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Biome Breakdown: The Effects of Climate Change on Agriculture in Nigeria and Thailand

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Abstract

This article analyzes how climate change affects the agricultural sectors of Nigeria and Thailand. It focuses on exploring three areas that are critical for agriculture: increases in precipitation variability, increases in long-term surface temperatures, and increases in extreme weather events. The paper shows that these three effects of climate change have widespread and destructive repercussions on agriculture. Based on the available data, Thailand has thus far experienced more significant effects than Nigeria. However, given Nigeria's lower level of development, Nigeria is more vulnerable to climate change than Thailand. There are some options to alleviate the impact of climate change in both countries, but they do not constitute permanent solutions. Mitigating climate change is the only way to guarantee the food security of these two countries.

I. Introduction

Climate change is one of the most critical and widespread threat facing our world in the modern day. It is an issue ubiquitous in nature, touching every inch of the earth, affecting all species of life, and posing a threat to humans especially in developing countries. Agriculture, which is indispensable to humans, is exceptionally susceptible to climate change. Increases in temperatures and changing weather patterns can have serious and long-term adverse effects on agricultural output and the sustainability of agricultural locations, which subsequently decreases food supply and causes a potential crisis for the human population in many developing countries.

This article will discuss the effects of climate change on agriculture in Nigeria and Thailand. These two nations have been chosen particularly due to their differences in terms of income per capita levels and location. Nigeria is considered by the World Bank to be a lower middle-income country with areas of desert, semi-arid climate, and savanna, while Thailand is considered to be an upper middle-income nation with a tropical climate and high levels of precipitation. Nigeria is located on the west coast of Africa along the Gulf of Guinea, while Thailand is located in Southeast Asia as part of the Lower Mekong Basin. While both countries are major rice producers, Nigeria is one of the largest rice importers in the world, Thailand is one of the world's largest rice exporters. This

article seeks to explore how, despite different environmental conditions and locations, climate change affects distinct regions in surprisingly similar fashions.

There are various ways climate change is affecting agriculture in these two countries. In this article, these changes are grouped into three categories: precipitation variability, increases in temperature, and changes in extreme weather events. Observational and statistical information will be presented for each country and the data will be compared and contrasted against each other. Following this introduction will be a brief review of literature. The third section provides some empirical background for both countries, while the fourth section provides the main discussion, before the last section offers some conclusions, including some observations on how each country's level of development affects its ability to manage the effects of climate change on their agricultural sector.

II. Literature Review

The amount of available literature on the topic of climate change and agriculture in Nigeria and Thailand is relatively sparse. Furthermore, due to the dynamic nature of climate change, older literature becomes quickly outdated and obsolete. This limits the scope of usable data to the relatively more recent observations. This literature review focuses therefore on some major contributions made within the last ten years.

- Ajetomobi (2016) analyzes how extreme weather conditions affect the mean and the variability of the yields of eleven staple crops in Nigeria. Using advanced econometric estimation methods, the research involved the use of a pooled panel data of 36 Nigerian states and the federal capital territory of Nigeria over the period of 1991-2012.
- Neo (2012) delves deeply into the statistics of current and projected crop yields in Thailand and how specific environmental changes lead to them. All studies found that there is a 100 percent chance that crop yields will decrease over the entire country by 2100, but the rates at which these declines would occur varies based on study and location. In addition to these statistics, the effects of industrialization and manmade alterations on the environment, such as dams, are explored in detail. The most signification assertion stated in this article is that Thailand is specifically vulnerable to climate change effects compared to both the rest of the Lower Mekong Basin and the world.
- Oluwatayo and Ojo (2016) use yam production in Nigeria to illustrate how climate change is affecting crops in the area and how farmers are adapting to those changes. As most agriculture in Nigeria is rain-fed, Nigerian crops are more susceptible to variable weather and precipitation changes; the use of less sophisticated technology and indigenous techniques allows farmers to be more connected to their crops and take notice of environmental changes. Oluwatayo and Ojo provide suggestions on how to combat these changes and maximize crop yield.
- Wassmann et al. (2009) analyze examples of extreme weather events and climate variability in Thailand and how it affects rice productivity. Bringing tangibility to sheer facts and figures, the article discusses droughts, specifically that of 2004, extreme weather events, and heat stress that all have caused crop damages in the past. As rice is the most prominent crop in Thailand, Wassman et al. provide important data and insight into how climate change affects food production and the country's economy, despite the article focusing mostly on rice.

- Yamauchi (2014) discusses the impacts of climate change on agriculture and irrigation in the Lower Mekong Basin. The article is broad in scope, covering almost the entirety of the Southeast Asian mainland and discusses all proven effects of climate change on agriculture in that region. Some of the effects include: increased weather variability, increased evapotranspiration rates, shifting and intensifying of dry and wet seasons, all contributing to a decrease in crop yield. Yamauchi refrains from discussing yield declines in detail, but focuses more on the specifics changes in weather and climate.

