ANALYSIS OF NORMALIZED RAINFALL INDEX AND IMPACT VULNERABILITY STATUS OF SORGHUM FARMERS TO CLIMATE CHANGE IN GUSAU STATION, ZAMFARA STATE, NIGERIA

BY

[1]Philemon, Albert Chinda, [1]Ibrahim, Saraya and [2]Nnachi, Solomon Uduma

[1]Department of Geography, Faculty of Social Science,
University of Maiduguri, P.M.B. 1069 Maiduguri, Borno State, Nigeria
E-mail: philemonalbert@gmail.com. sarayaibrahim@yahoo.com
07033091614, 07033362025

[2]Department of Geography, Faculty of Science,
Ahmadu Bello University, Zaria-Nigeria.
E-mail: solonnachi@yahoo.com
07037695570

ABSTRACT

This study statistically analysed both the Normalized Rainfall Index (NRI) and Impact Vulnerability Status (IVS) of climate change on sorghum farming in Zamfara State based on rainfall records for Gusau station from 1971-2010. The results of the various statistical tests showed that the coefficients of Skewness and Kurtosis for the rainfall series for the period were normally distributed at 95% confidence level. The five-year and ten-year running means for annual rainfall series during these periods both showed lengthy dry periods below the long-term mean from 1971-2001 with steady increases above the mean from the early millennium to the end of the period. Trends in sorghum yield pattern from 1996 to 2010 revealed that from 1996-2002, sorghum yield dropped below normal but as at 2003 to 2008 and at the end of the period, there was a significant rise in yield production. The Pearson's Product Moment Correlation coefficient (*r*) was used to show any significant relationship between the annual rainfall totals and sorghum yields from 1996 to 2010 and this revealed that the coefficient was positively but not perfectly correlated (+0.289). In assessing IVS, the rainfall totals from 1971 to 2010 were subjected to the NRI as propounded by Tűrkes (1996) which showed that millet farmers were highly vulnerable to climate change (drought and flooding) within the 2nd and 4th decadal periods (1987, 2002, 2003 and 2008). Other non-vulnerable periods had annual rainfall amount between 600mm and 900mm. Nevertheless, the findings of this study recommends among the following that planting the best short duration seed variety in periods of drought, application of organic manure and fertilizers for sorghum in cases of drought to boost soil fertility, crop rotation to reduce pests attack and updating and improving and monitoring continuous rainfall data will improve maize productivity in the area.

Keywords: ***Adaptive Strategies, Biophysical or Impact Vulnerability, Climate Change, Five-Year and Ten-Year Running Means, Normalized Rainfall Index, Pearson's Product Moment Correlation Coefficient, Skewness and Kurtosis.***

Word count: *297 words*

INTRODUCTION

The growing awareness that the earth's climate is changing is at an alarming rate and the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) affirms that climate change is no longer in doubt but is now unequivocally apparent based on evidence from scientific observations of increases in global average air and ocean temperatures. Although extreme violent weather has occurred throughout history, recent upsurge in climate related hazards is confirming the argument for global warming and climate change. The on-going climate change and its associated global warming are expected to cause distinctive climate patterns in different climatic zones, which will impact negatively on the ecosystem (Ayuba, *et al.*,2007), most especially in developing countries due to their low level of technology and coping capabilities making these areas vulnerable (Jagtap, 2007; Nwafor, 2007).

The Intergovernmental Panel on Climate Change (IPCC) report in Deressa, *et al.*, (2008), defined Vulnerability to climate change as the degree to which a system is susceptible, or unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is majorly a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.

The Impact or Biophysical approach to Vulnerability assesses the level of damage that a given environmental stress causes on both social and biological systems. It focuses mainly on physical damages on yield and income. For instance yield impacts of climate change can be analysed by modelling the relationships between crop yields and climate variables (Adams, 1989). Most developing countries are adversely affected. By 2020, between 75 and 250 million people in developing nations are projected to be exposed to increased water stress; crop yields from rain-fed agriculture could be reduced by up to 50% in some regions by 2020; agricultural production, including access to food, may be severely compromised (IPCC, 2007). Nigeria is one of such countries already being plagued with agricultural problems as can be witnessed in most parts already being plagued with recurring higher temperatures, irregular rainfall and longer periods of droughts. Already, climate change rate is gradually exceeding the adaptive capacity of a broad

