Climatic Suitability forCocoa Production in Nigeria

Abstract

Cocoa is one of the major cash crops that contribute more to the gross domestic product (GDP) of Nigeria and West Africa as a whole. Its contribution to the economic development of Africa and the world in general cannot be over emphasized. However, it has been discovered that cocoa is susceptible to changes in climatic parameters which has made it difficult to be grown in every part of the country, hence, the need to underscore the areas that are climatically suitable for the production of cocoa in Nigeria. This study was carried out to determine the climatic suitability pattern for the production of cocoa in Nigeria.A series of multi-year climate and crop yield simulations were performed for the present day (1976-2005), Mid-term (2021-2050) and long-term (2071-2100) under RCP 4.5 emission scenario using Fuzzy Logic Method (FLM) in ArcGIS (10.4.1). The results showed that some regions that are climatically suitable for cocoa production in the present day have not been explored. The regions with moderately suitability was projected to decrease the year 2050 while regions with marginally suitable, will increase by the year 2050. The remaining land that are notsuitable will also decrease by the year 2050. The very suitable region was projected to increase by the year 2050 and by 2100. Also, a land area suitable and moderately suitable for cocoa production was projected to increase in land mass by the year 2050 and 2100. However, the region with marginally suitabilitywill decrease by 2050 and year 2100. Meanwhile, the area that is not suitable by 2050 will increaseby the year 2100. Which means there is a decrease in climatic suitability of cocoa by 2100 as projected.
Keywords: Climatic parameters,suitability evaluation, cocoa production, climate change, Nigeria.

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1. Introduction

The second-most important agricultural export for Nigeria is cocoa. More than 80% of the cocoa grown in 14 of Nigeria's 36 states comes from the southwest geopolitical region. The primary causes of Nigerian farmers' inability to produce cocoa at the same level as their counterparts in Ghana and Côte d'Ivoire are aging plantations, varying worldwide prices, deteriorating soil fertility, and government support of crude oil extraction over agriculture (Alao, 1999). Crude oil

Comment [fl1]: The introduction is good and clear, however, the author has not elaborated on the climatic conditions in Nigeria that affect agricultural activities in general and the cocoa crop in particular. I think the climatic trends during the period from the success of the cocoa crop to its decline need to be elaborated in this section. Whether climate change trends influenced the government's decision to switch to oil would be interesting to explore.

has remained the major source of foreign exchange profits since the 1970s, while cocoa—a flexible, durable, and renewable source of income—has not yet regained its previous position.Regarding contributions to domestic output, employment, and foreign exchange profits in the 1960s, the agriculture sector was the most significant (Idowu et al., 2007) Three decades later, the situation remained largely unchanged, with the exception that oil now serves as the primary source of foreign exchange earnings instead of oil. Prior to the discovery of crude oil in Nigeria, the growth, development, and stability of the country's economy were significantly influenced by key agricultural goods from the South, West, and East, including cocoa, groundnuts, cotton, and rubber; and the South and North, which produced groundnuts and cocoa (Oyekale*et al.*, 2009). Nigeria had even previously ranked second in the world for both palm oil and cocoa production.

Cocoa was Nigeria's top foreign exchange export during this time. The agricultural sector's carelessness with regard to the exploration and exploitation of crude oil is what gave rise to the problem of unemployment. Prior to the 1960s, agriculture was the most significant economic sector, contributing more than 50% of the GDP and 75% of export revenues. Because agricultural development was neglected due to the petroleum industry's quick growth, the sector saw a relative fall in its production (Akinwumi, 2013).

The volume of agricultural output and income from cash crops have significantly decreased over time as a result of declining agricultural productivity brought on by Nigeria's oil discovery. Due to the neglect of non-oil crops like cocoa, cassava, and palm oil, among others, that made Nigeria great in the first Republic, Nigeria's dependence on oil is disastrous for the country's economic development (Akinwumi, 2013). Therefore, Nigeria transitioned from a state of self-sufficiency in basic consumables to one of substantial dependence on imports between the mid-1960s and the mid-1980s. Underinvestment, a gradual shift from rural to urban areas, rising consumer preferences for imported commodities (especially rice and wheat), and out-of-date farming practices have pushed the level of food production considerably below the rate of population expansion.

