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Review of ecological perspectives on climate change in Nigeria

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Abstract
A review has been carried out on the ecological perspectives on climate change in Nigeria. The country is one of the leading producers of crude oil and a major contributor of greenhouse gases that cause climate change. The current and future consequences of climate change have been discussed with local examples of ecological effects. Efforts to control climate change are highlighted at local and global scales since the effects are not restricted within national boundaries. It is recommended that greenhouse gas emissions should be reduced through efficient energy use, diversification of energy sources away from fossil fuels and safe agricultural practises.

1. Introduction

The Intergovernmental Panel on Climate Change, IPCC (2007) defines climate change as a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and /or the variability of its properties, and that persists for an extended period typically decades or longer. Although the length of time it takes the changes to manifest matters, the level of deviation from the normal and its effects on the ecology are most paramount. This prompted Ayoade (2003) to state that secular variations in climate occurring over a period of 100 to 150 years may not qualify as a climate change if conditions will quickly reverse later, but a change in climate usually takes place over a long period of time of at least 150 years with clear and permanent effects on the ecosystem. Climate change is different from the generally known terms like climatic fluctuations or climatic variability. These terms denote inherent dynamic nature of climate on various temporal scales. Such temporal scale variations could be monthly, seasonal, annual, decadal, periodic, quasi-periodic or non-periodic.

There is a growing consensus in the scientific literature that in the coming decades the world will witness higher temperatures and changing precipitation levels. The effects of this will lead to low/poor agricultural products. Evidence has shown that climate change is already affecting crop yields in many countries (IPCC, 2007; Deressa *et al*, 2008; BNRCC, 2008). This is particularly true in low-income countries, where climate is the primary determinant of agricultural productivity and adaptive capacities are low (SPORE, 2008; Apata *et a*l, 2009). Many African countries, which have their economies largely based on weather-sensitive agricultural productions systems like Nigeria, are particularly vulnerable to climate change (Dinar *et al*, 2006). This vulnerability has been demonstrated by the devastating effects of recent flooding in the Niger Delta region of the country and the various prolonged droughts that are currently witnessed in some parts of Northern region. Thus, for many poor countries like Nigeria that are highly vulnerable to effects of climate change, understanding farmers' responses to climatic variation is crucial, as this will help in designing appropriate coping strategies.

Evidence from literature and past studies has revealed that the recent global warming has influenced agricultural productivity leading to declining food production (Kurukulasuriya and Mendelssohn, 2006; IISD, 2007; Lobell *et al*, 2008). In order to meet the increasing food and non-food needs due to population increase, man now rapidly depleting fertile soils, fossil groundwater, biodiversity, and numerous other non-renewable resources to meet his needs (Abrahamson, 1989; Ehrlich & Ehrlich, 1990). This resource depletion was linked with other human pressures on the environment. Possibly the most serious of human effect is the injection of greenhouse gases into the atmosphere. The reality of the impact of climate change on agricultural development has started showing signs (Adams *et al*, 1988; Fischer *et al*, 2002; Spore, 2008). A substantial body of research has documented these wide-ranging effects on many facets of human societies (Wolfe *et al*, 2005; ODI, 2007; Apata *et al*, 2009.).

Rough estimates suggest that over the next 50 years or so, climate change may likely have a serious threat to meeting global food needs than other constraints on agricultural systems (IPCC, 2007; BNRCC, 2008). Specifically, population, income, and economic growth could all affect the severity of climate change effects in terms of food security, hunger, and nutritional adequacy. If climate change adversely affects agriculture, effects on human are likely to be more severe in a poorer world. Wolfe *et al* (2005); Stige, (2006), and Orindi *et al*, (2006) worry that rising demand for food over the next century, due to population and real income growth, will lead to increasing global food scarcity, and a worsening of hunger and malnutrition problems particularly in developing countries.

Climate change is caused by two basic factors, which include natural processes (bio-geographical) and human activities (anthropogenic).

The natural processes are the astronomical and the extraterrestrial factors. The astronomical factors include the changes in the eccentricity of the earth's orbit, changes in the obliquity of the plane of ecliptic and changes in orbital procession while the extra-terrestrial factors are solar radiation quantity and quality, methane from decay of natural vegetation and volcanic eruptions among others.

On the other hand, the anthropogenic factor in climate change involves human activities such as fossil fuel combustion, wood burning, rice cultivation in paddies, livestock farming, manufacture and use of chlorofluorocarbons (CFCs) as aerosol propellants, fire hydrants, foaming agents and eat transfer media in refrigerators and air conditioning systems. They either emit large amount of greenhouse gases into the atmosphere that depletes the ozone layer or activities that reduce the amount of carbons absorbed from the atmosphere. The human factors that emit large amounts of greenhouse gases include industrialization, burning of fossil fuel, gas flaring, urbanization and agriculture. On the other hand, human activities that reduce the amount of carbon sinks are deforestation, alterations in land use, water pollution and agricultural practices.

