Adaptation to the Impact of Climatic Variations on Agriculture by Rural Farmers in North-Western Nigeria

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Abstract

The impact of climatic variations on crop yields and the adaptation by farmers in north-western Nigeria are examined using the modeling approach and farm surveys. Accordingly, regression models which relate climate data to crop yields were constructed. The results showed that rainfall has a positive relationship with crop yields in the region and explained over 70 percent of the variations in the yields of sorghum, millet and maize, all of which were significant at the 0.05 level. Evaporation also had a significant but inverse relationship with crop yields. Other climatic elements in the experiment provided minimal levels of explanation. The farm surveys found that rural farmers in north-western Nigeria were quite innovative when it comes to adapting to drought. The study concluded that the impact of climatic variations on crop yields in north-western Nigeria can be substantial especially under drought conditions. The need to update farmers' adaptive strategies is emphasized.

Keywords: Northern Nigeria, Climate change, Drought, Crop-climate models, Farm surveys, Adaptation strategies

1. Introduction

Farming in northern Nigeria is predominantly rural, with over 80 percent of the farmers practicing rain-fed, subsistence agriculture. These peasant farmers produce for subsistence rather than for sale. Thus the aim of food crop production is not to maximize profit but to feed one's family. In the process of meeting family nutritional needs, surplus agricultural products are however disposed in the local markets for money. Climate plays an important role in the agricultural productivity of many parts of northern Nigeria and, with very low level of technology and rigid adherence to traditional ways of farming, recent variations in the weather and climate of the region have taken severe toll on crop production. Indeed, crop production in many parts of northern Nigeria is frequently seen as a matter of lottery since rainfall varies substantially both in time and space, and the variability largely determines the yields and productivity of crops in the area.

Since the early 1970's, drought has affected many parts of northern Nigeria with agricultural outputs varying widely from year to year and from one location to the other. The constraints posed by climate change on agriculture in this region range from pronounced seasonality of rainfall (which confines cultivation to short periods of three to five months) to severe and recurrent droughts (which disrupt the usual pattern of seasonal water availability). Most of the droughts also exhibit such characteristics as false onset of the rains, late onset of the rains, pronounced breaks during the rainy season, and early cessation of the rains; leading to drastic alterations in the pattern of seasonal rainfall distribution (Adefolalu, 1986; Anyadike, 1993; Aondover et al., 1998; Ekpoh, 1999a; Dai et al., 2004; Anyanwole, 2007). These are very important climatic limitations placed on crop production in the region because it makes the correct timing of farm operations (which is crucial for obtaining optimum yields) difficult. As a result, there have been repeated crop failures and declining yields which have led to falling farm income and the associated problems of food shortage, malnutrition and general impoverishment of local inhabitants (Derrick, 1974; Mortimore, 1989, Ekpoh, 1999b; Mortimore and Adams, 2001). It is therefore important that the impact of drought on crop yields be examined, together with an evaluation of existing responses by farmers to drought, if future adjustment options must be of value (Kates, 1985; IPCC, 2001, 2007). As Riebsame (1988) observed, measuring individuals' perceptions and activities can provide insights into how people see and adjust to climate change and variability, and such user-information is relevant when communicating results of climate impact studies and projections of future climate changes to users.

2. Study Methods

The study methods adopted for this study were in two directions (Fig. 1). The first involved modeling the relationship between climatic variations and crop production. The second involved farm surveys to elucidate information from farmers on the adaptive or coping strategies to climate change. A combination of these methods provided information on both the sensitivity of crop yields to climatic variations, as well as, the coping strategies adopted by farmers in northern Nigeria.

2.1 Crop-Climate Modeling

The study adopted the modeling approach in examining the impact of climate variation on agricultural production. A model within the present context can be viewed as a system which receives and translates a set of input variables into a set of output variables through a number of processes. Crop-climate models may be considered as simplified representations of the complex relationships between climate and crop performance. In that sense, crop-climate models are the quantitative tools that can be used to translate a climatic perturbation into a tangible biophysical effect. Such models attempt to isolate and quantify the effects of the various factors that influence crop production and yield. Usually, the input variables in crop-climate models will include any combination of climatic controls such as rainfall, temperature, evaporation, radiation, humidity and wind speed. Other input variables can include the soil properties (such as the structure and texture) and various farm management practices (e.g. irrigation; application of fertilizers and pesticides). The output variables on the other hand usually include some measure of crop productivity, such as yield, biomass potential, and land suitability (Kates, 1985; Parry and Carter, 1988b).