Between 1960 and 1970, the most significant agricultural export crop was cocoa, which greatly increased the nation's foreign exchange earnings. Prior to the 1970s, the government of Nigeria

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had a policy of little government intervention with regard to agricultural development in general and cocoa production in particular. In 1970–1971, the production grew gradually to 308,000 metric tons. The introduction of liberalization under the Structural Adjustment Programme (SAP) policy phase led to better farm gate cocoa prices and, in the short term, higher output. Additionally, Idowu et al. (2007) linked the 1986 launch of the SAP program to Nigeria's ongoing economic downturn and declining total cocoa output.Therefore, the aim of this study is to determine the climatic suitability pattern for cocoa production in Nigeria.

2. Materials and Methodology

2.1 Study area

This study was conducted in Nigeria located at 10^{o} North and 8^{o} East. The country has a land area of 98.3 million hectares, of which only 71.2 million hectares are cultivable (FMARD, 2001; NBS, 2007). Nigeria's climate varies from a very wet coastal region with more than 3500mm of annual rainfall to the Sahel region in the country's northwest and northeast, which receives less than 600mm. Interannual rainfall variability, especially in the north, is a major contributor to climate hazards, particularly droughts and floods, which have disastrous consequences on food production and are linked to other tragedies and sufferings. It is a common occurrence for some regions of Nigeria to receive less than 75% of their yearly rainfall, and this is especially concerning in the country's north. The year-round high temperatures in Nigeria are a defining feature. The dry season has so much effect on the cropsand this is particularly worrisome in the northern part of Nigeria. Nigeria is characterized by high temperature regimes throughout the year.

The highest temperatures occur during the dry season; rains moderate afternoon highs during the wet season. In the south, mean maximum temperatures range between 30 °C and 32 °C, while in the north, they are between 36 °C and 38 °C.The mean temperatures for the country are between 27°C and 29°C. Although average temperatures vary little from coastal areas to inland areas, inland areas, especially the northeast, have greater extremes, with temperatures reaching as high as 44 °C before the onset of the rains or dropping as low as 6 °C during an intrusion of cool air from the north from December to February. Already, average temperature increases of about

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0.2°C and 0.3°C have been observed within regions of the country, while drought persistence has characterized the Savanna region since 1960.

2.2 Data Sources

The data used for this study were sourced from the archive of the National Meteorological Agency (NIMET). The data for the study were national aggregates and climate variables (temperature and rainfall) obtained from secondary sources. International Institute of Tropical Agriculture (IITA), Ministry of Agriculture and Natural Resources, Cocoa Research Institute (CRIN), and the IPCC site

2.3 Data Analysis

Multi-Criteria analysis was adopted in producing an index evaluation of climatic suitability for cocoa production in Nigeria. To delineate the study area into zones of suitability potential, a raster geodatabase was created and organized in different data layers, which included an evaluation that focused mainly on the climatic variables of ensemble values. Each input map, with its specific weight and the inner score, was used to determine the suitability potential of every location within the study area by taking advantage of the spatial analysis function of the ArcGIS 10.4.1 Package. The grid raster data structure was adopted, and each raster cell value is a result of the score sum from the explanatory factors listed above. The Fuzzy Logic Method (FLM) was adopted to conceptualize the input layers. FLM requires that all input data be in grid (raster) format with cell values ranging from 0 to 1 depending on their association with the model; thus, the Fuzzy Membership Tool and Fuzzy Logic Combinational Operators were employed to standardize and integrate the members, respectively. In this case, the highest-rated suitability potential areas would be the locations where all explanatory factors have the highest score.