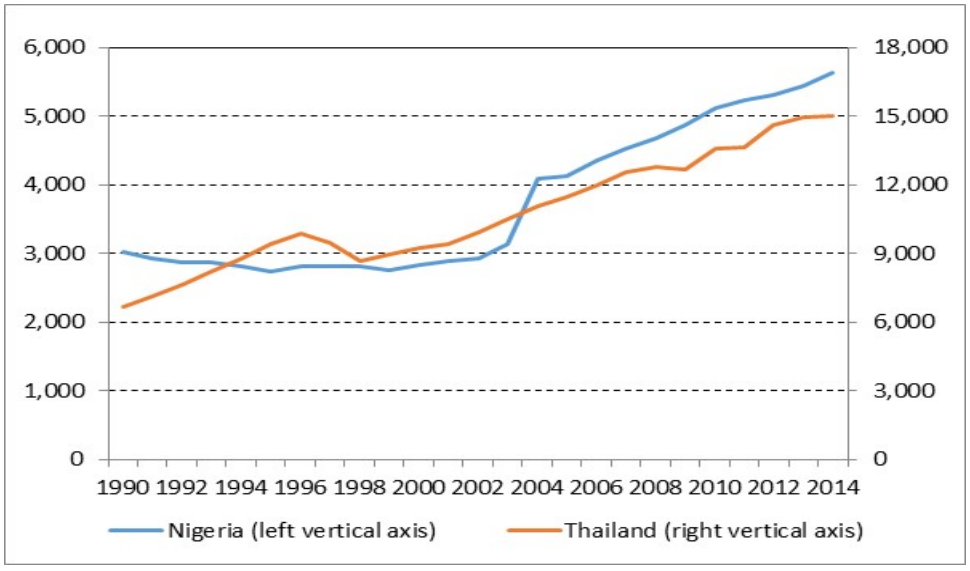
III. Empirical Background

This section is structured into two sub-sections: the first sub-section provides general information on both countries evolution and level of development based on three indicators (income per capita, poverty, and life expectancy); the second sub-section provides some background on the agricultural sector in Nigeria and Thailand. Both sub-sections provide a basis for the later evaluations of the impact of climate change on each country.

III.1. Evolution and Level of Income per capita, Poverty, and Life Expectancy

Figure 1 displays purchasing power parity (PPP)-adjusted gross domestic product (GDP) per capita for Nigeria and Thailand between 1990 and 2014.[1] Thailand's PPP-adjusted GDP per capita increased from $4,298 in 1990 to $15,735 in 2014, with an almost steady growth rate over the last 25 years, excluding the drop in 1997 and 1998 due to the Asian crisis, and a period of some fluctuation between 2009 and 2012. Regardless, Thailand's GDP per capita has more than tripled since 1990.

Figure 1: GDP per capita in PPP, PPP in current international $, 1990-2014



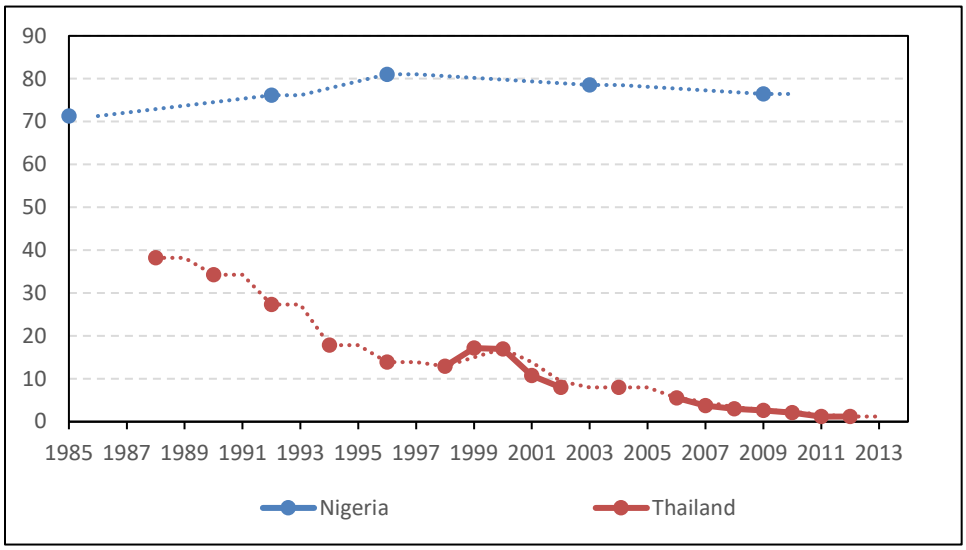
Source: Created by author based on World Bank (2016).

[1] Given that the initial levels of GDP per capita are very different between Nigeria and Thailand, Figure 1 displays Nigeria's GDP per capita on the left vertical axis, while that of Thailand is measured via the right vertical axis.

Unlike Thailand, Nigeria did not experience much growth in GDP per capita until about 2003. Its PPP-adjusted GDP per capita remained almost stagnant from 1990-2003. It then jumped from $3,143 in 2003 to $4,129 in 2004, and then grew at a relatively steady rate, similar to that of Thailand. Overall, Nigeria's GDP per capita nearly doubled from $3,030 in 1990 to $5,639 in 2014. In any case, Figure 1 exhibits the fact that Thailand's population is much better off economically than Nigeria's population.

