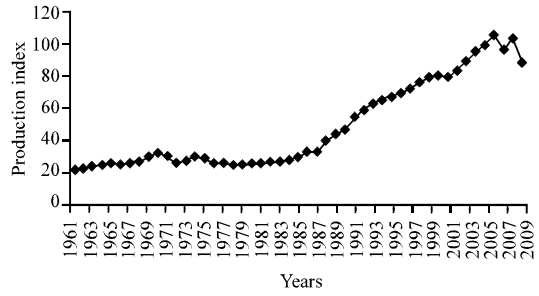

Fig. 1: Crop production index for Nigeria (1961-2010) (World Bank, 2011)

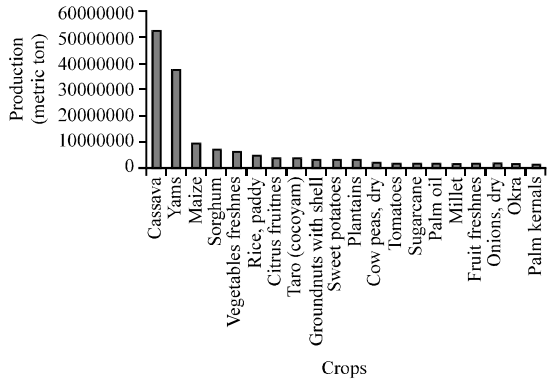

Fig. 2: Crop production in Nigeria in 2011 (FAO, 2013)

period 2004-2006 (World Bank, 2011). Figure 1 shows the crop production index for Nigeria from 1961-2010. The trend shows a decline from 2006.

Agricultural contribution to National Gross Domestic Product (GDP) has been hovering around 40-41% annually, since 2003. The largest sub-sector contribution to this national output is from the crops sub-sector which annually ranged between 36 (2003-2005) and 37% (2006-2007). The livestock sub-sector contribution to GDP is almost constant at 2.6% while that of fishing is at 1.37%. The agricultural sector GDP growth rate is the highest contributor to non-oil GDP growth rate. After an initial dip from 6.64% in 2003 to 6.50% in 2004, the growth rate appreciated per annum from 2004 (7.06%) to 7.43% in 2007 (Azih, 2011). With increases in crop yield, agriculture has become an important contributor to the Nigerian economy in the past decade despite the predominance of the oil sector (Izuchukwu, 2011). This is reflected in the status of Nigeria in the world ranking of crop production by the FAO. Nigeria ranks high in the production of several crops and is the highest producer of cassava and yam in the world. Figure 2 provides information on the production output of various crops in Nigeria.

Even though, crop production is on the rise in Nigeria, only <50% of the Nigeria's cultivable agricultural land is under cultivation. Crop production in Nigeria is dominated by smallholder and traditional farmers who use rudimentary production techniques with resultant low yields. These farmers are constrained by many problems including those of poor access to modern inputs and credit, poor infrastructure, inadequate access to markets, land and environmental degradation and inadequate research and extension services (Olajide *et al*., 2012). This suggests a lot is still needed to ensure Nigeria is headed towards sustainable agriculture. This also suggests that there are huge investment opportunities in the agricultural sector in Nigeria. Land evaluation is, therefore a useful planning method to optimize the opportunities in the agricultural sector in Nigeria.

AGRICULTURAL LAND EVALUATION

Demand for land for agricultural purposes is increasing globally implying a limitation in land resources. This has necessitated a yearning for decisions leading to the most beneficial use of limited land resources. Evidence based decisions made for optimal benefits of land resources have considerable implications for conserving land resources for the future. The function of land evaluation in this regard is to bring about an understanding of the relationships between the condition of the land and the uses to which it is put into and to present planners with comparisons and promising alternative options (Njar *et al*., 2012). The information and recommendations from land evaluation are important for land use planning processes which often follows land evaluation (George, 1997).

Land use evaluation determines land use options which are important for land use planning. Van Diepen *et al*. (1991) described land use planning as; the allocation of land to various categories of use according to criteria formulated during the land evaluation process. In determining land use options, it is important to consider management related attributes (George, 1997). This is because management related attributes which include inputs and socioeconomic settings influence production levels. The management related attributes define land utilisation types. A land utilisation type has been defined as; a use of land defined in terms of a product or products, the inputs and operations required to produce these products and the socioeconomic setting in which production is carried out (FAO, 1996).

There are basic requirements that allow for the efficient and sustainable functioning of each land utilisation types. The major requirements for rainfed crop production land utilisation type border on crop physiology, technology of management systems and avoidance of land degradation (George, 1997).

