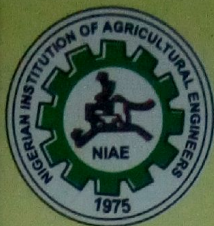




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**NIGERIAN INSTITUTION OF
AGRICULTURAL ENGINEERS
(NIAE)**



PROCEEDINGS OF THE



11TH INTERNATIONAL CONFERENCE & 32ND ANNUAL GENERAL MEETING



Theme:

**AGRICULTURAL
ENGINEERING
FOR ECONOMIC
TRANSFORMATION**



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Climate Change: Impact on Agricultural Productivity in Temperate and Tropical Regions

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Abstract

This paper discussed the impact of climate change on agriculture as a vital issue. It compared the effects of climate change on agriculture in temperate and tropical regions. It further discussed the following: the influence of climate change on crop production; the biophysical impact of climate changes associated with global warming; specific studies in temperate and tropical regions on climate change; impact on agriculture; global estimates of agricultural impacts and adaptation to climate change.

Keywords: Climate change, Global warming, Temperate, Tropics, Agriculture, Adaptation.

1. Introduction

Climate change is a change in climate that is attributable directly or indirectly to human activities that alters the atmospheric composition of the earth which leads to global warming (Medugu, 2011). Climate change has the potential of affecting all natural and human systems and may be a threat to human development and survival socially, politically and economically. Agriculture is the basic activity by which humans live and survive on the earth. Assessing the impacts of climate change on agriculture is therefore a vital task.

In both developed and developing countries (Nigeria inclusive), the influence of climate on crops and livestock persist, despite irrigation, improved plant and animal breeds and the growing use of chemical fertilizers. The continued dependence of agricultural production on light, heat, water and other climatic factors, the dependence of much of the world's population on agricultural activities and the significant magnitude and rapid rates of possible climate changes all combine to create the need for a comprehensive consideration of the potential impacts of climate on global agriculture.

The temperate and tropical regions differ significantly in their biophysical characteristics of climate and soil and in the vulnerability of their agricultural systems and people to the climate. This paper focused on the impact/effects of the climate change on agricultural productivity. These changes occur as a result of high levels of carbon dioxide in the atmosphere and associated global warming. The projected climate changes for the temperate and tropical areas in the climate models project larger temperature increase in the temperate region than in the tropical region (Rosenzweig and Liverman, 2011).

1.1 Comparison of Temperate and Tropical Agriculture

The tropics are the geographical area lying between 23.5 deg. N and 23.5 °S latitude, while the temperate regions are found above these parallels. Climatologically, the tropics are characterized by high year-round temperatures and weather is controlled by equatorial and tropical air masses. Tropical precipitation is primarily convective. In the more humid tropical regions, annual rainfall is often above 2000 mm and falls in almost all months of the year while in the drier tropics; rainfall can be below 50mm and be very seasonal. The remainder of the region lies between these precipitation regimes, with distinct wet and dry seasons. Agriculture is frequently limited by the seasonality and moisture availability.

In the mid-latitude temperate zone, weather is controlled by both tropical and polar air masses. Precipitation here occurs along fronts within cyclonic storms. The temperate region also has many different climate regions with warmer and cooler temperatures and seasonal rainfall. Temperate agriculture is often characterized and predominantly limited by seasonally cooler temperatures.

Reported experiments have shown that even though yield per day is often higher in the tropics, total crop growth season is shorter (Haws, *et al.*, 1983). Leaf expansion and phasic development are faster in the tropics because of higher temperatures during vegetative growth, but crop yields are consistently found to be higher in temperate regions than in the tropics (Food and Agriculture Organization (FAO) 1990). Many factors contribute to this result. Soils in the humid tropics tend to be highly leached of nutrients because of high rainfall and erosion, and are therefore unproductive. Soils in the drier tropics are often hampered by accumulations of salts and lack of water (Barrow, 1987). Temperate soils are generally viewed as more favourable to agriculture than tropical soils because of higher nutrient levels. However, there are exceptions in both regions, with high productive volcanic and fluvial soils found in the tropics, and poorly developed and infertile soils in temperate regions.

Agricultural production is also severely limited in many humid tropical regions by the wide range of weeds, pests and diseases that flourish in consistently warm and moist climates. The growth of some crop varieties, which require long hours of daylight to reach maturity, is also limited by the invariable day lengths of the tropics. Solar radiation, which is critical to plant growth, and whose intensity is controlled by the angle of the sun, day length and cloudiness, is lower in winter and higher in summer in temperate zones. In the tropics, solar radiation is often limited by cloudiness during the rainy season (Barrow 1987).