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range of crops and tree population used in Nigeria ten years earlier than the prediction of the IPCC's climate model prediction of 2020 (IPCC, 2007). Although Nigeria is blessed with a vast landmass totalling 98.3 million hectares with about 74 million hectares arable, coupled with agriculture's contribution to the nation's Gross Domestic Product (GDP) of about 41.5 %, yet it is still a net importer of food and the output of food per capita from Nigeria is among the least in South Saharan Africa. The share of Nigeria's agricultural products in total exports plummeted from over 70% in the 1960s to less than 2% in 2010 (Akoroda, 2010). In Nigeria, post-harvest losses are 20 to 40 percent because harvesting, processing and storage techniques are inefficient and supply is unstable (The *Guardian* Newspaper, October 16, 2011).

The Normalized Rainfall Index (NRI) is used as a quantifiable measure of drought and flooding index in assessing every agricultural or seasonal year from which adaptive strategies were devised as propounded by Turkes (1996). The NRI uses annual or seasonal rainfall totals and the standard deviation to indicate the water level of any given season.

Grain crop production is a vital parameter used to assess vulnerability impact because of the crops' adaptive mechanism in relation to drought when subjected to periodic moisture stress (Jones *et al.*, 1981; Ashley, 1993). Awoyemi, *et al.*, (1986), Sowunmi and Akintola (2011) likewise estimated that maize was part of the grain crops which accounts for over 60-70 percent of the cereal production in most semi-arid areas of Nigeria but they depend entirely on rainfall for moisture supply which is most at times irregular and unpredictable. The Federal Ministry of Environment (2003) also opined that most grain crops like millet, sorghum and maize were part of Carbon four (*C4*) crops common in Nigeria either functioning above or below-optimal conditions with relative increases in carbon dioxide (CO_2) levels in the atmosphere. The study stressed that expected changes in crop development and phenology due to climate change can cause shortening or lengthening of the crop cycle that could lead to increases or decreases in productivity and could also affect nutritional value, taste and storage quality of the crops while increases in CO_2 can lower crop water requirements by reducing transpiration per unit leaf area.

Sorghum also known as Guinea corn, is the second most important cereal crop grown in Zamfara state after millet. It is grown in all parts of the state. Sorghum grows best in sandy-loam to clay-loam soils that are well drained and fertile for best yields. There are several varieties of sorghum; the Long season Short *Kaura 5912* variety which takes 120 to 150 days to mature and develop and which does not do very well in the state and the Medium duration *KSV-8* variety which take 100 to 120 days to grow and mature (Maurya*et al.*, 1995).

The study area; Zamfara state is located in the Sudano-Sahelian region of the savannah. Rainfall distribution combined with human activities has influenced Biogeophysical Feedback Mechanisms (BFM) reinforcing climate change impacts over the Northern part of Nigeria. Thus, the objective of this research will be to: (i) determine annual rainfall trends in Zamfara state from 1971 to 2010 (40 years); (ii) determine any trend in sorghum pattern from 1996 to 2010 (iii) determine any significant relationship between the annual rainfall data to that of annual sorghum yield data in the state from 1996 to 2010 (15 years) (iv) assess the Normalized Rainfall Index (NRI) and the status of Impact Vulnerability of sorghum farmers from 1971 to 2010 in a bid to generate modern adaptive strategies to minimize climate change incidences and boost sorghum yield in the future.

THE STUDY AREA

Zamfara state (Figure 1) covers a total area of 39,762 square kilometres (Zamfara Agricultural Rural Development Authority, 2008).