In the present study, the regression model was used to assess the effects of climatic variations on crop yields in some parts of northern Nigeria. The crops selected for analysis were sorghum, millet and maize. The choice of these three crops was based on their importance both in the local diet and in their widespread cultivation throughout northern Nigeria. Three districts in northern Nigeria were also selected for the study and they include Kano, Katsina and Zaria. Their selection was based on the fact that they are found in a corridor the traverses the entire Sudano-Sahelian zone of northern Nigeria, a zone that frequently suffers from drought. By this unique study location, it should be possible to extend the findings of this study to other parts of northern Nigeria and indeed the larger West African Sahel.

Two sets of data were needed as inputs in the construction of the regression models. These were crop yield data (acting as the dependent variable) and climatic data (representing the independent variable) (Table 1). In all cases, the yields of sorghum, millet and maize were used in the models. However, climatic variables varied widely from model to model, and they include rainfall, evaporation, solar radiation, temperature, sunshine hours, and humidity. The relationships between the dependent variable and the independent variable were examined through equations of the form: $Y = a + bX + e$;

where Y = the dependent variable; a = intercept on y-axis; b = partial regression coefficient of the independent variables; X =the independent variable; e = the random error term representing the proportion of unexplained variation. On the whole, a total of eighteen separate models were constructed and the results are presented in Tables 2-4. It is instructive to note that the dependent variables were regressed singly on the independent variables, thus avoiding the problem of co-linearity, especially among solar radiation, temperature and sunshine hours.

2.2 Farm Surveys

To assist in gaining insight into the responses of farmers to a highly variable climatic environment, farm surveys were conducted in six major sites, two in each of the three selected study districts of Kano, Katsina and Zaria (Fig. 2). The criteria for site selection was based primarily on functional attributes, such as, a rural farming community that has experienced drought previously and co-operation of village heads and principal subjects to the study. It should be pointed out, however, that the surveys were not 'village studies' in the classic sense of comprehensive data collection on a multitude of all aspects of the rural economy. Such research has already been undertaken by teams and individuals from research institutes in northern Nigeria (Smith, 1955; Luning, 1967; Hill, 1972; Norman, 1972; Norman, Simmons and Hays, 1982; Watts, 1983; Iliya, 1988; Simmons and Hays, 1982;; Mortimore and Adams, 2001). The present survey was specifically concerned with the ways in which peasant farmers perceive drought and the measures adopted by them to combat drought (Oguntoyinbo and Richards, 1978; Apeldoorn, 1981; Mortimore, 1989; Mortimore and Adams, 2001).

The interview frames consisted of open-ended structured questions which represent a rough guide to the questions asked but are in no sense a standard and exhaustive list of the avenues investigated. The administration of the questionnaires was done with the help of field assistants who proved invaluable in view of the language and cultural barriers which confronted the researcher. The field assistants were particularly helpful with interpretation and procedures for obtaining permission from local authorities. The interviews were conducted at the convenience of the farmer both with respect to time and place of interview. This required a lot of patience on the part of the researcher and scheduled visits were frequently interrupted at the flimsiest excuse. Nevertheless, a total of two hundred and seventy farmers were successfully interviewed (out of the projected 300) during the period of survey which lasted for six weeks. The major concern of the survey was not with representative sampling, rather 'purposiveness' of sample formed the main object.

