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THE ROLE OF CLIMATIC SCENARIOS IN FARMERS' ADJUSTMENTS TO CLIMATIC VARIATIONS IN NORTHERN NIGERIA

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ABSTRACT

Irregular rainfall is the primary reason for severe crop yield reductions in the Sahel of West Africa, with sometimes very serious consequences for society and national economies. To that extent recent drought events in the Sahel have overprinted their rhythms, causing widespread dislocation to human beings and their economic activities. Accordingly, this study provides a procedure for predicting future crop yield trends using scenarios of climatic events. In the process, models which relate rainfall to agricultural yields were constructed for three sites in Northern Nigeria. The models were constructed for a 17-year period spanning 1969-1985, the severe drought years. In all cases, the model input variables were rainfall and crop yield data. All the models were tested for their predictive capabilities using crop yield data for 1986-2006. In order to assess the potential effects of drought on agricultural yields in the West African Sahel, the study created scenarios of future climatic changes based on arbitrary data and analogues of historical climatic data. The results indicated that a possible climatic change which involves up to 50% reduction in the mean rainfall for locations in the West African Sahel will reduce yields substantially and in many cases could lead to total crop failure. The study concludes that scenario experiments are useful tools in guiding farmers on adjustment options during drought events. Additionally, supplementary irrigation schemes must be pursued vigorously by all stakeholders if farming is to remain lucrative in the region.

KEY WORDS: Climate Change, Rainfall variability, Sahel, Crop yields, Scenarios

INTRODUCTION

It is obvious that weather and climate have profound influence on human beings as they are essential for food production, health and general well-being. With recurrent droughts in the Sahel of West Africa since the early 1970s, the dynamics of the ecosystem have changed dramatically, becoming rather desiccated. To that extent, agricultural systems in these semi-arid areas are more susceptible to the vagaries of weather and climate than elsewhere in the tropics. Thus, farmers in drought-prone regions of Africa must respond to the challenges of drought in one or two ways. They can either wait until drought occurs before they resort to ad hoc mitigation measures. Alternatively, procedures may be developed before the occurrence of a drought event. Such procedures will define possible mitigation measures under various climatic scenarios.

Northern Nigeria is the main cereal growing region of Nigeria. Under the semi-arid conditions of many areas beyond latitude 9^o North, crop yields per hectare in Nigeria varies greatly from year to year primarily because of annual fluctuations in the weather and climate, although diminished soil fertility and plant pest/diseases also contribute to large yield variations. Weather variations not only cause great yearly variations in yield, but climatic differences within northern Nigeria result in considerable differences in yield per hectare among different parts of the region. Under these conditions, assuring some degree of yield stability to the farmer has become a priority to national and local governments, and to research scientists in the region. Kowal and Kanabe (1972) and Kowal and Kassam (1978) have presented a comprehensive agro-climatic analysis of growing various crops in northern Nigeria. These studies, among others have provided the basis for much of our understanding of crop responses to climatic fluctuations. Agricultural productivity in the West African Sahel is particularly sensitive to rainfall. The highly variable nature of rainfall in this region has been largely responsible for the frequent crop failures. Therefore, any effort aimed at finding solution to the problems of recurrent drought and incessant crop failures would bring the much needed relieve to farmers in this region, and this is the primary objective of the present study.

Drought phenomenon in perspective

Drought is a condition of extreme but short-term climatic variation which results in insufficient rainfall to meet the socio-economic demands of a region in terms of water supply, agriculture and ecosystem requirements. It is an abnormal condition relative to some long-term average condition of balance between rainfall and evapo-transpiration (often referred to as normal) in a particular area. Unfortunately, the causes of drought are still poorly understood. In the Sahel of West Africa, drought is often attributed to the inability of the monsoon-bearing, south-west wind to penetrate the sub-region up to the desert margins in any particular year. However, this rather simplistic explanation fails to explain many important characteristics of rainfall such as late onset, early cessation and definite breaks within the rainy season. Contemporary research on the causes of drought focuses more on sea-surface temperatures and wind patterns over Africa (Nicholson, 1999). Indeed, some drought events in the Sahel of Africa have been linked to the El Nino/Southern Oscillation (ENSO)