4. Results and Discussion

The map of current cocoa-producing areas in Nigeria is presented in Figure 1, while the maps for the climatic suitability for cocoa production in Nigeria in the present day, midterm, and long

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term are presented in Figures 2 to 4. Figure 2 indicates the climatic suitability map for cocoa production at present in Nigeria, that is, where cocoa could be grown presently apart from the present cocoa-producing areas according to cocoa climatic requirements for growth as determined by the ICCO (2008). The Fuzzy Logic Method (FLM) in ArcGIS (10.4.1) converted the climatic data for the Nigeria cocoa belt based on current suitability with the currently cocoa-producing areas. Table 1 shows a summary of the land areas that are climatically suitable for the production of cocoa in Nigeria at present, by the years 2050 and 2100. Out of the total land area of about 923,768 km^2 available in Nigeria, according to NBS (2011), 8.4% (77,596.51 km^2) of the land areas are very suitable for cocoa production, that is, the areas with rainfall between 1500 and 2000 mm, a maximum temperature between 30-32 ^oC, and a minimum temperature between 18 and 21 ^oC, according to ICCO (2013), while 21.2% (195,838.82 km^2) are suitable. Similarly, the area that is moderately suitable is about 29% (267,892.72 km^2) of the whole land area, while 4.3% (39,722.02 km^2) of the land areas are marginally suitable. The climate of the remaining 37.1% (342,717.93 km^2) is not suitable for cocoa production. This shows that there are some parts of the country that still have a high potential for cocoa production in terms of climatic suitability but have not been cultivated for cocoa production at the moment.

There was also an increase of about 20% in the projected land areas that are very suitable for cocoa production due to climate change and variability in the midterm, while there was a decrease in the areas that are suitable by the year 2050. Also, there was a projected decrease in the areas with moderate suitability of about 10.7% by the year 2050. For areas that are marginally suitable, an increase of about 15.8% was projected by the year 2050. The remaining land that is predicted not to be suitable, according to Table 1, will also decrease to 21.4% by the year 2050 due to a change in the climate. According to Laderach *et al.* (2011), the climatic suitability of cocoa for the west African rainforest belt where cocoa is being cultivated presently will not decrease as previously envisaged.

The study was also in contrast with Schroth *et al*. (2016), who predicted a possible decrease in the area suitable for cocoa production by 2050, mainly due to increased temperatures. Some parts of the north-western part of Nigeria are projected to be marginally suitable by the year 2050.

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The changes in climatic suitability are predicted to take place by the year 2100, as shown in Figure 4. The very suitable belt increased from 20% by the year 2050 to 26.2% by 2100. Also, a land area suitable and moderately suitable for cocoa production increased from 9.3% and 10.7% to 15.8% and 21.3%, respectively, in land mass by the year 2100. However, the marginally suitable landmass was reduced from 39.0% in 2050 to 15.3% by the year 2100. Meanwhile, the area that was not suitable in the midterm will be increased from 21.0% to 21.4% by the year 2100, which means there will be a decrease in the climatic suitability of cocoa by 2100, as predicted. This may be a result of decreasing rainfall, which may lead to an increase in the risk of drought to which cocoa is vulnerable (Anim-Kwapong and Frimpong, 2005). To continue producing cocoa, they have to depend on the widespread adoption of adaptation strategies (Schroth *et al*., 2016).

Conclusion

The climatic suitability evaluation for cocoa production in Nigeria was carried out during the course of this study. The results showed that the land areas that are very suitable for cocoa production will increase by 2050 and 2100, while the areas suitable for cocoa production will decrease by 2050 and increase by 2100. The areas that are not suitable will also decrease by the year 2050 and increase slightly by the year 2100. That is, the regions with moderate suitability were projected to decrease by 10.7% by the year 2050, while the regions with marginal suitability will have an increase of 15.8% by the year 2050. The remaining land that is predicted not to be suitable will also decrease to 21.4% by the year 2050 due to the change in the climate. The very suitable belt was projected to increase from 20% by the year 2050 to 26.2% by 2100. Also, a land area suitable and moderately suitable for cocoa production was projected to increase from 9.3% and 10.7% to 15.8% and 21.3%, respectively, in land mass by the year 2100. However, the marginally suitable landmass will be reduced from 39.0% in 2050 to 15.3% by the year 2100. Meanwhile, the area that was not suitable in the midterm will increase from 21.0% to 21.4% by the year 2100, which means there will be a decrease in the climatic suitability of cocoa by 2100, as projected. We recommend that this type of study be extended to other cash crops in the country so as to boost the GDP of Nigeria.