Figure 2 displays the percentage of the population of each country that is living under $3.10-a-day.[2] Thailand's poverty headcount decreased from about 38.2 percent in 1988 to 13.9 percent in 1996, after which it increased slightly during the Asian crisis, but continued to decline shortly after. In 2012, only 1.23 percent of Thailand's population lived below $3.10-a-day. Nigeria's poverty headcount stands in stark contrast to that of Thailand. Its initial percentage of the population under $3.10 was recorded at 71.3 percent in 1985, and for the next eleven years, its poverty headcount grew, reaching a peak at 81 percent of the population in 1996. Since 1996, the percentage has been on the decline. It was last measured at 76.5 percent in 2009, which is higher than it was in 1985.

Figure 2: Poverty Headcount Ratio (percent of population under $3.10-a-day)



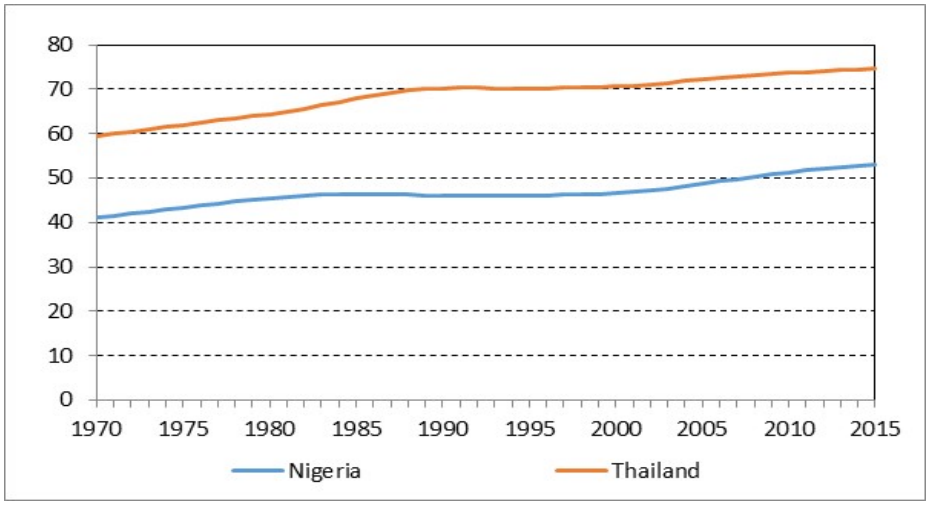
Source: Created by author based on World Bank (2016).

The average life expectancy within a population gives a general idea of the quality of life within that population. Figure 3 displays the average life expectancy at birth of individuals in total years from 1970-2015. In 1970, the average life expectancy in Nigeria was 41.2 years. This value grew slightly until 1983, when average life expectancy stagnated at about 46 years until 2002. In 2003, average life expectancy began to grow again, this time at a higher speed, ending at the average age of 53 years in 2015. In Thailand, average life expectancy stood at 59 years in 1970, growing swiftly, reaching 70 years in 1989. Average life expectancy then also stagnated, in the case of Thailand until about 2004, but began to increase again, finally reaching 74.6 years by 2015. While

[2] The value of $3.10-a-day was chosen because it is upper of the two international poverty lines (the other international poverty line being $1.90 a day, which would show an even larger discrepancy between the two countries).

the average life expectancy of individuals in both Thailand and Nigeria have increased greatly over the span of the last 45 years, life expectancy is significantly higher in Thailand, by over 20 years, and has been increasing at a higher growth rate. This indicates a higher quality of life in Thailand than in Nigeria, as life expectancy generally increases with greater levels of sanitation, more accessibility to medical facilities, a more civil political state within a country, and greater availability and quality of food.

Figure 3: Average Life Expectancy at Birth (in years), 1970-2015



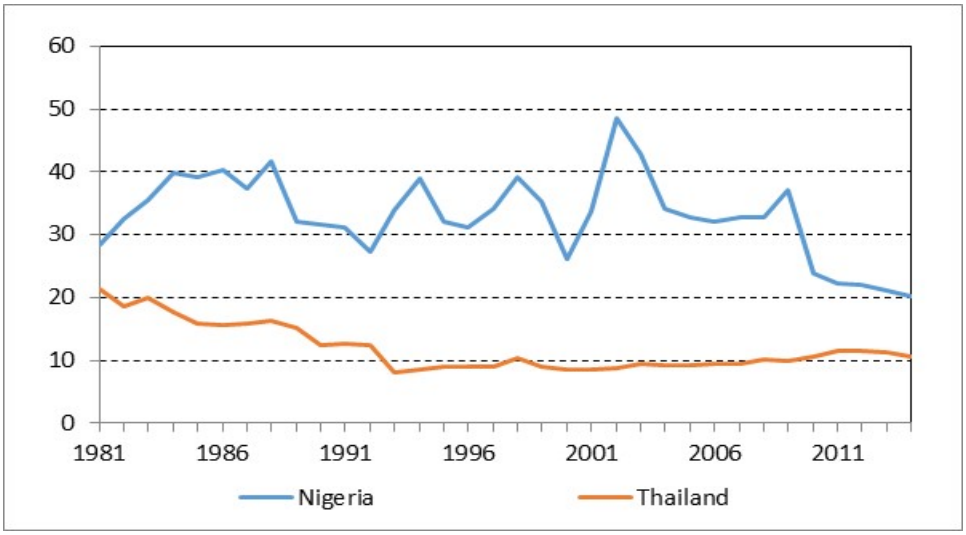
Source: Created by author based on World Bank (2016).