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phenomenon, a periodic fluctuation in the intensity of the inter-tropical atmospheric and oceanic circulation that is usually coincident with an anomalous warming of the eastern tropical Pacific Ocean (Semazzi, Mehta and Sud., 1998). Additionally, changes in albedo, evapo-transpiration and soil moisture, surface temperature and roughness, and the amount of dust generation are seen as possible triggers to a drought condition. Drought can have severe impact on food production, water supplies, vegetation and even the soil.

Approaches to climate impact studies

The sensitivity of an economic activity to climatic variation can be analyzed in two main ways. One approach is the use of semi descriptive case studies, concentrating on particular periods of apparently marked climatic impact on specific phenomena. The second approach is to construct a model of the crop climate interaction and to test the model against historical actuality using time series data of chosen dependent (e.g crop yield) and independent (e.g climatic) variables. With this second approach, it is possible to predict isopleth shifts, and this could facilitate the identification of areas affected by climatic change or variability (Parry 1985). The premise in this approach is that crop yield boundaries or margins which separate one zone from the other could undergo a spatial shift for a given change of climate, thus making it possible to define impact areas and intensity. For instance, if a certain threshold value for crop yields is accepted as limit of profitable cultivation, it is possible to illustrate and map the shifts on the limits of that threshold value for a given climate change. This approach portrays the impact of climatic change in terms of the resultant change in the probability of harvest success or failure.

Furthermore, variations in climate can be simulated by perturbing the original meteorological data using arbitrary or historical rainfall scenarios. These scenarios of changing climates could then be used as inputs in a crop-climate model to examine possible impacts of a climate change on a known phenomenon and to map the geographical shifts of the probability isopleth. The areas delimited by these shifts represent areas of specific climatic impact. It is therefore feasible to adopt this approach in assessing the climatic sensitivity of various phenomena, some of which are directly affected by climate (e.g measures of agricultural potential), and some of which are somewhat remotely related (e.g actual agricultural yield or national food production level) (Parry, 1985)

From this kind of analysis, it is also possible to estimate the impact that might result today (with present day technology) from a recurrence of a climatic event known to have had a severe impact in the past. For instance, what would be the impact on sorghum yields if Kano state were to suffer a similar drought to the one experienced in 1972/73. This is precisely the kind of question which the present study attempts to answer.

METHODS AND MATERIALS

The multiple regression model was developed to assess the effects of climatic variations on crop yields in three locations in northern Nigeria. The locations selected were Kano, Katsina and Zaria. Three crops, sorghum, millet and maize were also selected for analysis. In all cases, the model input variables were crop yield data (dependent variables) and climatic data (independent variables).

In any modeling experiment for climate and crop yield, the essence should normally be to consider whether the model provides a reasonable level of explanation for crop yield variations in terms of goodness of fit and statistically significant coefficients. In this study, not only did the modeling experiment explore the responses of crop yields to annual and seasonal climatic data for various climatic elements such as rainfall, temperature and evaporation, it also experimented with the monthly values of these variables in order to coarsely match the seasonal climatic parameters with the crop-growing (phonological) phases of pre-sowing, sowing, germination, vegetative, flowering, seeding, ripening and harvest. This process allowed the modeling experiment to pin-point the specific periods in which crops were particularly sensitive to climate.

Crop-climate models

The relationships between the dependent variable and the independent variables were examined through equation of the form:

$Y= a + b_1 \log x_1 + b_2 \log x_2 + \ldots\ldots\ldots\ldots b_n \log x_n +e$

Where Y = the dependent variable, a = the intercept on y-axis., b_l-b_n = the partial regression coefficients of the independent variables., x_l-x_n = the independent (climatic) variables., e = the random error term representing the proportion of unexplained variation.