Several methodology used for land evaluation for agriculture and other purposes have been developed by various scholars as highlighted in the theoretical framework. Riveira and Maseda (2006) reviewed rural land use planning models. The models reviewed include Expert systems (Zhu *et al*., 1996; Yialouris *et al*., 1997; Jun, 2000), Mathematical models (Weerakoon, 2002; De Oliveira, *et al*., 2003) and Spatial simulation models (Parker *et al*., 2003; Barredo *et al*., 2004). Riveira and Maseda (2006) found that the framework for land use planning and land evaluation should not be confined to assessing the physical characteristics alone but should consist of the analysis of physical suitability, economic viability, social consequences and potential environmental impacts.

The FAO framework allows for a multi-criteria evaluation and integration with spatial infrastructure, such as Geographic Information Systems (GIS) in mapping optimum land uses. Ashraf (2010) stated that the multi-criteria evaluation approach within GIS context involves land suitability evaluation based on the FAO framework by overlapping maps with GIS techniques for land suitability classification. GIS and remote sensing play a vital role in linkage and analyses of data in land evaluation, in particular for detection (direct/indirect), extrapolation, interpretation and monitoring (Van Lynden and Mantel, 2001).

GIS and agricultural land evaluation: The use of GIS in the management of agricultural resources is increasing rapidly due to improvement in spaceborne remote sensing satellites in terms of spatial, spectral, temporal and radiometric resolutions. The use of GIS and remote sensing in land evaluation has attracted the attention of several scholars (Rossiter, 1994; Patil *et al*., 2005; Salam and Rahman, 2007; ESRI, 2009). It is stated in literature that almost all land evaluation projects present results as maps. The location and other spatial characteristics of evaluation units are often important land characteristics in the evaluation itself (Rossiter, 1994).

The Geographic Information System (GIS) is a technique with a utilitarian value with regards to agricultural land evaluation. GIS is defined as; an assemblage of computer equipment and a set of computer programs for the entry and editing, storage, query and retrieval, transformation, analysis and display and printing of spatial data (Rossiter, 1994). GIS provides an opportunity for an integrated assessment of the resource development potential within a given time and scale. This contributes in ensuring that development tallies with environmental sustainability in the pursuit of sustained economic outputs (Petja *et al*., 2009). Agricultural development, therefore requires the use of GIS in planning to ensure effective coordination, implementation and monitoring to achieve the objectives of sustainable production. Despite the utilitarian value of GIS and remote sensing in land evaluation for sustainable agriculture which has been emphasized, the practice is still relatively an emerging technique in Nigeria.

Rilwani and Gbakeji (2009) looked at the challenges and prospects of geoinformatics in agricultural development in Nigeria. A critical analysis of the prevailing situation in Nigeria revealed the shortcomings of the current methods of data collection, analysis and management. The challenges of agricultural development highlighted in Rilwani and Gbakeji (2009) include technological development, inconsistency and inept implementation of government policies, low level of investment, small land holdings, heterogeneity of cropping systems and market imperfection. The study emphasized the need to adopt geoinformatic methods to improve agricultural productivity to meet the nutritional need of the teeming Nigerian masses as well as for export income.

The study by Rilwani and Ikuoria (2006) showed that there are numerous crop-yield prediction models that relate crop yields to a single set of factors. These models have been of limited utility, largely because they are location-specific. Most of the models are based on the biophysical assessment of land potential alone and other important factors of crop production, such as socioeconomic factors and climate are held constant. There is, therefore a need to utilize comprehensive land evaluation methods for crop farming in Nigeria in line with the new concept of precision farming.

Nuga (2001) reviewed the application of GIS for sustainable land resource management in Nigeria. According to Nuga (2001), the current methods of agricultural land evaluation in Nigeria suffer from a number of inherent deficiencies that limit their usefulness as a tool for effective land use planning. The need for the integration of GIS with processes of land evaluation for improved quality of land decisions and sustainable land use and management was emphasized.

Uchua *et al*. (2012) mapped and analysed agricultural systems in the lower River Benue basin in Nigeria using GIS. The study acknowledged the recession of the lower River Benue which has led to some adverse ecological changes and the decline of agricultural production in the face of rapid population growth in the area. The agricultural systems analysed in the study include irrigated areas, lowland rice-based, upland cereal and tuber-based, plantation or tree crop, agroforestry-based as well as fishing and livestock. The study revealed the need for suitability mapping for the predominantly cultivated crops in the basin.

