The Role Of Climate, Soil And Crop On Sustainable Agriculture In Nigerian Ecological Zones: A Brief Overview

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Abstract
Farming sustainably means growing crops and livestock in ways that meet three objectives simultaneously: Economic profit, Social benefits to the farm family and the community, Environmental conservation. Agricultural productivity is highly sensitive to changes in the climate and also depends largely on the soil management practices and the various cropping systems. All these must be employed in the six ecological zones of Nigeria, ranging from a belt of mangrove swamps and tropical forests along the coast to open woodland and savanna on the low plateau which extends though much of the central part of the country, to the semi-arid plains in the north and highlands to the east to meet the three objectives of sustainable agriculture which are Economic Benefit, Social benefit to the Community and Environmental conservation.

Introduction
Sustainable Agriculture has been on the global agenda for some several decades now. The word "sustain," from the Latin sustinere (sus-, from below and tenere, to hold), to keep in existence or maintain, implies long-term support or permanence. Sustainable agriculture describes farming systems that are "capable of maintaining their productivity and usefulness to society indefinitely. Such systems must be resource-conserving, socially supportive, commercially competitive, and environmentally sound. Farming sustainably means growing crops and livestock in ways that meet three objectives simultaneously: Economic profit, Social benefits to the farm family and the community Environmental conservation (Sullivan, 2003). It is a system of agriculture that will maintain its productivity over the long run. Sustainable farming could be Organic farming, biodynamic, permaculture, agroecological systems and low input. The goal of sustainable agriculture is to minimize adverse impacts to the immediate and off-farm environments while providing a sustained level of production and profit. Sustainable agriculture is influenced by environmental climate, soil types and the various crops and types of farm practices employed.

Climate is the meteorological conditions, including temperature, precipitation, and wind that characteristically prevail in a particular region over a long period of time. It is a change in the climate that persists for decades or longer, arising from either natural causes or human activity (IPCC, 2007). The earth’s climate is influenced by many factors which include the amount of energy coming from the sun, amount of greenhouse gases and aerosols in the atmosphere and properties of the earth’s surface, which determine how much of the solar energy is retained or reflected back to space which makes the climate changes over time. Also climate change is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Rapid global climate change is expected to impact agriculture by causing shifts in temperature, precipitation, soil quality, pest regimes, and seasonal growth patterns. To cope with climate change that is likely to be both rapid and unpredictable, agricultural systems must be resilient and able to adapt to change. Resilient agriculture systems are those that are more likely to maintain economic, ecological and social benefits (Sustainable Agriculture PPT) in the face of dramatic exogenous changes such as climate change and price swings. In the face of uncertainty, food production systems should be established which are diverse and relatively flexible, with integration and coordination of livestock and crop production.

Soil supports the growth of most plants and fibre and contributes to the wellbeing of Nigerians and their economic stability. Healthy soil, an essential component of a healthy environment, is the foundation upon which sustainable agriculture is built. Agricultural productivity depends largely on the topsoil, the uppermost layer, which is about 15 to 20 cm deep for
most soils. Topsoil serves many functions. It provides a rooting zone for plants, supplies a balance of plant nutrients, and retains stores and releases moisture for plant use. It also enhances seed germination and root penetration, and supports a complex community of beneficial microorganisms which decompose organic wastes, recycle plant nutrients, and protect plants from pests. All these functions are essential for maintaining the tilth, fertility and productivity of agricultural soils. Soils with these capabilities are considered by many to be "healthy soils" (Parr et al., 1992). Today soil degradation is the single most destructive force diminishing the world's soil resource base (Parr et al., 1992). Soil degradation is the most serious crisis facing the agricultural industry in the long term. It has been a major problem for years and will continue to be unless urgent action is taken, sustainable agriculture will be a thing of history because soil is the bedrock of sustainable farming. Brown and Wolf (1984) reported that worldwide the mean annual loss of topsoil is estimated at 0.7 percent. Studies have shown that when the topsoil is removed, or where it has been severely eroded, crop yields are from 20 to 65 percent lower compared with non-eroded soils (Langdale et al., 1979; Massee, 1990; Parr et al., 1992). Unless we take further action, we shall lose the competitiveness of our agricultural industry in the next few years. The health of the agricultural industry depends on both the quantity and the health of the soil (Acton and Gregorich, 1995). In the light of this, the soil must be properly managed and even adapting to climate change is irrelevant unless we focus on rebuilding and management of healthy topsoil.