A total of eight multiple regression models were constructed using the following sets of independent variables: (Model1): seasonal rainfall and mean seasonal temperature; (Model 2): logarithms of seasonal rainfall and mean seasonal temperature; (Model 3): seasonal rainfall and seasonal potential evaporation; (Model 4): logarithms of seasonal rainfall and seasonal potential evaporation; (Model 5): rainfall in May/June, July, August, and September/October; (Model 6): logarithms of rainfall in May/June, July, August, and September/October; (Model 7): the ratio of rainfall to potential evaporation in May/June, July, August, and September/October; (Model 8) logarithms of the ratio of rainfall to potential evaporation in May/June, July, August, and September/October.

Of the eight regression models developed for this study, model 6 provided the highest level of explanation in terms of goodness of fit and statistically significant coefficients regarding variations in crop yields in all the three study sites. The models' coefficients of determination (R^2) are presented in Table 1 (a) – (h).

Table 1: Coefficient of determintion (R^2) for the multiple regression models

Model 1

Location	Sorghum	Millet	Maize
Kano	71.7	68.0	78.8
Katsina	70.7	77.5	74.7
Zaria	62.1	62.7	57.0

(b) Model 2

Location	Sorghum	Millet	Maize
Kano	75.9	72.7	81.0
Katsina	75.0	78.8	73.4
Zaria	62.2	61.3	56.0

(c) Model 3

Location	Sorghum	Millet	Maize
Kano	78.5	66.0	76,3
Katsina	76.2	78.3	55.8
Zaria	62.1	58.8	51.3

(d) Model 4

Location	Sorghum	Millet	Maize
Kano	79.3	71.0	78.9
Katsina	77.7	78.9	56.6
Zaria	61.9	56.3	48.4

(e) Model 5

Location	Sorghum	Millet	Maize
Kano	72.9	64.8	79.4
Katsina	75.4	80.7	70.2
Zaria	70.5	78.7	68.7

(f) Model 6

Location	Sorghum	Millet	Maize
Kano	85.8	84.2	86.1
Katsina	88.4	82.9	84.5
Zaria	87.6	83.8	83.6

(g) Model 7

Location	Sorghum	Millet	Maize
Kano	63.2	48.8	61.9
Katsina	66.3	63.4	64.1
Zaria	22.2	23.3	29.9

(h) Model 8

Location	Sorghum	Millet	Maize
Kano	80.2	70.5	77.1
Katsina	88.4	65.7	79.5
Zaria	48.7	27.8	46.6

Model Validation and Selection

An essential prerequisite for the effective use of crop-climate models for scenario experiment is that they should be adequately tested and validated. The multiple regression models developed for this study were tested through the analysis of model responses to systematic adjustments in input variables and model parameters. In all cases, the behaviour of the regression coefficients during the test period for model 6 was very stable. Accordingly, Model 6 was selected for validation tests using data for the period from 1986-2006. Comparison of the model's predictions with the observed yield trends closely matched each other, indicating that the models were valid for use in scenario experiments (Tables 2, 3 and 4).

Table 2, Model 6: Predicted and observed yields for sorghum, millet and maize in Kano

Year	Sorghum	Sorghum	Millet	Millet	Maize	Maize
	Observed yield (kg/ha)	Predicted yield (kg/ha)	Observed yield (kg/ha)	Predicted yield (kg/ha)	Observed yield (kg/ha)	Predicted yield (kg/ha)
1986	666.3	651.4	501.8	539.8	858.8	857.8
1987	649.8	620.2	509.3	497.4	801.8	751.9
1988	585.0	570.8	480.0	463.0	737.5	689.1
1989	484.5	493.6	463.5	448.2	539.0	554.1
1990	257.5	260.4	311.5	338.6	200.0	209.3
1991	478.8	504.2	418.8	443.9	521.3	588.7
1992	596.5	603.8	484.5	479.0	698.5	741.0
1993	546.2	431.8	422.8	411.0	622.6	588.0
1994	608.5	607.4	469.8	491.8	739.5	700.2
1995	645.0	639.7	532.5	531.2	788.2	738.0
1996	502.5	511.7	473.5	478.4	684.5	678.0
1997	640.2	657.2	556.3	543.6	740.5	808.9
1998	553.3	469.6	448.3	430.5	605.2	565.7
1999	577.4	557.9	513.0	463.7	631.5	587.3
2000	379.5	424.3	415.5	410.2	400.0	442.2
2001	317.3	342.7	324.6	321.3	443.5	441.8
2002	525.5	540.5	420.5	454.6	688.5	658.3
2003	518.2	522.5	480.0	462.6	641.5	655.2
2004	433.5	424.5	384.7	397.8	516.3	501.3
2005	667.2	717.6	544.2	566.5	822.5	862.2
2006	550.0	530.7	475.3	452.3	573.2	558.2