Contemporary challenges to sustainable agriculture: The United Kingdom's Department for International Development (DID, 2002) listed five key environmental

challenges that potentially threaten the future viability of agricultural systems, particularly at regional and local levels. These include land degradation, limits to water availability, loss of biodiversity, declining agricultural genetic diversity and climate change. For the purpose of this study, these challenges are reviewed under climate change, population growth and public health with policy implementation issues as a common factor.

Climate change: Climate is the primary determinant of agricultural productivity. Given the fundamental role of agriculture in human welfare, concerns have been expressed about the potential effects of climate change on agricultural productivity (Adams *et al*., 1998; Tiwari, 2000). The intergovernmental panel on climate change IPCC (2007) defined climate change as a change in the state of the climate that can be identified by using statistical tests and other methods to detect changes in the mean and/or the variability of its properties and that persists for an extended period typically decades or longer. The global warming trend has continued beyond four decades without reversal (IPCC, 2007) and there are heightened concerns that the current warming of the earth's climate is being influenced by anthropogenic with evidence from increases in global average air and ocean temperatures (Odjugo, 2011). According to Odjugo (2011), climate change is caused by two basic factors namely natural processes (biogeographical) and human activities (anthropogenic). The natural processes are the astronomical and extraterrestrial factors. The astronomical factors are the eccentricity of earth's orbit, obliquity of ecliptic and orbital precession. The extra terrestrial factors include solar radiation quantity (sunspot) and quality (ultra violet radiation change).

The effects of climate change on agriculture are several and real. Agriculture plays a significant role in the carbon cycle and is associated with global land clearance that has led to substantial carbon emissions. In 2005, agriculture contributed an estimated 10-12% of global greenhouse gas emissions (IPCC, 2007). Agriculture influences the storage of carbon in the soils and some agricultural practices have led to the direct release of greenhouse gases, specifically methane and nitrogen emissions. Agriculture can be affected by climate change and could suffer important adverse impacts (Mendelsohn, 2000). Higher temperatures may eventually reduce yields of desirable crops while encouraging weed and pest proliferation. Changes in precipitation patterns already being witnessed increase the likelihood of short run crop failures and long run production declines. Although, there will be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative and pose threats to global food security (Nelson *et al*., 2009). Iglesias *et al*. (2009a) provided a summary of key factors that are expected to be modified with climate change (Table 1). These include

Table 1: Climate change and related factors relevant to agricultural production at the global scale

Climate and related physical factors	Expected direction of change	Potential impacts on agricultural production	Confidence level of the potential impact
Atmospheric Carbon dioxide (CO_2)	Increase	Increased biomass production and increased potential efficiency of physiological water use in crops and weeds	Medium
		Modified hydrologic balance of soils due to Carbon/Nitrogen ratio modification	
		Changed weed ecology with potential for increased weed competition with crops	
		Agro-ecosystems modification	High
		Nitrogen cycle modification	High
		Lower yield increase than expected	Low
Atmospheric Oxides (O_3)	Increase	Crop yield decrease	Low
Sea level	Increase	Sea level intrusion in coastal agricultural areas and salinization of water supply	High
Extreme events	Poorly known but significant increased temporal and spatial variability expected	Crop failure	High
		Yield decrease	
		Competition for water	
	Increased frequency of floods and droughts		
Precipitation intensity	Intensified hydrological cycle but with regional variations	Changed patterns of erosion and accretion	High
		Changed storm impacts	
		Changed occurrence of storm flooding and storm damage	
		Increased waterlogging	
		Increased pest damage	
Temperature	Increase	Modifications in crop suitability and productivity	High
		Changes in weeds, crop pests and diseases	
		Changes in water requirements	
		Changes in crop quality	
	Differences in day-night temperature	Modifications in crop productivity and quality	Medium
Heat stress	Increases in heat waves	Damage to grain formation, increase in some pests	High

Iglesias *et al*. (2009a)

changes in sea level andcarbon-dioxide among others. Soil erosion which has major consequences for agricultural productivity is one of the factors directly affected by climate conditions.

Climate change will have a global effect on agriculture. In the United States (US), agriculture produces approximately 300 billion dollars a year in commodities. The production of these commodities is vulnerable to climate change through the direct effects of changing climate conditions on crop and livestock development and yield, as well as through the indirect effects arising from changes in the severity of pest pressures, availability of pollination services and performance of other ecosystem services that affect agricultural productivity. Around the mid-century, temperature increase is expected to exceed 1-3°C and precipitation extremes will intensify. The yields of major US crops and farm returns are projected to decline (Walthall *et al*., 2012).