Improved crop productivity is based on sufficient knowledge of the science of soils on which they are grown and the environmental conditions governing the plants. Also the agronomic practice or cropping system employed increases organic matter in the soil, improves soil structure, reduces soil degradation, and can result in higher yields and greater farm profitability in the long-term. Increased levels of soil organic matter enhances water and nutrient retention, and decreases synthetic fertilizer requirements. Better soil structure in turn improves drainage, reduces risks of water logging during floods, and boosts the supply of soil water during droughts. In a nutshell, good cropping system contributes to sustainable agriculture.

To feed the world and to feed it well, global food production will need to double and the only answer to this is sustainable agriculture. So Sustainable agriculture should not be an either/or proposition, such that a farm either is or is not sustainable. It should be a must. The problem, however, is that half of the habitable land on Earth is already used for farming. As resources are limited, the challenge is to achieve global food security while having a positive impact on the environment and society. Sustainable agricultural practices provide the solution.

Nigeria contains six ecological zones, ranging from a belt of mangrove swamps and tropical forests along the coast to open woodland and savanna on the low plateau which extends though much of the central part of the country, to the semi-arid plains in the north and highlands to the east (USDA). The principal food crops are yams, cassava, and maize to the south, and millet, sorghum, and cowpeas in the drier north. Cocoa, rubber, oil palm, groundnuts, and cotton are the main cash crops which are generally destined for export (USDA). But as it is, the natural vegetation zones resulted from the interaction of the climate, humidity and rainfall (Oyenuga, 1967), and soils (Iloeje, 2001). These factors have been modified by human activities and man’s pattern of land use (Oyenuga 1967; Iloeje, 2001). Based on the above, Oyenuga (1967) classified Nigeria into nine (9) agro-ecological zones viz:- The mangrove forest and coastal vegetation; the freshwater swamp communities; the tropical high forest zone; the derived Guinea savannah with relict forest; the southern Guinea savannah zone; The northern Guinea savannah zone; The Jos plateau; The Sudan savannah, and The Sahel savannah. However, Iloeje, (2001) grouped the country into forests and savannah zones. These two major zones were further sub-divided into three zones each such as Forests that consist of salt-water swamp; fresh-water swamp; high forest; and Savannah zone that consist of guinea savannah; Sudan savannah and Sahel savannah. FAO (2009) also grouped Nigeria ecological zones into nine (9) major zones which include Freshwater swamps Forest, Lowland Rainforest, Mangrove Forest, Montane Savanna, Sudan Savanna, Guinea Savanna, Jos Plateau, Derived Savanna and Sahel Savanna.

**Sustainable Agriculture**

Sustainable Agriculture is an integrated system of plant and animal production practices that will satisfy human food and fiber needs, enhance environmental quality, make the most efficient use of, nonrenewable resources, sustain economic viability and enhance quality of life (Farm Bill, 1990). It is a commitment to satisfy human food and fiber needs and to enhance the quality of life for farmers and society as a whole, now and into the future (Sustainability PPT).

SARE, the Sustainable Agriculture Research and Education Program (www.SARE.org) defines sustainable agriculture as an agricultural production and distribution system that: Achieves the integration of natural biological cycles and controls; Protects and renews soil fertility and the natural resource base; Optimizes the management and use of on-farm resources; Reduces the use of nonrenewable resources and purchased production inputs; Provides an adequate and dependable farm income; Promotes opportunity in family farming and farm communities, and Minimizes adverse impacts on health, safety, wildlife, water quality and the environment.
Goal of Sustainable Agriculture

Sustainable agriculture depends on a whole system approach whose overall goal is the continuing health of the soil and the people. Therefore it concentrates on long term solutions to problems instead of short term treatment of symptoms (Sullivan, 2003).