Table 3, Model 6: Predicted and observed yields for sorghum, millet and maize in Katsina

Year	Sorghum	Sorghum	Millet	Millet	Maize	Maize
	Observed yield (kg/ha)	Predicted yield (kg/ha)	Observed yield (kg/ha)	Predicted yield (kg/ha)	Observed yield (kg/ha)	Predicted yield (kg/ha)
1986	378.6	373.7	324.6	315.4	394.0	383.5
1987	431.3	427.8	387.2	370.4	456.2	436.7
1988	404.4	396.5	325.0	331.2	430.3	409.2
1989	385.2	381.6	351.2	321.2	438.6	450.6
1990	350.0	354.6	286.5	293.2	268.3	300.0
1991	445.2	445.8	384.5	384.7	517.4	509.7
1992	422.6	411.1	370.2	356.9	516.2	478.7
1993	390.0	395.0	322.5	341.1	426.5	447.0
1994	437.2	451.5	409.5	399.5	508.2	503.0
1995	380.4	354.8	300.0	315.1	422.6	409.9
1996	450.0	464.1	375.6	406.2	531.6	557.5
1997	451.4	449.1	412.5	396.6	539.0	549.7
1998	3992.4	385.2	328.2	339.2	432.6	464.4
1999	378.0	387.5	302.6	322.9	430.2	414.2
2000	355.2	345.7	290.0	299.5	402.0	410.9
2001	273.5	308.6	281.0	268.8	374.6	363.1
2002	357.0	357.0	303.7	303.7	433.2	413.6
2003	223.6	209.9	216.4	207.4	165.3	161.4
2004	328.4	338.8	323.5	326.6	350.0	342.6
2005	477.5	455.1	378.2	394.7	527.4	538.2
2006	421.6	438.1	392.6	379.2	491.3	487.0

Table 4, Model 6: Predicted and observed yields for sorghum, millet and maize in Zaria

Year	Sorghum	Sorghum	Millet	Millet	Maize	Maize
	Observed yield (kg/ha)	Predicted yield (kg/ha)	Observed yield (kg/ha)	Predicted yield (kg/ha)	Observed yield (kg/ha)	Predicted yield (kg/ha)
1986	765.2	747.7	550.2	546.2	853.2	844.1
1987	750.4	758.5	547.6	531.8	860.2	839.0
1988	718.2	742.8	526.2	517.4	789.6	816.3
1989	825.0	826.6	560.2	558.9	870.0	879.7
1990	709.6	719.5	508.6	524.5	816.2	818.9
1991	752.4	750.2	527.2	538.5	838.2	833.0
1992	482.5	531.0	492.5	494.8	750.5	768.5
1993	735.6	767.8	525.2	528.0	831.6	832.2
1994	720.2	750.1	517.4	523.6	819.2	828.9
1995	950.0	944.7	601.2	604.4	934.6	941.4
1996	775.2	776.1	547.2	556.7	847.4	859.6
1997	740.0	685.5	539.2	524.3	840.6	816.1
1998	749.2	755.0	537.3	538.5	855.0	840.9
1999	722.2	704.6	500.0	511.1	821.6	806.7
2000	695.2	641.8	490.0	496.2	799.6	789.0
2001	690.2	675.5	515.2	505.2	775.0	792.2
2002	767.4	771.2	563.4	548.8	853.6	849.8
2003	688.5	656.3	518.6	492.2	782.5	775.0
2004	779.2	808.6	520.3	561.4	886.3	874.6
2005	862.3	881.9	565.2	576.1	890.0	903.7
2006	726.5	698.8	542.5	510.3	817.6	809.5