The human factors have been proven to be responsible for the ongoing unequivocal climate change or global warming (IPCC 2007). The emitted greenhouse gases are carbon dioxide (CO_2), chlorofluorocarbons (CFCs), Methane (CH_4) and nitrous oxide (N_20) among others. CO_2 currently contributes the highest rate of the greenhouse gases followed by CH_4, CFCs N_2O and others (like halons, tropospheric ozone, sulphuric hexafluoride (SF6) among others). Although CO_2 has the highest contribution to greenhouse gases, its potency is far lower. For instance, a gram of CH_4 is about 23 times higher than the effects of the same volume of CO_2 and a gram of sulphuric hexafluoride (SF_6) released into the atmosphere is about 22,000 times that of CO_2 with respect to tropospheric zone depletion. The life time of CO_2 in the atmosphere varies, but obviously less than ten years, while that of CH_4, N_2O, CFCs and SF_6 are 12.2, 120, 50-1700 and 3200 years respectively (Smith 1994; Msumba 2006).

Although the potency of CO_2 released into the atmosphere through human activities may be significantly lower than many other greenhouse gases, the much greater volume of its emissions still makes it the most important influence in humans' enhancement of the natural greenhouse effect.

2. The Current and Future Consequences of Global Climate Change

Global climate change has already had observable effects on the human environment. Glaciers have shrunk, ice on rivers and lakes is breaking up earlier, plant and animal ranges have shifted and trees are flowering sooner. Effects that scientists had predicted in the past would result from global climate change are now occurring: loss of sea ice, accelerated sea level rise and longer, more intense heat waves.

Scientists have high confidence that global temperatures will continue to rise for decades to come, largely due to greenhouse gasses produced by human activities. The Intergovernmental Panel on Climate Change (IPCC), which includes more than 1,300 scientists from the United States and other countries, forecasts a temperature rise of 2.5 to 10 degrees Fahrenheit over the next century. According to the IPCC, the extent of climate change effects on individual regions will vary over time and with the ability of different societal and environmental systems to mitigate or adapt to change. The IPCC predicts that increases in global mean temperature of less than 1.8 to 5.4 degrees Fahrenheit (1 to 3 degrees Celsius) above 1990 levels will produce beneficial effects in some regions and harmful ones in others. Net annual costs will increase over time as global temperatures increase. The Earth's average temperature has increased about 1 degree Fahrenheit during the 20th century. One degree may sound like a small amount, but it's an unusual event in our planet's recent history. Earth's climate record, preserved in tree rings, ice cores, and coral reefs, shows that the global average temperature is stable over long periods of time. Furthermore, small changes in temperature correspond to enormous changes in the environment.

Some of the regional effects of global change forecast by the IPCC include:

North America: Decreasing snowpack in the western mountains; 5-20 percent increase in yields of rain-fed agriculture in some regions; increased frequency, intensity and duration of heat waves in cities that currently experience them.

Latin America: Gradual replacement of tropical forest by savannah in eastern Amazonia; risk of significant biodiversity loss through species extinction in many tropical areas; significant changes in water availability for human consumption, agriculture and energy generation.

Europe: Increased risk of inland flash floods; more frequent coastal flooding and increased erosion from storms and sea level rise; glacial retreat in mountainous areas; reduced snow cover and winter tourism; extensive species losses; reductions of crop productivity in southern Europe.

Africa: By 2020, between 75 and 250 million people are projected to be exposed to increased water stress; yields from rain-fed agriculture could be reduced by up to 50 percent in some regions by 2020; agricultural production, including access to food, may be severely compromised.

Asia: Freshwater availability projected to decrease in Central, South, East and Southeast Asia by the 2050s; coastal areas will be at risk due to increased flooding; death rate from disease associated with floods and droughts expected to rise in some regions.

Table showing projected effects of global climate change is shown in table 1.

Table 1. *Global Climate Change: Recent Effects*

Phenomena	Likelihood that trend occurred in late 20th century
Cold days, cold nights and frost less frequent over land areas	Very likely
More frequent hot days and nights	Very likely
Heat waves more frequent over most land areas	Likely
Increased incidence of extreme high sea level *	Likely
Global area affected by drought has increased (since 1970s)	Likely in some regions
Increase in intense tropical cyclone activity in North Atlantic (since 1970)	Likely in some regions

Climate is an important environmental influence on ecosystems. Climate change affects the ecosystem in a variety of ways. For instance, warming could force species to migrate to higher latitudes or higher elevations where temperatures are more conducive to their survival. Similarly, as sea level rises, saltwater intrusion into a freshwater system may force some key species to relocate or die, thus removing predators or prey that were critical in the existing food chain.

Climate change not only affects ecosystems and species directly, it also interacts with other human stressors such as development. Although some stressors cause only minor effects when acting alone, their cumulative impact may lead to dramatic ecological changes. For instance, climate change may exacerbate the stress that land development places on fragile coastal areas. Additionally, recently logged forested areas may become vulnerable to erosion if climate change leads to increases in heavy rain storms.

2.1. Global Warming and Population Change

It may seem that there has been a recent interest in associating climate change and global warming with “over population” and that by implication; countries such as China and India have to do more to help contain global warming. It is believed that rich countries have a lot to do themselves because there were agreed upon reasons why developing countries were exempted from initial greenhouse gas emission targets because it was the emissions from rich countries that accumulated in the atmosphere for so long to trigger climate change.

3. Climate Change in Nigeria

The temperature trend in Nigerian since 1901 shows an ever increasing pattern. The increase was gradual until the late 1960s and this later gave way to a sharp rise in air temperatures from the early 1970s, which continued till date. The mean air temperature in Nigeria between 1901 and 2005 was 26.6^{O}C while the temperature increase for the 105 years was 1.1^{O}C. This is obviously higher than the global mean temperature increase of 0.74 OC recorded since 1860 when actual scientific temperature measurement started (Spore 2008; IPCC 2007). Should this trend continue unabated, Nigeria may experience between the middle (2.5^{o}C) and high (4.5^{o}C) risk temperature increase by the year 2100.