The goal of sustainable agriculture is to minimize adverse impacts to the immediate and off-farm environments while providing a sustained level of production and profit. Inherent to this goal is the understanding that sustainability must be extended not only globally, but indefinitely in time, and to all living organisms including humans. Simply stated, sustainable agriculture refers to the ability of a farm to produce food indefinitely, without causing irreversible damage to ecosystem health (Sustainable Agriculture PPT). Sustainability aims to balance between what is taken out of the soil with what is returned to it, without relying on outside inputs. “Sustainable agriculture is one that produces abundant food without depleting the earth’s resources or polluting its environment. It is agriculture that follows the principles of nature to form systems for raising crops and livestock that are, like nature, self-sustaining. Sustainable agriculture is also the agriculture of social values, one whose success is indistinguishable from vibrant rural communities, rich lives for families on the farm, and wholesome food for everyone” (Kluson, 2012).

Principles and Practices of Sustainable Agriculture

Sustainable agriculture needs to be brought back into the development agenda by employing adequate sustainable practices. Practices that require high inputs of chemical fertilizers, pesticides, hybrid seeds and mechanized irrigation system are not only too expensive for farmers but are also leading to soil degradation. The road to sustainability is long and complex. Each farm represents a unique combination of biological, climatic, soil and management conditions to secure sustainability (Fabian et al., 2008). Fabian et al., 2008 however listed the principles that will help farmers move in the direction of more sustainable agro ecosystems. These includes: Using water and nutrients efficiently; keeping soil covered throughout the year; Reduction or elimination of tillage in a manner consistent with effective weed control; Diversifying farming enterprise to spread agronomic and economic risk; Rotating crops to enhance yields and facilitate pest management; Use of cover crops and green manure and/or animal manure to build soil quality and fertility; Protecting water quality; Development of ecologically-based pest management programs; Integrating crop and livestock production; Increasing energy efficiency in production and food distribution and maintaining profitability.

Components of Sustainable Agriculture

Sustainable describes farming systems that are “capable of maintaining their productivity and usefulness to society indefinitely. It is a system that comprises of three components namely: Economy; Social/ community and the Environment (Figure 1). It therefore means growing crops and livestocks in ways that meet three objectives simultaneously: Economic Benefit; Social benefit to the Community and Environmental conservation.

![Three-Legged Stool of Sustainability](image1.png)

Figure 1. The three-legged stool of sustainability (Adapted from Toward a Sustainable Agriculture PPT)
Economic Profitability and sustainability
To be truly sustainable, a farm must be economically viable. Economically viable means that farmers can produce enough for self sufficiency and gain sufficient cash to pay for labour and other costs of production (Sullivan, 2003). The environmental and social benefits of sustainable production methods do not always translate into immediate economic gains. That said, sustainable agriculture practices can have a positive economic impact on a farm. For example, diversifying the farm with several crops and markets helps to reduce financial risk. Over time, improved soil and water quality, as well as other environmental benefits from sustainable practices, may raise the value of the farm. Selling products directly to local markets in the community reduces shipping and fuel costs and can potentially decrease transportation costs. While sustainably grown produce may not bring the full price premiums sometimes paid for certified organic products, growers selling directly to individuals and specialty markets can still capture added value.

Production costs can be variously affected by sustainable methods. Fertilizer and pesticide costs are generally reduced on a sustainably managed farm because, for example, legumes and crop rotations tend to be less expensive than their synthetic alternatives. Labor costs are often higher than conventional systems. The higher labor costs are most often attributed to the increased time required for monitoring and managing pests on sustainable farms. Planting material costs can be lower for growers saving their own seed or producing their own stock. However, those using organic planting material often pay more for seed or other planting material.