III.2. State of Agriculture in Nigeria and Thailand

To understand the implications of climate change on agriculture in two distinctly different environments, it is important to have some basic understanding of the agricultural sector in each country. The two most significant aspects in this respect are the share of agriculture in GDP and how technologically advanced agriculture is within a country. These factors demonstrate how economically impacted a nation will be by agricultural variation and how well equipped a country is to combat those variations.

Figure 4 exhibits what percent of each country's GDP can be attributed to agriculture. This information is important as it illustrates how a disturbance or change in production of agriculture would affect the economy of the country and to what extent. Historically, Nigeria has been much more economically agriculturally based. In 1985, agriculture as percentage of GDP was at about 39 percent and greatly fluctuated in the years following, until reaching a peak in 2002 at 48.5 percent. From then on, it has been on the relative decline and is now at its lowest percentage of 20.2 percent of GDP being attributed to the agricultural sector. In Thailand, agriculture as a percentage of GDP was at a rate of 15.8 percent in 1985 and maintained this value until 1990, when it began to decline. From 1990 to 2014 the percentage of Thailand's GDP attributed to agriculture fluctuated around 10 percent, ending in 2014 at about 10.5 percent. The significance of Nigeria's economy being more agriculturally-based than Thailand is that if something were to negatively affect agriculture within the country, it would have a much larger effect on Nigeria than on Thailand.

Figure 4: Agriculture Value Added (percent of GDP), 1985-2014



Source: Created by author based on World Bank (2016).

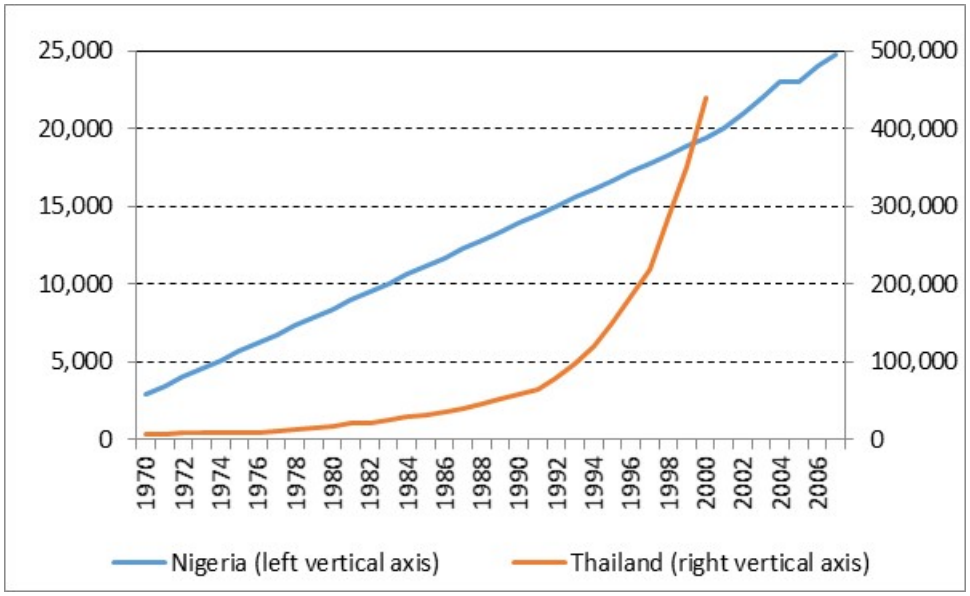
Even though Nigeria is one of the largest producers of rice in Africa, it is also one of the largest rice importers in the world. [3] Moreover, Nigeria is the largest producer of cassava in the world, grown predominantly by smallholders on small plots for local consumption.[4] In the case of Thailand, rice is the far most important crop for domestic production as well as for Thailand's agricultural exports. Thailand is the second largest exporter of rice in the world market.[5] In addition to being an important crop for both countries, rice is very dependent on water and is especially vulnerable to climate change, particularly changes in precipitation.

Technology has an enormous impact on the agricultural production levels of a country. The invention and increased distribution of modern agricultural machinery and technology has been the most significant factor in the continued growth of crop yields around the world. Technology also affects how well farmers can adapt to weather system disturbances and other difficulties associated with climate change.