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Table 1: Summary of the Land Areas (Km^2) Climatically Suitable for Cocoa Production in Nigeria

S/No	Climatic suitability	Present day Suitability	Midterm Suitability (Bythe Year 2050)	Long-term Suitability (Bythe Year 2100)
1.	Very suitable	77,596.51	184,753.60	242,027.2
2.	Suitable	195,838.82	85,910.42	145,955.3
3.	Moderately	267,892.72	98,843.18	196,762.1
4.	Marginally	39,722.02	360,269.52	141,336.5
5.	Not Suitable	342,717.93	193,991.28	197,686.4

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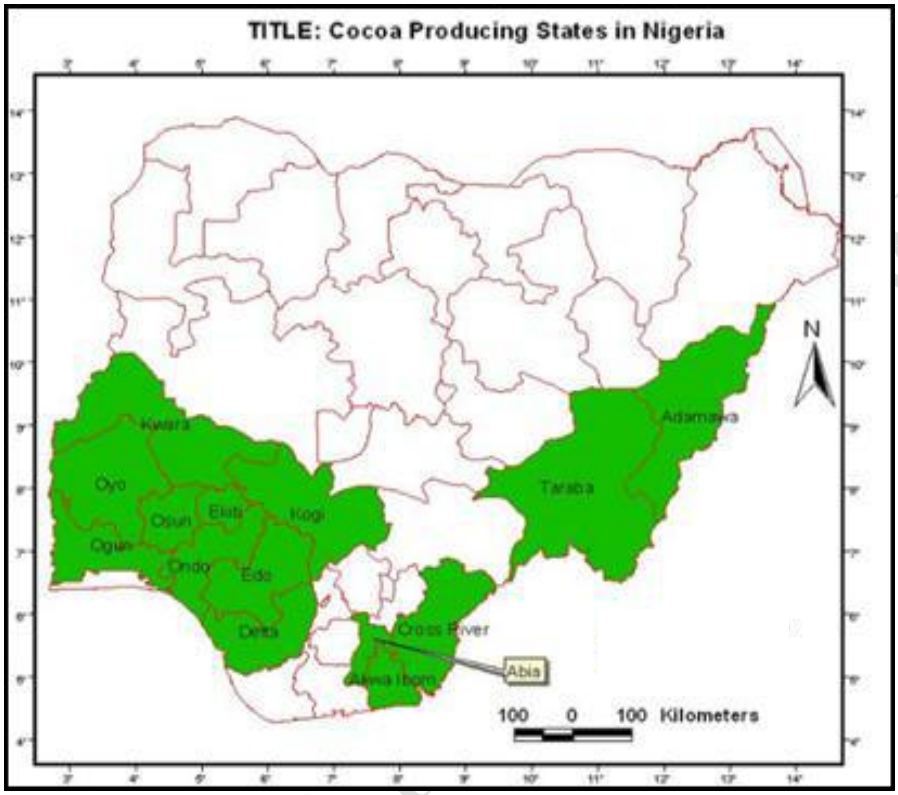