Agricultural crops and cropping systems have been developed for, and adapted to these varied regimes of soil, diseases and pests (Haws *et al.*, 1983). The main commercial agricultural crops and their adaptations include:

- i. Cassava and sugarcane, which only grow in tropical areas and have a crop duration of one year or longer. Cassava is drought resistant, but sugarcane requires irrigation in dry areas or dry period.
- ii. Groundnut, sorghum and sweet potato which grow in both tropical and sub-tropical regions in relatively dry seasons.
- iii. Rice, which is mainly grown in tropical and subtropical zones in the rainy season or with irrigation.
- iv. Maize and field beans grow in both zones, preferably with seasons with enough rain.
- v. Wheat, soyabean and potato are crops of the subtropical and temperate zones and grow in the tropics at high (cooler) elevations.
- vi. Sugar beet is grown only in the temperate zone.

Fruits such as bananas, pineapples, stimulants e.g. coffee, tea and spices grow best in the tropics. Tropical regions also provide winter season produce for temperate zones. In temperate agriculture, plant breeding and fertilizer use produced dramatic yield increases for many crops in the early twentieth century. Recently in the tropical regions, there are similar increases for crops such as wheat, maize and rice, which benefited from the technological package of improved seeds, fertilizer, mechanization and pesticides known as the Green Revolution.

In both temperate and tropical regions, irrigation has been developed in areas where dry seasons exist and adequate water can be reserved from other seasons or brought in from adjacent regions. Irrigation is an important remedy against climate variability and climate change.

Technology, different farming systems and economics also contribute to the yield differences in temperate and tropical regions. Agriculture in temperate regions is characterized by high levels of inputs such as quality seed, fertilizer, herbicides and pesticides and a high degree of mechanization and capitalization. European agriculture is particularly intensive and there are wide variations in the use of technology. In tropical regions, many farmers cannot afford inputs and governments cannot afford to subsidize them. In some parts of the tropics, traditional technologies, such as multiple cropping and terracing, act to buffer the system against climate variability, conserve soil fertility and increase yields (Rosenzweig and Liverman, 2011).

The tropics are more dependent on agriculture and therefore more vulnerable to climate change, than the temperate regions. About 75% of the world's population lives in the tropics and two thirds of these people rely on agriculture for their livelihood; with low levels of technology, land degradation, unequal land distribution and rapid population growth. Many tropical regions are exceeding their capacity to feed themselves (Adams *et al.*, 1990).

Jodha (1989) argued that the unequal social structures and international position of many tropical countries also increase vulnerability to climate variability, as the people have no extra land, job savings or government assistance to see them through droughts or other climatic extremes. When the economic system is oriented towards export rather than subsistence agriculture, climate change may threaten the whole national economy and food system. Those regions that cannot feed their populations depend mostly on cereal imports from the U.S.A., Canada, France, Australia, Argentina and Thailand (FAO, 1990).

1.2 The Influence of Climate Change on Crop Production

Climate impacts on agriculture lies on the biophysical Sciences. The rates of most biophysical processes are highly dependent on climate variables such as radiation, temperature and moisture which vary regionally. For

example, rates of plant photosynthesis depend on the amount of photosynthetically active radiation and levels of atmospheric carbon dioxide (CO₂). Temperature is an important determinant of the rate at which a plant progresses through various stages towards maturity (World Meteorological Organization, 1979). The accumulation of biomass is constrained by the availability of moisture and nutrients to a growing plant. Nix (1985) and Parry (1978) have examined the impacts of climate variations on agriculture using case studies, statistical analyses and simulation models and have clearly demonstrated the sensitivity of both temperate and tropical agricultural systems and nations to climate variations and changes.

In the temperate regions, the impacts of climate variability, particularly drought, on yields of grains in North America and the Soviet Union have been of particular concern because of their effects on world food security. In the tropics, drought impacts on agriculture and resulting food shortages have been widely studied, especially when associated with the failure of the monsoon in Asia or the rains in Suddano-Sahelian Africa. In the temperate regions, climatic variations are associated with economic disruptions; in the tropics, droughts bring famine and widespread social unrest (Pierce, 1990).

1.3 The Biophysical Impact of Climate Changes Associated with Global Warming

It is believed that global climate change will bring higher temperatures, altered precipitation and higher levels of atmospheric CO₂ (IPCC, 1900a). Higher temperatures hasten plant maturity in annual species. This shortens the growth stages during which pods, seeds and grains can absorb photosynthetic products. This is one reason why yields are lower in the tropics than in the temperate regions. Crop yield depends on both the rate of carbohydrate accumulation and the duration of filling periods. The economic yields of both temperate and tropical crops grown in a warmer and CO₂ – enriched environment may not rise substantially above present levels, despite increases in net photosynthesis (Rose, 1989).