Iglesias *et al*. (2009b) mentioned climate change as one of the serious challenges agriculture will face in the European Union in the coming decades. Policies for agriculture and water resources are some of the determinant factors that would limit possible adaptation options to climate change in Europe. Iglesias *et al*. (2009b) further stated that an improved understanding of the climate-agriculture-societal response interactions is highly relevant to European policy.

Climate change affects food and water resources that are critical for livelihood in Africa where much of the population especially the poor, rely on local supply system that are sensitive to climate variation. Disruptions of existing food and water systems may have devastating implications for development and livelihood. In Nigeria, agriculture is the main source of food (Manyong *et al*., 2005) and the source of raw materials used in the processing industries, as well as a source of foreign exchange earnings for the country. Agriculture in Nigeria is mostly rainfed (Ayinde *et al*., 2011) and any change in climate is bound to impact its productivity in particular and other socioeconomic activities in the country.

Odjugo (2011) assessed climate change and global warming in Nigeria over two climatic periods 1901-1938 and 1971-2008. Odjugo (2011) found that temperature in Nigeria increased by 1.78°C between the two climatic periods. This is above the global temperature average rise of 0.74°C for 100 years (IPCC, 2007). Rainfall decreased by 91 mm in Nigeria between the two climatic periods with major shifts in double and single rainfall peaks. The study also highlighted an increase in rainfall in the coastal areas. Ayinde *et al*. (2011) assessed the effect of climate change on agricultural productivity in Nigeria using climatic data from 1975-2005. Ayinde *et al*. (2011) found an occurrence of rainfall variability (interannual) and unreliability. There were sharp reductions in annual temperature with unsteady trends and variations. There is evidence of climate change in Nigeria as intense rainfall has increased due to a reduction in the onset and cessation periods of rainfall and an increase in drought in the Northern parts due to desertification (Anuforom, 2013). The current evidence presented suggests that Nigeria, like most parts of the world is experiencing the basic features of climate change.

Population growth, increased income and HIV/AIDS: In addition to climate change, other challenges facing sustainable agriculture are associated with population and income growth. A total of 870 million people remain chronically undernourished, mostly in developing countries and there are serious concerns about the implications of growing populations on global food security (FAO, 2009, 2012). The growth in world population and the displacement of populations increases the demand of agricultural land for housing. According to the United Kingdom, Department for International Development (DID, 2002), agriculture has performed remarkably well over the last 50 years by keeping pace with rapid population growth and delivering food at progressively lower prices. This success has been at the expense of the natural resource base, through overuse of natural resources as inputs or through their use as a sink for pollution. This supports the assertion by Shrestha and Rayappa (1990) that agricultural development and population growth are related.

The concern of scholars regarding sustainable agriculture and population growth is whether agriculture will be able to meet future global food demands without adversely affecting the resource base. Are the current approaches sufficient enough to enable agriculture provide sufficient food and act as an economic growth driver despite resource constraints? It is stated in literature that in developing countries, crop production is not expected to keep pace with growing demand associated with both population growth and changing patterns of consumption, such as increasing demand for livestock products. It therefore, behooves on governments especially in developing countries to make principles of sustainability a core part of agricultural policies and provide incentives and enabling conditions for sustainable resource use.

Wilkes *et al*. (2013) hinted that increasing income levels in developing countries will heighten demand for food and land use change in the near future. This is

because majority of the sustainability plans are being developed in upper-middle or high income countries and sustainability plans are receiving inadequate attention in low income countries. According to Wilkes *et al.* (2013), national communications from many developing countries note the greater policy priority given to economic growth and poverty alleviation. Even though, economic growth is important, it should be pursued with a sustainability development plan to ensure a holistic maturation of a nation. As Iglesias *et al.* (2009b) noted, economic development drives technological change, population defines demand and consumption and land use change is influenced by policy.

Sustainable agriculture is also threatened by HIV/AIDS and other related diseases, such as Tuberculosis and Malaria. According to the United Nations (2004), majority of the population in the countries most affected by HIV/AIDS live in rural areas. In many African countries, farming and other rural occupations provide a livelihood for >70% of the population. Hence, it is to be expected that the HIV/AIDS epidemic will cause serious damage to the agriculture sector in those countries, especially in countries that rely heavily on manpower for production.

