CLIMATIC SUITABILITY OF BAUCHI AND GOMBE STATES FOR SORGHUM AND COWPEA PRODUCTION, NIGERIA.

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Abstract.
This study assesses the climatic suitability of Bauchi and Gombe States for sorghum and cowpea production. Two sets of data, climatic and agricultural data, were collected from Bauchi State Agricultural Development Programme (BSADP) and Gombe State Agricultural Development Programme (GADP). The data were subjected to various agro-climatic and statistical analyses.
Agro-climatic analysis includes the computation of derived agro-climatic parameters such as: onset of rainy season, cessation of rainy season, length of rainy season and hydrologic ratio.
Step-wise regression analysis selected only one critical climatic variable influencing the yields of sorghum and cowpea in Bauchi and Gombe States. For sorghum, this is mean hydrologic ratio (R^2=29.74%), while for cowpea, we have mean annual relative humidity (R^2=17.91%).
Climatic suitability assessment of the study area was done by rating the data collection stations based on their scores on the critical variables identified by the step- wise regression. The results of the assessment were used to classify the study area into agro-climatic zones for sorghum and cowpea productions. Based on the climatic variable that is critical to sorghum and to cowpea yields as identified by the step-wise regression, the study area is delineated into three (highly suitable, suitable and marginally suitable) zones for the two crops.

Keywords: Climatic Suitability, sorghum, cowpea, yields. Step-wise regression

Introduction

Climatic suitability is used to produce Agro-Climatic Zones based on land suitability and productive potentials under specific uses (FAO, 1976). Agro-Climatic zones are zones which used to describe the production of agricultural activities based on their water requirements (Jackson, 1977). The reliability of rainfall amounts critical for the growth of specified crops over a given area must be assessed before such crops are introduced. Otherwise persistent crop failures arising from the unreliability of rainfall will make the cultivation of such crops uneconomic and may lead to famine and misery among peasant farmers.

Based on the above, Singh, et al (1997) summarized cowpea ecological zones in West Africa as follows: a primary production zone lying between 300mm and 1000mm annual rainfall; a secondary zone between 1000mm and 1,400mm rainfall and a tertiary zone above 1,400mm annual rainfall.

Adebayo (1997) did a similar study by zoning Adamawa State based on the agro-climatic classification for upland rice production. This involves two steps mainly: Climatic suitability assessment of the data collection stations and production of land suitability map for rice production.

The resulting map divides the state into three (3) zones such as (zone1) as being highly suitable for rice production; suitable zone (zone11) and marginally suitable zone (zone111).

Against this background, the specific objective of this study is to delineate Bauchi and Gombe States into proper agro-climatic zones for sorghum and cowpea production

The Study Area

Defunct Bauchi State (now Bauchi and Gombe states) is located between latitudes $9^0 30^1$ and $12^0 30$ north of the equator and longitudes $8^0 45^1$ and $11^0 50^1$ east of the Greenwich Meridian (expressed in Universal

Transverse Mercator (UTM)). It extends 330km long from North to South and 320km wide from East to West. It shares common boundaries with Jigawa and Yobe States to the North, Kano state to the North West, Kaduna State to the West, Plateau and Taraba States to the South and Adamawa and Borno states to the east (fig.1). The two states occupied a total land area of 66,510,045sqkm which represents about 7.2% of Nigeria's total land area (BSADP, 1983). It has a current population of about 6.8 million (census, 2006). The study areas have 31 Local Government Areas, 20 in Bauchi state and 11 in Gombe state.