Figure 1: Map showing cocoa-producing States in Nigeria

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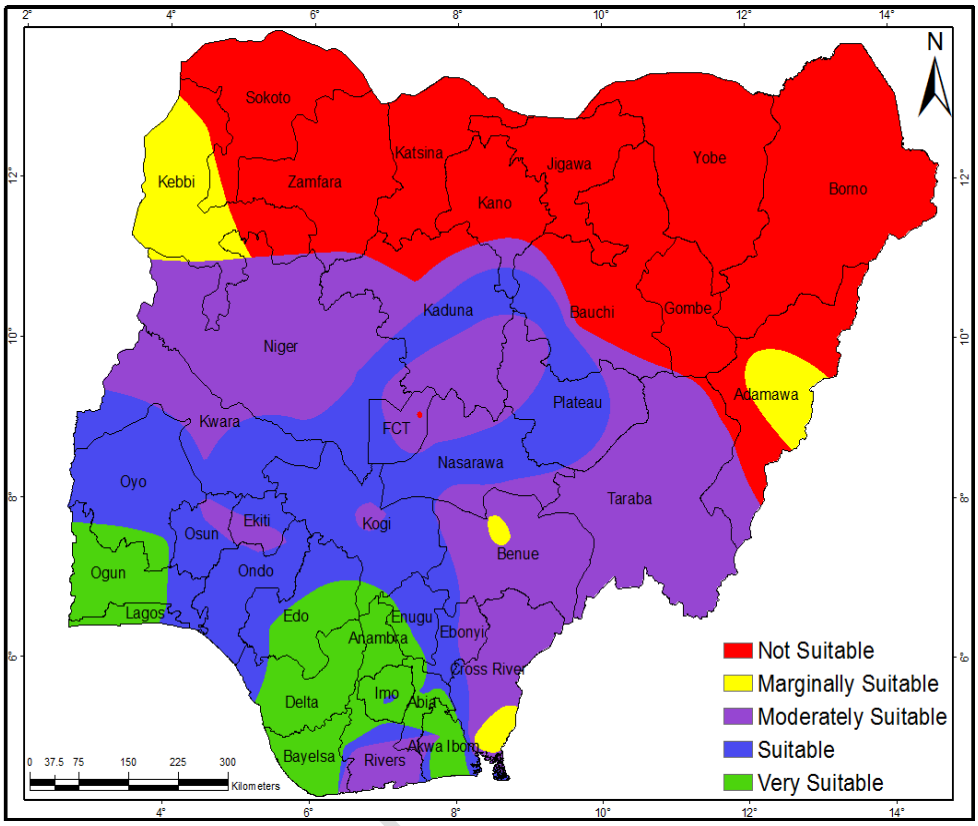

Figure 2: Map Showing the Present day climatic suitability for cocoa production in Nigeria

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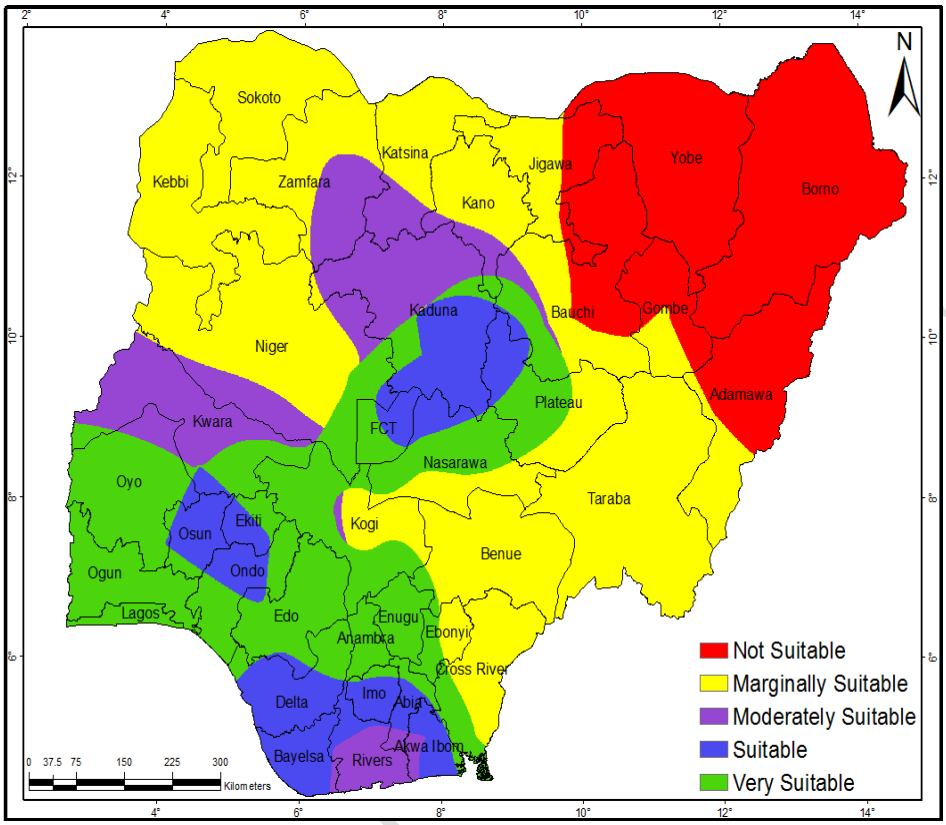