As can be seen in Figure 5, the number of agricultural machinery has increased steadily in Nigeria, while it has increased exponentially in Thailand. [6] In 1970, Nigeria had 2,900 tractors, while Thailand had 7,000 tractors. Thirty years later, in year 2000, which is the last year such data is available for both countries, Thailand's number of tractors (which stood at 439,139) has been more than 20 times higher than in Nigeria (which had 19,400 tractors in 2000). This clearly shows that Thailand's farmers have more access to technology and are better assisted by machinery to produce crops quicker and easier. Nigeria does not have this luxury, and is therefore not as equipped to cope with climate disturbances as Thailand. Farmers in Nigeria will have to find alternative ways to sustain their current agricultural output.

[3] Food and Agricultural Organization (FAO) of the United Nations (2016).
[4] Food and Agricultural Organization (FAO) of the United Nations (2016).
[5] Ricepedia: The Online Authority on Rice (2012).
[6] According to the World Bank (2016), agricultural machinery refers to the number of wheel and crawler tractors (excluding garden tractors) in use in agriculture.

Figure 5: Numbers of Agricultural Machinery (all available years)



Source: Created by author based on World Bank (2016).

IV. Precipitation, Temperature, and Extreme Weather Events

Climate change is a complex and multifaceted issue that has an innumerable amount of effects on the world we live in today. This section explores the three most significant issues climate change inflicts on their environments for which some data is available for both Nigeria and Thailand: increases in precipitation variability, increases in temperature, and changes in extreme weather events.

IV.1. Increased Precipitation Variability

One of the most significant misconceptions about climate change around the globe is that its effect on the environment is uniform and not varied in nature. An example of this is the popular belief that "global warming" simply implies a broad increase in temperate, while it actual leads to increase in temperature variability as well.[7] This example is very similar to the concept of precipitation variability, increased changes in the nature of rainfall in an area. These changes include both increases and decreases in rainfall amount as well as the location and time of year during which precipitation is most common. This change in climate affects both Thailand and Nigeria, posing the most significant threat to the agricultural productivity of both nations.

In the simplest sense, increased precipitation variability constitutes changes in rainfall amounts or patterns of any kind. These changes in precipitation in Thailand can be seen in Table 1, which provides information on the variability of average amount of rainfall as well as the standard deviation of rainfall amounts. The comparisons made in Table 1 are between two collections of data: a baseline that includes values taken from data collected between 1985-2000, and a projection that includes data from 2010-2050, some of which is actual and some of which is predicted. It can be seen in Table 1, that while the percentage change in average annual rainfall remains relatively

[7] Vasseur et al. (2014).

the same at a 1 percent, the standard deviation in annual rainfall (which measures the variability of precipitation) has increased significantly with a change of 13 percent.

Table 1: Changes in Annual Rainfall in the Lower Mekong Basin

	Baseline 1985–2000	CC-B2 2010–2050	Changes	% Of change to baseline
Annual rainfall (mm)				
Average	1,619	1,642	23	1
Standard deviation	515	583	68	13
10 % Exceedance	1,082	995	−87	−8
90 % Exceedance	2,258	2,404	146	6

Source: Yamauchi (2014).

This increased variability has an enormous impact on the agriculture of Thailand. Changes in precipitation have a wide variety of repercussions on the weather and seasons, which cause issues for crops in terms of when to plant them, their growth, and their harvest. The most significant repercussion is the increased variability of the wet and dry seasons.[8] This variability includes both a change in precipitation rates as well as times in which precipitation occurs. Changes in the amount of precipitation in an area cause an increase in drought and flood occurrences, which inflict extensive damage to crops and greatly reduces production.[9] In the case of flood increases, crops will drown under inches of excessive and unpredictable rain. In the case of drought, which are projected to happen more frequently in the future, crops will dehydrate and die.

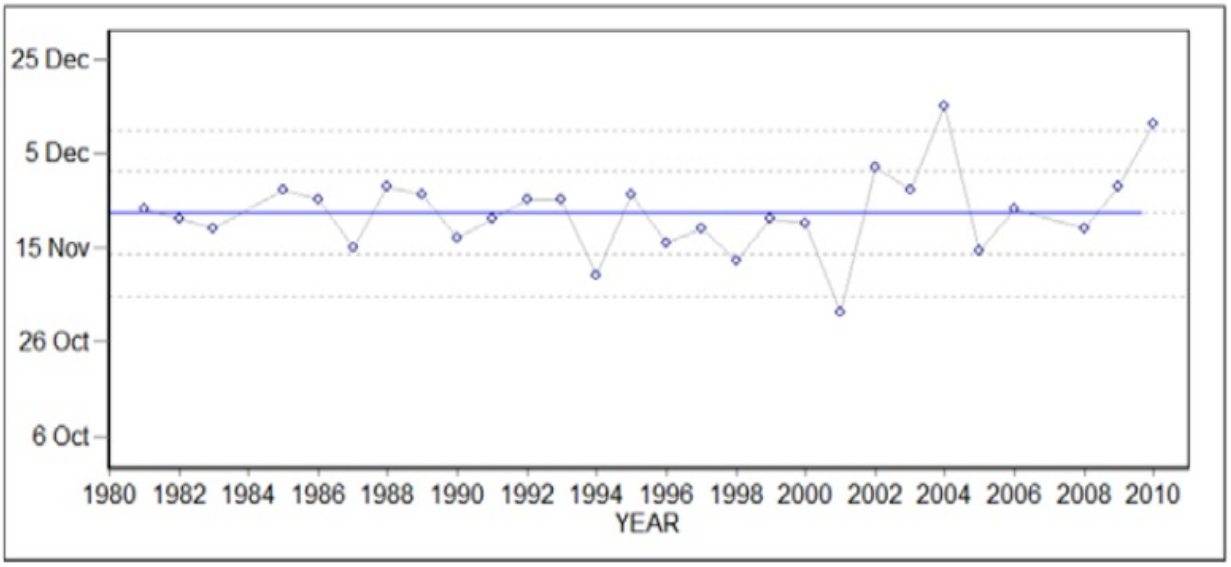
Furthermore, it is expected that there will be an increases in evapotranspiration rates.[10] Elevated rates of evapotranspiration can cause heat stress to plants and increase drought risk further, which will call for more use and development of irrigation pathways.[11] A shifting in the times at which precipitation will occur will move the start and end dates of the wet and dry seasons and causes changes to the planting cycle. However, due to the higher unpredictability of the seasons, farmers are uncertain about when to plant and transplant rice crops, a delicate process that is very dependent on the weather and precipitation rates.[12] If rice is planted too early, rain may not come in time and the plants will die; if rice is planted too late, crops may not have finished their growing season by the time the wet season is over. This has the potential to greatly decrease crop yield, threaten the country's food security, and hence cause damage to the economy of Thailand.

