Ecological Intensification for Sustainable Agriculture: The Nigerian Perspective

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Abstract

Nigeria has vast potential resources such as land, water and large population that can be utilized for maximum agricultural production to combat its food insecurity and malnutrition challenges. It is estimated that over 70% of the total land area covering 68 Mha (million hectares) can be employed for agricultural production, while only 33 Mha is used for cultivation. Also, of the estimated 3.14 Mha irrigable land, only about 220,000 ha or 7% is engaged coupled with the ecological diversity that can support a large community of livestock. It also has a surface and underground water of about 267.7 billion m^3 and 57.9 billion m^3, respectively, and over 70% of the population of 200.9 million people are participants in the agricultural sector. All these have contributed to the Nigerian economy in terms of food supply, a national food market, employment, national income generation, livelihoods and industrialization. Agriculture in Nigeria employs approximately 26 million people; more than 80% of the population are involved in small scaled farms that represent half of all jobs accounting for 20% of Nigeria's gross domestic products (GDP). In Nigeria, sustainable agricultural production has been a priority in the policy implementation all in a bid to overcome the general persistent problems of food shortages, insecurity and malnutrition. However, agricultural productivity has been constrained by a range of setbacks in Nigeria, which include but not limited to climate change, youth unemployment and poor policy implementation and consistency, lack of education, inadequate agri-digitalization, poor farming practices, finance, lack of mechanized agriculture among others. The agricultural sector has been grossly affected by climate change as seen in its glaring consequences such as droughts, floods, invasion of pests and diseases. It is on account of these recognizable huge

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potentials but surrounded by myriads of challenges in the Nigerian agricultural sector that this review study seeks to determine the best practices that would ecologically intensify sustainable agricultural production in Nigeria. This study used a qualitative and descriptive appraisal of agricultural practices within the context of ecological and agricultural intensification with a view to identify the factors that are responsible for the poor agricultural productivity. Against the background of the concept of sustainable agriculture and agricultural intensification, the paper assesses the levels of agricultural productivity and its challenges in Nigeria. This present chapter mainly covers and delineates the theoretical base for this assessment. It focuses on agricultural practices in Nigeria and interrogates their sustainability. It further examines the policy implications of our assessment. Finally, it recommends appropriate policies that will lead to sustainable intensification of agriculture while maintaining or enhancing environmental health and services.

Keywords

Agriculture · Eco-intensification · Food security · Nigeria · Policy · Planning · Sustainability

Abbreviations

ADP	Agricultural Food Development Programme
APPEALS	Agro-processing productivity enhancement and livelihood support
ATA	Agricultural transformation agenda
DFRRI	Directorate for Foods, Roads and Rural Infrastructure
GDP	Gross domestic products
GHG	Greenhouse gases
IRDP	Integrated rural development programme
Mha	Million hectares
NAFSS	National Agricultural and Food Security Strategy
NALDA	National Agricultural Land Development Agency
NPFS	National programme for food security
OFN	Operation feed the nation
PIA	Presidential initiative on agriculture
RBRDA	River Basin and Rural Development Authorities
SI	Sustainable intensification
SSA	Sub-Saharan Africa
TVA	Tennessee Valley Authority
USAID	United States Agency for International Development

15.1 Introduction

Agriculture remains the dominant economic sector to Africa's future. It has established an extended social, economic and environmental footprint in Africa. Over 60% of the populations of SSA are small-scale agriculturists, while about 23% of SSA GDP's flows from agriculture. However, the continent is faced with the pressing need of providing food for about 1.5 billion people by 2030 and 2 billion by 2050. Practical solutions are expedient in order to attain food security for the fast growing population and highly urbanizing African cities with mostly scattered smallholder farms. This is a present problem for the African continent, since, it currently imports 15 billion (USD) on food imports (grains, edible oils and sugar), primarily from regions in Asia and South America (FAO 2020).

Achieving Africa's agricultural potential is dependent on its investment in the sector. You et al. (2010) reported that Sub-Saharan Africa (SSA) needs a minimum of 8 billion (USD) of investment in providing basic storage (without the inclusion of cold-chain investments for horticulture/animal products) and about 65 billion (USD) in irrigation to actualize its agricultural prospects. World Bank (2009a) report on Africa estimates that about a range of 480 to 840 million hectares of agricultural lands are still untapped and can be employed to increase production. Unfortunately, most of these lands are inaccessible due to poor transport infrastructures; most of them are under conflict zones or under forest cover or part of a conservation zone. Observation of issues such as market access, population density and agro-ecological conditions indicates that only about 20–30 million hectares of additional cropland in SSA, essentially in nine countries can be cultivated (Chamberlain et al. 2014; Meena et al. 2018).

This represents only a 10% fraction of the potential increase in African's cultivated land. This number can increase only if new infrastructure and investments are provided across inaccessible areas. Moreover, Africa continues to be a target for increased agric-production if more than 420 projects comprising ten million hectares have been completed between 2000 and 2016. Unfortunately, only a few of these projects have been implemented (Chamberlain et al. 2016; Meena and Lal 2018). This few implemented projects suggest that land expansion will not hinder increased production. Additionally, African countries and regions are at different levels of agricultural production. Some regions experience large agric-productions of about 100 hectare farm sizes that give large farm outputs and others use less than that. For example, Nigeria is mostly dominated by about 50 hectare farm sizes (Jayne et al. 2016).

Agriculture employs over half of the African population and is the largest contributor to the total GDP. Table 15.1 shows that agriculture contributes immensely to Africa's GDP. About 30 countries represented in Table 15.1 have agriculture as the dominant sector. Agriculture has created most of the jobs and livelihoods in Africa (Akanwa and Ezeomedo 2018). Also, the extractive industry has had a great impact on the GDP of 15 of these countries which happens to be either equal to or greater than that of agriculture. However, some countries have

Table 15.1 Gross domestic product of African countries (Source: NEPAD 2010)

Countries	GDP (USD)	Countries	GDP (USD)
Libya	11,314	Lesotho	836
Equatorial Guinea	11,033	Kenya	809
Seychelles	10,681	Comoros	802
Gabon	8724	Chad	767
Botswana	7627	Mali	691
Mauritius	7593	Benin	689
South Africa	7157	Gambia	616
Namibia	5651	Burkina Faso	597
Angola	4477	Zimbabwe	594
Algeria	4435	Rwanda	562
Tunisia	4200	Tanzania	548
Morocco	3248	Guinea-Bissau	508
Cape-Verde	3156	Uganda	500
Swaziland	3061	Mozambique	458
Congo	2983	Togo	458
Egypt	2788	Guinea	448
Sudan Republic	1705	Central African	435
Nigeria	1389	Eritrea	397
Djibouti	1383	Madagascar	391
Ghana	1311	Niger	381
Zambia	1221	Ethiopia	350
Mauritania	1194	Sierra Leone	325
São Tomé and Príncipe	1183	Malawi	321
Cameroon	1100	Liberia	226
Côte d'Ivoire	1036	Dem. Rep. of the Congo	186
Senegal	980	Burundi	180

succeeded in achieving industrialization. For example, South Africa operates a diversified and integrated economy and it generates 30% of the continent's GDP, even though it is home to barely 5% of its population. Additionally, North Africa is exceptional with its diverse secondary and tertiary sectors targeting the European market, with only 35% of GDP and 20% of the African population. Aside from North and Southern African countries, in some oil-producing countries in the Gulf of Guinea, with the exception of Nigeria, Cote d'Ivoire and Cameroon, agriculture employs half or more of the working population. The agricultural population in Africa stands at 530 million people, and is expected to exceed 580 million by 2020 (AGRA 2017a). The dependent population relying on agriculture accounts for 48% of the total population in Africa with a high of 70% is in East Africa (AGRA 2017b). A special feature of African agriculture in comparison to the rest of the world over the last 30 years is that the sector has continued to absorb a large proportion of the working population; half of all new entrants to Africa's working population have turned to agriculture, whereas in Asia, this statistic is only 30% (Mellor 2017).

Notably, Africa's food production is still insufficient and since the 1980s it has experienced stagnant growth due to inadequate infrastructure, sci-tech, policy implementation, increasing population growth and the impact of climate change among

other challenges that Africa must overcome. Certain African countries such as Botswana, Morocco, Cote'd Ivoire, Ethiopia, Ghana, Kenya, Rwanda and Senegal have nevertheless made huge reforms in their agricultural sector and gained strides in poverty reduction, while still harnessing the potentials of the sector (AGRA 2017c). This is because poverty is the greatest threat to food security or the ability to obtain sufficient food (Cunningham and Cunningham 2006). Central Africa has the highest percentage of hungry people in the world.

From the foregoing, the goal of this chapter is to appraise the agricultural practices within the theoretical context of ecological and agricultural intensification in order to identify the factors responsible for the poor agricultural productivity and to proffer solutions using Nigeria as a case study. This can be achieved by increasing agricultural production through sustainable agricultural intensification. This means fostering access to inputs—including the use of "smart" subsidy policies, encouraging the adoption of innovations and securing access to resources for women and young people in particular, possibly by law. Support will be offered as a matter of priority to family farms that make optimal use of land and labour on small surface areas. Recognizing the role of women in food production is, according to Cunningham and Cunningham (2006) a sure step to food security for all. All over the developing world they assert that women do 50–70% of farm work, but control only a tiny proportion of land, scarcely have access to capital or developmental assistance. Citing example of Nigeria they observe that home garden (cultivated by women) makes up on the 2% of all crop land but provides 50% of family food. They conclude that making land, credit, education and access to market available to women could contribute greatly to family nutrition.

This chapter discusses nine topical areas which include the concept of sustainable agriculture and the theory of agricultural intensification as put forward by Boserup (1965), and Ruthenberg (1980). Also, agricultural systems and practices in Nigeria, the ecological and agricultural intensification content of the Nigerian agricultural systems and practices were highlighted with a view to highlighting their success or failure.

Further areas reviewed include the sustainability of Nigerian agricultural systems and practices using the indicators of sustainability as outlined in the paper, the challenges and strategies confronting the success of ecological/agricultural intensification in Nigeria. Desired perspectives that will ensure successful and sustainable agricultural intensification in the country were identified. Policy implications for achieving the objectives of agricultural/ecological intensification were pointed out and finally, the conclusion and further areas for introspection were discussed.

15.2 Agriculture and Livelihoods in Sub-Saharan Africa

One striking phenomena globally is the continuous population increase which seems to have stabilized in global North, while in the global South; population growth is occurring at an astronomical rate much higher than in the heydays of growth in the developed world. For example, world population distribution and projections from

2012 to 2050 show that as at 2012 world population stood at 7.058 billion, while the projected population figures for 2025 and 2050 stand at 8.082 billion and 9.624 billion, respectively. The slices for the more developed countries for the three years are 1.243 billion, 1.292 billion and 1.338 billion, respectively. For the developing countries, their proportions for the three years are 5.815 billion, 6.790 billion and 8.286 billion, respectively. Africa's shares for the three years are 1.072 billion, 1.466 billion and 2.339 billion (Chandra 2014). In Africa Nigeria's shares of the population are 170.1 million, 234.4 million and 402.4 million, respectively for 2012, 2025 and 2050. In terms of density there were 184 persons/km^2 in Nigeria during 2012.

Another disturbing demographic aspect is urbanization, a process by which population movement is from rural to urban centres in addition to natural increase in cities. As at 1950 the more developed regions around globe had 58.3% of total global urban population, while the less developed regions had 41.7%. By 1975 the respective ratios were 46.4% and 53.6%, in 2000 they are 30.9% and 69.1%, respectively, and by 2030 projections give 20.5% and 79.5%, respectively (Cohen 2006).