Machinery costs (purchase, fuel, and repairs) will vary depending on the specific type of sustainable production system. Conservation tillage systems and reduced pesticide applications can cut costs related to machinery use and fuel costs. On the other hand, certain systems, such as ridge tillage, can require specialized equipment. Fuel and machinery costs can increase as a result of moving bulky materials, such as organic matter, for soil improvement purposes. The result is that some farms that utilize sustainable agriculture practices may be more profitable than their conventional farming counterparts, although the reverse can also be true. In addition to crop production methods, many other factors can affect the bottom line, including management, marketing skills, and experience (UK Cooperative extension Service).

The following indicators that a farm is achieving economic sustainability as listed by ATTRA:
The family savings or net worth is consistently going up.
The family debt is consistently going down.
The farm enterprise is consistently profitable from year to year.
Purchase of off-farm feed and fertilizer is decreasing.
Reliance on government payments is decreasing.

Social Responsibility and Sustainability
Social sustainability relates to the quality of life for those who work and live on the farm, as well as those in the local community.

Socially just means that it is an equitable system for all the people including those yet to be born. Fair treatment of workers, positive farm family relationships, personal interactions with consumers, and choosing to purchase supplies locally (rather than from a more distant market) are just some of the aspects considered in social sustainability (UK Cooperative extension Service).

The followings are indications that a farm is achieving social sustainability as listed by ATTRA:
The farm supports other businesses and families in community.
Dollars circulate within the local economy.
The number of rural families is going up or holding steady.
Young people take over their parents’ farms and continue farming.
College graduates return to the community after graduation.

Environmental Sustainability
Sustainable agriculture can be viewed as ecosystem management of complex interactions among soil, water, plants, animals, climate, and people. The goal is to integrate all these factors into a production system that is appropriate for the environment, the people, and the economic conditions where the farm is located.

Environmental concerns are central to sustainable agriculture. Sustainable agriculture is frequently described as: ecologically sound practices that have little to no adverse effect on natural ecosystems. However, more than that, sustainable agriculture also seeks to have a positive impact on natural resources and wildlife. This can often mean taking measures to reverse the damage (e.g. soil erosion or draining of wetlands) that have already occurred through harmful agricultural practices. Renewable natural resources are protected, recycled, and even replaced in sustainable systems. Also inherent to sustainable agriculture environmental concerns is the stewardship of non-renewable resources, such as fossil fuels. A key to successful sustainable production is healthy soil, with a central tenet that management practices “feed the soil and the soil feeds the crop.” Ecologically, this means that soil fertility is provided by adequate soil organic matter and biologically based
inputs that feed soil organisms, which release nutrients to plants. Sustainable methods of enhancing soil fertility and improving soil health include: using nitrogen-fixing legumes, green manure, and animal manure; minimizing or eliminating tillage; and maintaining year round soil cover.

However, depending on the condition of the soil, establishing healthy soils may take several years. This approach does not preclude the use of synthetic fertilizer that can be used to supplement natural inputs. However, fertilizer decisions are based upon soil test results and are applied on an as-needed basis. Synthetic chemicals known to harm soil organisms and soil structure must be avoided in sustainable agriculture.

Other sustainable concepts include: maximizing diversity through planned crop rotations, intercropping, and companion planting; protecting water quality; composting; year round soil cover; integrating crop and animal production; soil conservation practices; and attracting beneficial wildlife. Some traditional agricultural practices, such as moldboard plowing, are in conflict with sustainability since they can result in damage to soil structure. Rather, tillage practices should be appropriately timed, using implements that minimize damage to soil structure to the greatest extent possible (UK Cooperative extension Service).

ATTRA lists the following indicators that a farm is achieving environmental sustainability:

- There is no bare ground.
- Clean water flows in the farm’s ditches and streams.
- Wildlife is abundant.
- Fish are prolific in streams that flow through the farm.

The farm landscape is diverse in vegetation.