[8] Yamauchi (2014).
[9] Yamauchi (2014).
[10] Yamauchi (2014).
[11] Neo (2012).
[12] Yamauchi (2014).

Although rainfall is much less frequent in the tropical savanna and arid desert climates of Nigeria, the country still suffers from many of the same issues that inflict Thailand in relation to precipitation variability, in some senses to a greater extent. Nigeria is also experiencing changes in precipitation that are already leading to both increases and decreases in the amount of rainfall as well as shifting of the wet and dry seasons all together.[13] Increase in precipitation over a short period of time is arguably the most concerning change taking place as the soil in the area is not equip to deal with excess water so flooding occurs more easily. This flooding then leads to soil erosion and nutrient leaching, causing the land to become less arable and decreasing crop production in the short and long term.[14] Too little rainfall, of course, causes droughts that are expected to be more severe than in the past. This elevation of occurrence and intensity of droughts and flooding puts a strain on water resources and food security.

Changes in the onset and cessation of growing seasons are also very important for agricultural output in Nigeria. As can be seen in Figure 6, the variability in the onset of the growing seasons has been increasing in recent years; it actually more than doubled from the 1980s to the 2000s. As Figure 6 shows, it varied between November 15 to November 30 during 1980-1990, while it varied between October 28 to December 15 during 2000-2010.

Figure 6: Mean Onset (straight line) and Yearly Onset (dotted line) of Growing Seasons in Ibadan, Nigeria, 1980-2010



Source: Ufoegbune et al. (2016), Figure 3, p. 543.

These increases in variation cause many of the same problems seen in Thailand. Farmers cannot predict when to plant crops for optimal output and many plants end up dying due to droughts, which also have become less predictable and extremer. Nigeria is exceptionally affected by these changes as most of Nigeria's farmland has no irrigation system and is almost completely dependent on the weather to provide water to crops, as opposed to Thailand, which has heavily irrigated land

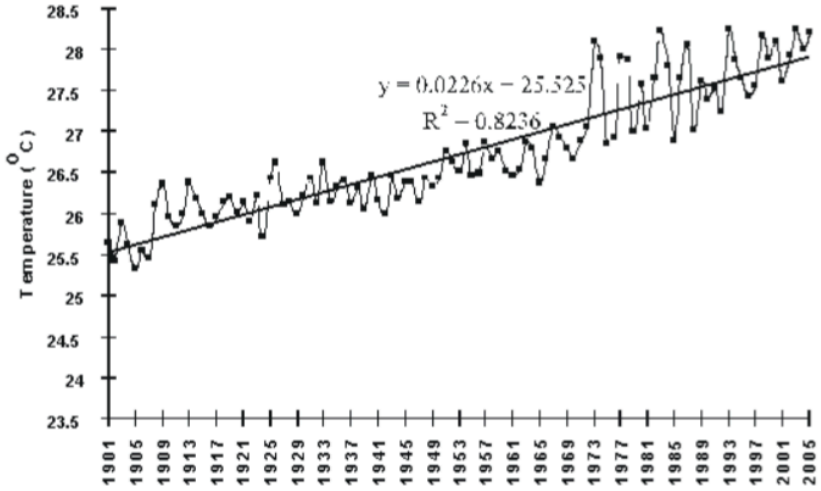
[13] Ufoegbune et al. (2016).
[14] Ayinde et al. (2011).

due to its extensive cultivation of rice.[15] Due to this fact, Nigeria will most likely take a larger hit in the agricultural sector in the long-run.