The above data have implications for resources and environment especially for food production. In the recent past, farming activities have spread to rural communities and cities providing livelihoods and increased economic output globally except in Africa where agricultural performance has been slowed down (Pretty et al. 2011). The African continent has vast resources in its abundant land, water, markets and human resources that have contributed to the global food market, while boosting its continental agricultural sector (GSMA 2015). These resources to a large extent have been able to provide for its growing population through its numerous smallholder farms though it has faced shortcomings in the process of combating food insecurity, hunger and malnutrition (Lowder et al. 2016; World Bank 2009b, 2019). SSA is fundamentally agrarian though there are other non-farming activities that have contributed to the economies of the countries in SSA (Rapsomanikis 2015). Agriculture has transformed the economies through increased food production and diversified products, intra-Africa trade, boosted the flow of products to various local markets and introduced the use of improved seeds. It has encouraged greater trade with nations outside Africa and more importantly it has created jobs, generated income and sustained livelihoods (McArthur and McCord 2014; Meena et al. 2020a, b).

In 2050, Africa's population is estimated to be dominated by women and youths totaling about two billion people (World Bank 2019). Africa's population has increased tremendously in the last couple of decades both in villages and cities. It is important to note that population increase has placed severe pressure on food supply and production in Africa (Obonyo 2018). Moreover, agricultural production in Africa has not increased as much as South America, but is comparable to agricultural growth in Asia. This estimation is a call to the need for food security, intensification and transformation of the agricultural sector whereby climate volatility can be minimized (Wiebe et al. 2017; Siba 2018; Siba and Signé 2017; Akanwa et al. 2019, 2020; Akanwa and Joe-Ikechebelu 2020).

However, agricultural growth has not matched unprecedented demographic growth especially in rural communities where population has increased tremendously. Generally, this has affected food production levels in Nigeria where the growing population has by far bypassed food supplies making agricultural practice different from the rest of the world. Also, agriculture has provided job opportunities for majority of the young working population in Nigeria and there are estimates that about 330 million young Africans by 2025 will require employment. Unfortunately, with high unemployment rates in other sectors of the economy only agriculture which provides various means of generating income for young people (World Economic Forum 2017).

However, in Nigeria the agricultural sector employs approximately 75% of the country's labour force. The sector has diverse potentials for socio-economic production and growth covering multi-faceted approaches that can sponsor food supplies that can feed both West and Central Africa regions. This is important since there is a relationship between agriculture and food security; moreover, Africa is largely besieged by hunger and undernourished people. It is of great concern since the numbers of undernourished people in Africa have increased in the past 30 years with observesations showing that 20% of total SSA received less than the minimum amount of food to sustain health and in 1995, 100 million people were malnourished. By the end of the 1970s Africa's marketed volumes of key agricultural exports were at the level of the 1950s, a serious defect in the concept of sustainable development.

Food insecurity in Africa is a persistent problem today especially in remote rural settings. The villages are mostly affected by inadequate farm products since all farming operations are basically carried out at the subsistence levels where majority can barely feed their families. Also, they lack primary facilities such as land, fertilizers, labour and machinery; in addition, rural farmers are poor and unable to boost their production levels thereby increasing food scarcity (Siba and Signé 2017). There is need for constant flow and access to food products to ensure that every trace of food insecurities or shortages is minimized. Agriculture in developed countries has transformed over the years, yet, Africa still practices smallholder farming or family farming which depends on family labour (Sustainable Food Lab 2017). This is responsible for Africa's 33 million farms which are less than 2 hectares amounting to 80% of all farms. Africa's farms workers are largely comprised of women, however, land tenure systems covering use and transfer of land right of ownership do not consider women as heirs unlike women domiciled in Asia and Latin America (Christine 2019).

Before now, SSA has experienced severe stress in agricultural production since it is a rainfall-dependent farming region making its production levels quite poor. This makes farmers work within poor budgets, scarce resources and labour even worse on degraded and infertile lands that have been farmed continuously over the years added to the erratic temperatures and rainfall patterns (Muoghalu 2019). In certain areas where drought and high temperatures are prevalent farmers have employed the system of intercropping shallow and deep rooted crops. For example, farming maize and beans, cowpea and sorghum, millet and groundnut interchangeably all targeted towards sustainable agriculture and livelihoods.

Hadley Centre for Climate Change has projected that regions showing threats of drought will experience more aridity to the degree of about 60–90 million hectares and by 2050–2090 some areas will become endangered. Fisher et al. (2005) argue that Southern African rain-fed agricultural productivity would be reduced by up to 60% between 2000 and 2020 and that even in areas in Africa where rainfall is adequate, the threats of flooding, deforestation and soil loss through sheet and gully erosion will pose serious challenges. In regions that produce minerals and fossil fuels agricultural productivity will face untold stress as the ecological devastation by the Niger Delta region of Nigeria shows. Before the oil boom in Nigeria in the 1970s, the nation was heavily dependent on agricultural sector where agricultural practice and crop and tree specialization and method of livestock breeding were configured on the basis of ecological conformities of soil, climate, altitude and biodiversity.

Shifting cultivation and crop rotation characterized agricultural practices dictated by land tenure system with lack of intensification knowledge and use. Farming implements were rudimentary, mainly digging sticks, hoe and cutlass and sickles which reduced the level of agricultural output. Relevance was placed on mainly food crop production: yams (*Dioscorea alata*), cocoyam (*Colocasia esculenta*), okra (*Abelmoschus esculentus*), vegetables (*Brassica oleracea*), maize (*Zea mays*), cassava (*Manihot esculenta*), plantain (*Musa paradisiaca*), bananas (*Musa acuminata*), kola nuts (*Genus cola*), cocoa (*Theobroma cacao*), oil palm (*Elaeis guineensis*), millets (*Pennisetum glaucum*), guinea corn (*Sorghum bicolor*) and tomatoes (*Solanum lycopersicum*) and were spatially distinguished (Adeniran et al. 2019; Fasimirin and Braga 2009).

British colonial intervention brought about plantation agriculture mainly for cocoa (South Western Nigeria), oil palm (South Eastern Nigeria) groundnut and cotton (Northern Nigeria) and rubber (Edo and Delta States) for export to metropolitan country. Population growth consequent on low morbidity and mortality and improved medical health and access, advent of oil and gas economy and urbanization rewrote the attention given to agriculture. Participation of able-bodied young men in agriculture decreased visibly following the large-scale migration of these men from their local communities to urban areas where they can get higher paying jobs.

Uncontrolled land tenure, alternative land use competition from other sectors and mode of land inheritance among some ethnic nationalities put severe pressure on land, often resulting in fragmentation of landholding. The net effect is that aggressive intensification of agriculture was not possible. Other countries have intervened to make large-scale agriculture through land collectivization and pooling of small and scattered small farms possible. The attempt to do so through the Land Use Act of 1978 failed woefully because of lack of courage and political commitment. The result has been precipitous decline in food production and food insecurity.

Despite the apparently laudable agricultural programmes introduced in Nigeria: the Green Revolution, Operation Feed the Nation, National Agricultural Land Development Agency (NALDA), the Directorate for Foods, Roads and Rural Infrastructure (DFRRI), the River Basin and Rural Development Authorities (initially 11, later increased to 18 and finally brought down to 11), Agricultural Food

Development Programme (ADP), later transformed into the Integrated Rural Development Programme (IRDP), Presidential Initiative on Agriculture (PIA) (2002–2007), National Agricultural and Food Security Strategy (NAFSS, 2008–2011) and Agricultural Transformation Agenda (ATA, 2011–2015), food production is not yet where it should be in terms of productivity, putting more money in the pockets of farmers, self-sufficiency and operation within ecological limits.

In an assessment by Biswanger et al. (2017) indicators of agricultural intensification are weak—only 41% of households use inorganic fertilizer, 34% use agrochemicals, while use of organic manure is low—only 3%. Terrorism and Fulani cattle herdsmen take a toll on agricultural productivity. To worsen all these, agricultural intensification in West Africa is barely being introduced through diverse means (Okike et al. 2005).

The result is a higher incidence of hunger where about 80% of the people still live under poor conditions, presently. Nigeria happens to be the poverty capital of the world. The resultant effect is malnutrition. As research has demonstrated the three latest government initiatives focused on rice and cassava production which did not provide the desired increased crop output in yields but only succeeded in destroying forested areas thereby interfering with environmental services forests provide (Udondian and Zimilia 2018). In addition, all Nigerian food production programmes have not stated "sustainable intensification" (SI) in clear terms as targets, but contain some elements of the concept, including supply of chemical fertilizers, pesticides, provision of irrigation technology all leading to higher yields. Regrettably Nigeria falls short of FAO suggested deployment of 10% annual budget to agriculture.

15.3 Conceptual and Theoretical Frameworks

Before we define agricultural intensification, it will be proper to premise that with an overview of sustainable agriculture (SA).

SA has been defined by the Brundtland Report (1987) as "agricultural and agrifood systems that are economically viable and meet society's need for safe and nutritious food, while conserving or enhancing natural resources and the environment for future generations". Apart from this perspective, Sulphey (2013) contends that SA is viewed differently by various entities. For example, industry views it as the responsible use of available resources to meet energy, food and fibre needs of the population.

Farmers see it as production that ensures environmental, economic and social harmony with surrounding areas. Governments view it as agricultural practices that are sustainable over time, while yet others see it as agricultural practices that are socially just and environmentally and culturally sound. In the midst of this plethora, SA was defined to cover four major areas, namely: the biophysical environment, institutional and policy environment, social and cultural concerns and economic viability (Sala et al. 2015). According to Sala et al. (2015) it presents the foundation for a solid and operational framework for sustainability assessment. Sustainability

assessment principles are presented in an integrated way so as to design a family of assessment tools. Hence, these assessment tools would enable the implementation of agricultural development goals and therefore reducing the colossal ecological and social damages. Moreover, these goals are aligned with the germane issues emphasized on agricultural sustainability by Smith and Donald (1995).

Firstly, a sustainable agriculture requires much more than just maintaining high crop production levels, but there must be consistent increase in crop yields especially for major crops that are on high demand. Without increase in yields, there will be challenges over food supplies and income generation for the working populace and even future generations. Secondly, intensifying crop production on deforested lands provides more options for conservation of other green areas. Thirdly, SA does not refer to shortages in food production levels; obviously, poor production levels are not sustainable from eco-social vintage points. On the other hand, high agricultural productivity approaches can cause immense harm to the environment. They also argue that sustainability in tropical agriculture includes the challenge of degraded lands, invasion of pest and diseases, coupled with the various impacts of weeds, the eco-social contribution of tree crops among others and the need to employ a combination of workable natural and modern agric-techniques.

One of the most prominent theories on the impact of increased population on agricultural production was proposed by Thomas Malthus in 1798. Malthus (1998) argued that the changes in quality of life are dependent on variations between birth and death levels. He further implied that the income accrued from labour is eventually reduced since agricultural lands were naturally fixed and hence, could not be increased. He contends that as humans continue to increase, food production rates, however, does not grow in tandem, making income levels of workers involved in agricultural production to reduce and bringing with it a decrease in birth rate and increase in death rate. As a result, agricultural production determines the extent of population increase. In addition Malthus argued that population growth impacts negatively on the ecology by destroying all forest resources and so resulting in environmental degradation and famine, as well as sabotaging agricultural transformation and inducing massive land destruction beyond recovery. Malthus' depositions were confirmed by Chu and Karr (2017) who discovered that where high populations have been steady over a long time that all human injustice on natural resources ranging from deforestation, biodiversity loss, stagnation and reverse productivity would prevail.

Boserup (1965) in contrast to Malthus' depositions argues that agriculture would intensify in response to increasing population pressure. That is, that increased demand on resources consequent on increased human growth can cause positive agricultural prospects and transformation. Boserup (1965), therefore, conceptualizes that growth in population levels (or land scarcity) is an independent variable that can stimulate agricultural intensification which follows agricultural extensification. In this way Boserup (1965) and Ruthenberg (1980) provided a framework for the analysis of the effect of increased population levels and market access on the intensification of farming systems. Over the last couple of years rapid rise in population has placed farming systems under pressure, while swift urban expansion

and economic growth have provided new markets opportunities for the distribution of agricultural products.

The evidential effect of rapid population growth on agriculture or decrease in land on agricultural production is that the length of fallow period has shortened or even been disappearing. Hence, this has increased low soil fertility levels where crop outputs are reduced even with the application of organic and chemical fertilizers. To further aggravate the situation there are inadequate investments targeted towards irrigation. Process of intensification is weak. Farm sizes are reduced as land inheritance results in land fragmentation. This diminution would have led to intensification and production.

