Impacts of climate change on crop production in Nigeria: a review

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The paper expounds the impact of climate change on crop production in Nigeria. Secondary information gathered mainly from literature was used for the discussion. It was observed that the two most important parameters impacting heavily on crop production in Nigeria were the rainfall and greenhouse emissions (CH₄ and CO₂) and the effect of the latter was more severe. Based on this study there is need to have knowledge of future climate change in order to avert its effects. The economic impact on crop may be in form of reduced yield, reduced revenue or both. The paper contends that, although farmers adopt different mitigation strategies to reduce the effect of climate change on crop production, they need to be very careful because some of the strategies have adverse environmental consequences.

Key words: Climate change, impact, crop, production, Nigeria.

INTRODUCTION

Agricultural production remains the main source of livelihood for most rural communities in developing countries, and Nigeria in particular. Agriculture provides a source of employment for more than 60% of the population and contributes about 30% of Gross Domestic Product (GDP) (Kadlinker and Risbey, 2000). The performance of the agricultural sector is determined by crop production, which depends on a large number of climatic factors. Most important climatic factors include endowment of soils, rainfall, temperature, and relative humidity. Based on the studies conducted by Bello et al. (2012) one can believe with a high level of confidence that Nigeria, like most parts of the world, is experiencing the basic features of climate change, as result of all these anomalies, holistic approaches on climate change are required in Nigeria to stem the tide of the erratic rainfall pattern that is currently bedeviling and bothersome since 1970s.

Climatic factors play an important role in the realization of higher or lower crop yield; as such knowledge of these factors is necessary to policy makers and the peasant/commercial crop farmers. Based on Roudier et al. (2011) in the vulnerable regions of sub-Saharan West Africa, a better quantification and understanding of climate impacts on crop yield is needed. The rain fed subsistence agricultural communities, the understanding of the climatic risk from the interaction of the climatic, environmental and socio-economic factors is important for designing appropriate, place-based and context-specific participatory adaptation strategies (Fasona et al., 2013). The knowledge of the effects of climate change on crop production is needed for the purpose of averting its effects to the total crop production in Nigeria, which repercussions leads to high crop production and food crop sufficiency in the country. According to Apata et al. (2010) hunger related deaths could double if grain productions do not keep pace with population growth in an unfavorable climatic environment.

Climate is considered to be the average of the observed pattern of weather in an area over a relatively long period of time (Intergovernmental Panel on Climate Change, 2009). The United Nation Framework on Climate Change defines climate change as a “change that is attributed directly or indirectly to human activity
that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods (United Nations Framework on Climate Change, 2007). Bello et al. (2012) identify climate change as one of the environmental life- threatening to economic development and sustainability of man-kind worldwide. Natural climate cycle and human activities have contributed to an increase in the accumulation of heat-trapping “greenhouse” gases in the atmosphere thereby contributing to increase in temperature in the global climate - global warming (Bello et al., 2012).

The issues of climate change have become very threatening, not only to the sustainable development of socio-economic and agricultural activities of a nation, but also to the totality of human existence (Adejuwon, 2004; Bello et al., 2012). According to United Nations Framework on Climate Change (2007) explanation on climate was very vivid and that ‘the effect of climate implies that the local climate variability that people have previously experienced and adapted to is changing and this change is observed in a relatively great speed’. Many countries in tropical and sub-tropical regions, of which Nigeria is included, are expected to be more vulnerable to warming because of additional temperature increase that consequently affects marginal water balance and harm agricultural sector (Mendelsohn et al., 2000).

The problem is expected to be more severe in Africa, where current information is poor, technological change has been slow and domestic economy depends heavily on agriculture (Action aid, 2008). Although there is a dearth of information regarding the impact of climate change on crop production in Nigeria, a review of some literature pertaining to the economic effects of climate change on crop cultivation could serve as a benchmark to the researchers to whom it may serve as an a priori expectations, to the farmers to whom it may serve as a guide during farm operations and to the policy makers to whom it may serve as a tool for planning.

Causes of climate change

The two most important climate parameters impacting heavily to crop production in Nigeria are the Rainfall and the Greenhouse emissions (CH₄ and CO₂).