Climatic Scenarios

Having validated the crop-climate models, the next logical step was to create climatic scenarios for use as independent variables in the impact models to predict potential yield responses to climatic changes. Scenario could be seen as a tool for stoking the imagination, which also involves the ability to predict or make forecasts based on some prevailing circumstances (Lave and Epple, 1985). A climatic scenario can be defined as "a suite of possible future climates, developed by using sound scientific principles, each being internally consistent, but none having a specific probability of occurrence attached (Robinson and Finkelstein, 1989). In climate-society interaction, three main methods are available for developing scenarios. These are: the analogue method, the modeling technique, and arbitrary scenarios. The analogue method is the one in which the regional climate and seasonal patterns of past climates (based either on proxy or instrumental data) are used to construct scenarios of future climate. In a sense, the concept of the past being the key to the present is very well entrenched in this approach. Climatic analogues based on proxy data usually make use of proxy information, either derived from recorded historical events or deduced from paleo-climatic investigations (Jacobson et al., 1987). Studies using this approach have proved highly successful, not only in establishing direct links between climate variations and their impacts, but also by affording the identification of significant climatic variables that needs to be analyzed (Parry and Carter, 1987; Budyko and Izrael, 1987).

The modeling approach involves the use of general circulation models (GCMs) to construct climatic scenarios with the purpose of quantitatively assessing the regional and seasonal patterns of climate changes. The major advantage of scenarios based on climate modeling is that they can be used to describe in a physically consistent manner, not only past and present climates, but also how climate could behave in response to a change in some external forcing such as deforestation or carbon dioxide doubling (2 X CO2). Among the existing general circulation models are those developed by: the Geophysical Fluid Dynamics Laboratory (GFDL); the Goddard Institute of Space Studies (GISS); the National Centre for Atmospheric Research (NCAR); and the Meteorological Office, Greenwich, England.

Arbitrary or synthetic scenarios are based on arbitrarily assigned values. The most often used method is that of calculating certain indices as displacement of existing mean condition. For instance, taking one or two or three standard deviation above and below the mean condition or 10 percent, 20 percent, 30 percent and so on above and below the long-term mean condition of any chosen climatic element such as rainfall, temperature, and so on. This method is most helpful in regions where climatic data do not extend far enough or are very unreliable to permit the development of the analogue method, or where predictions from GCMs are most unreliable, as in semi-arid tropics. This study adopted a combination of arbitrary and historical scenarios and it must be emphasized that the study does not consider them as predictions of the future or direct guides to policy; rather they represent a systematic means of exploring the implications of hypothesized conditions.

Sensitivity experiments using rainfall scenarios

A sensitivity analysis based on arbitrary rainfall criteria was conducted in conjunction with selected historical rainfall scenarios (extreme events) to estimate the potential impacts of drought on crop yields in Northern Nigeria. The synthetic rainfall scenarios were computed by first of all calculating the mean seasonal rainfall for the number of years for which the crop climate models discussed earlier were constructed. This was followed by a systematic scaling down and scaling up of the 1969-1985 average seasonal rainfall using a constant factor of 10 percent. This arrangement resulted in the creation of a number of dry and wet rainfall scenarios. The mean condition was the 0% case while the extremely dry and extremely wet conditions were denoted by the - 50 percent and +50 percent cases respectively. Between the mean and the extreme cases were scenarios representing various dry conditions, such as -10%, -20%, -30% and -40% rainfall events, and those representing wet condition such as, +10%, +20%, +30% and +40% rainfall events. However, it must be pointed out that the present study concentrated on the dry rainfall scenarios because drought (rather than flood) is the serious environmental phenomenon that affects crop production in northern Nigeria.