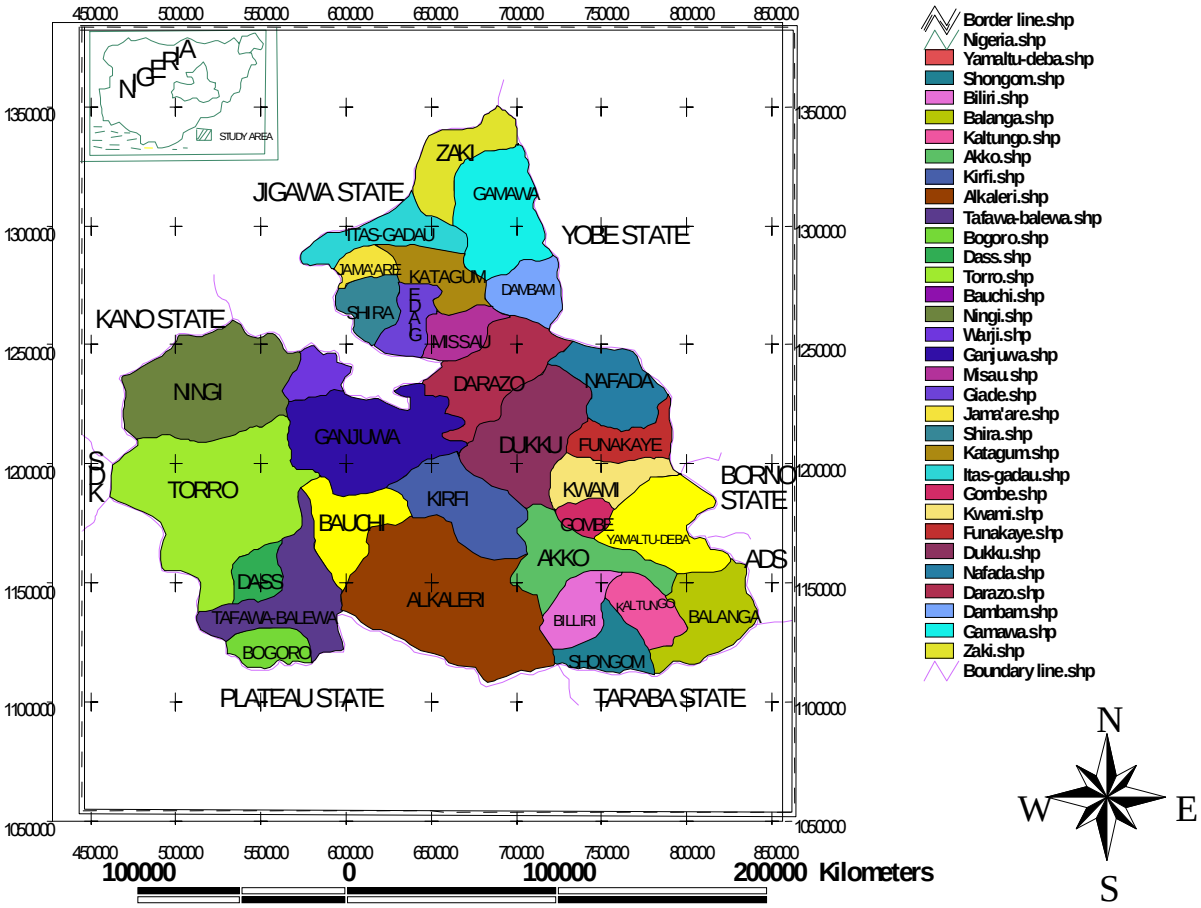

Fig.1: The Study Area

The study area has a mild climate with April as its hottest month (40^0 C) and January - February as its coldest months (11^0C), (Bauchi State, 1987). It has a mean annual maximum temperature of 32.4^0C and mean annual minimum temperature of 18.3^0C. Mean annual rainfall ranges from 700mm in the North to 1250mm to the South and South West.

The geology of the study area exerted an enormous influence on soil development. Half of the area that is underlain by the Kerri Kerri Formation has shallow to moderately shallow iron soils, with sandy loams on iron pan (Mustapha *et al*, 2002). On the Chad Formation in the north, the soils are sandy, and developed on clays and silty clays; but are mostly blanketed by sand dunes. Soils in the eastern part of Gombe State are shallow to deep loamy, sandy clay, loam and vertisols with cracks that have weathered from shales. They also observed that it is on these soil types that most of the grain cereals and legumes are grown.

The main stay of the economy of the study area is agriculture. Out of which about 80% of the total states populations derive their living from the land. Agriculture, directly and indirectly is the largest employer, the largest consumer of inputs as the largest contributor to inter state trade. The states rural population density of between 40 and 60 per square kilometer offer a very favorable man/ land ratio compared

with other states, and this permits the cultivation of cereals, and legumes in large quantities (Bauchi State, 2003).

Traditional manual mixed cropping predominates throughout the states with sorghum preponderant in the typical cropping mixtures. Sorghum, millet and cowpea are grown all over the state, while maize is grown mainly in Gombe, Bauchi, Dass and Tafawa Balewa Local Government Areas. Katagum, Jama'are, shira, Ningi and Gamawa Local Government Areas are noted for groundnut cultivation.

Cotton is mainly grown in Gombe, Kumo and Misau Local Government Areas. While Rice is cultivated in Udubo in Katagum and Dass Local Government Areas. These products provide raw material for agro-based industries like Tomato Company, cotton ginnery, and groundnut oil mill in the states.