Temperate and tropical regions differ in both current temperature and the temperature rise predicted for climate change. The relative magnitude of combined CO₂ and temperature effects will likely be different in the two regions. Increases in temperature will also lengthen the frost-free season in temperate regions, allowing for longer duration crop varieties to be grown and offering the possibility of growing successive crops (moisture conditions permitting). In tropical locations where increased temperatures may move beyond optimal, negative consequences may dominate.

1.4 Physiological Effect of CO₂

Apart from climate change, CO₂ has other effects on crop plants called “Fertilizing” effects. Most plants growing in enhanced CO₂ exhibit increased rates of net photosynthesis. The higher photosynthesis rates are then manifested in higher leaf area, dry matter production, and yield for many crops (Acock and Allen, 1985). High CO₂ has contributed to upward shifts in temperature optima for photosynthesis and to enhanced growth with higher temperatures (Idso *et al.*, 1987).

1.5 Soils

Climate change will also have an impact on the soils, a vital element in agricultural ecosystems. Higher air temperatures will cause higher soil temperatures, which should generally increase solution chemical reaction rates and diffusion-controlled reactions (Buol *et al.*, 1990). Solubility of solid and gaseous components may either increase or decrease, but the consequences of these changes may take many years to become significant (Buol *et al.*, 1990). Higher temperature will also accelerate the decay of soil organic matter, resulting in release of CO₂ to the atmosphere and decrease in carbon/nitrogen ratios, although these two effects should be offset somewhat by the greater root biomass and crop residues resulting from plant responses to higher CO₂.

In temperate countries where crops are already heavily fertilized, there will be no major change in fertilizer application practices, but alterations in timing and method (e.g. careful adjustment of side-dress application of nitrogen during vegetative crop growth) are expected with changes in temperature and precipitation regimes (Buol *et al.*, 1990). In tropical countries, where levels of fertilizer applied are not always adequate, the need for fertilizer application will probably increase.

1.6 Sea Level

Rise in sea level is another predicted effect of global warming. It will cause increased flooding, salt water intrusion and rising water tables in agricultural soils located near the coasts. This is particularly crucial in tropical countries such as Nigeria and Bangladesh, with large agricultural regions and high rural population located near on their coastal regions.

1.7 Pests

Pests are organisms that affect agricultural plants and animals in ways considered unfavourable. They include weeds, certain insects, arthropods, bacteria, fungi, nematodes and virus. Climate variables such as temperature, wind and humidity control the geographic distribution of pests. Climate change is likely to alter their ranges. Insects may extend their ranges where warmer winter temperature allow their over-wintering survival and increase the possible number of generations per season (Stinner *et al.*, 1989). Pests and diseases from low latitude regions, where they are much more prevalent, may be introduced at higher latitudes. As a consequence of pest increase, there may be an increase in the use of agricultural chemicals in both temperate and tropical regions for their control.

2. Specific Studies in Temperate and Tropical Regions on Climate Change Impact on Agriculture

Very few integrated regional studies have been completed on climate change impacts on agriculture. Parry *et al.* (1988) reported an integrated agricultural sector studies in high-latitude regions of Canada, Finland, USSR and Japan. They concluded that warmer temperatures may aid crop production by lengthening the growing season, but that potential for higher evapotranspiration and drought conditions may be detrimental.

Adams *et al.* (1990) conducted an integrated study for the use of linking models from Atmospheric Science, Plant Science and Agricultural Economics. While the outcomes depend on the severity of climate change and the compensating effects of carbon dioxide on crop yields, the simulations suggest that irrigated average will expand and that regional patterns of US agriculture will shift with predicted global warming. With the more severe climate change scenario tested, the movement of US production export markets will be substantially reduced.

The Missouri, Iowa, Nebraska and Kansas (MINK) study integrated within the agricultural sectors and across other sectors, incorporated both the physiological effects of CO₂ and adaptation by farmers to the climatic conditions of the 1930s (Roseberg and Crosson 1990). They are of the view that even with the relatively mild warming (1.1^o) of the 1930s and with farmer adaptation and CO₂ physiological effects taken into account, regional production declined by 3.3 % with the IPCC (1990a) estimate of 2.5 °C warming for double CO₂ conditions. These results imply agricultural losses of about 10% for equilibrium warming of doubling of carbon dioxide equivalent (Cline, 1991).

Parry *et al.* (1988b), in their studies of the impact of climate changes on agriculture in Kenya, Brazil, Ecuador, India and Australia; used the impacts of past climatic variations, rather than projections of future climate, to provide insights into the sensitivity of agriculture to climate change.

Liverman (1991) described how global warming may affect Mexican agriculture, using GCM output to project declines in moisture availability and maize yields at several sites in Mexico. A number of conferences and publications have recently raised concern about the possible impact of global warming on tropical regions, but explicit analyses of how global warming may affect tropical agriculture have not been concluded (Suliman, 1990 and Universidad de Sao Paulo, 1990).