According to the intensification of farming systems model known as Boserup and Ruthenberg (BR) model, rising population levels and market opportunities can lead to a continuous cycle of agricultural intensification. The factors behind the soaring population density, market access, growth of cities and economic growth, which led to reduced farm size, would stimulate increased application of organic manure and fertilizer to alleviate the consequences of threatened soil fertility, investment in mechanization, land and irrigation. All these will potentially offset negative impacts of an increasing population on available agricultural lands, maintain or increase per capital crop production and even increase income levels generated by farmers. Rising population levels thus orchestrates the need for intensification, while access to larger market provides the opportunity. Increase in output depends on increased labour and other inputs per unit area of cultivated land.

It is however argued that even though agricultural intensification is dependent on population growth and opportunities to market access, the agro-ecological potential of a place is a critical factor, which is dependent on human migration to areas with high potential such as the tropical highlands in East and Central Africa. However, while governments may choose to invest on public facilities such as roads and a market which enables them to maximize food productivity levels that would provide for the high population.

This was the philosophy behind roads and rural infrastructure development in the General Babaginda institutional infrastructure of the Directorate for Foods, Roads and Rural infrastructure in Nigeria in the mid-eighties (1987–1990). Investments in roads and markets are traceable to the capacity of cities demand levels on food products and distances from rural communities. However, market access is dependent on two factors, namely the demands from cities and those for export markets. Here, the developed roads make accessibility easier for the farmers.

With rapid population growth and expansion coupled with ineffective policy implementation, it is likely that institutional or agro-ecological environment intensification would lead to involution and diminution of eco-social health and ecological damages. Gerber et al. (2010) defined involution as the situation where high demand for food products merges with high labour referred to as intensive intensification, though this happens at small decreasing and average returns to inputs. Moreover, traditional agricultural intensification is carried out in three major ways (1) increasing yields per unit area of land, (2) increasing intercropping intensity (e.g. two or more crops per unit area of land or other inputs (such as water) or livestock intensity (such

as faster maturing breeds); (3) changing land use from low value crop or commodities to those getting higher market prices or have better nutritional content (Pretty and Stella 2011).

On the other hand, ecological intensification implies green concept which involves diverse use and application of natural ecological functions. It pursues a functional design that can serve several agro-ecosystems, while it obtains natural sustainability and applies regulatory natural functions for its agro-economic design (Kumar et al. 2020; Banerjee et al. 2020; Raj et al. 2020). Since agricultural systems are amended ecosystems, sustainable agro-ecosystems seek to move most of the recovered properties towards natural systems without necessarily jeopardizing its productivity. This means that agro-ecological design of systems should produce both crops and ecological products (Jhariya et al. 2019a, b). Sustainable agro-ecological systems refer to all contributions made on the natural, social and human segments of the economy, but when it is unsustainable it degrades both the present and future resources (Pretty and Stella 2011). Tittonell (2014) has argued that the present approach to agricultural intensification cannot be sustained both socially and thermodynamically since it is neither ecological nor eco-efficient. Hence, it is not appropriate in terms of global food security as it also endangers the environment by biodiversity destruction. From the foregoing, all these emphasize the necessity for substitutes in agricultural intensification practice.

Clearly, continuous agricultural activities on a particular piece of land can degrade the natural/forest resources and productivity rates thereby producing high levels of waste and pollutants (Pretty and Stella 2011; Jhariya et al. 2018a, b). For example, an important index of intensification is seen in the influential capacity of externalities to negatively affect the productivity abilities of farm land thereby destroying the environment and people who live in them downstream of farming areas. For instance, fertilizers/pesticides not used up by plants are flushed during run-off draining into public water supplies carrying pollutants that can threaten the survival of soil organism and aquatic life such as fishes and turtle species (Meena et al. 2020).

Highly intensive farming practices will consume greater energy such that consumption of fossil fuels in the short term will increase in rural areas causing increase in Greenhouse Gases (GHGs). Intensive agriculture, such as paddy rice, emits large quantities of methane. Because of this, intensive agriculture calls for monitoring of pollutants/GHG emissions that can trigger local or global warming that threaten climate change, monitoring the health of soils (such as soil erosion), organic manure, acidity/alkaline levels of trace metals and compaction (Akanwa and Joe-Ikechebelu 2020; Khan et al. 2020a, b).

These considerations gave rise to the concept of SI which is now popular with global research and international bodies on policy-making and practice such as FAO and the World Economic Forum agribusiness world and large-scale international donor organizations. The motto of this concept encourages eco-efficiency, which implies maximum production at minimal waste and pollutants emission on the environment. Pretty et al. (2011) define SI and made specific references to the Africa continent where SI refers to the process of producing high outputs within a particular

land area. It exploits natural resources to provide capital and effective environmental performance, while the negative effects on the environment are adequately minimized.

Dore et al. (2011) defined it as a unique means or process of generation of new products and services at higher quality and output levels using different technology. Environmental bodies at the grassroots level and global organizations have expressed displeasure at the use of SI, which they regard as an incomprehensive approach to best describe the complex strategy of intensification. In 2008, the international organization—FAO called for a global attention over the need to increase food supply levels for a fast growing world of 9 billion people in 2050 and in doing so every sci-tech strategy should be put in place to double food production levels (Graziano da Silva 2012). With this, biotechnology claimed that the world cannot feed itself without genetically modified crop cultivated. The fertilizer industry followed such that at a gathering of African Ministers of Agriculture in Nigeria in the presence of fertilizer industry executives in 2006, they agreed to encourage higher use of fertilizers from the then 8kg/ha to an average of 50kg/ha by 2015 to achieve African Green Revolution.

However, there are four basic limitations to food production and sustainable development of the ecosystems comprising water, soil, biodiversity and land. Pretty (2008) contends that a defined sustainable approach should include the following valuable conditions during and at the end of the process of food production:

1. Farming systems should apply the use of crop and livestock varieties that have inherent high quality and productivity abilities to provide high output levels;
2. The overuse of external means can be avoided except when it is expedient;
3. The application of natural agro-ecological processes that aid in high food production is encouraged such as nutrient-cycling among others;
4. The application of excessive high technology is reduced in order to avoid their negative effects on health and environmental risks;
5. The use of human and social capital in the area of innovative ideas, knowledge of proven ideas and concepts that can be applied to contend with common problems such as pests, diseases, soil management among others and
6. The application of proven means to manage persistent problems that have huge impacts on the environment should be practiced as they affect global warming, GHGs emission, plants and animal extinction, spread of pests and weeds among others.

The Royal Society (2009) defines SI to refer to an effective means that considers the maximum use of land space, high food productivity and low environmental degradation. It encourages the end product of high food supplies rather the process which can incorporate technologies such as new breeds, varieties and other approaches. It is distinct from other applied concepts of agricultural intensification because of its unusual combination of factors that pursues peculiar goals targeted at productive enhancement. SI combines various approaches, methods and technologies aimed at providing higher food supplies within a given area while

exploiting natural resource. It also provides policies that allow natural resource expliotation and the production of higher food supplies while environmental protection is guaranteed.

However, problems have been pointed out as to the workability of SI especially at the early process where food productivity and other important products along the food chain are high while upgrading the state of natural resources. Pretty and Zarean (2014) have argued that SI concept is complex and yet every aspect needs to be included in the process; hence, this makes it a herculean task to capture all the process knowing that agro-ecological approaches are multi-faceted and can only be practiced based on location, community needs and farmers priorities. Similarly, Milder et al. (2012) argued that SI approach has no distinctive methods or processes that clearly separate an alternative from a conventional practice that a farmer can apply; it all depends on the need and capacity to apply agro-ecological principles to industrial farms. Elliot et al. (2013) posit that where researches are targeted at achieving increased crop outputs and environmental outcomes, the end products will be based on applied conditions programmed to give environmental improvements, timing and weightings employed.

Jennings (2007) has called for an "agronomic revolution" to achieve sustainable agriculture because crop yield gaps in rice, for example, result from agronomic failings. Agronomy refers to proper care of plants and livestock under peculiar conditions that coincides with the emergence of the concept of agro-ecology which shows the relevance for investing in science and practice. This confronts farmers with various best options of seeds and breeds and their care under local ecological contexts. Since SI is multi-faceted, it requires appropriate skills, knowledge and managerial technology for farmers to know that farm inputs can complement or contradict biological processes and ecosystem services that inherently support agriculture (Royal Society 2009). Farmers require the assurance that increased productivity levels generate high income through sales. Additionally, this creates social trust, connectivity and ways of doing things which are valuable to agric learning of other areas such as soil management and maximizing input efficiencies.

15.4 Agricultural Systems and Practices in Nigeria

The agricultural systems in Nigeria include shifting cultivation, terrace agriculture, sedentary cultivation or permanent farming, mixed cultivation and intensive irrigated cultivation (Onakuse 2012; Asadu and Asadu 2015). Shifting cultivation or bush fallowing (in which mixed cropping is practiced) is a system in which farm lands are rotated involving short periods of land occupancy and extended periods of fallow.

The main determinant of this system is the ratio between the length of the time the soil will sustain cultivation with satisfactory results and the periods required for restoration of fertility. The fallow period ranges from 5 to 15 years depending on the availability of land and the fertility of the soil. Shifting cultivation has been dubbed

an inefficient system in terms of agricultural productivity. It requires about 60.75 ha of land per farm family in the Savanna zone and 40.5 ha in the rainforest region per farm family. These figures are dream figures given conditions of food arable land area, individualized land tenure in the south, increasing population density in Nigeria today and peasant agriculture with traditional hoe and knife technology. In Africa crop parcels are very small (60–86%) had sizes ranging from 0.25 to 2 acres compared to average farm size in Africa of 2.5 ha; North America (121 ha), Latin America (67 ha) and Europe (27 ha) (Kanu et al. 2014; OSMARD (Ondo State Ministry of Agriculture and Rural Development) 2004).

Nielsen and Calderón (2011) identified four main problems of soil fertility emanating from bush fallow systems: maintenance of soil fertility vis-à-vis rapid population growth and urbanization; difficulties of getting farmers to adopt innovation; inability of the system to keep pace with rapid population increase and consequent increases in food requirements and finally the shortening of fallow periods (an inevitable response to rapid population growth) with its grave consequences of soil erosion and soil ruination.

Terrace agriculture is found in Benue, Plateau, Borno, Adamawa, Taraba and Enugu States. It represents a community located on hill-top and this defence regime requires that farmers will adjust to the rigorous movement around the upland environment. The system is based on four principles—prevention of erosion by fallowing; heavy use of animal and human waste to build up the nutrient status of the soil; a simple rotation of the crops to minimize depletion of soil fertility; and the planting and protection of trees to provide supplementary animal and human food (Durán and Pleguezuelo 2008; Raj et al. 2019a, b).

Sedentary or permanent or continuous cultivation, cushioned on simple crop rotation and intensive use of manure on permanent well-defined land holdings, is practiced in the densely populated areas of Zaria, Katsina, Kano and parts of Anambra and Imo States. It is sustained by the application of household organic manure and crop rotation (Muoghalu 1995).

Mixed farming, an innovation introduced by the various State ministries of Agriculture, is a rudimentary system involving a balance of crops and livestock on individual holdings and the use of animal manure to reduce the need for bush fallowing (Onakuse 2012). Although traditional form of this system existed in some parts of today's north-eastern geopolitical zone (Babalobi and Akinwum 2000), obstacles to this system include the nomadic culture of cattle Fulani, who have no interest in crop production (Ducrotoy et al. 2016).

Finally is the intensive irrigated cultivation, a development occasioned by the seasonality of rainfall in Nigeria and its unreliability especially in the Sudan Savanna zone of northern Nigeria, plagued by meteorological, agricultural, hydrological and environmental droughts. Adelodum and Choi (2018) identify four principal methods of irrigation—flood water irrigation often called the Fadama schemes, the shadoofs, canal irrigation and overhead irrigation. The Fadama or naturally/seasonally flooded swamps are widespread in Nigeria around Kano, Bida (Niger State), Zaria (Northern Kaduna State) and Sokoto State where sugarcane, rice and various forms of

vegetables are grown. This system is also practiced in riverine areas in Anambra State in which rice is grown, as well as in Ebonyi and Enugu States. The shadoof, used to supplement the water supplied by the seasonal floods, produces vegetables in the drier areas of Oyo and Kwara States.