Data and Methods

The data used for the study were archival data on rainfall (mm), temperature (oc), relative humidity (%), sunshine (Hrs) evaporation (mm/day) and crop yields (kg/ha). The data on crop yields were obtained from Bauchi State Agricultural Development Programme (BSADP) and Gombe State Agricultural Development Programme (GADP) for 26 years (1982 - 2007). Data on climatic variables were obtained from the Headquarters of the Bauchi State Agricultural Development Programme (BSADP) as well as the Gombe State Agricultural Development Programme (GADP) for the same period (1982 -2007) for 23 functional weather stations spread across the two states. The crops selected for the study were sorghum and cowpea.

From the climatic data collected, the following parameters were computed.

1. Onset of the rainy season (date(s))
2. End of the rainy season (date(s))
3. Length of the rainy season (days)
4. Hydrologic ratio.

The onset/end of the rainy season in the study area was computed from Walter's (1967) method. The method is expressed as:

$$\text{Onset/end} = \frac{DM\,(51 - A)}{TM}$$

Where DM, is the number of days in the month containing the date of onset/end; A, is the accumulated total rainfall of the previous months; TM, is the total rainfall for the month in which 51mm or more is reached; and 51mm, is the threshold of rainfall for both onset/end month.

The hydrologic ratio in the study area was computed from Adefolalu's (1988) method as: $R = \frac{P}{PE}$

Where P, is mean annual rainfall and PE, is the potential evaporation.

Step- wise regression analysis was used to identify the critical climatic variables influencing sorghum and cowpea yields in the study area. The agro-climatic zoning of the state for sorghum and cowpea production was done based on the climatic suitability assessment of the 23 Stations that was used in this study. The suitability assessment exercise was done in two stages. The first step involves the identification of the most important climatic factors influencing sorghum and cowpea yields using the technique of step –wise regression analysis. The second stage involves the quantitative rating and assessment of the stations to be used in this study for sorghum and cowpea production based on the rating scales devised in this study.

In devising the scales for scoring various parameters, emphasis was placed on the range of values obtained in this study. The rating procedure adopted was based on Clarke's principle (Clarke, 1951). This entails multiplying the score of selected parameters in each of the stations, to give station's suitability index for sorghum and cowpea production. By multiplying the score, the sorghum and cowpea production in each station will be limited to least favorable climatic parameters (i.e. the law of minimum). This is preferred to the additive method of computing indices which assumed the different parameters add together without interference (Gbadegesin and Nwagwu, 1990). Based on the range of values obtained in this study, the climatic suitability classes for sorghum and cowpea production in old

Bauchi State were determined to map the States into suitability zones for sorghum and cowpea production.

Results and Discussion

1. Agro-climatic classification of Bauchi and Gombe States for Sorghum Production.

The result of the step-wise regression analysis shows that only one of the nine observed and derived climatic variables contribute significantly to the yields of sorghum and cowpea in the study area. These are mean hydrologic ratio (X_4) and mean annual relative humidity (X_7) respectively. For sorghum this is mean hydrologic ratio (R^2=29.74%) while for cowpea, we have mean annual relative humidity (R^2=17.91%).

The agro-climatic classification of Bauchi and Gombe States for sorghum production involves two steps namely: climatic suitability assessment of the data collection stations and production of land suitability map for sorghum production. The only one climatic parameter which significantly contributed to the yield of sorghum as identified by the step-wise regression analysis was used in the assessment. This is mean hydrologic ratio (X_4).

The scale for scoring the parameter, based on the range of values obtained in this study is shown in Table 1. Three suitable classes were obtained and shown in Table 2. While Table 3 shows the computation of the suitability indices for the data collection stations used in the study.

The highly suitable zone (zone 1) covers about 20% of the study area's land area and found stretching from Torro to Tafawa-Balewa local government areas in the southern part of the study area. The suitable zone (zone 11) covers about 70% of the study area's land area and found in some parts of the western, central, eastern and northern areas of the study area. It includes Bauchi, Alkaleri, Dambam, Darazo, Dukku, Gamawa, Jama'are, Ganjuwa, Misau, Katagum and Zaki local government areas just to mention few. While the marginally suitable zone (zone 111) is found in the extreme north eastern part of the study area mainly around Nafada local government area. The three suitability zones (Fig. 2) conform to the pattern of the distribution of the climatic variable used for the classification.

Therefore, the suitability zones map shows the areas to effect a re-structuring of the land use for sorghum production in the study area for optimum yield. In the marginally suitable zone for sorghum production, the consequence is low yield. Therefore, it may be necessary to discourage large scale cultivation of sorghum.