Rainfall

Rainfall regime is the most important climatic factor influencing crop cultivation activities particularly in tropical regions of Nigeria (Ayanlade et al., 2010). Rainfall can vary considerably even within few distance and different time scale. This implies that crop yield is exceedingly variable over space and time which will have a big effect in determining the kind of crop to be grown, farming system to be adopted and the sequence of farm operations (Adejuwon, 2005). Rainfall can also be seen as the supplier of soil moisture to crops, although, moisture do not depend on rainfall alone but also on various concerns such as the evapo-transpiration and surface runoff (Intergovernmental Panel on Climate Change, 2009). A study conducted by Fasona et al. (2013) revealed that the rainfall of the wooded Savannah region of Nigeria which is increasing at 0.6mm/decade under the present climate will decline by about 4mm/decade under future climate.

During the dry season, when annual rainfall is less than the amount of water that a crop transpires, this can have two effects (Stern and Coe, 1982) first, during the latter part of growing season, insufficient soil moisture may restrict transpiration below the potential rate with reduction in yield and growth. Second, after harvesting the crop, there may be a deep layer of soil which must be recharged to field capacity early enough to support the growth of next crop.

Ayanlade et al. (2010) Reported that rainfall variability is very high in most part of northern guinea Savannah (Yola, Minna, and Kaduna) except Jos which has a unique pattern and a significant relationship with tuber yield (cassava and yam)? Ayanlade et al. (2010) further showed that rainfall pattern affect output of agricultural produce but, Owusu-sekere et al. (2011) observed that since the peak monthly rainfall is declining there is probability that lower amount of rainfall may occur in future which may have effect on crop output.

Methane (CH₄)

This is the most significant greenhouse gas released within the agriculture sector. Most of the methane releases come from paddy fields (91%) and less significantly from animal husbandry (7%) and the burning of agricultural wastes (2%) (Intergovernmental Panel on Climate Change, 2009). Albeit, the quantification of rice paddy emissions has proven difficult as the emissions vary with the amount of land in cultivation, fertilizer use and water management, density of rice plants and other agricultural practices including Livestock and associated manure management causes 16% of the total annual production of CH₄ (Intergovernmental Panel on Climate Change, 2009). These emissions are a direct result of the ability of cattle to utilize large amounts of fibrous grasses that cannot be used as human food, or as feed for pigs and poultry. Buffalo and cattle contribute about 80% of the global CH₄ emissions from domestic livestock.
annually (Intergovernmental Panel on Climate Change, 2009).

**Carbon-dioxide (CO₂)**

Primarily, deforestation due to agricultural expansion has caused a major source of carbon emissions. When natural vegetation is converted into agricultural land, a large proportion of soil carbon can also be lost as plants and dead organic matter are removed. This event contribute approximately to a one-third of total CO₂ emissions globally (Cumhur and Malcolm, 2008). Therefore, CO₂ is also released during the burning of agricultural crop waste and to lesser extent; CO₂ is also released from the fossil fuel used in agricultural production and from livestock production. Nowadays, high-intensity of animal production has become the biggest consumer of fossil energy in modern agriculture (Intergovernmental Panel on Climate Change, 2009).

**Effects of climate change on crop production**

There are four ways in which climate affects Crop production:

(i) Changes in temperature and precipitation directly affect crop production and can even alter the distribution of agro-ecological zones. Based on this, the temperature of Nigeria is projected to increase by about 0.02°C/decade, a rate that is lower than the present 0.06°C/decade.

(ii) Increased CO₂ is expected to have a positive effect on crop production due to greater water use efficiency and higher rates of plant photosynthesis.

(iii) Runoff or water availability is critical in determining the impact of climate change on crop production, especially in Africa.

(iv) Crop losses can result from climate variability and the increased frequency of changes in temperatures and precipitation (including droughts and floods).

A large body of literature has been developed to analyze these effects, both in developed and in developing countries, although the impact of climate change on agriculture became a topic of interest only in the 1990s (Jane and Fredrick, 2007). The interest was spurred by the expectation that accumulation of CO₂ and other greenhouse gases will lead to global warming and other significant climate changes. Although there are a large number of studies on the effects of climate change in general, and global warming in particular, on crop in developed countries, there is a paucity of such studies in developing countries. However, there is growing interest in studying these effects and making comparisons.