Development of large-scale integrated hydroelectric dams for purposes of agriculture is a development that started in the 1960s. The major dams are all concentrated in the north and include Kainji Dam, Tiga Dam and Bagauda (in Kano State), the Dadinkowa tomato irrigation scheme, Jebba, Bacita Sugar Estate and the Chad Basin. Other comprehensive multipurpose irrigation schemes are the River Basin and Rural Development Authorities (RBRDAs) aimed at all round socio-economic development of all the resources—water, land, plant, animal, etc.,—of all the major drainage basins in the country.

Originally 11, these were increased to 18 and later reduced to 11. Some of the powers/functions of RBRDAs germane to this chapter include—providing an expanded development of ground water supplies that can serve several purposes; providing watershed management schemes for flood and erosion control, building and managing dams, dykes, drainage systems, wells/boreholes, irrigation and drainage systems; providing irrigation schemes for the production of crops and livestock; and monitoring pollution water bodies within the authority's area in accordance with national standards.

According to Phelps and Kaplan (2017), the system of livestock production is governed by three major factors: the degree of specialization in animal husbandry, the degree of mobility and the type of animals. The factors produced five specialized systems of livestock farming: nomadic cattle breeding, settled montane cattle breeding, controlled cattle breeding, cattle ranching and intensive stock breeding, fattening and milking.

Since almost all parts of Nigeria receive fairly enough rainfall for agriculture, two major ecological/environmental factors affect livestock specialization. The long dry season and the presence or absence of tsetse fly is the vector of trypanosomiasis. The first restricts the use made of the northern Savanna during period of low humidity, while the second restricts the use which can be made of the southern guinea Savanna during periods of high humidity (King 2006; Enete and Amusa 2010). Scarcity of water and tsetse fly prevalence localize livestock to a few convenient places in the northern grasslands, some of which are experiencing the tragedy of the commons due to over stocking of livestock. This is made worse by periodic droughts such as those of 1968 and 1972–1973. Some northern states are improving rural water supplies, especially in Borno and Yobe states, through irrigation by exploiting artesian wells in the southern and western parts of Lake Chad (Fig. 15.1).

In terms of livestock population cattle is by far the most significant numbering over 8 million by 1982, followed by sheep over 7 million. Goats numbering over 20 million are widespread in the north and south. Pigs numbered about 1.4 million and are dominant in the south and non-Muslim Middle Belt, while camels, horses and donkeys numbering about 3.1 million are beasts of burden are mostly found in the north (Gentry et al. 2004).

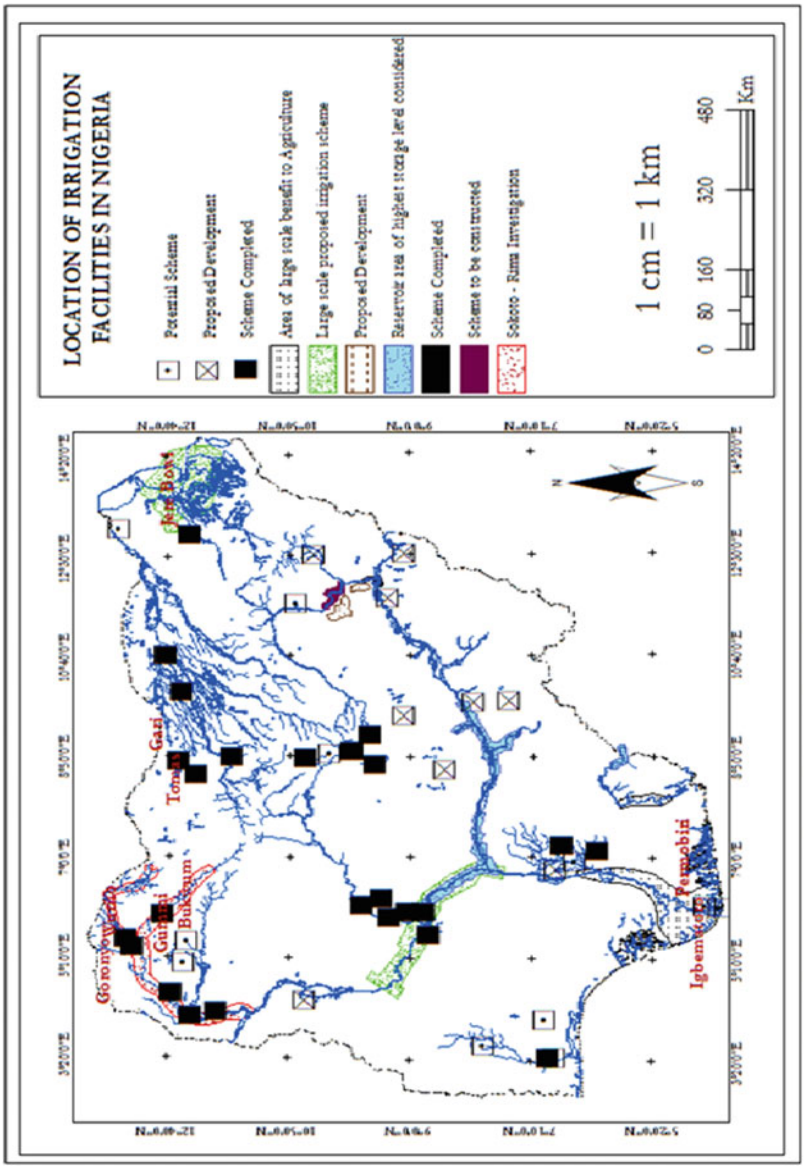

Fig. 15.1 Showing the location of irrigation facilities in Nigeria

Nomadic cattle rearing involves a form of transhumance, a latitudinal movement from the north to the south in the dry sea and a vertical movement from upland to lowland and back again in the wet season. This system found especially among the Fulani herdsmen combines the rearing of livestock. Distances moved from the north to the south ranges from 100–480 km. Movement is also made to the Fadamas, flooded river valleys, which provide grass after the rainy season. This pattern of livestock farming has been generating intermittent bloody clashes between livestock farmers and crop farmers and has become a major security issue in Nigeria. Settled montane cattle breeding, practiced on the Mambilla Plateau in Adamawa and Taraba States is not constrained by the dry season and tsetse fly factors. The perennial availability of grassland has led the Fulani cattle herders to adopt permanent settled life. Competition for land with crop farmers is intense but conflicts are mediated by a land use committee.

Controlled cattle grazing is a strategy to manage land during the dry season. It employs rotational grazing through provision of wells by which natural growth of the season can be used all through the year. Under this scheme, 109 grazing reserves have been set up under the Grazing Reserve Law of 1965 in the North East geopolitical zone.

The fourth system, the Cattle Ranching scheme was launched in post-independence era to be public enterprise. They were meant to breed or fatten cattle for the market. These were set up at Gombole, Borno State, and at Manchok and Mokwa (Niger State), Obudu (Cross River State), Upper Ogun (Ogun State). Dairies which produce fresh milk were established near Lagos, Ibadan, Jos (Vom) and Kano. During the wet season, the cattle grazed improved pastures and in the dry season they are fed with cultivated fodder crops (hay and guinea corn) and concentrates (cotton seed and molasses). From these ranches, cattle are slaughtered, refrigerated and shipped to southern cities. Obudu in Cross River State, another Plateau, houses another ranch outside the tsetse fly zone and wetter than Mambilla, stocks over 3500 cattle of Adamawa Gudali species and exotic species and produces meat for south-eastern urban markets.

Finally high prices of certain animal products in urban areas influenced the development of commercial public sector projects using concentrates, sown pasture and cultivated fodder. The first intensive pig farm and one of the largest was established in Kano in the 1940s. Crop residues and grain are bought from local farmers, supporting 12,000 animals, which were fattened yearly for pork product factories. Other farms have been set up in Minna and other urban places in the south (Ironkwe and Amefule 2008). Improving livestock productivity would require improvement in inputs, increasing available rangelands; increasing fodder production, better use of crop residues, the introduction of sown pastures, more use of concentrates and injecting improve livestock.

Fishery

Nigeria has vast inland water resources estimated at about 12.5 million hectares, comprising the rivers Niger, Benue, Gogola, Argungu, Komadugu, Yobe, Anambra, Cross River, Ogun, Osun and numerous other smaller rivers in addition to the Lake

Chad, Kainji Lake, and Oguta Lake. All these produce over 5 million metric tons of fish annually. Creeks and lagoons are important fishing grounds in Nigeria (Fig. 15.2).

We can divide the fishing industry in Nigeria into three: Artisanal (producing 80% of annual fish output), industrial and land-based aquaculture. Lake Chad dominates the industry with a total production of 25%. Most of the fish caught in the first category are smoked in absence of large-scale refrigeration facilities. The Argungu fishing waters have given rise to a growing annual tourist festival based on River Rima. Large scale fishing has expanded since 1960 and is based on distant Marin and inshore and costal grounds, operated by foreign trawlers from Russia, Japan and Poland in charter to Nigerian companies. These companies have established the efficient and far-flung distribution and marketing network furnished with cold storage facilities. Ogbonna (2001) stated that shrimp catch in Nigeria was 10,807 tons in 1997, pink shrimp (*Penaeus notialis*) being the most common shrimp species with the increase in demand, shallow water brown shrimp is now caught in larger quantities. The small-sized fish caught by the shrimping vessels are sold at local markets, fresh, smoked or dried by women. In 1999, 187 vessels were licensed for inshore shrimp fishing. The major companies with large fleets are joint-ventures. All are grouped within a "Nigerian Trawler Owners' Association" (NITOA). However, Cross River and Rivers states have entered partnerships with foreign countries to enhance the fishing industry. Inland aquaculture is expanding rapidly not only to provide employment, but also to boost fish production. These are based mostly in the burgeoning urban centres especially Lagos, Ibadan, Port-Harcourt, Onitsha, Kano, etc.

15.5 Ecological Intensification in Agricultural Practice in Nigeria

Here, we look at agricultural practice in terms of ecological zones and their crops, agricultural inputs, proportion of land under different crops, agricultural output and productivity, crop yields, farming methods, state of forests and biodiversity.

Developing countries including Nigeria experience food shortages and acute hunger. African Development Bank Group (2018) pointed a horrendous picture of African agriculture. Since 1970 many African countries face acute hunger and starvation. Foods produced locally have been inadequate to satisfy the fast growing population; while per capital earnings cannot support enough food importation. For example, Nigeria food production index was 69 from 1990–2002 and 105 from 2003–2005. For crop production, corresponding indices were 68.7 and 105. For livestock production corresponding indices were 76.8 and 107.0, respectively. Cereal yield for 1990–1992 was 1.135 kg/ha and 1.460 kg/ha for 2003–2005, a slight rise. Total catch of fish by artisanal, industry and aquaculture was 360, 219.90; 27, 701.0 and 25, 204.6 metric tons, respectively, in 1997 (World Bank 2009c). If we examine the data for the production of individual food crops, the horrendous picture painted by hutchie becomes clear. Table 15.2 shows the production of food crops

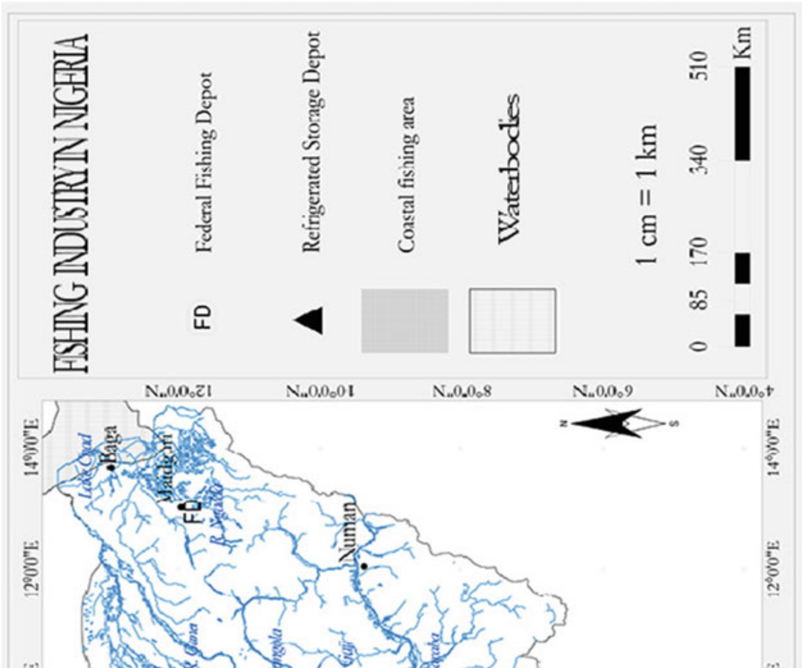

Fig. 15.2 Showing the fishing industry in Nigeria

Table 15.2 National production of food crops in Nigeria (Source: National Bureau of Statistics 2007)