The questionnaires were administered to the respondents in a discursive manner rather than straightforward questioning. Information was obtained outside the arranged interviews, especially during casual discussions with groups of farmers in the field. This flexible approach became necessary in order to extract much information on farmers' responses to drought. By encouraging the farmer to talk at length, information emerged which was not readily remembered or deliberately omitted as a result of farmers' mistrust of the motives of the investigation. It was therefore necessary to stress regularly, the independence of investigation from government or its agencies. Most farmers traditionally associate rural or farm surveys with land prospecting for development which might entail loss of farmlands, or with tax assessments. They were particularly sensitive to questions regarding farm acreage, farm input or total output. Accordingly, some respondents were un-cooperative and had to be left out of the exercise. Few supplied information of doubtful authenticity (especially on crop production levels), and such information were discarded during the course of data processing. Nonetheless, the overall response was encouraging and a reasonable level of co-operation was maintained throughout the survey. The consistency and objectivity of information collected was considered adequate inspite of the difficulties associated with cultural and language barriers. The results of the survey are presented and discussed in sections 3.2 – 3.10.

3. Results and Discussion

3.1 Climate impact on crop yields

The main concern of all the eighteen regression models constructed for this study was with the role of weather and climate in determining the final grain yield of sorghum, millet and maize in the Kano region of northern Nigeria. From the results in Tables 1-3, it is evident that crop yields in the Sudan-Sahel zone of northern Nigeria are strongly and positively influenced by rainfall. This is seen from the coefficient of determination (R^2) value of 72.6 percent for sorghum, 71.2 percent for millet, and 77.8 percent for maize; all of which are significant at the 0.05 level of confidence. Yields also show a significant, but negative relationship with potential evaporation (PE), with very high coefficient of determination (R^2) of 76.5 percent for sorghum, 55.3 percent for millet, and 93.0 percent for maize, all of which have P-values of less than 0.05. The results also show a weak, insignificant relationship with temperature, radiation, sunshine hours and humidity. From these results it is apparent that simple linear regression between annual climatic data and crop yields can give fairly good results, especially in semi-arid regions. The regression models have provided what might be considered to be reasonable levels of explanation for crop yield variations in terms of goodness of fit and statistically significant coefficients for rainfall and evaporation. The results clearly show the dominance of rainfall and evaporation as major climatic parameters affecting crop yields in the study region. This is so because soil moisture, which is often regarded as the single most important parameter in determining crop yields in semi-arid environments, can be coarsely derived from a relationship between rainfall and evaporation (Baier, 1977; Kowal and Kassam, 1978). However, this observation does not exclude the usefulness of other elements especially sunshine and humidity which are critical in photosynthesis. Temperature, of course, is quite useful during germination, maturity and harvesting. These findings are not altogether surprising as earlier studies have shown that crop yields are very sensitive to rainfall in northern Nigeria due to the erratic nature of rainfall amounts and distribution (Kowal and Kanabe, 1972; Peacock and Heinrich, 1984; Ekpoh, 1999b). In view of the serious relationship between climate and crop yields in the study region and the probability of more uncertain weather and climate, it is important that farmers adapt appropriately to existing environmental conditions. Sections 3.2 to 3.10 explore the responses of farmers in this region to climatic variations.

3.2 Main cause of poor yields

On the question of what was responsible for poor yields, all the respondents in Katsina district said drought. Majority of the respondents in Kano similarly attributed the main cause of poor yields to drought. Only 10% of the respondents thought it was poor soils. In Zaria, 63.3% of the respondents said poor yields were caused by drought; 33.3% said poor soils and only 3.3% mentioned pest and diseases. It is of great significance that farmers in northern Nigerian have a clear perception as to the major cause of poor yields. Mortimore (1989) has observed that expectation of rainfall, although not stated quantitatively in terms of the ‘normal’, nevertheless guide decisions made by indigenous land users.

3.3 Yield trend since 1969

On the question of yield trend since 1969, all the respondents in Katsina said the situation has been worsening compared with production levels before 1969. The declining yields were blamed on the uncertain rainfall pattern since the Sahelian drought of the 1970s. Loss of seeds due to droughts and out migration was some of the factors mentioned for the overall decreases in levels of production in spite of moderate rainfalls in some years. In Kano, 83.3% of the respondents said the trend was getting worse, 13.3% said they could hardly indicate any difference and 3.3% said there were signs of improvement. In Zaria, however, 43.3% of the respondents said there were improvements compared to late 1960s and early 1970s; 30% of the respondents said the situation was virtually the same; and, 26.7% said the trend was getting worse.