Role of climate, soil and crop sustainable agriculture and climate change

Climate change is a complex biophysical process. It is not possible to predict precise future climate conditions, but the scientific consensus is that global land and sea temperatures are warming under the influence of greenhouse gases, and will continue to warm regardless of human intervention for at least the next two decades (IPCC, 2007).

Climate is the meteorological conditions, including temperature, precipitation, and wind that characteristically prevail in a particular region over a long period of time. It is a change in the climate that persists for decades or longer, arising from either natural causes or human activity (IPCC, 2007). Climate change, or global warming, refers to the increase in temperatures over the last 100 years due to greenhouse gas emissions from human activities, CO₂, methane and nitrous oxide, as well as others. It is now very clear that the global climate is changing, principally as a result of burning fossil fuels and agriculture related land use change which contributes to the greenhouse effect. According to the IPCC Fourth Assessment Report (IPCC, 2007), the temperature of the earth’s surface is expected to increase between 2 and 5 degrees Celsius (°C) over the next century, assuming greenhouse gas emissions continue to rise at current rates. This is gradually warming the planet and having a number of knock-on effects in terms of changing rainfall patterns, rising sea levels, and more unpredictable weather events.

Climate change is expected to lead to more frequent, more extreme or more unpredictable occurrence of existing natural hazards (such as temporal distribution of rainfall, floods, droughts, hurricanes, and cyclones). It can also result in the emergence of new hazards which did not occur previously in a particular locality, such as new types of pest outbreak or disease resulting from rising temperature. Gradual changes in the climate and natural environment are putting pressures on livelihoods which are dependent on natural resources (Clements et al., 2011). Climate change upsets the balance of natural systems. For instance, higher temperatures cause sea levels to rise, and unpredictable weather conditions upset patterns of precipitation.

Climate change is perhaps the most serious environmental threat to the fight against hunger, malnutrition, disease and poverty in Nigeria and on the bigger scale Africa, mainly through its impact on agricultural productivity. It affects agriculture in several ways, including its direct impact on food production and its most adverse effects is felt mainly by developing countries, especially those in Africa, due to their low level of coping capabilities (Nwafor 2007; Jagtap 2007) and Nigeria is one of these developing countries (Odjugo, 2010). As the planet warms, rainfall patterns shift, and extreme events such as droughts, floods, and forest fires become more frequent (Zoellick 2009), which results in poor and unpredictable yields, thereby making farmers more vulnerable, particularly in Africa. It is projected that crop yield in Africa may fall by 10-20% by 2050 or even up to 50% due to climate change (Jones and Thornton, 2003), particularly because African agriculture is predominantly rain-fed and hence fundamentally dependent on the vagaries of weather. Crops are exposed to quite different conditions from those that suit them best, and productivity can be gravely affected. Although changes in some places can be favorable for production, in general climate change brings more risks for farmers, who have to adapt their methods to new conditions. The supply of raw materials for food businesses can be disrupted, and the quality and price adversely affected.

Biodiversity is affected by changing climate and in turn it affects crop health and therefore supply. When biodiversity is compromised species die out or are exposed to new pests. Climate change interlinks issues such as water availability and biodiversity (Schuttelaa et al., 2009).
Agricultural activity is highly sensitive to climate change, largely because it depends on biodiversity and environmental conditions. Sufficient freshwater supplies, fertile soil, the right balance of predators and pollinators, air temperature and average weather conditions all contribute to maintaining agricultural productivity. As agriculture depends directly on environmental conditions, climate change impacts on agriculture are becoming increasingly evident. Changes in rainfall cycles are impacting on agricultural yields as water availability is decreasing in already arid zones and water excesses (floods) are being experienced in other areas. A warmer climate with changes in patterns of drought or increased precipitation, will affect agricultural production in Nigeria and Africa in general. Some agricultural land may no longer be cultivatable, growing seasons will change and productivity will decrease, particularly in Africa. In the middle and high latitudes of the northern, hemisphere, longer growing seasons could have a positive effect on crop yields (where rainfall is not negatively affected).