	1994/95	2000/01	2005/06	%
Food crops	In 1000 metric tons			
Millet (*Pennisetum glaucum*)	7271.23	4158.86	4323.86	−59.46
Guinea corn (*Sorghum bicolor*)	6329.91	4963.48	5039.20	−79.62
Beans (*Phaseolus* spp)	2338.15	1581.90	1650.09	−70.57
Yam (*Dioscorea* spp)	23,395.75	24,654.74	25,707.45	+9.88
Maize (*Zea mays*)	5120.70	4719.37	5768.94	+12.66
Cassava (*Manihot esculenta*)	23,831.39	27,702.93	35,614.05	+49.49
Rice (*Oryza sativa*)	1994.02	3159.65	3286.50	+64.79
Melon (*Cucumis melo*)	287.25	231. 91	357.65	+24.39
Cocoyam (*Colocasia esculenta*)	1560.45	1700.13	2149.32	+37.76

from 1994/95 to 2005/06 for millet, guinea corn, beans, yam, maize, rice, melon and cocoyam.

In terms of agricultural input, we look at percentage of total arable land devoted to agriculture, land devoted to cereals, fertilizer application and the proportion of land under irrigation. In terms of proportion of total land under agriculture, from 1990–1992, 79.2% of total land was given over to agriculture, while for 2003–2005, it was 80.4%, a slight increase. Total slice of land cultivated with cereals was 66,416,700 ha in 1990–1992 and for 2003–2005, it was 199,572,300 ha, an increase of 1105.16% due mainly to various rural development schemes introduced. The total land under irrigation was 0.7% of all the land under agricultural production in the period 1990–1992 and 0.8% in 2003–2005 (World Bank 2009b). In 2002, while irrigation contributed 50% to the world's food supply, in Nigeria it was 8.5%. Studies and proposals showed that 2.7 Mha out of 72 Mha have been identified for irrigation. In recent times, about 1 Mha of lands are under irrigation (see Fig. 15.2) (Arav and Uza 2002). The World Bank source shows that fertilizer use in Nigeria was 142.2 g/ha in 1990–1992 and a reduced 63.9 g/ha in 2003–2005, a decrease of 55.06%.

It was observed from Table 15.2, that food products such as yam, rice, cassava among others exhibited a decrease in their levels of production. Yam, a major staple food item throughout the country showed a marginal increase of 5.38% as at 2000/2001 and an increase in productivity of 9.37% in 2005/06 on the output in 2000/01; cassava showed a better performance with 16.24% growth rate in 2000/01 and a 28.56% increase in 2005/06 over that of 2000/01. The picture for rice is dismal with an improvement of 58.43% in production in 2000/01 vis-à-vis 1994/95 figure and only sliding down to a mere 4.02% increase in 2005/06 over the figure for 2000/01 production year. Considering that rice is a major staple food for all Nigerians, it is a poor showing. In effect, apart from a few crops on Table 15.1, the rest have violated the norm of agricultural sustainability that yields should continuously rise, without which it would be impossible to improve incomes and compensate for population increases. As at 2006 population census annual population increase was put at 3.18% between 1991 and 2005 (National Population Commission 2006). Fertilizer

application fell by 55.06% in 2003–2005. Taken in totality, it is, therefore, clear why Nigeria has been ranked as the second largest importer of rice in the world (Index Mundi 2019) and that she expended between $6 and $8 billion to import food annually (Stephen 2019).

Since agriculture includes forestry a comment on the condition of national forest resources is necessary. It is notable that as at 1990 total forested area was 172,000 km^2, while in 2005 it had gone down to 111,000 km^2 giving a loss of 64.43%. Average annual rate of deforestation stood at 2.7% in 1990–2000 and 3.3% as at 2003–2005. As of 2000 the National Coordinator of the National Forestry Commission observed that Nigeria was losing between 100–400,000 ha per year (USAID 2008). As at 2004 total known species of higher plants numbered 4715, while in 2008 a total of 171 species were already threatened. For animal species total known species stood at 1189 in 2004 and by 2008 it was 79. Nationally protected area was 56,000 km^2 representing 6.2% of total land area.

The inability to consume quantitative and qualitative food has practical visible health effects. Starving children become visible symptoms of deepening economic deterioration. The World Development Report (World Bank 2009b) reports that as at 2009, prevalence of malnutrition in Nigeria showed 27.2% of under 5 age children being underweight and 43.0% suffering from stunted growth. Underweight is the most common malnutrition indicator. It must be noted that mild underweight increases the risk of death among under 5 age children, inhibits their cognitive development and perpetuates the problem across generations. In the same vein women lacking vital nutrients are more likely to have low birth weight babies. Stunting is used as a proxy indicator of long-term changes in malnutrition.

Taking an example with cotton and groundnut, the key export crops from the Sudan ecological region of Nigeria, cotton production fluctuated from 387,940 metric tons in 1994/95 to 380,080 metric tons in 2000/01 to 481,180 in 2005/06. For groundnut, corresponding statistics were 3,092,350, 2,240,113 and 2,752,730 metric tons, respectively, a continuous slide (World Bank 2009b).

A sliding productivity of key agricultural export commodities and equally sliding performance in food production create dilemma in terms of food importation. The unfortunate development is that shortage of money to finance food importation makes political leadership cut back on money for social services, especially health and education, two sectors that should really drive sustainable development.

There is need to emphasize a few issues before drawing the curtain on sustainable agricultural development in Africa, particularly in Nigeria. Firstly, Nigerian agricultural enterprise is prosecuted in definite ecological zones in conformity with climate, pedologic and vegetation zones of the country. Three ecological zones are generally recognized as the Southern tree and root crop zone, which occupies the rainforest belt; the mixed crop and tree zone of the Guinea Savanna belts (Middle Belt) in which climate conditions allow the growth of both root and grain crops; and the northern Savanna Zone, which is dominated by grain economy and covers the Sudan Savanna (Fig. 15.1) (Muoghalu 1995).

Conspicuous crops of the southern tree and crop zone include maize, yams, water yam, kola, cocoa, cassava, oil palm, rubber, and plantain and raffia palm. The Guinea

Savanna zone produces rice, yams, vegetables, guinea corn, cassava, livestock, cow pea, seed and nuts, soya beans, Irish potato, while the Sudan Savanna Zone produces rice, groundnuts, guinea corn, soya beans, millet, cow peas, wheat, vegetables, seeds, nut and livestock. The ecological zones and their agricultural crops cultivated in Nigeria are given in Fig. 15.3.

Secondly, it appeals that from 2007 crop production increased as shown on Table 15.3. Of particular note is that rice, maize, beans, potatoes, cassava and palm oil grew by over 7.0%, bolstered by the implementation of the National Programme for Food Security (NPFS). The major factors in the increase are the visible increase in the quantity of assorted fertilizers procured and distributed nationwide, rehabilitation and expansion of existing irrigation schemes and the abolition of tariffs on imported agro-chemicals. Thirdly, the Federal Government targeted intervention on 13 strategic crops as shown on Table 15.3 in addition to the use of improved cassava cuttings and expansion of processing facilities is also a major factor. The production of paddy rice had a boost of 7.3% increase in 2008 because of the adoption of the high yielding NERICA rice type and Rice Box Technology by farmers (Central Bank of Nigeria 2008). As of 2019–2020 private investors are investing on extensive mechanized rice production. In Anambra State, Coscharis started producing on a 4,000 hectare farm in Ayamelum LGA backed up by processing facility located at Igbariam in Anambra East LGA.

Fourthly, it bears stressing that crop production in Nigeria must battle continually with low input, land degradation, lack of water, storage facilities, poor infrastructure (especially road and railway rehabilitation and new construction), climate change and population growth (AFDB 2013). Some scholars have isolated a fourth ecological zone known as the high attitude zone, specializing in the production of temperate and subtropical crops. The Jos, Adamawa and Obudu Plateau readily come to mind with market garden products, carrot, tomatoes, onions, pepper, potatoes and livestock.

15.6 Sustainability of Nigerian Agricultural Systems

How sustainable are the agricultural practices in Nigeria vis-a-vis the maintenance of ecological balance? This discussion will be conducted within the confines of the definition of sustainable agriculture and sustainable development advanced in the earlier part of this chapter. Specifically, we will isolate the Brundtland Report (1987) definition and Smith and Donald (1995) definition and ecological intensification as the framework of analysis.

In terms of ecological constraints, the following deserve special mention. Deforestation constrains agricultural sustainability because its reduction causes a reduction in the quantity of rainfall, exposes the soil to desiccation and engenders slower plant/crop growth. Deforestation has been ahead of human population growth rate in negative decline. The enormity of deforestation is gleaned from the fact that Nigeria had the highest deforestation rate as published by the Food and Agriculture Organization from 2000–2005 having lost 55.7% of its primary forests (Food and

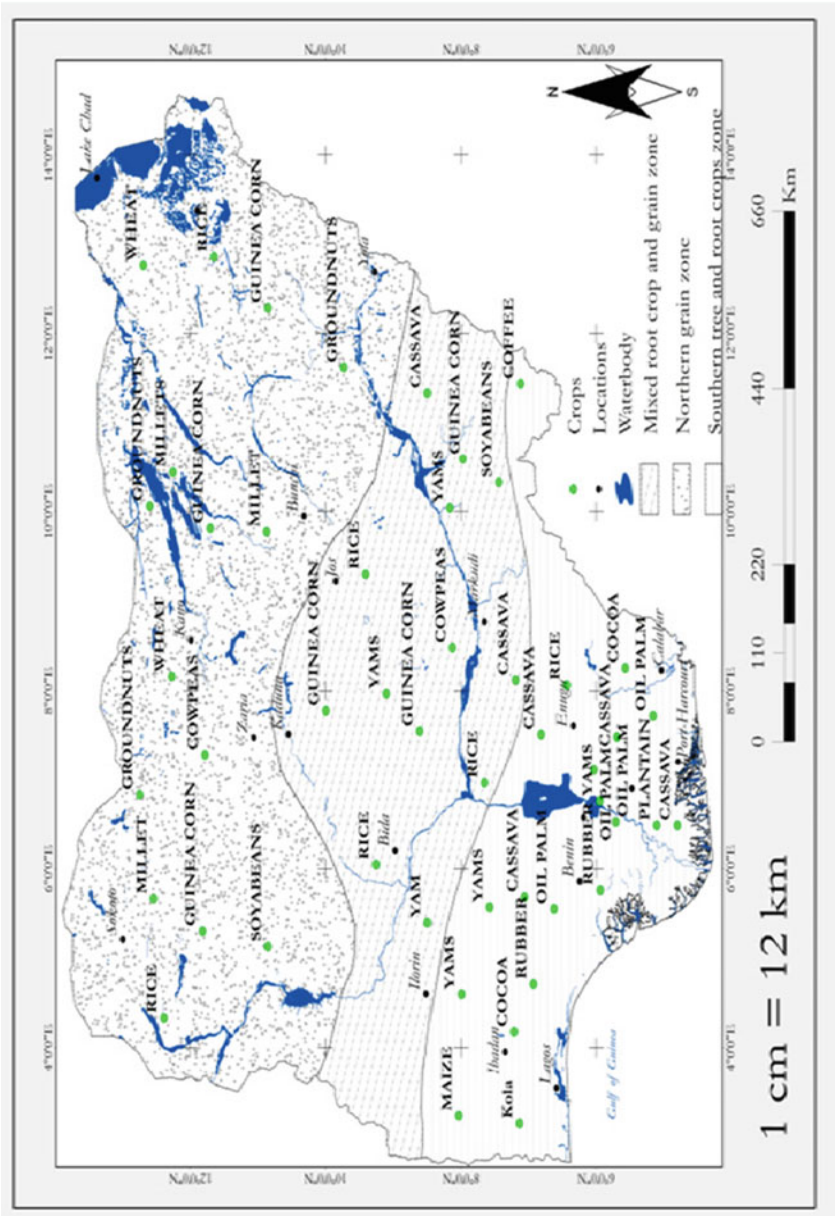

Fig. 15.3 Showed the ecological zones in Nigeria and the distribution of agricultural products