2.1 Global Estimate of Agricultural Impacts

Global estimates of agricultural impacts have been fairly rough today due to lack of consistent methodology and uncertainty about the physiological effects of CO₂ (Rosenzweig and Liverman, 2011). General studies of how climate change might affect agriculture include those of Warrick (1988) and Kane *et al.* (1989), who predicted improvements in agricultural production at high latitudes and reductions in the Northern hemisphere mid-continental agricultural regions. The IPCC (1990b) concluded that while future food production should be maintained, negative impacts were likely in some regions, particularly where present-day vulnerability is high.

An international project of the US Environmental Project Agency (EPA), "Implications of Climate Change for International Agriculture: Global Food Trade and Vulnerable Regions," has been established to estimate the potential effects of green house gas-induced climate change on global food trade, focusing on the distribution and quality of production of the major food crops for a consistent set of climate change scenarios and in CO₂ physiological effects. Other goals of the project are to determine how currently vulnerable food deficit regions may be affected by global climate change; to identify the future locations of those regions and the magnitudes of their food-deficits; and to study the effectiveness of adaptive responses, including those of genetic resources, to global climate change (Rosenzweig and Liverman, 2011).

As part of the EPA project, crop specialists are estimating yield changes at over 100 sites in over 20 countries, under common climate change scenarios using compatible crop growth models. The focus is on staple food

crops such as wheat, rice, maize and soyabeans. The crop models are those developed by the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT, 1990). The choice of IBSNAT crop models was based on several criteria including the fact that the models simulate crop response to the major climate variable of temperature, precipitation and solar radiation, and include the effects of soil characteristics on water availability for crop growth; the models also have been validated for a range of soil and climate conditions; and they are developed with compatible data structures so that the same soil and climate data bases could be used with all crops.

2.2 Adaptation to Climate Change

This exists at the various levels of agricultural organization. In temperate regions, farm level adaptation include changes in planting and harvest dates, tillage and rotation practices, substitution of crop varieties or species more appropriate to the changing climate regime, increase in fertilizer or pesticide applications and improved irrigation and drainage systems. Governments can facilitate adaptation to climate change through water development projects, agricultural extension activities, incentives, subsidies, regulations and provision of insurance.

Similar adaptations could occur in tropical regions. In Mexico, preliminary results from the EPA International Agricultural project suggest that severe declines in maize yields under global warming could be mitigated if climate change is accompanied by increases in irrigation, fertilizer use and the use of drought resistant varieties. The major problem in the tropics, compared to most temperate regions, is the relative lack of resources, institutions and infrastructure to provide such adaptation.

3. Conclusions

In general, the tropical regions may be more vulnerable to climate change than the temperate regions for several reasons. On the biophysical side, temperate C3 (the first product in their biochemical sequence of reactions has three carbon atoms) crops are likely to be more responsive to increasing levels of CO₂.

Tropical crops are closer to their high temperature optima and experience high temperature stress, despite lower projected amounts of warming. Also, insects and diseases, already much more prevalent in warmer and more humid regions may become even more widespread.

Tropical regions may also be more vulnerable to climate change because of economic and social constraints. Greater economic and individual dependence on agriculture, widespread poverty, inadequate technologies and lack of political power are likely to exacerbate the impacts of climate change in tropical regions.

Due to global warming, plant breeders should place more emphasis on development of heat and drought resistance crops. Research is needed to find out the current limits to these resistances and the feasibility of manipulation through modern genetic techniques. Both architecture and physiology may be genetically altered to adapt to warmer environmental conditions. In some regions it may be appropriate to take a second look at traditional technologies and crops as ways of coping with climate change.

At the regional level, those charged with planning for resource allocation, including land, water, and agriculture development, should take climate change into account. In coastal areas, agricultural land may be flooded or salinized; in continental interiors and other locations, drought may increase these eventualities and can be dealt with more easily if anticipated.

As climate factors change, a host of consequences will ripple through the agricultural system, as human decision involving farm management, grain storage facilities, transportation, infrastructure, regional markets and trade patterns respond. For example, field-level changes in thermal regimes, water conditions, pest infestations and most importantly, quality and quantity of yields may lead to changes in farm management decisions based on altered risk assessments. The consequences of these management decisions could result in local and regional alterations in farming systems, land use, and food availability ultimately. Impacts of climate change on agriculture may reverberate throughout the international food economy and global society. At the national and international levels, the need of regions and people vulnerable to the effects of climate change on their food supply should be addressed. In many cases, reducing vulnerability to current climate variability should also serve to mitigate the impacts of global warming.

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