Climate models suggest that Africa’s climate will generally become more variable, with high levels of uncertainty regarding climate projections in the Africa Sahel zone. Temperatures in West Africa, and particularly the Sahel, have increased more sharply than the global trend, and the average predicted rise in temperature between 1980/99 and 2080/99 is between 3°C and 4°C, which is more than 1.5 times the average global trend.

For Nigeria, a recent study by DFID (2009) predicts a possible sea level rise from 1990 levels to 0.3 m by 2020 and 1m by 2050, and rise in temperature of up to 3.2°C by 2050 under a high climate change scenario. This is based on IPCC climate change assumptions, latest research findings and results of a consultation exercise in Nigeria. The low estimate predictions are for sea level rise of 0.1 m and 0.2 m by 2020 and 2050 respectively, and a temperature increase of 0.4 to 1°C over the same time periods. Sea level rise of 1m could result in loss of 75% of the Niger Delta. Accelerated climatic changes are expected to lead to potentially large impacts across Africa, including Nigeria, in the future. The scale of climate change will increase with high anthropogenic emissions, greenhouse gas (GHG) concentration, and average global temperature. PACJA’s 2009 study predicts that the economic cost of a mean average global temperature of 1.5°C by just after 2040 will result in mean economic cost equivalent to 1.7 per cent of Africa’s GDP. As the mean temperature rises to 2.2°C by 2060, economic cost increase to the equivalent of 3.4 per cent of Africa’s GDP. By 2100, with a mean temperature rise of 4.1°C, the economic costs are equivalent to about 10 per cent of the continent’s GDP. With specific reference to Nigeria, DFID’s (2009) study1 predicts that climate change could result in a loss in GDP of between 6% and 30% by 2050, worth an estimated US$100 to 460 billion dollars. By 2020, if no adaptation is implemented, between 2-11% of Nigeria’s GDP could potentially be lost. Because of the resultant disruption of economic activities, climate change is no longer just an environmental issues but a development issue. It has become a major threat to the sustainable development of Nigeria, like many other developing countries. The challenge now is to keep climate change from reversing all the development gains accumulated in the last few decades.

Sustainable Agriculture and Soil Management

Agricultural productivity depends largely on the topsoil, the uppermost layer, which is about 15 to 20 cm deep for most soils. Topsoil serves many functions. It provides a rooting zone for plants, supplies a balance of plant nutrients, and retains stores and releases moisture for plant use. It also enhances seed germination and root penetration, and supports a complex community of beneficial microorganisms which decompose organic wastes, recycle plant nutrients, and pro-tect plants from pests. All these functions are essential for maintaining the tilth, fertility and productivity of agricultural soils. Soils with these capabilities are considered by many to be "healthy soils" (Parr et al., 1992). Healthy soil, an essential component of a healthy environment, is the foundation upon which sustainable agriculture is built. Soil health, also called soil quality, is defined in agricultural terms as the soil's fitness to support crop growth without becoming degraded or otherwise harming the environment (Acton and Gregorich, 1995).

The Soil Science Society of America (1984) defines soil quality as an inherent attribute of a soil which is inferred from soil characteristics or indirect observations (e.g., compactability, erodibility, and fertility). Thus, soil quality has traditionally focused on, and has been equated with, soil productivity. The soil serves as an environmental filter for removing undesirable solid and gaseous constituents from air and water. Almost all recycling of organic materials, and the retention and release of water and nutrients for plants and soil organisms, occurs in the soil and is enhanced by a bio-logically-active and healthy soil. Although not well understood, soil quality may also play a major role in plant health and in the nutritional quality of the food that is produced. The availability of land and fertile soil is essential for healthy crops and livestock. Fertile soil also promotes biodiversity, efficient use of water and filtering, and avoids run-off of nutrients. It acts as a carbon sink, countering the forces of climate change.