Table 1: Graduated Scales for Scoring the Selected Climatic Parameter for Sorghum Production

Parameter	Range of values	Score
Hydrologic Ratio (X_4)	$\leq$0.20	1
	0.21-0.23	2
	0.24-0.26	3
	0.27-0.29	4
	$\geq$ 0.30	5

Table 2: Climatic Suitability Classes for Sorghum Production.

Suitability indices	Suitability class	Remarks
$\geq$ 5	I	Highly Suitable
2-4	II	Suitable
< 2	III	Marginally Suitable

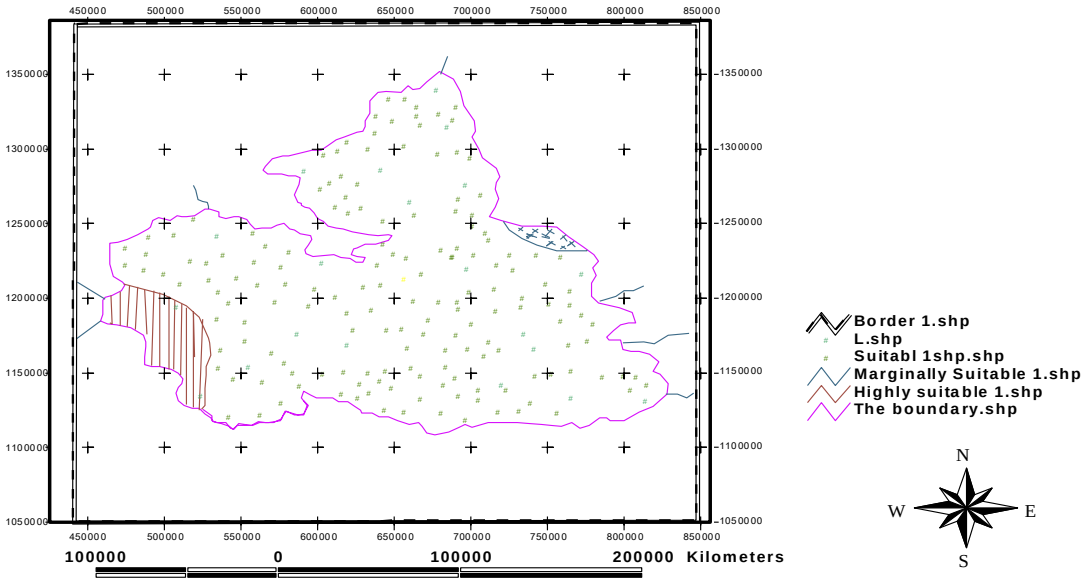

Fig.2: Agro-Climatic Classification of Bauchi and Gombe States for

Table 3: Computation of Climatic Suitability Index for Sorghum Production

Station	Total score or index	Suitability class
	X_4	
Alkaleri	3	II
Bajoga	2	II
Bauchi	4	II
Billiri	3	II
Dadin-Kowa	2	II
Dambam	3	II
Darazo	3	II
Dass	4	II
Dukku	2	II
Gamawa	3	II
Ganjuwa	3	II
Gombe	3	II
Jama'are	3	II
Kaltungo	3	II
Katagum	3	II
Kumo	3	II
Misau	3	II
Nafada	1	III
Ningi	4	II
Tafawa-Balewa	5	I
Tallasse	3	II
Torro	5	I
Zaki	3	II

2. Agro-Climatic Classification of Bauchi and Gombe States for Cowpea Production.

The only one climatic parameter which significantly contributed to the yield of cowpea as identified by the step-wise multiple regression analysis was used in the assessment. This is mean annual relative humidity (X_7).

The scale for scoring the parameter based on the range of values obtained in this study is shown in Table 4. Similarly, three suitable classes were obtained and shown in Table 5. While Table 6 shows the computation of the suitability index used in the study.

The suitability classes (Table 5) were used to divide the study area into agro-climatic suitability zones for cowpea production. The resulting map consisting of three zones is shown in Figure 3. The highly suitable zone (zone I) covers about 20% of the study area's land area is found in the eastern part of the study area. This includes Billiri, Kaltungo, Dadin-Kowa andTallasse (Balanga) local government areas. Suitability zone (zone II) covers 75% of the study area's land area. It includes Bajoga, , Dambam, Darazo, Dukku, Gamawa, Ganjuwa, Gombe, Jama'are, Katagum, Kumo, Misau, Ningi, Bauchi, Tafawa-Balewa, Dass and Torro local government areas just to mention few. The marginally suitable zone (zone III) is found in the extreme northern part of the study area and this include Zaki local government area.