Climatologically, the dry scenarios represent various intensities of drought while the wet scenarios reflect different magnitudes of flood. In addition to these synthetic scenarios, actual historical analogues of specific climatic regimes and specific extreme events were presented as percentages of seasonal rainfall compared to normal. Unlike the arbitrary scenarios which were constructed uniformly for all stations, the analogues of specific historical episodes were designed depending on the length and nature of rainfall data available at each station. For instance, 1973 rainfall-year is regarded as an extreme drought condition with only 50 percent of normal rainfall. Statistically, a 20 percent change in mean condition is approximately one standard deviation.

The rainfall scenarios were used as inputs in the regression models constructed earlier to examine the potential impacts of climatic variations on crop yields in three locations in northern Nigeria. The computation of the potential impacts of modifying precipitation data was done using Batch-File-Quattro programming. The results of the potential impacts of climatic change on crop yields in northern Nigeria and indeed, the West African Sahel are presented in Tables 5, 6 and 7.

Table 5: The effects of adjusted rainfall on crop yields in Kano

Scenario	Sorghum yield	Millet yield	Maize yield
-10% event	42.9 kg/ha (8.1%)	23.4 kg/ha (5.2%)	60.3 kg/ha (9.7%)
-20% event	90.9 kg/ha (17.2%)	49.7 kg/ha (10.9%)	127.7kg/ha(20.5%)
-30% event	145.3kg/ha(27.5%)	79.4 kg/ha (17.5%)	204.2kg/ha(32.7%)
-40% event	208.1kg/ha(39.4%)	113.7 kg/ha (25%)	292.4kg/ha(46.8%)
-50% event	282.4kg/ha(53.5%)	154.2kg/ha(33.9%)	396.8kg/ha(63.6%)
Mean Yield	527.8kg/ha	454.8kg/ha	624.2kg/ha

Table 6: The effects of adjusted rainfall on crop yields in Katsina

Scenario	Sorghum yield	Millet yield	Maize yield
-10% event	21.6 kg/ha (5.5%)	20.7 kg/ha (6.1%)	34.1 kg/ha (7.7%)
-20% event	45.8 kg/ha (11.7%)	43.8 kg/ha (12.9%)	72.3 kg/ha (16.3%)
-30% event	73.3 kg/ha (18.7%)	70.0 kg/ha (20.6%)	115.6 kg/ha (26%)
-40% event	104.9 kg/ha (26.7%)	100.2 kg/ha (29.5%)	165.5 kg/ha (37.3%)
-50% event	142.4 kg/ha (36.2%)	136.0 kg/ha (40%)	224.6 kg/ha (50.5%)
Mean Yield	393.0 kg/ha	340.2 kg/ha	444.5 kg/ha

Table 7: The effects of adjusted rainfall on crop yields in Zaria

Scenario	Sorghum yield	Millet yield	Maize yield
-10% event	54.0 kg/ha (7.3%)	20.7 kg/ha (3.9%)	28.7 kg/ha (3.5%)
-20% event	114.3 kg/ha (15.5%)	43.8 kg/ha (8.3%)	60.7 kg/ha (7.3%)
-30% event	182.6 kg/ha (24.7%)	69.9 kg/ha (13.2%)	79.1 kg/ha (11.7%)
-40% event	261.6 kg/ha (35.4%)	100.2 kg/ha (18.9%)	139.0 kg/ha (16.7%)
-50% event	354.9 kg/ha (48.1%)	135.9 kg/ha (25.6%)	188.6 kg/ha (22.7%)
Mean Yield	738.3 kg/ha	530.5 kg/ha	831.5 kg/ha

DISCUSSION OF RESULTS

The main questions addressed by this study are: what would be the effects on crop yields if the seasonal rainfall were to reduce by 10 percent, 20 percent, 30 percent, 40 percent and 50 percent of the 1969-1985 mean? (a longer-term rainfall mean such as the 1905-1985 mean could also be used if reliable data were available); Or, what would be the effects on yields if the 1972/73 or the 1983/84 droughts were to re-occur in northern Nigeria.