Despite the huge importance of soil in sustainable farming, soil is gradually being lost. Soil degradation is the single most destructive force diminishing the world's soil resource base (Parr et al., 1992). Soil degradation is the most serious crisis facing the agricultural industry in the long term. It has been a major problem for years and will continue to be unless urgent action is taken, sustainable agriculture will be a thing of history because soil is the bedrock of sustainable farming.
Soil quality can decline for many reasons: not just wind and water erosion but also such degradative processes as nutrient losses from runoff and leaching, depletion of soil organic matter, crusting, compaction, and desertification. It can also decline through the accumulation of toxic substances from excessive use of chemical fertilizers and pesticides, and atmospheric deposition or improper waste disposal (Sampson, 1981). Two billion hectares of land worldwide—twice the size of China—are seriously degraded, some irreversibly. Inadequate agricultural practices, such as the improper use of fertilizers and pesticides, lead to soil pollution, salinisation and loss of arable land. Forty percent of all arable land already suffers from some level of degradation. Farmers who work this degraded land face decreasing yields, resulting in lower income. It is therefore vital for them to adopt sustainable land use practices to keep soil healthy. This is also in the interest of companies, as fertile land is essential for securing their supply of raw materials. The maintenance or restoration of soil quality is highly dependent on organic matter and an array of beneficial macro organisms and microorganisms that it supports. The proper and regular addition of organic amendments such as animal manures and crop residues can effectively offset many of these degradative processes. It also is the best way to develop a biologically-active soil that requires less energy for producing crops; increases the resistance of plants to pests and diseases; and enhances the decomposition of toxic substances such as residual pesticides (Allison, 1973).

Table 1. Climate Change Impacts on Agriculture

<table>
<thead>
<tr>
<th>Climate phenomena</th>
<th>Impacts on agriculture</th>
<th>Probability</th>
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</thead>
<tbody>
<tr>
<td>In most terrestrial areas, days and nights will be warmer, less frequently cold and more frequently very warm</td>
<td>Better harvest in cold environments, worse in warm environments; insect pests more frequent</td>
<td>Almost certain</td>
</tr>
<tr>
<td>Most frequent heat waves and warm periods</td>
<td>Impoverishment of the crops in warmer regions due to heat stresses; increased risk of uncontrolled wildfires in currently cold mountain climates, yield increases</td>
<td>Very likely</td>
</tr>
<tr>
<td>More frequent intense precipitation events in most regions</td>
<td>Damage to crops, soil erosion, inability to cultivate the land due to water logging</td>
<td>Very likely</td>
</tr>
<tr>
<td>Increase in areas affected by drought</td>
<td>Lower yields, crop damage and even crop failure; major losses of livestock; increased risk of uncontrolled wildfires</td>
<td>Likely</td>
</tr>
<tr>
<td>Increased intensity of tropical cyclones</td>
<td>Damage to crops, uprooting of trees, damage to coral reefs</td>
<td>Likely</td>
</tr>
</tbody>
</table>

Source: based on IPCC, 2007

The prospect of climate change is not going to diminish soon, therefore a measure must be put in place to either ameliorate the effects of global warming on agriculture or an adaptive measure must be taken to cushion its effects. Policies that mitigate adverse impacts enhance positive impacts, and support adaptation to climate and global change, together with enhancing local food and water security must be developed.

Sustainable Agriculture and Crop Production

The agronomic practice or cropping system employed increases organic matter in the soil, improves soil structure, reduces soil degradation, and can result in higher yields and greater farm profitability in the long-term. Increased levels of soil organic matter enhances water and nutrient retention, and decreases synthetic fertilizer requirements. Better soil structure in turn improves drainage, reduces risks of water-logging during floods, and boosts the supply of soil water during droughts. Crop rotation is used to control weeds and diseases, and limit insect and other pest infestations and as a result significantly reduce pesticide use. Leguminous crops in the rotation fix atmospheric nitrogen and bind it in the soil, increasing fertility and reducing the need for synthetic fertilisers and the use of pesticides. Crop rotation has a number of agronomic, economic and environmental benefits which includes:

