Simulation of the Influence of Climate Change on Crop Yields and the Effects of Reforestation in Nigeria

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2013

SIMULATION OF THE INFLUENCE OF CLIMATE CHANGE ON CROP YIELDS AND THE EFFECTS OF REFORESTATION IN NIGERIA

BY

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SCP09/10/H/1277

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A THESIS SUBMITTED TO THE INSTITUTE OF ECOLOGY AND ENVIRONMENTAL STUDIES, OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D.) DEGREE IN ECOLOGY AND ENVIRONMENTAL SCIENCE

This is to certify that Olaniran Jonathan MATTHEW (SCP09/10/1277) carried out this research work in partial fulfilment of the award of the degree of Doctor of Philosophy (Ph.D.) in Ecology and Environmental Science of the Obafemi Awolowo University, Ile-Ife, Nigeria. We hereby confirm that this work has never been submitted elsewhere and the use of all materials from other sources has been properly and fully acknowledged.

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DEDICATION

This thesis is dedicated to the Space Applications and Environmental Science Laboratory (SPAEL), Institute of Ecology and Environmental Studies, Obafemi Awolwo University, Ile-Ife, Nigeria.

ACKNOWLEDGEMENTS

I am joyfully aware of all the people who worked behind the scenes to make this work possible. It is in line with a fine and generous tradition to express my profound gratitude to those who gave courage and support to a work like this. I would need at least a book of a size of this thesis to be able to accommodate the names of all those who believed in me and my work and helped to make that belief a reality.

Firstly, I like to specially eulogize my amiable supervisor, Prof. Ayobami T. Salami (my hero and role model); without him this work would still be just a dream. I say thank you very much, sir.

My sincere gratitude also goes to Dr. B. J. Abiodun of the Department of Environmental and Geographical Sciences, University of Cape Town, South Africa, my host supervisor abroad; a rare human being who puts others ahead of himself, always. I am so grateful unto you.

I am very grateful to Dr. O. O. Awotoye, my supportive Director for his wonderful leadership style. Also, other members of staff and colleagues in the Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, really deserve my appreciation.

Alaba, my dearest wife; I really appreciate your patience while I was in Cape Town, South Africa to get this work done. Abosede, my lovely and beautiful daughter; Abayomi and Olorunfemi my promising sons, I thank you so much for your endurance and prayer. I understood fully well how you felt when it took me so long, more than ever before, to return home. Thank you, so much.

The effort of these gentlemen towards obtaining crop yields data, used in this study, is highly applauded: Mr. Victor Atilola of Oyo State ADPS Office, Ibadan; Dr. Rasaq Oyeleke of the National Programme for Agriculture and Food Security, Abuja; Mr. Adebiyi of Osun State ADPS Office, Iwo and many others.

Finally, I appreciate all my friends at home and abroad whom God had used to enrich this work. Let me not forget to thank the Head, Space Applications and Environmental Science Laboratory (SPAEL), Institute of Ecology and Environmental Studies, Obafemi Awolowo University, Ile-Ife, for the financial support I enjoyed in the course of this study. This PhD research is a further study to the project entitled "**Modelling *the Impacts of Reforestation on Climate Change in Nigeria***" funded by the Ecological Fund Office (EFO), Abuja, within the framework of Presidential Afforestation project. I therefore wish to end these acknowledgments by thanking EFO, Abuja who provided the fund for SPAEL to execute the project.

All Glory to God Almighty!

Thank you all!!

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ABSTRACT

This study used a dynamical Regional Climate Model (RegCM3) to simulate the climate of Nigeria for 1999 - 2009, 1981 - 2000 and 2031 - 2050 time periods and the General Large Area Model (GLAM) for the yields of some staple food crops (maize, rice, sorghum, cowpea and groundnut) in the country. This was with a view to investigating the influence of climate change on crop yields and quantifying the effects of future reforestation in the country.

The daily climatic data (rainfall, solar radiation, ground surface minimum and maximum temperatures) required to drive GLAM were obtained from the simulation of RegCM3 forced with EH50M global climate model over Nigeria. GLAM was then calibrated for the simulation of yields of the selected food crops in Nigeria. For the GLAM calibration and validation, 11-year (1999 - 2009) climatic and observed yield data were used. The recent past (1981 - 2000; as the baseline) climate and crop yields were then simulated. Similarly, the future (2031 - 2050) climate projections with elevated CO_2 under the Intergovernmental Panel on Climate Change A1B scenario were carried out. The GLAM crop model was also used to simulate the adaptive potentials of the choices of some climate change adaptation options (*i.e.* irrigation farming, adoption of high temperature-tolerant crop varieties and change in planting routine) by peasant farmers. Seven different hypothetical reforestation options were considered for modelling the influence of reforestation on future climate and crop yields in the country. Four of these options assumed random reforestation (*i.e.* 25%, 50%, 75% and 100%) over the country, while the other three assumed zonal reforestation (*i.e.* south, middle-belt and north).

The results showed that RegCM3 replicated the essential features of Nigerian climate and adequately simulated their seasonal variations (*r*= 0.74 – 0.95; at p≤ 0.01) over various ecological zones of the country. GLAM gave a realistic simulation of crop yields (1999 - 2009) over Nigeria though with some biases (errors < 36% of the observed yields). The climate model predicted a significant increase (1 - 2^{o}C; *p* ≤ 0.01) in maximum temperature over the entire country in the future (2031 - 2050). Also, the southern and northern parts of the country were modelled to get wetter (1.5%) and drier (1.7%) respectively in the future. Furthermore, declines in future crop (*e.g.* maize: 21%, rice: 17%, sorghum: 18%, cowpea: 22%, groundnut: 23% over the Forest zone) yields were predicted over the entire country. However, adoption of some climate change adaptation options reduced (6 - 12%) the negative effects of climate change on crop yields or offset the negative effects and enhanced (2 - 78%) the yields. Reforestations lowered (1 - 2%) temperatures and induced (3 - 12%) rainfall over the reforested areas; but increased (1 - 2%) temperatures and reduced (1 - 2%) rainfall outside the reforested areas. Also, reforestations further increased the negative effects of climate change on crop yields by 1 - 2% over the Forest zone while over the Sahel, the negative effects on the yields were reduced by 1 - 2% or completely offset and improved by 1 - 8%.