Rainfall trend in Nigeria between 1901 and 2005 shows a general decline (Fig 3). Within the 105 years, rainfall amount in Nigeria dropped by 81mm. The declining rainfall became worst from the early 1970s, and the pattern has continued till date.

This period of drastic rainfall decline corresponds with the period of sharp temperature rise (Fig 2). Although there is a general decrease in rainfall in Nigeria, the coastal areas of Nigeria like Warri, Brass and Calabar are observed to be experiencing slightly increasing rainfall in recent times (Odjugo 2005, 2007). This is a clear evidence of climate change because a notable impact of climate change is, increasing rainfall in most coastal areas and decreasing rains in the continental interiors (IPCC 1996; NEST 2003). Odjugo (2005, 2007) observe that the number of rain days dropped by 53% in the north-eastern Nigeria and 14% in the Niger-Delta Coastal areas. These studies also showed that while the areas experiencing double rainfall maximal is shifting southward, the short dry season (August Break) is being experienced more in July as against its normal occurrence in the month of August prior to the 1970s. These are major disruptions in climatic patterns of Nigeria showing evidences of a changing climate.

3.1. Ecological Implications of Climate Change

Increasing temperature (global warming) and decreasing precipitation in most parts of the world are the greatest effects of climate change. These bring about either negative or positive ecological effects in different parts of the world. The increasing temperature has led to increased land based ice instability and its melting. The thawing of the Arctic, cool and cold temperate ice, the increasing rainfall in some parts of the world and expansion of the oceans as water warms has started impacting on sea level rise, coastal inundation and erosion. The current global estimate of sea level rise is 0.2 m and it is projected to increase to 1 m by the year 2100 (Hengeveld *et al*. 2002; 2005). The implication is that the present 0.2 m sea level rise has inundated 3,400 km^2 of the coastal region of Nigeria, and if the sea level rise attains the projected 1m on or before 2100 then 18,400 km^2 of the coastal region may be inundated (NEST 2003). Coastal settlements like Bonny, Forcados, Lagos, Port Harcourt, Warri and Calabar among others that are less than 10 m above the sea-level would be seriously threatened by a metre rise of sea-level. The sea incursion due to sea-level rise means salt-water intrusion into the fresh water, invasion and destruction of mangrove ecosystems, coastal wetlands and coastal beaches. The worst impact is population displacement, which may result in communal crisis. The coastal inundation and erosion with their associated population displacement are currently major environmental problems in Nembe, Eket and other coastal settlements in Bayelsa, Delta, Cross River, Rivers, and Lagos States of Nigeria.

It is estimated that a metre rise in sea level will displace about 14 million people from the coastal areas of Nigeria (Abu 2007). Young (2006) also observes that sea-level rise up to a metre will displace 10, 13 and 72 million people in the coastal areas of Egypt, Bangladesh and China respectively. The increasing temperature and decreasing rainfall have led to frequent drought and desertification. The Sahara desert is observed to be expanding to all directions trying to engulf the Sahellian region of Africa with annual expansion of 1-10 km (Odjugo and Ikhuoria 2003; Yaqub 2007). Odjugo and Ikhuoria (2003) also observe that Nigeria north of 12oN is under severe threat of desert encroachment and sand dunes are now common features of desertification in states like Yobe, Borno, Sokoto, Jigawa and Katsina. The migrating sand dunes have buried large expanse of arable lands, thus reducing viable agricultural lands and crops' production. This has prompted massive emigration and resettlement of people to areas less threatened by desertification. Such emigration gives rise to social effects like loss of dignity and social values. It often results in increasing spate of communal clashes among herdsmen and farmers and such clashes resulted in the death of 186 people in six northern states of Nigeria between 1998 and 2006 (Yugunda 2002; Yaqub 2007). Akonga (2001) also shows that most of the destitute that emigrated as a result of drought and desertification usually move to nearby urban areas to beg for alms thereby compounding the already tense urbanization problems. Climate change will alter all aspects of the hydrological cycle ranging from evaporation through precipitation, run off and discharge (Mcguire et al. 2002). The global warming and decreasing rainfall together with the erratic pattern of rainfall produce a minimal recharge of groundwater resources, wells, lakes and rivers in most parts of the world especially in Africa thereby creating water crisis. In Nigeria, many rivers have been reported to have dried up or are becoming more seasonally navigable while Lake Chad shrunk in area from 22,902 km2 in 1963 to a mere 1304 km2 in 2000. This shows that what is left of Lake Chad in the year 2000 is just 5.7% of 1963 (Odjugo 2007). Awake (2009) also confirms the fact that Lake Chad has shrunk by 95% since the 1960s and Aral Sea in Central Asia was the fourth largest lake in the planet in 1960, but by 2007 it had shrunk to 10% of its original size. Lake Chad and so many rivers in Nigeria, especially in Northern Nigeria, are in the danger of disappearing.