HIV/AIDS undermines agricultural systems and affects the nutritional situation and food security of rural families. The FAO (2002) estimated that in the 25 most-affected African countries AIDS has killed 7 million agricultural workers since, 1985. It is forecasted that 16 million people will die of AIDS between 2002-2022. Given the fact that HIV/AIDS is concentrated among the age group of 15-45 years old who are most able bodied, then agriculture suffers most in terms of production and market for the accruing products. HIV/AIDS leads to income disruption and eventually cessation as able-bodied people in society succumb to the epidemic while others have their productive time diverted from farm production to attend to the sick or burials and funerals. HIV/AIDS has been documented to be eroding the skills and knowledge acquired as people die in their prime age before passing on knowledge and expertise to the next generation. Other related diseases pose similar threats to agriculture.

CONCLUSION

Sustainable agricultural development is currently receiving attention from the Nigerian government. However, there is a need to encourage more agricultural land evaluation studies utilising GIS analysis techniques with manipulative capabilities to integrate multiple variables. This will ensure a holistic presentation of information when needed to enhance policy making and implementation of sustainable agricultural programmes in Nigeria. This study has used relevant literature to emphasize the importance of sustainable agriculture and the use of GIS techniques in enhancing agricultural land use evaluation in Nigeria.

RECOMMENDATIONS

This study has demonstrated through relevant literature that the issue of agricultural sustainability is a global contemporary discussion. It is important for Nigeria to keep pace with the international community towards the sustainable development of her agricultural sector.

The robust sustainable development plans being implemented by the Nigerian government has provisions for agricultural development. However, one of the first and basic activities in agricultural land use planning is the comprehensive appraisal of land resources, land use types and agricultural systems. This will ensure a focused and strategic implementation of agricultural policies nationwide with optimised results. This study, therefore recommends a comprehensive national agricultural land use evaluation study to add to existing baseline information and provide new knowledge which will enhance the implementation of vision 20:2020 and thetransformation agenda. Agricultural land evaluation studies in Nigeria should consider the following parameters as below:

Summary of relevant data types and parameters for agricultural land evaluation studies in Nigeria

Data type	Base source	Years	Parameters
Soil	Satellite image of study area, soil samples, soil data	Recent 40 years data	Type, texture, Infiltration rate, nutrient content
Slope	Satellite image of study area, topographic map	Recent	Gradient and erosion
Water resources	Satellite image of study area, volume, flow, discharge and flood data	Recent 40 years data	Drainage system, seasonal variation, water table, flood hazard, irrigation potential
Vegetation	Satellite Image, topographic map	Recent	Type, coverage, pattern, development stage
Land use	Satellite image of study area, land use map	Previous and recent	Existing land use type, land use potential, % of deviation
Rainfall	Monthly and annual rainfall data	Two climatic cycles or at least 40 years	Monthly rainfall averages, annual rainfall averages, trends of intensity and amounts (onset, cessation, droughts, thunderstorms)

Continue

Data type	Base source	Years	Parameters
Temperature	Monthly and annual temperature data	Two climatic cycles or at least 40 years	Monthly temperature averages for the period, annual averages, trends of intensity, suitability for crop farming
Humidity	Monthly and annual humidity data	Two climatic cycles or at least 40 years	Monthly humidity averages for the period, annual averages, trends of intensity, suitability for crop farming
Evapotranspiration	Monthly and annual evapotranspiration data	Two climatic cycles or at least 40 years	Monthly averages for the period, annual averages and trends
Communities	Satellite image of study area, socioeconomic survey	Previous and recent	Location, community size, proximity to farmland and transportation routes, predominant agricultural type, potential to process produce, average income, farming cooperatives, environmental problems, health challenges
Location of strategic (large) markets	Satellite image of study area, socioeconomic survey	Recent	Location, type, proximity to transportation routes, commodity type
Transportation routes	Satellite image of study area Socioeconomic survey	Previous and recent	Location, modes, type, condition and coverage
Main processing centres for agricultural produce			Methods of processing, gender involvement, scale, income, coverage
Agricultural systems (Crop yield, livestock, fish, etc.)	Agricultural records and Socioeconomic survey	Previous records (10-20 years) Recent	Method of cultivation, crop yield, important centres, storage, commercial practices, income
Relevant literature	Journals, reports, books, Conference proceedings	Previous and recent	Comparism, literature review, suitability assessment and adaptation to climate change
Remote sensing and GIS suitability analyses	Raster, vector, attribute, coordinates	Modern GIS and spatial analyses software	Study area, sampling map, classification and suitability maps, maps of other themes

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