The results as shown in Tables 5, 6, and 7 indicate that a 10% decrease in the mean rainfall of Katsina would depress the yields of sorghum millet and maize from the 17-year average of weather based yield estimates by 5.5% for sorghum, 6.1% for millet and 7.7% for maize. The corresponding yield losses for Kano would be 8.1% for sorghum, 5.2% for millet and 9.7% for maize. For a decrease of 20% in the mean rainfall, the yield losses at Katsina would be 11.7% for sorghum, 12.9% for millet and 16.3% for maize. The yield losses at Zaria would be 15.5% for sorghum, 8.3% for millet and 7.3% for maize. In Kano the figure would be 17.2% decline for sorghum, 10.9% for millet and 20.5% for maize. Yield losses at Zaria would be 15.5% for sorghum, 8.3% for millet and 7.3% for maize.

A -30% rainfall event in Katsina would lead to 18.7% loss for sorghum, 20.6% for millet and 26% for maize. In Kano, the yield losses would be 27.5% for sorghum, 17.5% for millet and 32.7% for maize. The figures for Zaria would be 24.7% for sorghum, 13.2% for millet and 11.7% for maize. With a loss in precipitation of up to 40%, the yield losses for Katsina would be 26.7% for sorghum, 29.5% for millet and 37.3% for maize. At Kano, the corresponding yield losses would be 39.4% for sorghum, 25% for millet and 46.8% for maize. In Zaria, the yield losses would be 35.4% for sorghum, 18.9% for millet and 16.7 percent for maize.

The 50% rainfall decline is typical of the 1973 and 1984 rainfall receipts in northern Nigeria when most stations received half of the long-term mean rainfall. Under the 50% rainfall scenario, crop yields in most locations would slump beyond the half point mark. In Kano, sorghum yields will decrease by 53.5%, millet by 33.9%, and maize will slump by a whopping 63.6%. In Katsina, yields will be depressed by 36.2% for sorghum, 40% for millet and 50.5% for maize. The corresponding yield losses in Zaria will be 48.1% for sorghum, 25.6% for millet and 22.7% for maize.

CONCLUSION

From the results of the study it is evident that the severity to drought on crop yields would be greater in Kano and Katsina than in Zaria. This is probably explained by the latitudinal position of Katsina and Kano, compared with that of Zaria. For peasant farming to have survived through the centuries in these parts of northern Nigeria, it means that farmers already posses the ingenuity and adaptive capability for coping with a highly variable climate. However, as Wish (2006) pointed out, the increase in the intensity and frequency of drought events in West Africa have rendered the traditional methods of adaptation ineffective, thus making it difficult for farmers to cope. Therefore, if information on the yield implications of the different rainfall scenarios could be made available to farmers at the beginning of the cropping season (Sivakumar, 1988), then farmers could plan whether to increase the area under cultivation or to reduce same depending on the expected scenario. Crop zonation practices could also be adopted to maximize production in favorable zones. Farmers can also switch to drought-tolerant crops and more efficient farming methods provided accurate forecast is available to them.

Finally, the study observes that the environment of crop production in northern Nigeria (specifically areas roughly north of latitude 11^0 30') is climatically harsh so that regardless of the crops they plant, farmers in these parts of Nigeria are constrained by unreliable rainfall and the prospect of frequent crop failure. Thus, for farming to remain lucrative and sustainable in the West African Sahel, farmers must be provided with relevant information on the agro-climatology of the region. This calls for the establishment of more meteorological stations at distances that are not more than 50 kilometres apart so that the minutest spatial differences in the climatology of the region can be monitored and detected for proper planning. Furthermore, the collection of climatic data should be given top priority through proper funding of the meteorological stations, so that equipment maintenance and appropriate staffing can be guaranteed. The services of the agricultural extension workers will come handy in the dissemination of such climatic information, together with rigorous development of demonstration model-farms to convince the skeptic. Also, perennial irrigation (which could include inter-basin water transfer from southern rivers to dry northern areas) must be seriously pursued by all stake holders else, farmers in this region may remain doomed to an existence of hunger and poverty.

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