The traditional approach used to study the impact of climate change on crop is a production function method which relies on empirical or experimental production functions to predict environmental change (Mendelsohn and Shaw, 1994). To overcome the main weakness of this approach, most studies employ a method that corrects the bias in the production function technique by using the economic data on the value of land to analyze the impact of climate on crop. This method is referred to as the Ricardian approach. Although Timmins (2001) argues that while the Ricardian method is extremely practical for predicting the consequences of global warming with limited data, it may yield biased results when land use decisions depend on the climate attributes being valued and when land has unobserved attributes that differ with the use to which it is put.

**Ricardian approach studies**

Mendelsohn et al. (2000); Mendelsohn and Shaw (1994) use the Ricardian technique to estimate the value of climate change in United State of America agriculture, using cross-sectional data for about 3000 Counties. Their results showed that climate has complicated effects on agriculture, which can be highly non-linear and vary by season. Specifically they find that increased temperatures are likely to reduce average farm values, but increased precipitations do improve farm values. Their findings further shows that a scenario of increasing temperatures by an average of 5°C and corresponding average precipitation of 8% leads to a loss in land value from warming to an annual neighborhood damage of 4 to 5%. However, the same policy change scenario results in a 1% gain when using the crop revenue approach. A number of studies that employ the Ricardian approach have supported findings by Mendelsohn and Shaw, (1994) of an adverse impact of climate change on agriculture.

Mendelsohn et al. (2000) Use the same approach to analyze the relationship between climate and rural income based on country data for two United States and Municipals from Brazil. The results suggest that favorable climate increases crop net revenues and thus per capita incomes. They concluded that climate is an important determinant of household welfare and therefore providing new technology and capital may be an ineffective strategy for increasing rural incomes in hostile climate regions.

Mendelsohn et al. (2000) Explore climate change impacts on African agriculture using the Intergovernmental Panel on Climate Change (IPCC) forecast of future CO₂ levels in the atmosphere by 2100.
Because of the lack of African studies that calibrate climate sensitivity, the authors rely on studies of climate sensitivity for the US. Their results show that the most pessimistic forecast implies that African countries may lose 47% of their agricultural revenue because of global warming, while a cross-sectional forecast suggests losses of only 6% of agricultural GDP. With the expected fall in the contribution of agriculture to GDP over time, the authors conclude that the damage from climate change to African agriculture may be expected to range from 0.13% to 2% of GDP by 2100. They further argue that every region in Africa will experience some negative climate change impacts. They caution that their findings may be quite optimistic given that they are based on US climate response functions, and they call for African countries to estimate the climate effects and to understand adaptation options for Africa.

Seo et al. (2005) also employ the Ricardian approach to measure the impact of climate change on Sri Lankan agriculture, focusing on four major crops. The authors find that global warming is expected to be harmful to Sri Lanka but increases in rainfall will be beneficial. They also find that with warming, the already dry regions are expected to lose large proportions of their current agriculture, but the cooler regions are predicted to remain the same or increase their output. They concluded that climate change damages could be extensive in tropical developing countries but will depend on actual climate scenarios.

Tol (2002) assesses the impacts of climate change on agriculture, forestry and other aspects of human welfare using Global Circulation Model (GCM) based scenarios of climate change. This study is based on a number of countries. The results showed that a 1°C increase in the global mean surface air temperature would have a positive impact on the OECD, China and Middle East countries but a negative effect on others. The author further argues that the distributional aspects of climate change and the uncertainty about the impacts can be extremely large. (Kumar and Parikh (1998) use farm level data to examine the agricultural impacts and adaptation options of climate change in India. They find that adverse climate change would lead to huge losses in agricultural revenues, even if farmers were to adopt their farming practices to climate change.

Molua (2002) in an analysis of the impact of climate on agriculture in Cameroon finds that increased precipitation is beneficial for crop production and that farm level adaptations are associated with increased farm returns. Etsia et al. (2002) reported that a combination of increasing CO₂, temperature and rainfall is likely to have adverse effects on agricultural production in Tunisia. These results supported findings of Rosenzweig and Parry (1994) who reveal that increased CO₂ and temperatures reduce rice production in India.