Figure 3: Map showing the climatic suitability for cocoa production in Nigeria by the year 2050

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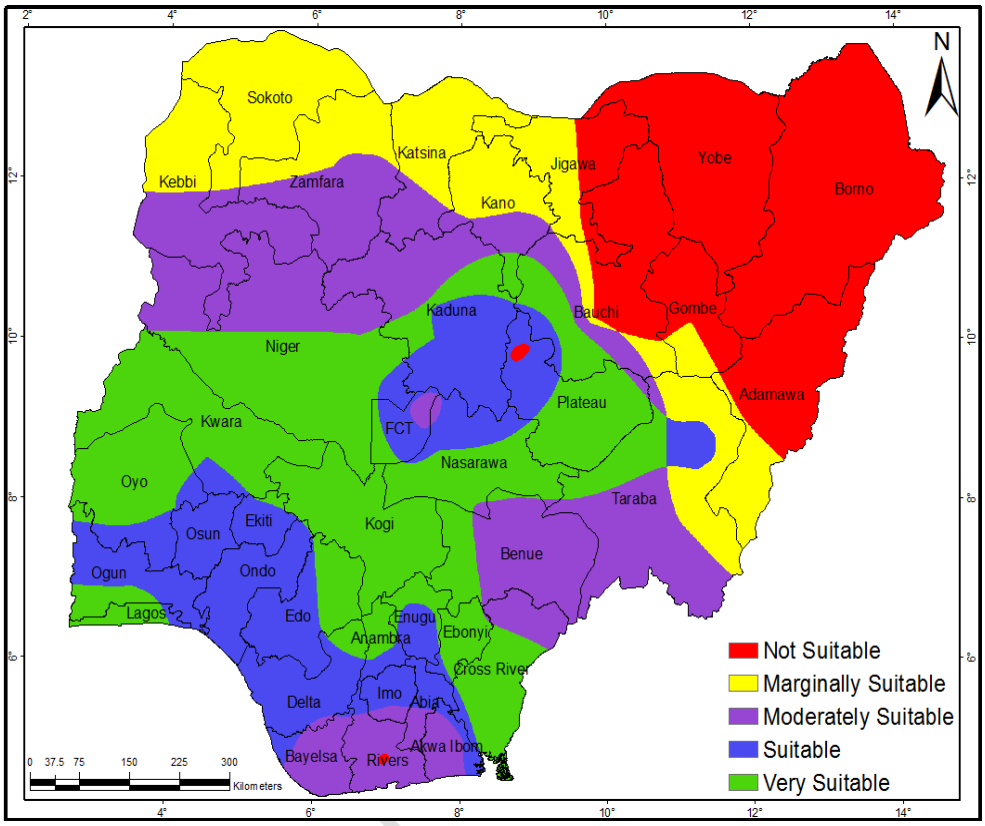

Figure 4: Map showing the climatic suitability for cocoa production in Nigeria by the year 2100

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