IV.2. Increases in Temperature

While it is true that temperatures are on the rise around the world, certain regions are experiencing temperature changes in a variation of ways, and how those changes affect an area are specific to the location. While the global mean temperature increase has been about 0.8° Celsius (1.4° Fahrenheit) between 1885 and 1994,[16] the average rise in temperature in Nigeria over the past 100 years has been about 1.1 °Celsius (C).[17] Figure 7 displays the average recorded air temperature in Nigeria per year and clearly illustrates that temperatures have been on the incline, at least since 1905. This incline was rather steady until about 1970, when it began to steepen at a previously unprecedented rate.

Figure 7: Air Temperature in Nigeria from 1901-2005



Source: Odjugo (2010).

The effects of these temperature increases on crops are extensive. The most obvious impact is heat stress and a lack of water that can cause plants to become dehydrated, as the environment is no longer suiting their temperature needs. Evapotranspiration also increases as temperature increases; extended periods of drought combined with higher than usual temperatures causes these increased rates.[18] These repercussions contribute to a decrease in crop yield and a threat to the food security of a nation that is experiencing hunger and starvation. Nigeria cannot afford these losses.

Thailand is also experiencing temperature increases above the global average. The mean minimum temperature in the country has increased by 0.8 °C and the mean maximum temperature has increased by about 1.2 °C. These escalations will not only continue, but at a higher rate than they

[15] World Bank (2016).
[16] Carlowicz (2010).
[17] Odjugo (2010).
[18] Yamauchi (2014).

have in the past. It is expected that by 2100, temperatures will have reached an increase of at least 2.5 °C, and up to 3.5° C in certain regions.[19] These changes will have similar effects as those expected and already observed in Nigeria. Heat will put stress on vulnerable rice plants, causing dehydration and death.[20] Evapotranspiration will increase greatly and the warm season will extend, causing crop cycling issues and less time in which to cultivate, grow, and harvest output. These factors will be limiting to production, especially the decrease in length of the planting season. This will have a significant economic impact on the whole country as rice is one of their largest exports, constituting nearly 10 percent of the country's GDP.[21]

IV.3. Changes in Extreme Weather Events

Ajetomobi (2016) examined changes in extreme weather, focusing on changes in extreme temperature and extreme rainfall. Concerning extreme temperature, Ajetomobi (2016) concludes that the average yields are negatively affected for cassava, cocoyam, cotton, millet rice, sorghum, yam and maize, while the impact on the yield of groundnut, cowpea and melon is positive. With regards to extreme rainfall, Ajetomobi comes to the conclusion that the average yields are negatively correlated for cassava, rice and sorghum, while the average yields are positively correlated for the other crops. However, in regards to the effects of total amount of rainfall over each crop growing season, the effect is negative for cotton and millet, insignificant for sorghum, yam, maize and melon, and positive for cassava, cocoyam, groundnut and rice.

Despite these mixed results on mean yields, Ajetomobi's results show that both temperature and precipitation extremes can result in wide fluctuations of Nigeria's crop production, which could make crop prices unstable, and hence, have a negative impact on Nigeria's agricultural sector as well as for food consumers. As reported by Akinboade (2012), the Director General of the Nigerian Meteorological Agency had identified extreme weather conditions as the reason for Nigeria's underdevelopment.

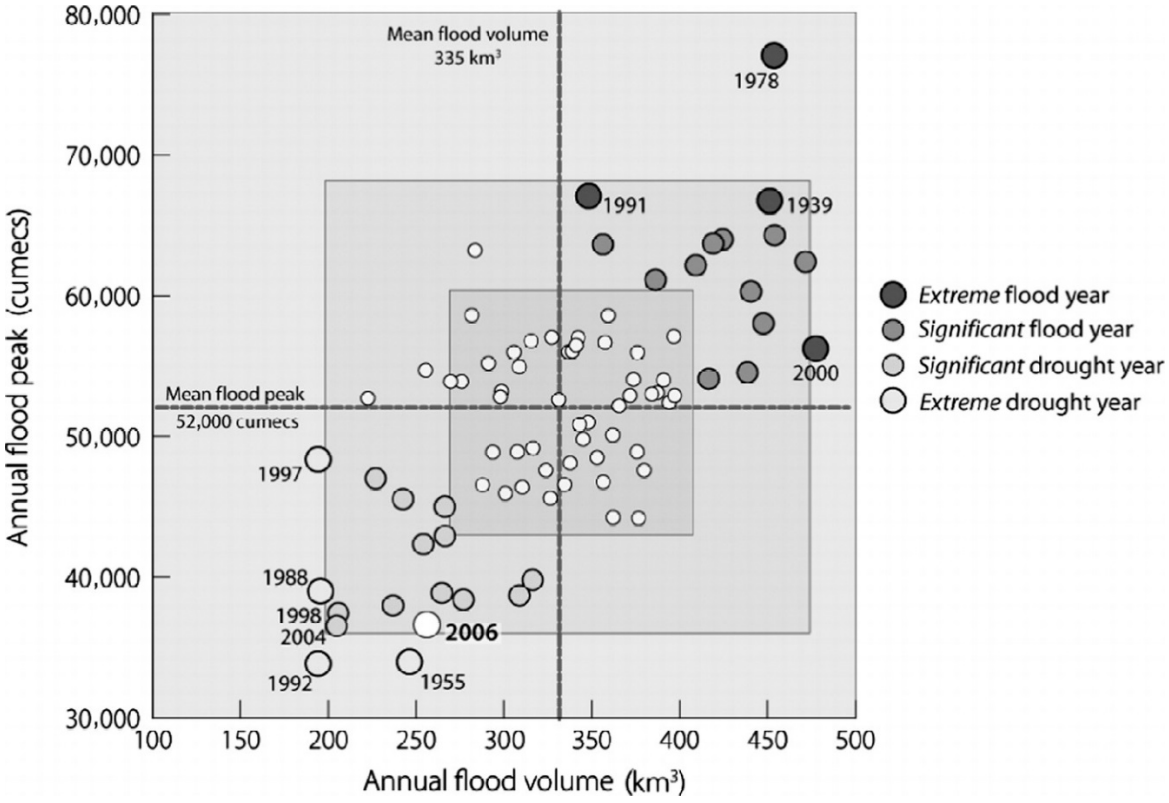
Given that Thailand experiences a monsoon season each year, Thailand is already prone to natural disasters.[22] Yet climate change is beginning to cause changes within these natural weather cycles that aggravate the negative impacts on the country. In the past, monsoons provided a consistent and controlled inundation, which is the basis of paddy rice production. Disturbances to this system could have significant unfavorable consequences on agricultural output as well as the general environment of the country.[23] In the last 25 years, Thailand has endured four of its most extreme flood events in history, occurring in 1992, 1997, 1998, and 2011. While floods are important to Thailand's agricultural cycle, the intensification of floods due to changes in monsoon patterns and severity are harming agricultural production.