The water scarcity will create the tendency for concentration of users around the remaining limited sources of water. Under such circumstances, there is increased possibility of additional contamination of the limited sources of water and transmission of water borne diseases like cholera, typhoid fever, guinea worm infection and river blindness. Odjugo (2000) and DeWeerdt (2007) note that the increasing temperature will mean northward migration of mosquitoes and malaria fever which will extend from the tropical region to warm temperate region while the sporogony of the protozoa causing the malaria accelerates from 25 days at $10^{O}C$ to 8 days at $32^{O}C$. This paper also conceptualizes the relationship between climate change and human health (Fig 4). As shown in figure 4, the excessive heat, increasing water stress, air pollution and suppressed immune system occasioned by climate change will result in increasing incidence of excessive death due to heat exhaustion, famine, water related diseases (diarrhoea, cholera and skin diseases), inflammatory and respiratory diseases (cough, and asthma), depression, skin cancer and cataract. One of the greatest effects of climate change is the worsening condition of extreme weather events like drought, flood, rainstorms, windstorms, thunderstorms, landslides, avalanches and tsunamis, among others (Odjugo 1999, 2001b; Changnon 2001). Odjugo (2008) notes that the frequency and magnitude of wind and rainstorms did not only increase, they also killed 199 people and destroyed property worth ₦85.03 billion in Nigeria between 1992 and 2007. Buadi and Ahmed (2006) had similar result when they reported that rainstorms claimed 42 lives in southern Cameroon between 2000 and 2005. Between 1950 and 2000, the increasing frequency and intensity of rainstorms have created enormous damages estimated at $87 billion in property losses, $19 billion in crop losses and losses of over 12,000 human lives in the United States of America alone (Changnon 2001).

Climate change has started to, and will continue to impact negatively on agriculture and food security especially in tropical and subtropical regions because greenhouse gas emissions would increase the risk of hunger by additional 80 million people by 2080 in Africa and southern Asia (Odjugo 2001a; DFID 2006; Nwafor 2006, 2007; DeWeerdt 2007). Odjugo (2008) shows that climate change has led to a shift in crops cultivated in northern Nigeria. The paper (Odjugo 2008) quoting Ahmed (1978) reveals that as at 1978, the preferred crops the farmers cultivated were guinea corn followed by groundnut and maize, but due to increasing temperature and decreasing rainfall amount and duration occasioned by climate change, the farmers as a means of adaptation in 2007 shifted to the production of millet followed by maize and beans. Another major problem to agriculture in Nigeria due to climate change is the reduction of arable lands. While the sea incursion is reducing the arable land of the coastal plains, the desert encroachment with its associated sand dunes is depriving farmers of their agricultural farmlands and grazing rangelands. Moreover, the frequent droughts and lesser rains have started shortening the growing season thereby causing crops failure and food shortage. It has been shown that drought, desert encroachment and coastal inundation have started affecting the country's ecosystem leading to ecological destabilization due to climate change impact in the semi-arid region of Northern Nigeria (Odjugo and Ikhuoria2003; Ayuba et al. 2007). Planning Implications Singer and Avery (2007) show that it is impossible for man to stop the natural causes of climate change but much can be achieved in either to stop or drastically reduce the human causes of climate change. If human activities that deplete the ozone layer are to a very large extent reduced and the carbon sinks are well-managed and protected, then the on-going global warming will seriously decline.

To reduce the emission of greenhouse gases, clean and environment friendly technologies are needed. Industrial productions should convert to machines that emit limited or no greenhouse gases. Automobiles and industrial machines should be improved upon to use only ethanol, solar engines, electric engines or hybrid electric engines. Gas flaring especially in the Niger Delta region of Nigeria should be reduced to the barest minimum. Nigeria should encourage the use of renewable energy sources such as photovoltaic cells in a small scale. Moreover the use of fuel cells that convert hydrogen fuel directly into electricity without first burning it to produce heat should be encouraged. Policy-makers should encourage energy efficiency and other climate-friendly trends in both the supply and consumption of energy. Efficiency can also be improved upon by providing appropriate economic and regulatory framework for consumers and investors.

A "Clean Development Mechanisms" is needed from the developed countries. This will enable the developed nations to finance emission-avoiding projects in developing countries. Promoting such clean technologies will bring credit to the industrialized nations rather than transferring non-environment friendly technologies to developing world like Nigeria. The protection, sustainable management and enhancement of terrestrial and marine ecosystems, which act as carbon sinks and reservoirs to greenhouse gases are also very important. This means deforestation should be reduced to the barest minimum and afforestation highly encouraged. Protection of the forest requires improved agricultural practices through the use of fertilizer rather than the current dependence on the natural fertility of the forest soils as mostly practised in Nigeria. The widespread use of low-cost solar energy cookers instead of wood burning devices will also limit the current pressure on the Nigeria forest for firewood. Moreover, bush burning either for hunting, farm clearing or by herdsmen to facilitate the sprouting of fresh grasses for their animals to graze on should be stopped. Oil spillage in the creeks and coastal areas of Nigeria should be guarded against in order to enhance carbon sink in the coastal waters. Changes are needed in building and furniture materials in Nigeria. Roofing materials, doors and furniture in most buildings, in Nigeria, are made of wood. Odjugo and Ikhuoria (2003) noted that average of 320 sticks was used to support the decking of a three-bed-room flat building, plus the plywood used for the floor of the decking. They also stated that these supporting sticks and plywood are hardly used twice since they are sold as fuel wood immediately they are removed as support. One could therefore appreciate the number of trees destroyed annually with the current vertical growth of Nigerian cities. The deforestation processes can be reversed if iron and steel and aluminium are used for construction of our buildings and household furniture. Ultra-violet rays due to ozone layer depletion result in increasing occurrence of skin cancer and cataracts. To reduce the effects of skin cancer and eye cataracts, appropriate clothing that covers most part of the body should be worn, especially by albinos and those fair-skinned and to be accompanied by hat and sunshade glasses while under the sun. It is therefore advisable that those with black skins should avoid toning their skins because such act will make them highly susceptible to skin cancer.