Improved soil structure - with higher levels of organic matter and better water provision resulting in higher yields in the long-term.
Enhanced pest and disease control – as producers use fewer inputs to fight pests, and so can decrease both costs and environmental impacts due to the reduction in pesticide use.
Smarter use of nutrients – creates a more balanced nutrient cycle at the field level and helps farmers to use fewer inputs to maintain nutrient availability. This results in lower costs and increased profit margins. For example, using legume crops in the rotation can reduce the need for additional synthetic nitrogen fertiliser, lowering costs for farmers, reducing water pollution from runoff and in some cases providing farmers with an extra income stream.
Nigerian Ecological Zones

Nigeria contains six ecological zones (Figure 3), ranging from a belt of mangrove swamps and tropical forests along the coast to open woodland and savanna on the low plateau which extends though much of the central part of the country, to the semi-arid plains in the north and highlands to the east. The principal food crops are yams, cassava, and maize to the south, and millet, sorghum, and cowpeas in the drier north. Cocoa, rubber, oil palm, groundnuts, and cotton are the main cash crops which are generally destined for export.

Between the arid north and the moist south lies a Guinea Savanna Zone sometimes referred to as the middle belt. This area produces staples such as yams, sorghum, millet, cassava, cowpeas, and corn, with rice an important crop in some places. The middle belt's southern edge represents the lower limits of the northern grain-dominated economy. The most significant commercial crop of the middle belt is sesame (or benniseed).

Rainfall is heaviest in the south, where the rain forests and woodlands benefit from abundant precipitation and relatively short dry seasons. Root crops are the staples in the south, including cassava, yams, cocoyams, and sweet potatoes. The main cash crops in the south are tree crops, which in general are grown on large plantations that include cacao, oil palm, and rubber. However, almost 85 percent of Nigeria’s current palm oil production is from unorganized wild groves. The northern third of Nigeria experiences a dry season of five to seven months, and lies mostly in the Sudan and Sahel Savanna zones. Staples in the north are millet, cowpeas, and a drought-resistant variety of sorghum known as guinea corn. Sorghum is Nigeria’s most widely cultivated grain, accounting for more than 45 percent of the total area. Sorghum cultivation spans from the north to the middle belt where precipitation and soil moisture levels are low. Corn is also cultivated, as well as rice in suitable lowland areas. Wheat is a fadama (lowland) crop, irrigated along broad valley bottoms in the north, especially in the Lake Chad basin. The north’s principal commercial crops are cotton and groundnuts.
Conclusion

Sustainable Agriculture is an integrated system of plant and animal production practices that will satisfy human food and fiber needs, enhance environmental quality, make the most efficient use of, nonrenewable resources, sustain economic viability and enhance quality of life.

It therefore means growing crops and livestocks in ways that meet three objectives simultaneously: Economic Benefit, Social benefit to the Community and Environmental conservation. Agricultural activity is highly sensitive to climate change, largely because it depends on biodiversity and environmental conditions. The prospect of climate change is not going to diminish soon, therefore a measure must be put in place to either ameliorate the effects of global warming on agriculture or an adaptive measure must be taken to cushion its effects.

Agricultural productivity also depends largely on the topsoil, the uppermost layer, which is about 15 to 20 cm deep for most soils. Healthy soil, an essential component of a healthy environment, is the foundation upon which sustainable agriculture is built. The health of the agricultural industry depends on both the quantity and the health of the soil. Therefore the soil must be properly managed to enhance sustainable agriculture.

The agronomic practice or cropping system employed increases organic matter in the soil, improves soil structure, reduces soil degradation, and can result in higher yields and greater farm profitability in the long-term.

All these must be employed in the six ecological zones of Nigeria, ranging from a belt of mangrove swamps and tropical forests along the coast to open woodland and savanna on the low plateau which extends though much of the central part of the country, to the semi-arid plains in the north and highlands to the east to meet the three objectives of sustainable agriculture which are Economic Benefit, Social benefit to the Community and Environmental conservation.
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