3.4 Satisfaction with current production levels

Asked if they were satisfied with their current levels of production; all the respondents in Katsina said no. Many of the respondents complained that they were not satisfied because what they were producing at present was often insufficient for the year-round family consumption, not to mention surplus for storage and sale. A large number of respondents in Kano (i.e. 96.7%) also said no, while 3.3% said yes. In Zaria, 43.3% of the respondents said they were satisfied, while 56.7% said they were not satisfied.

3.5 Start of the rainy season

Respondents in Katsina and Kano districts were less specific on the start of the rainy season than their counterparts in Zaria district. In the Katsina district, only 3.3% of the respondents said the onset of the rainy season normally commenced towards the end of May, 20% said early June, 50% said middle June and 26.7%

said end of June. In Kano, 30% of the respondents said middle of May, 40% said end of May, 23.3% said early June, while only 6.7% said mid-June. But in Zaria, majority of the respondents said they normally expect rain to start by mid-May. Only 3.3% said early May and 10% said end of May. The wide variations in the perceived date of commencement of the rainy season in Katsina and Kano districts could probably be attributed to the high degree of variability associated with the rainfall regime of these areas. It should be pointed also that Zaria is located in a more favourable southern section of northern Nigeria and therefore less vulnerable to fluctuating rainfall regime since rainfall in Nigeria decreases from the south to the north. In contrast, Katsina and Kano lie within the Nigerian Sahel proper, with more problematic rainfall regimes.

3.6 Pre-season moisture estimation

On the issue of being able to tell (at the beginning of the season) if a season would receive adequate rainfall, majority of the respondents in Katsina, Kano and Zaria districts said it was virtually impossible for any farmer to make that prediction or forecast in advance. However, some were of the opinion that if the rains started early, then it was likely the season would receive adequate rainfall. Similarly, they associated delayed rainfall with poor prospects of receiving adequate seasonal moisture. The respondents in Zaria district claimed that the seasonal rainfall in Zaria is normally adequate for cultivation except during severe drought conditions, such as those that occurred in 1973, 1983 and 1993. In general, only 3.3% and 6.7% of the respondents in Katsina and Kano respectively thought it was possible to predict the pre-season moisture regime.

3.7 Sowing time

Asked when they normally start sowing, majority of the respondents in Kano and Katsina said they usually sow after the first rains. Some of the respondents pointed out that seeds would be burnt inside the soil if sowing was done before the first rains, which would result in loss of seeds and possible recourse to replanting. Most of the respondents also claimed to use additional criteria by digging the ground to ascertain if the first rains had soaked the soil sufficiently. By sufficiently, they meant a soil moisture depth of the length from the finger tip to the wrist (approximately 20-22cm). However, 10% of the respondents in Kano said they normally sow shortly before the start of rains, and they admitted to the high risk of premature germination or complete ‘seed frying’ associated with the practice, if there is delayed onset of the rains. This group of respondents pointed out that the main advantage of sowing before the start of rains was the cheap labour available at that time. In Zaria district, opinion on sowing time was divided with about 60% of the respondents saying that they often sow after the first rains; while the remaining 40% said they normally sow two weeks before the start of the rainy season.

3.8 Cropping pattern during drought year

This was a multi-dimensional question on measures of farm-level adjustments to drought. Asked about their cropping mixtures during drought, the majority of respondents in Katsina and Kano said they usually substitute early millet in place of sorghum, late millet and maize. Some of the respondents said they also plant cassava and quick-maturing cowpea in the fadamas (wetlands). None of the respondents in Katsina claimed to have maintained normal cropping mixtures during drought but 16.7% said they do so in Kano district. In Zaria, the response was again split between those that usually substitute early millet and those that claimed to maintain the usual mixtures. About 47 percent of the respondents said they normally increase the cultivation of early millet and quick-maturing cowpea, but decrease those of maize and sorghum, while the remaining 53 percent of the respondents said they maintain their usual cropping mixtures.