For the developing nations like Nigeria to survive the effects of climate change, serious adaptation measures are needed. There is the need to establish better-equipped weather stations as against the scanty and ill-equipped ones we currently have in Nigeria. With these, accurate weather forecast and predictions will be possible and this will help to prevent weather-related disasters through early warning and effective response system.

Previous studies reveal increasing temperature and decreasing rainfall amount and duration in Nigeria between 1901 and 2005. Temperature increase of 1.1^{O}C was observed in Nigeria for the 105 years while rainfall amount dropped by 81mm. While rainfall amount is generally decreasing in Nigeria, the coastal region of the country has been experiencing slightly increasing rainfall since the early 1970s. The short-dry-season popularly known as August break is currently being experienced more in the month of July as against August. Sea-level rise is observed to have inundated 3400km2 of Nigeria coastal region while desert encroachment is reducing arable lands from the northern part of the country by 1-10km a year. A shift in crops cultivated by farmers from long to short duration is also noticed. While the choice crops produced by 1978 were guinea corn, groundnut and maize, they were millet, maize and bean by 2007. Surface water bodies were also observed to be drying up, for example, Lake Chad is currently 5.7% of its size in 1960. Wind and rainstorms were observed to kill 199 people and destroyed property worth N85.03 billion in Nigeria between 1997 and 2007. While the activities of the developed nations are mostly responsible for the changing climate, the developing nations are those suffering more of the effects due to inability to cope as a result of poverty and low technological development.

If the developed world can immediately implement deep emission cuts and reduce their rate of water pollution while the developing countries practice clean technology and reduce their rate of deforestation and enhance their afforestation programmes, then the rate of carbon sinks will be improved and ozone layer depletion will decline. With cleaner atmosphere which will lead to self sustaining ozone layer rebuilding, the current rate of global warming will be drastically reduced and its effects on humans and the ecosystem will with time be a thing of the past.

4. Quantification of Major Indicators of Climate Change on Agriculture

Past studies have used a variety of approaches to capture climate change effects on agriculture (Parry *et al*, 2009; Wang *et al*, 2009; Deressa and Hassan, 2010). These approaches range from simply equating average future effects to yield losses observed in historical droughts to more quantitative crop simulation modelling, statistical time series and cross-sectional analyses. To date, simulation studies have been limited by a lack of reliable data on soil properties and management practices, and have provided only `best-guess' estimates with little to no information on uncertainties that result from choices in model structure, parameter values and scaling techniques (Frost and Thompson, 2000; Fischer *et al* 2002). In addition past studies have observed that statistical analyses have been limited by the poor quantity and quality of historical agricultural data relative to other regions, resulting in model estimates with wide confidence intervals (Naylor *et al,* 2007; Wang *et al*, 2009). Besides, studies have shown that Statistical and econometric techniques can be employed to establish a logical association between climate variation and change (Tebaldi and Knutti, 2007; Niggol and Mendelsohn, 2008).

A substantial amount of research has been conducted on the potential effects of climate change on agricultural productivity (Parry *et al.* 1999; Lobell and Burke, 2008 and Deressa and Hassan, 2010). Attempts are made in these studies to link the state-of-the-art models developed by researchers in separate disciplines, including climatology, agronomy and economics, in order to project future impact of climate change on agriculture and implication for population growth. Some of these studies include Kane et al. 1992; Rosenzweig et al. 1993; Rosenzweig and Parry 1994; Reilly *et al.* 1996 and Ayinde *et al,* 2010, that used climate induced changes in crop yields to estimate potential global economic effects. Others have examined the indirect impact on economic variables such as farm revenue and income, e.g. Mendelsohn *et al.* (1994) and Adams et al (1998). The review of these studies helped to have an understanding of the physical and economic responses, and adjustments on climate change and agricultural production. However, in line with adaptation scenario of how farmers are coping or surviving under this climate variability, these studies assumed that farmers could adapt to climate change by changing crop varieties and timing of planting and harvesting, while in the without adaptation scenario it is assumed that farmers do not make any adjustments over time.

The conversion of land to agricultural use and exploitation of diverse other natural resources has generally increased the capacity of Earth to support human beings. In recent decades, however, the human enterprise has grown so large that it is seriously altering the global environment (Holdren & Ehrlich 1974; FAO, UNFPA and IIASA 1982; Kane et al, 1992; Fischer et al, 2002 and Wang *et al*, 2009). Humanity is now rapidly depleting fertile soils, fossil groundwater, biodiversity, and numerous other non-renewable resources, to support its growing population (Ehrlich & Ehrlich 1990; Adams *et al.* 1998). This resource depletion, coupled with other human pressures on the environment (e.g., production of toxic wastes, changing the composition of the atmosphere) is undermining the capacity of the planet to support virtually all forms of life (Ehrlich *et al.* 1989).