The study concluded that reforestations had both positive and negative impacts on future climate and crop yields in Nigeria. It improved future crop yields over Nigerian Savannas, but worsened it over the Forest zone.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

One of the most fundamental objectives of agriculture is the sustainability of food security (Tangermann, 2000). Therefore, the agricultural sector might be considered most essential for human survival. In terms of job creation, agriculture is the major sector that drives the economy of Nigeria, the most populous country in Africa. This is so because, the sector engages more than 70% of the Nigerian labour force (Akande, 2003; Adegboye, 2004), contributes about 41% of the Gross Domestic Product (FMARD, 2000), provides more than 5% of the total national exports, and accounts for 88% of non-oil earnings (Koyenikan, 2008). Hence, any improvement in agriculture would ensure sustainable economic development in the country by increasing the rural incomes, reducing poverty and hunger as well as promoting food security (Irz *et al.*, 2001).

However, climate change is a major constraint to agricultural production and food security in Nigeria and other developing countries of the world that rely largely on rain-fed production systems (Okolo, 2004). Thus, the recent decline in agricultural productivity in Nigeria is linked to climate change and the change (in climate) is projected to exacerbate the decline because it would induce climatic conditions that might be unfavourable for agricultural practices in future (Adejuwon, 2004; Challinor *et al.*, 2004; IPCC, 2007). Consequently, the uncertainty and risk associated with climate change/variability and crop yields could also make famers abandon farming and convert the farmlands to non-agricultural enterprise (Apata *et al.*, 2009) that would further worsen the food security in Nigeria.

Nigeria and many other African countries remain more vulnerable to climate change risks as a result of poor technology advancement, economic instability, poor educational development and inadequate irrigation infrastructure (Shah *et al*., 2008; Nellemann *et al*., 2009). Food production, including access to food, in many African countries is projected to be severely compromised by climate variability and change (IPCC, 2007). This means that areas suitable for agriculture would be negatively affected by climatic change and the yield potentials of many high profile crops produced in the region, particularly along the margins of semi-arid, arid and coastal areas, are expected to decrease. FAO (2008) estimates indicate that the number of hungry and malnourished people due to insufficient food availability and lack of access to food, have increased from about 90 million in 1970 to 225 million in 2008, and was projected to rise to about 325 million by 2015.

Therefore, the expectation is that agricultural productivity needs to be vigorously increased to provide more food to meet the demands of growing populations and ensuring adequate access to food and its benefits now and for future generations (Oyiga *et al*., 2011). In line with this objective, the United States President, Barack Obama invited four African leaders (President Yayi Boni of the Republic of Benin, Ethiopia's Prime Minister Meles Zenawi, President John Mills of Ghana and Tanzania's President, Jakaya Kikwete) to join the G8 leaders' summit at Camp David on May 19, 2012 for a session on food-security concerns in Africa (The Nation, 2012). Although the reason for the exclusion of the head of government of the most populous country in Africa could not be ascertained, the meeting reviewed the food security situation in Africa with a view to finding lasting solutions to the impending food crisis.

In a related development, the pressures on Nigeria’s forests to provide economic resources have led to unabated deforestation which has been recognized as a major driver of biodiversity loss (Salami, 2006) and an environmental change that significantly contributes to increasing atmospheric greenhouse gas (IPCC, 2000). The rich biodiversity in Nigeria's forest has been subjected to heavy logging and agricultural clearance throughout the 20th century and now, and the area covered by forest is rapidly shrinking (Salami *et al.*, 1999). For example, between 1990 and 2010 alone, Nigeria lost an average of 2.38% per year or a total of about 47.5% in twenty years (FAO, 2010). Salami (2006) in his independent study, based on a national study that utilized multi-date satellite images, put the rate of deforestation in the country at 1.36% per annum due to encroachments, excisions and outright de-reservations.

Previous studies have revealed that when the forest or vegetation is removed, the Earth loses a valuable resource that was continuously absorbing carbon dioxide already in the atmosphere (Mery *et al.*, 2005; IPCC, 2007). The burnt or decaying wood releases the carbon stored in trees as carbon dioxide thereby increasing the level of this heat-trapping (greenhouse) gas in the atmosphere. So losing a stand of tree is a double loss as we lose an ecosystem that absorbs greenhouse gases and the carbon storage provided by the trees. Recent studies suggested that about five billion of the 32 billion tonnes of carbon dioxide emitted annually through human activity are absorbed by forests (World Bank, 2004; Mery *et al.*, 2005; IPCC, 2007). Also, a global estimate of about 1.7 billion tonnes of carbon was reported to be released annually due to land use change with major portion from tropical deforestation (IPCC, 2007). This represents about 20% of current global carbon emissions, which is greater than the percentage emitted by the global transport sector with its intensive use of fossil fuels.

Similarly, deforestation has been found to be a significant contributing factor to the West African regional warming (*e.g.* Tamayo and Degawan, 2007; Abiodun *et al.*, 2008; Omotosho and Abiodun, 2007; Sylla *et al.*, 2010a). Hence, in the recent effort to seek common solutions to combat global warming and its negative impacts, one area that is receiving a lot of attention is reforestation (Tamayo and Degawan, 2007).