Areas cultivated during drought were reduced in Katsina and Kano. Respondents in Katsina and Kano said the decrease was often due to lack of seeds and labour. They claimed that most of the young men migrate to the cities in drought years leaving farm work to their parents. This led to a decline in “area cultivated” since elderly persons can only do very little. In Zaria, the area cultivated remained unchanged during drought. The use of animal manure and household refuse also declined in Katsina and Kano but was not affected in Zaria. Respondents in Katsina and Kano said experience showed that crops on fertilized and manured field withered earlier during drought. Mortimore (1989) has also noted that yields are lower in a dry year on manured than unmanured land. Moreover, the reduced number of herbs in drought years implies that little animal manure is produced. Means of transporting household refuse to the fields are also seriously affected because most of the donkeys die as a result of drought. Hired labour similarly declined in Katsina and Kano since seeds and cash are normally scarce, coupled with decreased area of cultivation. From the foregoing, it is clear that normal farming activities are often disrupted drastically during drought years in Katsina and Kano districts, but only slightly affected in Zaria district.

3.9 Alternative sources of water supply

On the question of remedial measures if the growing season did not receive adequate rainfall, majority of the respondents in Katsina and Kano said they were completely helpless with no alternatives. Few respondents said they could get water from nearby wells and earth-dams to water their crops for up to two weeks. However, they pointed out that availability of water in the earth-dams depended on sufficient rain falling at the beginning of the season; otherwise the little water collected may be lost completely through seepage and intense evaporation. Few respondents maintained that their crops would perish completely (as was the case during the 1972/73, 1983/84 and 1993/94 droughts) due to lack of alternative sources of water supply. The water supply situation in Katsina and Kano districts is made more precarious by the general lack of surface streams, since a greater part of these regions occupy watershed areas. In Zaria, however, some of the respondents said they could channel water from nearby streams to their farms. The tributaries of River Kaduna drain most of these southern areas.

3.10 Future prospects for coping with drought

Asked how they would cope with future droughts, the reply in all the three districts was that government should provide them with money to buy more seeds so as to increase production in good rainfall years. One hundred percent each in both Katsina and Kano, and 93.3 percent in Zaria said they will welcome a loan from the government so that they could buy more seeds. Only 6.7 percent in Zaria suggested self-help through community co-operatives. Many of the respondents claimed that they lost much of their seed stock during the drought years of the early 1970s, 1980 and early 1990s and has not recovered fully since then. James (1973) had earlier observed that following the drought in 1972, many farmers in Katsina ate their seed reserves long before the start of the 1973 planting season. Together with abortive replantings, Apeldoorn (1981) also observed that the majority of the poor farmers find it extra difficult to regain their former positions due to problems of recurrent drought.

In the past, the Nigerian government had attempted to assist the rural farmers by establishing agricultural and co-operative banks, with the sole responsibility of granting low-interest loans to farmers. However, the question of collateral had often derailed such programmes as rural farmers could hardly afford the exorbitant collaterals requested by the banks. Moreover, lessons from the past also indicate that whenever money is set aside to improve agricultural production, wealthy rural leaders such as traditional chiefs, landlords, traders, money lenders and absentee businessmen usually hijack such monies and divert them to other purposes (Brown, 1991; Floyd and Ekpoh, 2005). In 2009, the Central Bank of Nigeria (CBN) in collaboration with the Federal Ministry of Agriculture and Water Resources came out with a 200 Billion Naira credit facility, which was to be disbursed to farmers under the Commercial Agricultural Credit Scheme (CACS). So far, neither the commercial farmers nor their rural counterparts seem to have accessed the facility due to the difficult legibility requirements. Already there are speculations that the money might be hijacked by politicians and diverted to others uses, as used to be in the past. However, with such monitoring and policing agencies as the Due Process Office (DPO), the Independent Corrupt Practices Commission (ICPC), and the Economic and Financial Crimes Commission (EFCC) in existence, it cannot be ‘business-as-usual’. These bodies, together with civil society groups, have become watch-dogs that have helped to instill discipline in the disbursement of public funds in Nigeria. Hopefully, the corruption and squandering of resources which used to characterize the disbursement of agricultural loans in the past will be eliminated.