In Figure 8, each box represents a standard deviation away from the historical mean annual flood volume; floods or droughts one standard deviation away are considered "significant" while those two standard deviations away are considered "extreme". The scatterplot shows that, with the exception of 1939 and 1955, all of the most extreme events are within the last 40 years. Most significantly, this graph does not include the massive floods of 2011, which were declared "the

[19] Neo (2012).
[20] Wassmann et al. (2009).
[21] World Bank (2016).
[22] Adamson and Bird (2010).
[23] Adamson and Bird (2010).

worst in history in terms of amount of water and people affected."[24] Climate change is also increasing instances of natural disasters such as typhoons, extreme tropical storms, and, as previously discussed, drought.[25] Winds, heavy rains, and erosion could destroy fields of agricultural land leading to extensive losses. Predictions have been made that by 2030, the occurrence of extreme weather events will have escalated by at least 5 percent.[26] Combined with rising sea levels that may cause mass inundation and salinity intrusion,[27] Thailand could be looking at significant losses in not only active crops but arable land.

Figure 8: Scatterplot of the Values of the Annual Flood Hydrograph, 1924-2006



Source: Adamson and Bird (2010).

V. Conclusion

As the human population continues to burgeon, efficient agricultural practices and maximum outputs become increasingly crucial. Yet, ironically, the same population so dependent on agriculture is causing the deterioration of the very system it requires so desperately. Human-induced climate change is leading to precipitation variability, increased temperatures, and elevated occurrences of natural disasters that are threatening global agricultural productivity, more specifically the food security and economic productivity of the countries of Thailand and Nigeria.

[24] News Wires.
[25] Adamson and Bird (2010).
[26] Neo (2012).
[27] Adamson and Bird (2010).

Due to the differing economic statuses, poverty levels, and technological advancements of the two countries explored in this article, it is expected that the effects of climate change on agriculture will affect the two nations to varying extents. Of the two, by general definition, Thailand is the more advanced country. It has a higher income per capita, lower infant mortality rate, longer life expectancy, and higher literacy rate than Nigeria; all indicative factors of the advancement level of a nation.[28] Due to its greater wealth and more educated and healthy population, Thailand will most likely be more capable of combatting climate change and alleviating its effects.

Nigeria, on the other hand, will bear the raw brunt of the effects climate change has on agriculture. With a large percentage of its population trapped in poverty and very little agricultural technology to employ, Nigeria has fewer options to contest its repercussions. These repercussions include reductions in food levels for the country's population and decreased economic activity as a decline in agricultural output could limit stocks of exportable goods. While the effects of climate change on Thailand may be objectively larger in absolute terms, Nigeria will hurt more in relative terms.

While the impact of climate change on agriculture is extensive and rapidly impending in Nigeria and Thailand, some adaptations are available to mitigate the negative effects in both nations. Nigeria can shift its planting cycles and use mixed cropping systems. Thailand can expand irrigation and diversify its crop selection. However, none of these options provide permanent solutions. The only complete and absolute solution to the problems explored in this article is addressing climate change as a whole. For this is not a matter that can be conquered from country to country or issue by issue. Climate change is a multifaceted and complex obstacle that must be undertaken in its entirety. Steps can be taken to delay the inevitable, or steps can be taken towards permanent solutions. For Nigeria and Thailand, as well as the rest of the world, the decision is theirs to make.

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