Table 15.3 Growth in major crop production (%) (Central Bank of Nigeria 2008)

Crop	2007	2008	Crop	2007	2008
Wheat	6.6	6.3	Plantain	6.6	6.0
Sorghum	5.9	6.0	Potatoes	7.3	6.4
Rice	7.7	7.3	Yam	5.4	5.9
Maize	7.1	7.0	Beans	7.0	7.2
Millets	6.3	6.6	Cassava	7.4	9.1
Soya beans	5.7	5.7	Palm oil	11.4	9.0
Rubber	6.8	6.4	Cocoa	5.5	5.6

Agricultural Organization 2005; Rhett 2005). Every year more than 400,000 ha of forests are devastated. The high rate of deforestation is attributed to rising human population, lack of political will on the part of governments (State, Federal and Local Governments) to enforce regulations against deforestation and re-afforestation, poverty, agricultural practices of shifting and bush fallow systems of cultivation, mining of solid minerals, exploitation of oil and gas deposit, bush fire, livestock over-grazing, infrastructure development, desiccation and desertification, urbanization, fuel wood exploitation, wars and terrorism, hydroelectric projects, pollution, hunting and poaching.

There are constraints arising from soil degradation, especially erosion. Soil erosion affects agriculture in marginal areas because of a combination of steep slopes and poor vegetation, which aid fast run-off and wind erosion, in addition to diminishing infiltration potentials. Intense and heavy rainfall in southern Nigeria is increasing the range of gully erosion because of increase in overland flows in fragile sandstone-dominated environment. Soil and coastal erosion adversely affect over 80% of the land of Nigeria. Africa's largest single erosion complex exists in Nigeria. While sheet erosion is fairly widespread, gully erosion presents spectacular catastrophe. Although gully erosion affects only 0.1% of total land area of Nigeria, the number of gullies is dauntingly large and sizes of some of them are astonishingly large (Akanwa and Ezeomedo 2018).

Figure 15.4 showed the spatial incidence of gully erosion covering five states in the South East geopolitical zone, Cross River and Edo States in the South-South geopolitical zone, Ondo State in the South-West geopolitical zone, Benue State (North Central) and Gombe in the North-East geopolitical zone.

In the Niger Delta Region coastal areas salt water intrusion from the Atlantic Ocean and inundation affect water supply, while intricate construction of roads and pipelines distort the Niger distributaries leading to depletion of mangrove trees. This affects breeding grounds for fish.

Drought, acidification and desertification constrain agricultural sustainability. The impact of drought on the availability of nitrogen and phosphorus is generally high after drought. Understanding nitrogen levels can lead farmers to sow inappropriate crops. The calculation of nitrogen should deal with the residual nitrogen from fertilizer application in the previous year as well as sub-soil and top soil nitrogen mineralization.

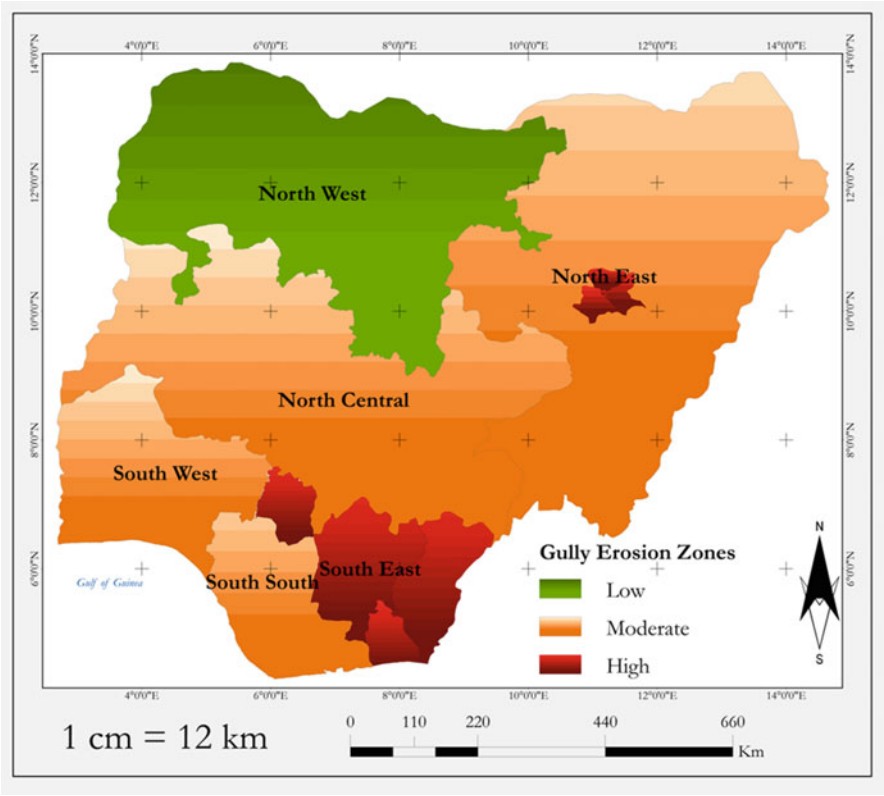

Fig. 15.4 The spatial incidence of gully erosion spread in Nigeria

From 10° North latitude in Nigeria is classed as the most desertification-prone area. Figure 15.5 showed the Desert-Prone Zones in Northern Nigeria covering Adamawa, Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe and Zamfara States. These are characterized by a gradual shift in vegetation from grasses, bushes and dotted trees to expansive areas of desert-like sand/sand dunes. At the moment Nigeria loses 351,000 ha per annum of its landmass to desertification, or an annual loss rate of 0.6 km (Federal Ministry of Environment 2012). As of 2012, 4830 km^2 were covered by sand dunes. In terms of livestock farming, the migration of human and livestock from the 11 frontline states southward has been the cause of life-threatening security issue between sedentary crop farmers of the North Central States, South-East and South-West and the Fulani nomadic livestock rearers. In addition, this migration is resulting to intensive use and degradation of marginal ecosystems of these areas.

As dry seasons decline they do not stop the growth of volunteer plants in fields, pastures and plantations. As they argue, weeds constitute the rationale why farmers abandon their swidden fields to clear new forests areas. Often annual burning to

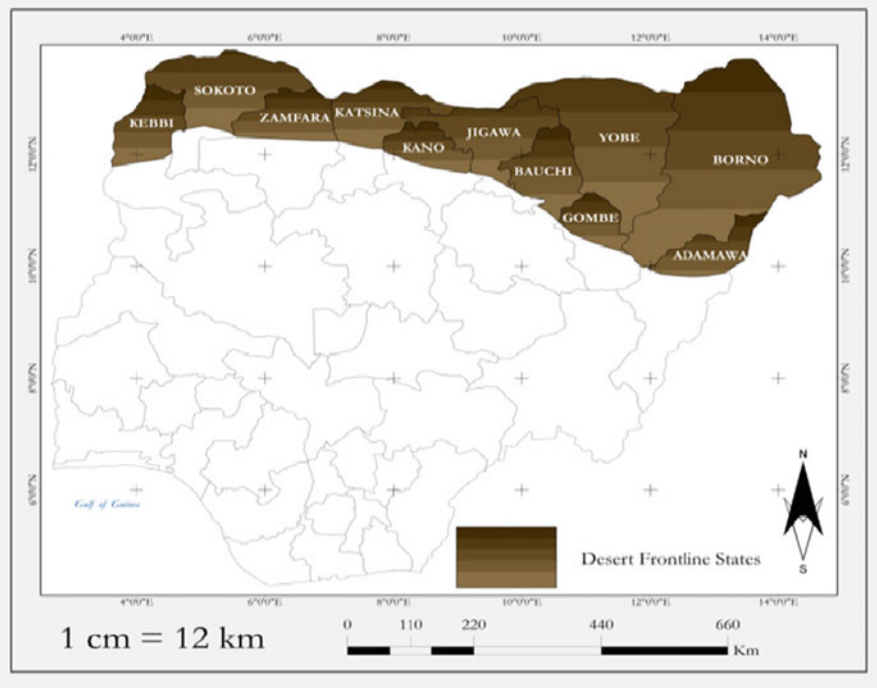

Fig. 15.5 Showed the desert-prone zones in northern Nigeria

control weeds leads to a buildup of perennial grasses, as is the case with many invasive species in Southern Nigeria.

The negative impact of crop diseases and pests in detracting from agricultural sustainability needs not belabouring. The hot and humid climate of Nigeria provides a favourable environment for the wide variety of pests and diseases afflicting livestock and crops. The effects of climate on pests and diseases are shown in their localization and occurrence as well as the geographical limits of the range of crop cultivation, variations in yield due to differences in the seasons or date of planting and annual variations in yield corresponding to changes in weather (Akanwa and Joe-ikechebelu 2020).

The disease of rosette which attacks groundnuts increases in intensity southward as the volume of rainfall increases. Ootheca afflicts cowpeas and causes yellow mosaic disease which thrives more in areas of heavy rainfall. Diseases of crops in Nigeria are of three types; virus, fungal and bacterial. Fungal diseases affect a great number of crops than viral diseases (Williams et al. 2017). The swollen root disease thrives in areas of high temperature and humidity. Cocoa is the major sufferer, leading to poor tree development and reduced yield. Most food crops are affected by a variety of viral diseases.

These include lanceolate, mottled leaf, leaf spot, brown and red leaf spot and mosaics. Lanceolate mottled leaf and mosaic affect yams; leaf spot affects cassava and yams, while leaf mosaics attack tobacco, kola nuts, groundnuts, cassava and yams. Stem borers damage maize, rice, millet, kola, coffee and oil palm, while worms destroy large fields of maize, yams and tobacco. Bolt worms affect cotton.

Grasshoppers such as locusts are dreaded as they invade large areas at the same time and damage a great variety of crops, causing widespread famine. A major animal disease is the trypanosomiasis, which is carried by the tsetse fly which is endemic in the forest belt. However, the N'dama and Muturu varieties of cattle are resistant to the tsetse fly.

The last ecological factor affecting agricultural sustainability we discuss here is climate change. Ample research evidence shows that Nigeria is already experiencing climate change extreme weather events (Odjugo 2010a; Ekpo and Nsa 2011). In a study spanning 105 years and involving 30 meteorological stations, Odjugo (2010a) showed that mean temperature has been constant until the late 1960s, when it started rising gradually till the year of study. He discovered that rainfall had experienced reduction of 81 mm from 1901–2005. Ekpo and Nsa (2011) in their study of Sokoto in North Western Nigeria from 1968–2008 discovered that rainfall reduced by 8.8% from the long-term mean from 1915 to 2008. The study also revealed late onset, early cessation and long breaks within the rainy season. Studies have shown that the length of rainy days have dropped by 55% in North-Eastern Nigeria in the last 30 years, while for the coastal areas, the drop is put at 14%. The double rainfall maxima have shifted farther south, while the "little dry season" usually experienced in August is now experienced in July (Odjugo 2010b; Ekpo 2009).

Crop specific studies and climate change effects have been conducted extensively in Nigeria. Odusina and Kassim (2004) discovered that rainfall variability affected rice production in the period of study from 1996 to 2011 in Ogun State. They showed that rainfall boosted rice production in the absence of flooding, while with flooding the reverse is the case. Their study however showed that the expected temperature at which rice production is constrained as shown by IPCC (2001) study has not been reached.