The respondents in Katsina and Kano said that government should open more boreholes in their villages and provide earth-dams near the farms. Those in Zaria emphasized the need for modern storage facilities which could help in the preservation of surplus grains during years with good harvest. The stored grains, they claimed, could serve as buffer stocks against famine in drought years. In all the districts, the respondents complained about the inadequacies of their existing storage mills, made primarily with mud and grass. These materials, they claimed, allow easy access to the grains by rats, birds and weevils. Moreover, the local storage mills suffer from frequent dampness at night, which may contribute to rapid deterioration of grain quality.

In Katsina, the respondents also complained of poor roads which they said made it difficult for the agricultural extension officers to visit their communities regularly. They wanted the government to construct good roads to link their villages with the local government headquarters so that more frequent visit from agricultural extension officers can be facilitated. Such visit, they claimed, would provide them with new knowledge on how to combat drought and can also provide warnings on impending drought.

4. Conclusion and Recommendations

From the modeling experiment, this study concludes that climatic variations especially in the form of erratic and inadequate rainfall, significantly affects the yields of crops in north-western Nigeria. Rainfall explains over 70 percent of variations in crop yields in the study area. It is equally evident from the responses obtained during field survey that farmers in northern Nigeria (especially those in Katsina and Kano districts with more northerly locations) appreciate the phenomenon of drought and have taken a number of measures to adapt their farming practices to drought. Prominent among the measures is the practice of preferring to cultivate short-season millet during drought year rather than maintaining the usual cropping mixtures of maize/sorghum/cowpea/millet/beans. This is a key adaptation strategy that offers great promise for successful cultivation under drought situations. Mortimore (1989) also noted that the abandonment of guinea-corn (sorghum), if the season is expected to be too short, is an important adaptation. With effective communication of research results to farmers by agricultural extension workers, selecting appropriate crop mixtures during drought episodes can prove to be an important adaptive strategy.

Another important measure of adjustment which some of the farmers have already adopted is the practice of mulching. The survey, however, revealed that only a few farmers were at present aware of this measure. This is a measure that should be encouraged and improved methods of mulching introduced. The dissemination of information on mulching to the rural farmers should not be a serious problem since the Nigerian government has already established the integrated Agricultural Development Projects (ADPs) in all the 'nooks and crannies' of the country. Under the ADPs, agro-service centres are located throughout Nigeria in such a way that farmers do not have to travel more than ten kilometers to reach a centre. The extension strategy of the ADPs is supposedly based on the diffusion of innovation model, with receptive 'progressive' farmers being instructed in new techniques. The intention being that they will then provide a demonstration effect for other traditional farmers living around them.

The practice of digging the ground at the start of rains to ascertain the depth of soil moisture is also very useful as it could limit the incidence of premature sowing due to false rainfall onset, and the consequent loss of seeds. This measure should be encouraged so that more farmers could use it to avoid unnecessary waste of seeds through replantings. However, the subsisting method of soil moisture determination is crude and unreliable and should be improved upon through agricultural extension education.

Majority of the farmers were conscious of the crucial role that supplementary irrigation can play in their cultivation during drought periods, as revealed by the overwhelming desire by them for the government to provide earth-dams and boreholes in their farms and villages. This is particularly true for Katsina and Kano districts. However, a great majority of them have never used this measure to combat drought because providing earth-dams or boreholes close to their farms was beyond their means. Such tasks can only be executed by wealthy urban-based farmers or through communal self-help project or by government. Unfortunately, the well-off farmers in the communities are often not prepared to share their wealth with the less privileged. As some respondents pointed out during the survey, "this is an era when people are obsessed with the acquisition of private material objects, to the extent of turning blind-eye to the plight of other members of the community". This same sentiment had earlier been expressed by Sutherland (1985) who noted that the intrusion of capitalist relations of production during Nigeria's colonial era destroyed the bases of co-operative organization, and individual households face crises in isolation. Under these circumstances it can only be hoped that individuals and groups will find it essential to foster co-operation so that they can find solutions to their problems, especially in the provision of earth-dams, since government cannot be expected to do everything.