The magnitude and pace of change that climatologists believe probable are unprecedented in human history (Abrahamson 1989; Cairns & Zweifel 1989; Lashof 1989; NAS 1987; Schneider 1989). Should such change occur, there will inevitably be wide-ranging effects on many facets of human societies. Current patterns and future plans of energy use and industrialization will require major revision (Rosenzweig, 1994, Reilly, 1996 and Mendelsohn *et al.* 1994). International tensions are likely to heighten over claims on freshwater where scarce supplies are further reduced (Fischer, et al, 2002; Lobell and Burke, 2008 and Ayinde *et al*, 2010), transnational migration of environmental refugees (Jacobson 1988), and ultimate responsibility for global warming and its effects (Adams *et al*, 1998).

The global production and distribution of food is inadequate for a large fraction of the rapidly expanding global population of 5.8 billion people under present and foreseeable economic systems (WRI 1987; Brown 1988; Brown & Young 1990; Ehrlich & Ehrlich 1990). The agricultural and food-distribution systems may be further stressed by shifting of temperature and precipitation belts, especially if changes are rapid and not planned for (see, for example, Adams *et al.* (1990). In this paper investigation of the possible positive or negative effects of climate change on Nigerian food security was carried out by using a computer model and Statistical software packages of LIMDEP 6.0. Focus was on grain because it supplies over half of the calories in the average diet (of developing country nationals) and accounts for the vast majority of the international trade in food (WRI, 1989). The model adopted in the study was a simple, aggregate representation of agricultural systems and human populations that have been used by Daily & Ehrlich 1990.

Recently, international tensions and concerns are heightening over what the impact of climate will have on the environment and agricultural produce (NEST, 2004; BNRCC, 2008; Apata, *et al* 2009). Also, how agricultural and food-distribution systems will be further stressed up by the shifting of temperatures and precipitating belts, especially if changes are rapid and not planned for (NEST, 2004). The crucial issue in this review is whether agricultural output supply can keep pace with population increase under this climate variability. This will depend; both on the scope for raising agricultural productivity (including reducing waste during distribution), availability of inputs used in the agricultural sector (land, labour, machinery, water resources, fertilizers, etc.) and having sufficient information on climatic variables for possible effective adaptation and mitigation strategies.

Consequently, attempt is being made in this review to critically examine the effects of climate change on food demand and production as well as population increase in Nigeria. Past studies that have examined the impact of climate change on food production at the country, regional, or global scale (such as: Pearce *et al*. 1996; McCarthy *et al*. 2001; Parry *et al*. 2004; Nkomo *et al*, 2006; Stern 2007; Deressa, *et al*, 2008; BNRCC, 2008; Apata *et al*, 2009), have failed to provide critical insights in terms of effective and future adaptation strategies, although insights from these studies created the background for the present review. The U.S. Department of Agriculture (USDA) released two comprehensive reports that synthesize the scientific literature on climate change effects and adaptation strategies for U.S. agriculture and forests. The effects of climate change will be profound and far-reaching, according to the two reports, which drew on more than 1,000 peer-reviewed studies carried out by scientists in federal service, universities, non-governmental organizations, industry, tribal lands and the private sector. Providing a comprehensive view of the anticipated effects of ongoing climate change on U.S. farms, forests, grasslands, and rural communities over the course of the 21st century, the two reports are to be incorporated in the U.S. Global Change Research Program's 2013 National Climate Assessment, a bi-annual report to the President and Congress mandated by passage of the Global Change Research Act of 1990.

Rising levels of atmospheric carbon dioxide and temperatures along with changing patterns of precipitation will affect agricultural productivity, according to *Climate Change* and *Agriculture in the United States: Effects and Adaptation*. Though the effects on the whole will be mixed, ongoing changes are in general expected to have "detrimental effects on most crops and livestock" by the middle of the century and beyond.

Crop production may shift along with changing temperature and precipitation patterns, but that doesn't lessen the likely disruption to lives, livelihoods and communities in agricultural, forest and other areas where local economies across the country depend on natural resources, or to residents of urban areas ultimately dependent on the water, food, fiber and materials ecosystems provide. For example, the annual cost of weed control in the U.S. total more than $11 billion, according to the report. That's expected to increase with rising temperatures and carbon dioxide concentrations, which will add to rising food costs.

Similarly, rising temperatures and changing precipitation patterns will also have effects on livestock production. "Heat stress for any specific type of livestock can damage performance, production, and fertility, limiting the production of meat, milk, or eggs. Changes in forage type and nutrient content will likely influence grazing needs. Insect and disease prevalence are expected to increase under warmer and more humid conditions, diminishing animal health and productivity," the report authors note.

4.1. Global Climate Change, Forests, Adaptation and Resilience

Climate change is likewise likely expected to have significant effects on U.S. forests this century. According to *Effects of Climate Variability and Change on Forest Ecosystems: A Comprehensive Science Synthesis for the U.S. Forest Sector*, "wildfires, insect infestations, pulses of erosion and flooding, and drought-induced tree mortality are all expected to increase." More specifically, the area burned by wildfires is expected to at least double over the next 25 years. Insect infestations are expected to affect yet more land per year than fires.