Deressa (2003) use the Ricardian model to analyze the impact of climate on South African sugarcane production, using time series data for both irrigated and dry land farming. The authors finding reveals that climate change has significant non-linear impacts on net revenue with higher sensitivity to future increases in temperature than precipitation. Further, they find that doubling CO₂ leads to rises in temperatures by 2°C and precipitation by 7%, which would have a negative impact on sugarcane production. They also find out that irrigation in sugarcane production does not provide an effective option for reducing climate change damages in South Africa. Gbetibou and Hassan (2005) also use the Ricardian approach to analyze the economic impact of climate change on major South African field crops. They find that crops are quite sensitive to marginal changes in temperature compared to changes in precipitation. Contrary to findings by Deressa (2003) that irrigation would be an effective adaptation measure for limiting the harmful effects of climate change, and that the impact of climate change is agro-ecological zone specific and therefore, location is important in dealing with climate change issues.

Production function approach studies

Turpie et al. (2002) analyze the economic impact of climate change in South Africa. Their study addresses impacts on natural, agricultural, man-made and human capital. They use the production function approach to measure the natural capital lost from global warming. They predict the impact of climate change on rangelands will be positive, with the fertilization impact of CO₂ outweighing the negative effects of reduced precipitation. However, they find out that the impact of climate change on maize production will be negative both ‘with’ and ‘without’ CO₂ fertilization. Based on them estimates of impact of climate change for other crops were not reliable.

Other studies that use the production function approach argue that climate change may have beneficial effects on agriculture, especially in more arable lands, but adverse effects on more arid zones (for example Downing, 1992). The positive impact of CO₂ fertilization effects and rising temperatures may however be determined by the adaptation measures adopted by farmers. Studies that support this argument include Iglesias (1996) and Kurukulasiriya and Rosenthal (2003). Iglesias (1996) reported that with a combination of different adaptation strategies in Spain, farmers not only derived higher crop yields with increased temperatures but also used water and land more efficiently.
Fischer and Veldhuizen (1996) argue that climate change factors are significant determinants of millet productivity in Niger and predict a huge fall in crop productivity by 2025 as a result of global warming. Downing (1992) argues that potential food production in Kenya will increase if increased temperatures are accompanied by high rainfall, while marginal zones will be adversely affected by decreased rainfall.

Kurukulasiriya and Rosenthal (2003) noted that food productivity in Kenya may well increase with higher levels of atmospheric CO₂ and climate change induced increases in temperatures accompanied by some increases in precipitation, as predicted by several Global Circulation Models (GCMs). These arguments are also supported by Schultz et al. (2011) who argue that maize production in Zimbabwe is expected to fall as a result of increased temperatures that shorten the crop growth period. Downing (1992) also shows that shifts in agriculture-climate potential would affect national food production and land use in Zimbabwe. Schultz et al. (2011) in a study on South Africa, Lesotho and Swaziland found climate change to be associated with potential increases in maize production, though they argue that it is likely to have little effect in marginal areas where yields are already low.

Onyeji and Fischer (1994) in a study in Niger, Niger climate argues that climate has significant implications for agriculture because farmers tend to change their farming patterns with climate change and this is likely to have adverse environmental consequences. A study on Egypt climate reveals that adverse climate change will lead to a decline in agricultural production and in GDP (Yates and Strzepek, 1998). However, they argue that large instruments in adaptation are required to make significant gains in avoiding the adverse impacts of climate change on the economy. Benson et al. (1998) argue that global warming is likely to have adverse consequences for the Egyptian economy. Benson et al. (1998) also in a study involving a number of African countries argue that developing countries in Africa may be less prone to climate change shocks than industrial countries.

Although farmers’ adopt different measures to mitigate the impact of climate change on crop production, a combination of such measures yield better results. Finally, farmers need to be aware of future climate challenges and be careful in adopting adaptation measures because some of them have adverse environmental consequences.

### Conclusion and policy implication

From the foregoing, it could be deduced that although the impact of climate change varies between regions, crop production in Nigeria is likely to be among the worst-hit because the effect is more severe among the tropical regions to which Nigeria belonged. Similarly, crops are more sensitive to global warming associated to changes in temperature than they are to changes in precipitation. The economic impact of climate change on crop may be in form of reduced yield, reduced revenue or both.

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