To further assist the farmers in procuring improved seed varieties that are drought tolerant or drought escape (i.e. quick ripening seeds), government should encourage the policy of smallholder credit scheme by banks so that individual small farmers and farmers' co-operative societies can access credit with little or no collaterals. This has been done before in the late 1970s up to the early 1990s, but was hijacked by urban-based contractors and government officials who disguised as rural farmers or used proxy surrogates to access the loans, at the detriment of genuine rural farmers. In an article titled "A farm finance revolution", Brown (1991) observed that, with a population of 100 million consuming too much imported food, Nigeria had little option but to offer its small farmers virtually interest-free loans that did not require collateral, although a credit ceiling of five hundred Naira (N500) per farmer was rather insignificant for any meaningful production expansion, not to mention supplementary irrigation for combating drought. This time around, the credit ceiling should be properly evaluated to ensure that it would make significant impact on farmers' production. The question of collateral should be properly addressed so as not to scare away potential beneficiaries as the 2009 credit facility of 200 Billion Naira seem to suggest.

Finally, research into the causes of drought, its impacts, and possible options for mitigating the effects of drought should be intensified. The agricultural research institutes and faculties of agriculture in Universities should experiment on crops that will take advantage of new environmental conditions created by climate change in semi-arid parts of northern Nigeria. In this regard, the activities of such establishments as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Kano Sahel Center, the Semi-Arid Food Grain Research and Development (SAFGRAD), and Comite permanent Inter-Etats de lute centre la secheresse le Sahel (CILSS) readily come to mind. With the Agricultural Development Projects (ADPs) firmly established in every part of Nigeria, the task of disseminating research findings to local farmers would be relatively easy. Inspite of the fact that the semi-arid parts of northern Nigeria are traditionally marginal areas and therefore vulnerable to climatic variations, every effort should be made by all stake-holders to ensure that farmers in these parts continue to practice their trade by providing enabling environment for productive crop production, even in the face of climate change (UNDP, 2003). To do otherwise will intensify the problems of food shortage, malnutrition, migration, crime rate and poverty. This can lead to serious dislocation of those societies and their economies.

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Table 1. List of variables used in regression model construction

Dependent Variables	Independent Variables
Sorghum Millet Maize	Rainfall Potential evaporation Radiation Temperature Humidity Sunshine hours

Table 2. Sorghum sensitivity to climatic elements at Kano (P-values in parenthesis)

Climate variable	A	Regression coefficient	R^2	R^2 (adjusted)
Rainfall	98.3 (0.230)	0.623 (0.004)	72.6	70.7
Potential evaporation	1090 (0.000)	-6.97 (0.000)	76.5	73.1
Radiation	-433 (0.536)	8.64 (0.191)	23.0	12.1
Temperature	-5766 (0.564)	15.7 (0.529)	5.9	0.0
Humidity	-585 (0.243)	3.94 (0.046)	45.7	38.0
Sunshine hours	-1202 (0.204)	37.4 (0.083)	36.8	27.8

Table 3. Millet sensitivity to climatic elements at Kano (P-values in parenthesis)

Climate variable	A	Regression coefficient	R^2	R^2 (adjusted)
Rainfall	216.0 (0.011)	0.345 (0.006)	71.2	69.3
Potential evaporation	758.0 (0.000)	-3.68 (0.022)	55.3	48.9
Radiation	-291.0 (0.462)	6.76 (0.084)	36.7	27.7
Temperature	-6336 (0.288)	17.0 (0.258)	17.8	6.1
Humidity	-191 (0.541)	2.31 (0.064)	40.8	32.4
Sunshine hours	-636 (0.266)	23.7 (0.075)	38.4	29.6

Table 4. Maize sensitivity to climatic elements at Kano (P-values in parenthesis)