Flowing through the social-ecological system of the U.S., the direct and indirect effects "are likely to cause losses of ecosystem services in some areas, but may also improve and expand ecosystem services in others." Areas where current infrastructure and resource production are based on historical climate and steady-state conditions, which seems likely to be the case in most, if not all, areas, are likely to be most vulnerable. While detailing the substantial threats anticipated as a result of climate change, the two reports also highlight the need and offer recommendations for developing and enacting proactive, inclusive climate change adaptation strategies that imbue communities and ecosystems with greater resiliency. The ability of communities with resource-based economies to adapt to climate change is linked to their direct exposure to these changes, as well as to the social and institutional structures present in each environment. Human communities that have diverse economies and are resilient to change today will also be prepared for future climatic stresses. Although uncertainty exists about the magnitude and timing of climate-change effects on forest ecosystems, sufficient scientific information is available to begin taking action now. Building on practices compatible with adapting to climate change provides a good starting point for land managers who may want to begin the adaptation process. Establishing a foundation for managing forest ecosystems in the context of climate change as soon as possible will ensure that a broad range of options will be available for managing forest resources sustainably.

5. Efforts to Control Global Warming and Climate Change

Responding to the challenge of controlling global warming will require fundamental changes in energy production, transportation, industry, government policies, and development strategies around the world. These changes take time. The challenge today is managing the effects that cannot be avoided while taking steps to prevent the more severe ones in the future. Reducing emissions of greenhouse gases, also called greenhouse gas mitigation, is a necessary strategy for controlling global warming. There are two major approaches to slowing the buildup of greenhouse gases. One is to reduce the consumption of fossil fuels, thereby reducing greenhouse gas emissions. The other is to keep carbon dioxide out of the atmosphere by storing the gas or its carbon component somewhere else, a strategy known as carbon sequestration or carbon capture.

5.1. Carbon Capture

One way to keep carbon dioxide emissions from low and sustainable is to preserve and plant more trees. Trees, especially young and fast-growing ones, take up a great deal of carbon dioxide from the atmosphere and store carbon atoms in new wood. Worldwide, forests are being cleared at an alarming rate, particularly in the tropics. In many areas, there is little regrowth as land loses fertility or is changed to other uses, such as farming or housing developments. In addition, when trees are burned to clear land, they release stored carbon back into the atmosphere as carbon dioxide. Slowing the rate of deforestation and planting new trees can help counteract the buildup of greenhouse gases.

Carbon dioxide gas can also be captured directly. Carbon dioxide has traditionally been injected into depleted oil wells to force more oil out of the ground or seafloor. The same process can be used to store carbon dioxide released by a power plant, factory, or any large stationary source. For example, since 1996 this process has been used at a natural gas drilling platform off the coast of Norway. Carbon dioxide brought to the surface with the natural gas is captured, compressed, and then injected into an aquifer deep below the seabed from which it cannot escape. In most cases, the process of carbon capture would also involve transporting the gas in compressed form to suitable locations for underground storage. Deep ocean waters could also absorb a great deal of carbon dioxide, although the environmental effects may be harmful to ocean life. The feasibility and environmental effects of these options are under review by international teams.

5.2. Energy Sources

The total worldwide magnitude of consumption of fossil fuels is increasing by several percent per year. However, energy use around the world is slowly shifting away from fuels that release a great deal of carbon dioxide towards fuels that release comparatively less of this heat-trapping gas.

Wood was the first major source of energy used by humans. With the advent of the Industrial Revolution in the mid-1700s, coal became the dominant energy source. By the mid-1800s oil had replaced coal in dominance, fueling the internal combustion engines that were eventually used in automobiles. By the 1900s, natural gas began to be used worldwide for heating and lighting. In this progression, combustion of natural gas releases less carbon dioxide than oil, which in turn releases less of the gas than do either coal or wood. However, a reversal of this trend may be seen as reserves of oil are used up. Other fuel sources such as tar sands (also known as oil sands) are beginning to be utilized. Producing oil from tar sands involves extraction and refining processes that release carbon dioxide. In addition, the relative abundance of coal reserves in countries such as

China and the United States may lead to a new upswing in the use of coal for generating electricity. Newer technologies for cleaner coal-burning power plants may help offset the effects.

Significant reductions in carbon dioxide emissions can only be achieved by switching away from fossil-fuel energy sources. Nuclear power plants release no carbon dioxide at all, but nuclear energy is controversial for reasons of safety, security, and the high costs of nuclear waste disposal. Solar power, wind power, and hydrogen fuel cells also emit no greenhouse gases. These energy sources can be practical, low-pollution alternatives to fossil fuels. The hybrid electric vehicle (HEV), which uses both an electric motor and a gasoline or diesel engine, emits less carbon dioxide than conventional automobiles (e.g. Electric Car).

Other alternatives include biofuels e.g. made from plants, such as biodiesel (made from used and new vegetable oil) and ethanol (a plant-based gasoline additive). Use of these fuels can help reduce total carbon dioxide emissions from automobiles. However, the use of biofuels as brought up the challenge mitigating the effects of land use such as clearing of large expanse of forests and natural reserves by farmers in order to cultivate crops that would be used for producing ethanol. By and large, these biofuels have been implicated that as a major contributor of the greenhouse gases. So where do we go? According to Meyer *et al* (2010), recent research indicated that the production of biofuels from food crops such as corn, soya beans, etc can indirectly increase heat-trapping emissions because a higher global commodity prices with increasing demand would induce or motivate farmers to clear forests in order to expand crop production (Farione *et al.* in Meyer et al (2010). The way out perhaps is the use of environmental scientists as effective advocates in a cross disciplinary approach to convince policy makers to adopt:

i. Low carbon fuel standards measurable on a life-cycle basis tat determines, through samples, from production to the tailpipe of the auto-engine, facility or end-user.
ii. Possibly include indirect land-use emissions and adopt viable approaches of estimate the green house gases emitted.