A study by Ufoegbune et al. (2014) showed that water melon production is better in the dry season under irrigation technology regime than in the wet season with erratic rainfall regime. The former ensures longer life cycle for water melon, as well as relative safety from pest attack. A trend study by Oguntunde et al. (2014) on the relationship between cocoa production and climate change variables from 1976 to 2009 in Ondo State (which produces between 45 and 65% of all cocoa in Nigeria) showed a reduction of 910.44 metric tons per year or a total reduction of 30,044.52 metric tons for the period of study. This is attributable to rainfall, maximum temperature, minimum temperature, mean temperature, potential evapotranspiration and water vapour deficits. There was a rise in diurnal temperature range above average measurements in the past four decades.

Ukhurebor and Abiodun studied the annual rainfall data of forty years (1978–2017) for South-South, Nigeria. The results show that the differences between the two means of the equal-length time scales revealed variability of

7.00 mm. Similarly, the CV of rainfall was 0.145 signifying low variability. However, the anomaly results revealed that 21 years (52.5%) recorded less rainfall; while 19 years (47.5%) recorded much rainfall. The Sen's estimator slope revealed downward trend of 94 mm/year in 1978–1987 decades; while it recorded upward trends of; 90 mm/year, 30 mm/year and 118 mm/year during the 1988–1997, 1998–2007 and 2008–2017 decades, respectively.

The implication of this study is that there are variations in the rainfall. Consequently, there is an optimum need to sensitize the general public about its existence in order to take the necessary measures and adaptation options for its mollification and management (Olaniran and Sumner 2006). Shortened growing season leads to reduced crop performance as in the case of Bida, Ilorin, Zaria and Yelwa. The authors attributed these variabilities to the patterns of the northward and southward march of the Inter Tropical Discontinuity (ITD). Except for Makurdi, the authors recommended irrigation farming for the other 15 stations and their farming regions. In the alternative, genetically modified crops of shorter growing periods are recommended.

Odjugo (2010b) studied shift in crop production as an adaptation to climate change in semi-arid region of Sokoto and Zamfara from 1975 to 2007 and discovered increase in temperature and decrease in rainfall from 783 mm in 1975–1977 to 618 mm in 2005–2007 (a decrease of 146 mm). As a result of this, farmers switched to millet instead of guinea corn, followed by maize production (2–3 months production period) and beans and groundnuts, requiring only 3 months for production.

Apparently the most demonstrable evidence of climate change in Nigeria is to be found in the Lake Chad Basin, situated in an intense region of evapotranspiration in the semi-arid region of Nigeria's north eastern region. The basin has witnessed a diminution of its size. Rainfall has decreased from 800 mm to 400 mm (50% decreases) in the last 40 years, resulting in incessant drought. Decreased water in the region derives from dams constructed on the upper reaches of rivers draining into the basin, reduced rainfall, high evapotranspiration, scarcity of cloud cover and poor land management. Lake Chad has dwindled in size from a maximum surface area of 25,000 km^2 (9650 $miles^2$) in 1963 to just 1350 km^2 or 521 $miles^2$ today. In the 1960s the theoretical lake basin covered 2,397,423 km^2 straddling the borders of Nigeria, Chad, Niger and Cameroon. The US NASA forecasts show that the Lake could disappear by 2030.

Initially the Lake served as a source of fresh water, fisheries (120 species), pastoral and agricultural land for some 20–30 million people. Today it is at the brink of a humanitarian and environmental disaster, drying up. A reed *Typha australis* (known locally as *kachalla*) has been covering the River Komadugu-Yobe fertile plain since the completion of the Tiga Dam in Kano State. *Kachalla* has also been an ideal habitat for the destructive quelea bird, which ravage crops. As a result of the current ecological condition of Lake Chad, there has been 60% decline in fish production. Degradation of pasture lands had resulted to 46.5% shortage of dry matter as at 2006, a reduction in livestock population and threat to biodiversity (Nation Newspaper 2019).

Economic estimate of fish sold in the region is put at N 350 million per week or N 1.4 billion a month. Estimated 50,000 metric tons annual loss is sustained in fresh water fish supply due to desiccation, 55% estimated loss in pasture land due to desertification and 95% drop in quantity of milk product per cow as a result of poor cattle nutrition and massive reduction in crop yield in the past 20 years, 45% in tomato and 55% in wheat production (Kenechukwu 2016).

In Kano State only 42,000 metric tons of groundnut was produced in 1978 as against 500,000 metric tons in earlier years; in Borno State 400,000 cattle, 7 million animals and 3 million goats were affected by desertification and drought (Federal Ministry of Environment 2012). About 65% of the landmass was affected by desertification in Sokoto and Kebbi States, while 55% of land in Borno and Yobe States was affected.

Nigerian agricultural practice, despite ecological intensification, does not make for survival. The declining agricultural production does not guarantee adequate nutrition or even the supply of raw materials to local agriculture-based industries. A combination of climate change, desertification, deforestation, slash and burn practice, soil and gully erosion, poor land management and drought has affected productivity.

An evidence of this is that for 2004–2005 the values of agricultural export and import amounted to $623 million and $2285 million, respectively. For food, respective figures were $548 and $2024 million. A total of $1bn was posted as annual loss in non-timber forest products due to rapid deforestation, while 90% permanent loss is sustained in the natural habitat of pollinators, critical to agricultural productivity. About 1.5 million trees are being felled daily (Kenechukwu 2016).

Despite the fact that Nigeria has enormous water resources potential of about 319 billion m^3 and with surface water accounting for 267 billion m^3 and ground water of 52 billion m^3, it has only 220 dams with a combined capacity of only 33 billion m^3 (Federal Ministry of Environment 2012). With 11 River Basins and Rural Development Authorities, Nigeria has not tapped into its water resources for sustainable intensive agriculture.

In terms of soil, Nigeria's soil types are fluvisols, regosols, acrisols, ferrasols, alfisols, lixisols, luvisols, nitosols, arenosols and vertisols, all varying in their potentials for agriculture. Nearly 48% of Nigeria's soils, especially vertisols, alfisols, acrisols and arenosols are found in the dry land area of the country and these falls into low classes of productivity. The poor quality of soils is accentuated by deforestation, desiccation, desertification, sand dunes (barchans), soil and gully erosion, and increase in acidity and decrease in soil fertility that farmers seek out adaptation such that cassava has virtually supplanted yam cultivation in southern Nigeria (Onakuse 2012). The figures of cassava production were 23.83 m and 35.61 m metric tons for 1994/95 and 2005/06, respectively (National Bureau of Statistics 2007).

Inconsistencies in policy implementation and introduction of agricultural development programmes/systems have bedeviled agricultural productivity (Muoghalu 1992a). Each military or civilian administration introduced its own agricultural programme and dropped the one it met. The regional governments in the western

and eastern regions before independence in 1960 operated the Israeli-based farm settlement scheme. The military regime in 1972 introduced the Agricultural Development Programme (ADP) sponsored by the World Bank (later renamed the Integrated Rural Development Programme (IRDP) in the third and fourth plan (1975–1980 and 1981–1985)). The military introduced the 11 River Basin and Rural Development Authorities in 1976, modelled on the Tennessee Valley Authority (TVA) in the USA. By 1982, these have gulped N 1.56tr. In the main, corruption crippled them. While Obasanjo introduced "Operation Feed the Nation", Shehu Shagari came up with the Green Revolution, Babangida introduced the Directorate of Foods, Roads and Rural Infrastructure (Muoghalu 1992b).

A major constraint to agricultural productivity is agricultural landholding. As at 1974, landholding ranged from 0.405 ha to 3.04 ha for peasant farmers (Federal Ministry of Agriculture and Natural Resources (FMANR (Federal Ministry of Agriculture and Natural Resources) 1974). This has been on the decline. For example, in 1994/95 total hectare devoted to millet cultivation by peasant farmers was 7.53 Mha. This declined to 3.91 Mha in 2005/06, a decline of 48.07%. For guinea corn, the story is the same: 6.00 Mha in 1994/95 and 3.95 Mha in 2005/06 and for beans it was 3.467 Mha in 1994/95 and 2.313 Mha in 2005/06.

The categories of peasant farmer's access to land consisted of owner's land, family land, rented, squatter and others. For 1994/95 and 1995/96 the proportion of land farmed by these were 69.44%, 25.97%, 6.59%, 0.58% and 1.41%, respectively. For 2004/05 and 2005/06 corresponding proportions were 58.96%, 23.60%, 14.03%, 1.00% and 2.41% (National Bureau of Statistics 2007). This shows that land owners and family land cultivators decreased, while the rest increased. The extent of land farmed is a function of the failure of the Land Use Act of 1978, which was meant to give developers and investors access to land. Today most land many kilometres away from cities have been bought from real owners by land speculators. Even in villages poverty is forcing poor people to sell off their land to the rich capitalist few.

In terms of farm inputs, fertilizers come readily to mind. The application of fertilizers has witnessed sharp decreases. In 1994/95, 112,130 metric tons of fertilizer was used, while 63,262 metric tons was used in 2005/2006. Use showed spatial variation. For example, Benue, Borno, Jigawa, Kano, Katsina, Nasarawa, Niger, Plateau, Sokoto and Yobe States each used more than 3000 metric tons per annum, while southern States (Abia, Anambra, Bayelsa, Ekiti) used less than 300 metric tons (National Bureau of Statistics 2007). It must be observed that the intensity of fertilizer use is related to the landmass cultivated, the extent to which agriculture is the major economic engagement and the dominance of food crop cultivation over tree crops, relative affluence of farmers and readiness of farmers to adopt innovation.

15.7 Challenges and Strategies for Agricultural/Ecological Intensification in Nigeria

Federal Ministry of Agriculture and Rural Development (2000) stated some of the major challenges of agricultural sector in Nigeria to include lack of experience of improved farming systems, land tenure insecurity, low and unstable investment in agricultural research, financial constraints where there are high interest rates on loans, inaccessible credit due to tough conditions and expensive manually irrigated and controlled agriculture. Also, there are storage constraints where majority of the smallholder farmers practice poor storage methods, lack of post-harvest preservation skills and consistent theft of farm products accentuate the challenges. In addition, there are the issues of farm input constraints where prices of farm inputs are outrageously high, confusion on choice of variety of input to use, infrastructural constraints such as inaccessible roads, poor market facilities, marketing constraints where prices of goods fluctuate, presence of middlemen who make more financial gains at the expense of the rural farmers and intense competition**.** From the foregoing, increasing agricultural production can only be achieved through sustainable agricultural intensification. This requires the application of smart policies that would adopt innovations while granting access to local farmers (Idachaba 2000).

This involves improving the market structure to organize and expand the rural market services beyond the sale of local farm products to highly industrialized global market levels where it can enjoy organized international negotiations (Punch 2017; AGRA 2017a, c, d; AgroNature Nigeria 2018). Nigerian agricultural sector should promote investment in the area of providing local farmers with credit facilities to boost food supply and reduce risks (AFI 2017). This will involve the government at the federal, state and local government levels to support local farmers, presently; the Nigerian Federal Government has launched the Agro Processing Productivity Enhancement and Livelihood Improvement Support (APPEALS) project.

It is targeted to improve farmers' productivity and boost the agricultural sector by providing a loan of six hundred billion dollars to support 2.4 million farmers with zero interest across the nation (ThisDay 2020). APPEALS project in Nigeria is for small and medium farmers in Kano, Kaduna, Cross Rivers, Enugu, Lagos and Kogi. It is vital to revisit our nation's legal rights and access to lands so that local farmers can better enjoy access to large farm lands for farming either within the customary framework or a formalized modern law (Eboh 2004; IFDC/IITA/WARDA Report 2000; Kormawa et al. 2003).

In addition, climate-smart agriculture is vital for transforming and reorienting agricultural production systems and food value chains so that they support sustainable development and ensure food security under climate change. This will prevent climate-related disasters and crises and aid in rapid recovery in a sustainable manner. It includes protecting, restoring and improving food and agricultural systems under climate threats that impact food and nutrition security, agriculture, and food safety/public health. Further, agri-businesses should collectively be associated with the production, processing and distribution of agricultural products, including business entities involved in the production and distribution of agricultural inputs and

machinery to farmers and those involved in purchasing, aggregating, processing and distributing farm produce (CGAP 2018).