Climate variable	A	Regression coefficient	R^2	R^2 (adjusted)
Rainfall	143 (0.203)	0.728 (0.000)	77.8	74.6
Potential evaporation	1368 (0.000)	-9.08 (0.000)	93.0	92.0
Radiation	-218 (0.801)	7.68 (0.339)	13.1	0.6
Temperature	1935 (0.372)	-3.2 (0.914)	0.2	0.0
Humidity	-800 (0.151)	5.09 (0.023)	54.5	48.0
Sunshine hours	-1126 (0.334)	38.1 (0.149)	27.3	17.0

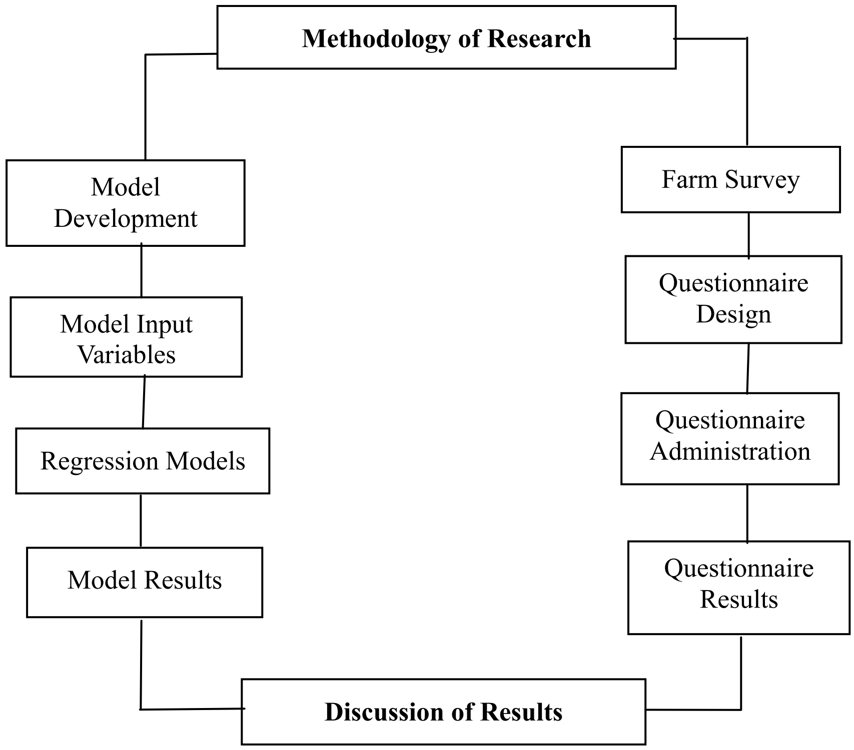

Figure 1. A flow chart showing the research methodology adopted in the study

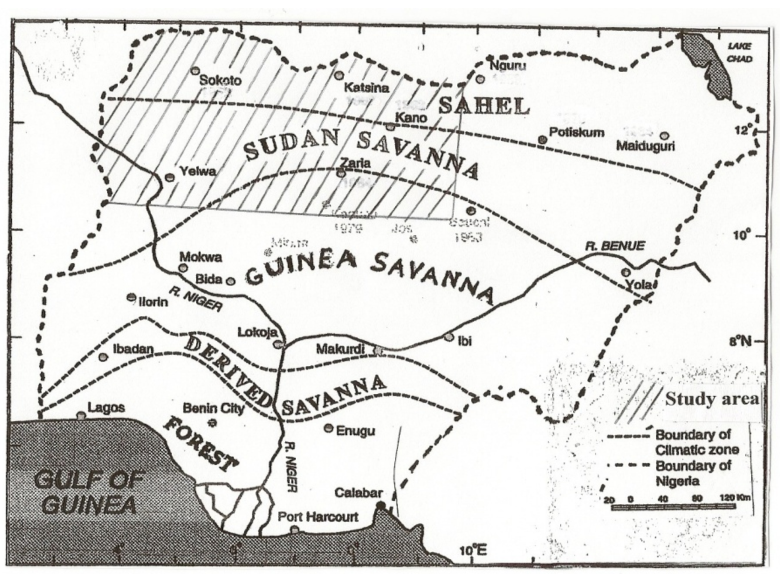

Figure 2. Map of Nigeria showing the study area