Therefore, based on the agro-climatic classification of the study area for sorghum and cowpea productions, the suitable areas for the production of both sorghum and cowpea include Dass, Dambam, Darazo, Gamawa, Ganjuwa, Jama'are, Katagum, Misau, Bauchi, Alkaleri and Dukku local government areas. For these places, it will be necessary to increase the area put under sorghum and cowpea cultivation in order to take advantage of the optimum climatic conditions obtained in the areas mentioned in the study area above.

Table 4: Graduated Scale for Scoring the Selected Climatic Parameter for Cowpea Production

Parameter	Range of values	Score
Mean annual relative Humidity (%) (X_7)	$\leq$50	1
	51-53	2
	54-56	3
	57-59	4
	$\geq$60	5

Table 5: Climatic Suitability Classes for Cowpea Production.

Suitability indices	Suitability class	Remarks
$\geq$ 5	I	Highly Suitable
2-4	II	Suitable
< 2	III	Marginally Suitable

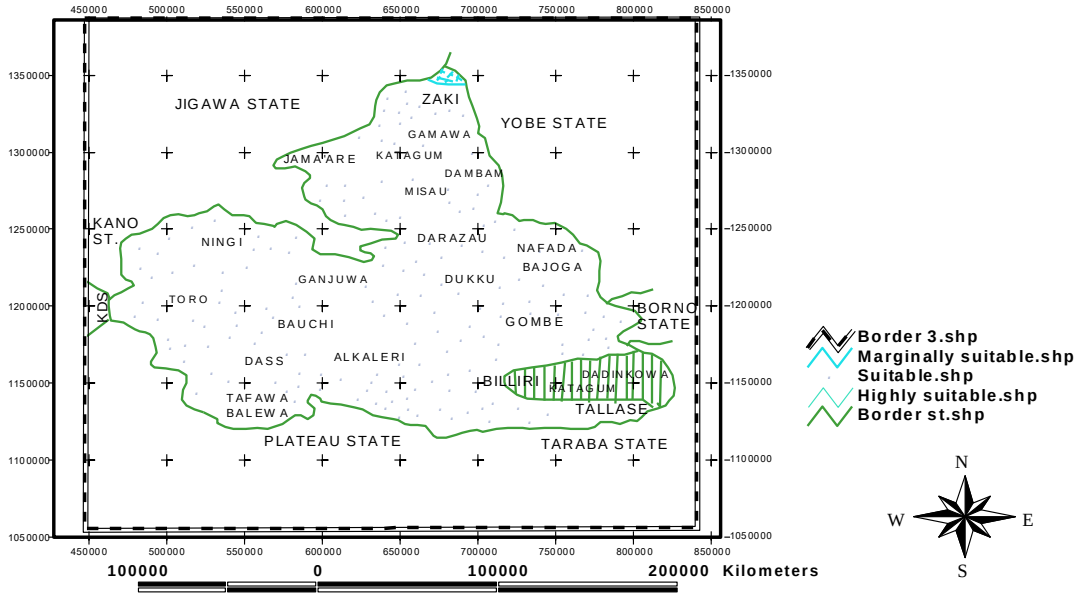

Fig. 3: Agro-Climatic Classification of Bauchi and Gombe States for

Table 6: Computation of Climatic Suitability Index for Cowpea Production

Station	Total score or index X_7	Suitability class
Alkaleri	2	II
Bajoga	2	II
Bauchi	2	II
Billiri	5	I
Dadin-Kowa	5	I
Dambam	2	II
Darazo	3	II
Dass	3	II
Dukku	2	II
Gamawa	2	II
Ganjuwa	2	II
Gombe	2	II
Jama'are	2	II
Kaltungo	5	I
Katagum	2	II
Kumo	4	II
Misau	2	II
Nafada	2	II
Ningi	3	II
Tafawa-Balewa	3	II
Tallasse	5	I
Torro	4	II
Zaki	1	III

Conclusion

From the climatic suitability assessment and zoning of the study area, places of optimum yield for sorghum and cowpea production were identified for restructuring of the present land use for sorghum and cowpea productions. The delineation of the study area into highly suitable, suitable and marginally suitable zones will assist the farmers to increase the land area for cultivation of sorghum and cowpea, as well as to avoid large scale farming of the crops in areas of marginally suitability. It is then expected that farmers, agricultural agencies and government will make use of these information, together with the advances in agricultural technology, to produce higher crop yields.

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