15.8 Research and Development in Ecological Intensification of Agricultural Practices in Nigeria

For ecological intensification in the agricultural sector in Nigeria to be achieved, there is need for digitally delivered information on areas such as agronomic best practices, pests and diseases, weather, and market prices, as well as more sophisticated digital services and farm management software tailored to the specific farmer, farm or field that enable smallholder farmers to make decisions that maximize output from their land, improve the quality of agricultural production and maximize farm revenues and profits via lower costs of production, improved ability to identify markets and/or better price realization (Addom and Enghild 2018; Bobbi 2018; Ehui 2018).

Businesses collectively associated with the production, processing and distribution of agricultural products, including business entities involved in the production and distribution of agricultural inputs and machinery to farmers for those involved in purchasing, aggregating, processing and distributing farm produce should be developed. The area of agricultural transformation should be harnessed since it is a necessity in Nigerian agric-business sector where agriculture is a vibrant, modern and sustainable business that creates value for farmers, entrepreneurs, youth and women, and produces affordable, nutritious and healthy food for all (African Center for Economic Transformation 2017).

In addition, the area covering pest and disease surveillance and monitoring at regional, national or even farm and field levels to record the prevalence and severity of pests and plant disease typically goes beyond simple monitoring but should include early warning and advice on pest and disease management.

The study of large, diverse, complex data sets generated from instruments, sensors, financial transactions, social media and other digital means should be given attention (Africa News 2018). Finally, women farmers should be given more attention through research studies, since they make huge contribution to the agricultural sector in Africa and Nigeria where over 64% of the labour force working in the agricultural sector are women who produce 80% of food resources.

15.9 Policy Implications for Sustainable Agricultural Intensification in Nigeria

Our discussion above has obvious policy implications for agricultural sustainability and agricultural and ecological intensification. The first is that Nigerian agriculture does meet the energy, food and fibre needs of the population. It does not create a balance of environmental, economic and social criteria of sustainable agriculture. It is not sustainable over time. Yields do not meet current needs as shown in variability

in annual productivity. Yields do not rise overtime to meet added consumption demand in line with population rise. Given increasing soil degradation and decreasing total annual yield, the system is incurring inter-generational debt for the future. Intensification of production on cleared existing space is no guarantee for uncleared portions of land, because deforestation, shifting cultivation, desertification and poor land management are consuming cleared and uncleared spaces.

Nigerian agriculture is characterized by low input investment. Fertilizers do not reach the real farmers; it is often corruptly diverted and rarely sold at government officially announced prices. Introduction of machinery for land preparation and other activities is beyond the reach of peasant farmers, while agricultural extension services are no longer there. There is the challenge of marginal lands. The practice of agroforestry is not widespread. Access to land is inequitable. The practice as at present does not guarantee long farm carrying capacity of the land as there is no soil evaluation to understand deficient soil nutrients. Wetlands along the coast are threatened by urban development, oil and gas industry, gas flaring, pollution from industry and intrusion of salt sea water.

An important question relates to whether sustainable agricultural development can be achieved within existing social, economic and political structures of the country. These relate to land availability and access. There is the crying need to integrate the conservation of ecological resources and development. This is because development projects often are sources of ecological degradation rather than solutions to problems. For example, sand stone and laterite quarrying, transport development (and its accompanying pollution) impact negatively on agriculture. These are important because desirable economic, social and political structures belong to the development aspect of SD, while sustainable aspects focus on ecological sustainability (Kates et al. 2005; Ndondiana and Elizabeth 2018).

Economic inputs in Nigeria's agriculture consist of access to productive assets-land, water, fertilizers, germicides and insecticides. These evoke social and cultural distribution of incomes that determine access. Not compromising the ability of future generations in meeting their own needs touches on water resources, land and soil degradation or even the displacement of agricultural or potential agricultural land by investments other than agriculture and keeping to sustainable ecological footprints in terms of land area on which farmers and consumers draw agricultural crops and livestock. It is necessary to ensure that agricultural wastes and those of other sectors are kept within the absorptive capacities of agricultural land, especially rivers and coastal areas for fishing and maintaining the ability of rivers to break down biodegradable wastes without ecological degradation.

Strategies for achieving social equity, social integration and social stability are essential attributes of SA. In this area terrorism and the creation of cattle colonies or the so-called RUGA or forced settlement for Fulani cattle rearers outside their States of origin cast ominous shadows on the sustainability of Nigerian agriculture. It is against the above observations that we present a few policy implications for the future of Nigeria's agriculture.

One, since the current land tenurial system stifles land utilization and modernization of traditional agriculture, in terms of land ownership, land use rights and land

acquisition, there is need for the enforcement of agrarian land use laws aimed at the unification of land use patterns and procedure with regard to freehold, purchase, leasehold, use rights, excessive fragmentation (which leads to scattering of tiny farm plots), inequality in the distribution of farmlands and excessive land use costs. There is an urgent need to re-examine the 1978 Land Use Act, to remove bottlenecks in its implementation, especially as few wealthy individuals are buying up available rural and rural–urban land.

The issue of farmers cultivating marginal land is related to the problem created by the imprecision and ambiguity of current land tenure system. It would have made sense to concentrate farming on optimal lands, but the factors of population pressure, areas receiving excessive rainfall, poor soils, steep slopes and inadequate drainage force the poor to farm marginal lands. The way out of the cultivation of marginal lands may lie in Tittonell (2014) strategy which requires the deployment of different crops and several varieties of each crop that requires different nutrients and have different abilities to tolerate environmental stress.

This is the platform in which research strategies will develop crop varieties that are resilient to moisture stress and to poor soils. A typical example already in operation is the case of cassava and mango displacing yam. Coming up with crop varieties that can withstand diseases and pests is necessary. Allied to this is the necessity for land evaluation which is the process of estimating the potential of land for a specific use or for a multiplicity or alternative uses. The uses may include the productive potentials of land for arable crops, livestock production, and forestry yield or water catchment areas. Land evaluation requires information from land, land use, economics, agronomy, forestry and geographic information system, thus emphasizing its multi-disciplinary nature.

The issue of soil conservation techniques is a priority in hilly and mountainous areas or areas of severe soil and gully erosion, as well as in the arid and semi-arid areas where wind erosion is aggressive. It must be borne in mind that fertilizers are not compensatory for soil fertility lost during erosion as sub-soils have different physical and chemical characteristics than the more friable and fertile top soils and these can interfere with proper root development. One strategy for soil conservation is to irrigate the land to conserve the top soil. Another strategy is to adopt grass and tree strips strategy to trap soils, leaving bands of natural vegetation along contours. Surplus water can be removed by grass water ways. In the bare surface areas netting can be used after seeds have been sown to achieve temporary erosion control until plants have grown to bind soil together.

In the extreme north where wind erosion is ferocious, the Great Green Belt project should be continued. But to counteract desertification the use of *Cactus opuntia* is highly recommended. This plant is recommended because it is well adapted to desert and desert-like and infertile soils, in addition to tolerating temperatures of up to 50–55 °C. It is drought resistant and can survive long periods of drought. Its preference for ecological tolerance is boosted by its vast economic utility providing highly nutritional fodder for animals, raw materials for production of drugs, cosmetics, confectionaries, while its plantations provide employment, income for farmers and better atmospheric conditions for the people through reduction of CO_2.

Much more importantly, the establishment of *Cactus opuntia* plantation in Local Government Areas of the 11 States of the shelter belt can make cattle Fulani herders adopt permanent settlement and embrace ranching as a new and modern way to herd cattle. Because of its fast growth, other advantages of *Cactus opuntia* can be realized through improved quality of meat, milk, leather and wool. This will remove one destabilization problem in the Nigerian nation-armed violence of cattle Fulani herders.

The use of agro-chemical, such as chemical inorganic fertilizer and synthetic pesticides should be minimized, as they pollute surface water bodies and encourage the proliferation of biotic plants in rivers and river plants, such as *water hyacinth* and *Typha australis* through eutrophication. Also pesticides can often be too costly for most crops in the humid tropics, but can be economically viable for certain cash crops to some extent. A better alternative as has been observed above, to deal with pests and diseases is to generate resistant crop varieties and build on traditional knowledge and modern methods of science, through poly-culture of several cultivars for each crop through biotechnological science. Genetic resistance is cheaper for farmers, consumers and the environment in the long run.

The use of herbicides can be encouraged because they have minimal environmental impact and can be cheaper than labour. But the use of inter crops that out-compete the weeds is preferable because they provide fodder, mulch or nitrogen fixation (Mobasser et al. 2014). The use of nitrogen fixing plants (e.g. *Centrosema*) can withstand trampling and heavy grazing. Weeds can also be shaded out by using various cropping systems, such as agroforestry.

Finally is the place of the individual farmers in agricultural intensification. How much does the individual farmer know of the intricate and delicate relationship between the ecosystem and his use of the same? Since the individual producers and consumers wish to maximize their utility of natural capital, there is every need to restrain their anthropocentric propensities. This emphasizes the need for information and knowledge sharing. The need for agricultural extension officers is undeniable, as well as the efforts of NGOs, CBOs, cooperative societies and agricultural research institutes in producing and disseminating knowledge. Farmers should be led into appreciating the need for responsible stewardship. Innovations that improve on traditional methods of production and land management should be introduced.

15.10 Conclusion

The chapter stated agricultural systems and practices in Nigeria in terms of addressing the tenets of agricultural sustainability, ecological and agricultural intensification. Nigeria scored low due to a multitude of factors, including poor land management practices, inadequate farm inputs, inaccessible land tenure system, poverty, corruption, inadequate and degraded infrastructure, inconsistency in policy and programme formulation among others. However, there are redeemable means for agricultural intensification in Africa and Nigeria. This should include the need for maximum budgetary allocation to the agricultural sector. Also, the Federal

Government should concern itself with general policy and programme formulation, the implementation realm should devolve on the states and local governments that closely interact with the real farmers. Further, research and development should address local ecological matters, not national global issues because the problems of agricultural productivity in Nigeria are primarily at the local level. This emphasizes the need for intensive research and development and cooperation between tertiary institutions in confronting the challenges of the agricultural sector. Unfortunately, these institutions are operationally distant from the real farmers and should be supplied with the facilitation for research.

Is there a real link between agricultural extension staff and those who churn out research? How relevant is the research to pressing agricultural challenges? What is the size of our multi-disciplinary strategy in addressing our ecological and agricultural challenges? What is the role of the digital economy in solving our problems? What is the impact of urbanization on the effort to increase agricultural productivity? Above all, how much do the policy formulators know about the inter-twining relationship between the biophysical environment and agricultural endeavours? What do we do with the geometrical rise in our population?

The perspectives are multitude, but suffice it to end by saying that for Africa to come out of her agricultural quagmire there is a crying need for agricultural revolution involving political, structural, financial, knowledge, communication, transparency and accountability in this re-engineering.

15.11 Future Perspective

From the foregoing, it is obvious that for agricultural production in Nigeria to attain sustainability it requires a radical revolution. This revolution should include a highly mechanized, digitalized, use of improved seeds resistant to climate change and vertical farming in urban areas all aimed at achieving a broad national agri-food supply beyond the subsistence smallholder farmers and pastoralism practiced in Nigeria. In addition, the consistent application of the right policies, innovation and investment in Nigeria's agriculture could be ecologically expanded for agri-production and industrialization through processed by-products that can meet international standards for exportation and thus yielding foreign exchange for the nation.

Government can apply the knowledge of ecological zones to improve macro-decisions on policy-making, as well as the design and implementation of their programmes. When this is fully implemented, it will provide a highly connected agricultural ecosystem that is efficiently more productive and transparent than ever before. The growing quantity and quality of agricultural data and digital agricultural solutions significantly can reduce the cost of service, inputs and information delivery to farmers and other value chain intermediaries. It must be a mass movement in which everybody is involved—the real farmer/producers, consumers, service providers, politicians, academics, civil societies, community organizations, men and women and youth, researchers, implementers and traders.

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