5.3. International Agreements

Mutual international cooperation is required for the successful reduction of greenhouse gases. The first international conference addressing the issue was held in 1992 in Rio de Janeiro, Brazil. At the United Nations Conference on Environment and Development, informally known as the Earth Summit, 150 countries pledged to confront the problem of greenhouse gases by signing the United Nations Framework Convention on Climate Change (UNFCCC). To date, more than 180 nations have ratified the UNFCCC, which commits nations to stabilizing greenhouse gas concentrations in the atmosphere at a level that would avoid dangerous human interference with the climate. This is to be done so that ecosystems can adapt naturally to global warming, food production is not threatened, and economic development can proceed in a sustainable manner.

The nations at the Earth Summit agreed to meet again to translate these good intentions into a binding treaty for emissions reductions. In 1997 in Japan, 160 nations drafted an agreement known as the Kyōto Protocol, an amendment to the UNFCCC. This treaty set mandatory targets for the reduction of greenhouse gas emissions. Industrialized nations that ratify the treaty are required to cut their emissions by an average of 5 percent below 1990 levels. This reduction is to be achieved no later than 2012, and commitments to start achieving the targets are to begin in 2008. Developing nations are not required to commit to mandatory reductions in emissions. Under the Kyōto rules, industrialized nations are expected to take the first steps because they are responsible for most emissions to date and have more resources to devote to emissions-reduction efforts.

The protocol could not go into effect unless industrialized nations accounting for 55 percent of 1990 greenhouse gas emissions ratified it. That requirement was met in November 2004 when Russia approved the treaty, and it went into force in February 2005. By the end of 2006, 166 nations had signed and ratified the treaty. Notable exceptions included the United States and Australia.

In 1998 the United States—then the world's single largest contributor to greenhouse gas emissions—became a signatory to the Kyōto Protocol. However, in 2001 U.S. president George W. Bush withdrew support for the treaty. He claimed that the treaty's goals for reducing carbon dioxide emissions would be too costly and would harm the U.S. economy. He also claimed the treaty put an unfair burden on industrialized nations. Opposition to the treaty in the United States was spurred by the oil industry, the coal industry, and other enterprises that manufacture or depend on fossil fuels. These opponents claimed that the economic costs to carry out the Kyōto Protocol could be as much as $300 billion, due mainly to higher energy prices. Proponents of the Kyōto Protocol believed the costs would prove more modest—$88 billion or less—much of which would be recovered as Americans switched to more efficient appliances, vehicles, and industrial processes.

The Kyōto Protocol, which expires in 2012, is only a first step in addressing greenhouse gas emissions. To stabilize or reduce emissions in the 21st century, much stronger and broader action is required. In part this is because the Kyōto provisions did not take into account the rapid industrialization of countries such as China and India, which are among the developing nations exempted from the protocol's mandatory emissions reductions. However, developing nations are projected to produce half the world's greenhouse gases by 2035. Leaders of these nations argue that emissions controls are a costly hindrance to economic development. In the past, prosperity and pollution have tended to go together, as industrialization has always been a necessary component of an economy's development. Whether or not an economy can grow without increasing greenhouse gas emissions at the same time is a question that will be critical as nations such as China and India continue on the path of industrialization.

In 2007 the European Union (EU) took the initiative in coming up with a new international plan to address global warming. At a “green summit” held in March, the 27 nations of the EU reached a landmark accord that went above and beyond the Kyōto Protocol in setting targets to reduce greenhouse gas emissions. The agreement set ambitious targets for the EU overall, but goals for individual EU nations and rules of enforcement were to be determined through additional negotiations.

In the accord EU leaders agreed to reduce emissions by 20 percent from 1990 levels by 2020—or by as much as 30 percent if nations outside the EU joined in the commitments. They also agreed that renewable sources of energy, such as solar and wind power, would make up 20 percent of overall EU energy consumption by 2020 (an increase of about 14 percent). The accord also called for a 10 percent increase in the use of plant-derived fuels, such as biodiesel and ethanol. In addition to these targets, EU leaders agreed to work out a plan to promote energy-saving fluorescent light bulbs, following the example of countries such as Australia and Chile that are officially phasing out less-efficient incandescent light bulbs.

6. Conclusion

Flexibility mechanisms as defined in the Kyoto Protocol should be adopted to achieve emissions reduction as part of the effort to address climate change issues. These falls into the following categories: Emissions Trading, Joint Implementation and Clean Development Mechanism. However, these have been highly controversial since some of the mechanisms face criticism for not actually leading to a reduction in emissions. A mechanism suggested for tackling climate change and warming has been the idea of using Carbon Sinks to soak up carbon dioxide. To aid in this, reforestation, or planting of new forests, have been suggested. This is a popular strategy for the logging industry and nations with large forests interests. While there may be some potential in this solution, it cannot be effective on its own. This is because it legitimizes continued destruction of old-growth and pristine forests which are rich ecosystems and have an established biodiversity base that naturally maintain the environment. Creating new forest areas would require the creation of entire ecosystems. It is also criticized for being a quick fix that does not tackle the root causes effectively and does not lead to, or promote actual emissions reduction. Alternative energy sources other than fossil fuels are recommended.

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