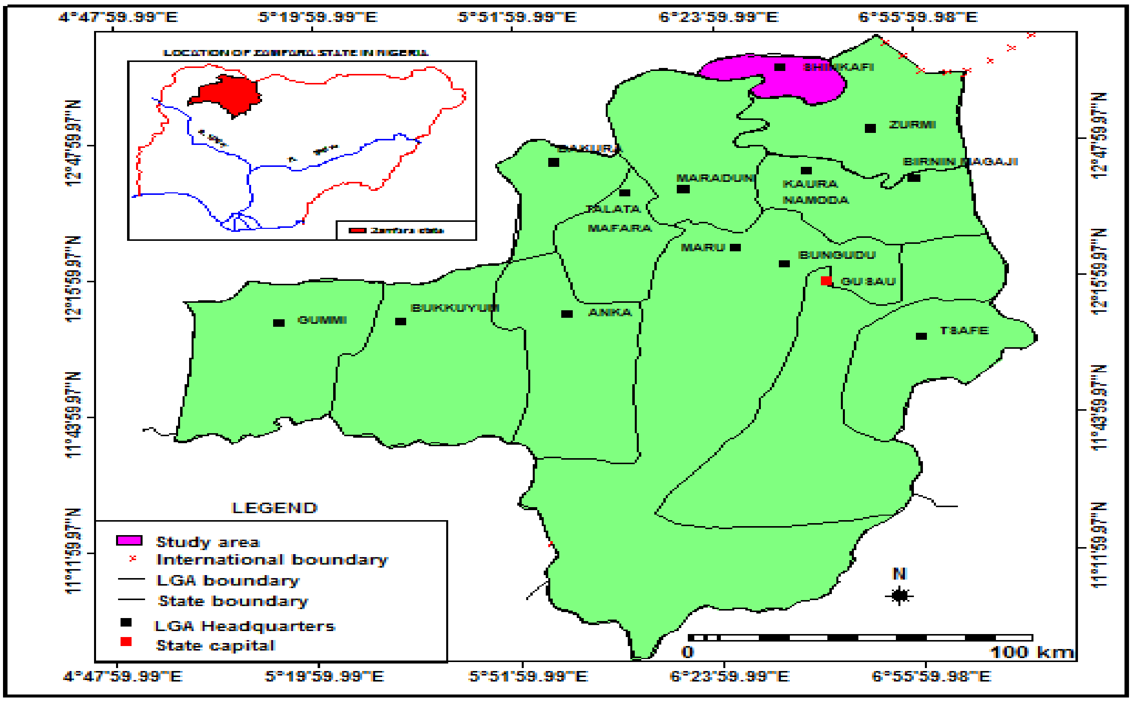


FIGURE 1: LOCATION OF STUDY AREA
Source : Administrative Map of Zamfara State, 2010

The Meteorological station at Gusau station (Zamfara state) number 1206.14is located on latitude 12^0 10' N of the Equator and on longitude 06^0 42'E of the Greenwich meridian. Its altitude is about 461metres and its year of establishment was in 1942(Nigerian Meteorological Agency, Abuja).The Nigerian Meteorological Services Department, Oshodi had confirmed that the station's data are reliable enough for climatic researches of this type due to its ability to record daily climatic readings. There is also a long and continuous period of daily rainfall records for the station, and there was no relocation of the station since its establishment in 1942; thus this station is deemed fit to be used in this study (Sawa, 2010).

The study area has a tropical continental climate of the AW type, characterized by distinct wet (April – October) and dry (November – March) seasons governed by the movement of the Intertropical Discontinuity (ITD) (Sawa, 2010).

MATERIALS AND METHODS

Annual rainfall records for 40 years (1971 – 2010) for the Gusau station was obtained from the Nigerian Meteorological Services Department, Oshodi, Lagos. The Standardized coefficients of Skewness (Z_1) and Kurtosis (Z_2) were both used in testing for the normality of the annual rainfall series during the specified periods. If the absolute value, Z_1 or Z_2 is greater than 1.96, a significant deviation from the normal curve is indicated at 95% confidence level.

The long-term mean of annual rainfalltotals from 1971 to 2010 was obtained by dividing the annual rainfall amounts by the number of years.The five-year and ten-year running means were also obtained by dividing the consecutive pentad and decadal totals by the number of years.

Sorghum yield data (kilogram of maize grain per area of land in hectares) produced by the state for 15 years (1996 – 2010) were obtained from the Zamfara State Agricultural Development Project (ZADP).The yield data obtained was derived from kilogram per land hectare from 1996-2010.

The Pearson's Product Moment Correlation coefficient (***r***) was computed to see if there was any significant relationship between annual Sorghum yield (dependent variable, **Y**) and annual rainfall data(independent variable, **X**) from 1996 – 2010. It is a form of linear regression analysis used to ascertain the strength or index of crop-climate relationship. Pearson was employed because the distribution is bivariate, continuous and normal. Both crop yield and rainfall data were harmonized by dividing by 100 to avoid bogus figures. The value ***r*** must fall within the ranges of $-1 \leq 0 \leq +1$. If the values tend towards +1, it indicates a perfect positive relationship but if it tends to -1, a perfect negative relationship has been established. If it is 0, there is no relationship established.

In determining the Impact Vulnerability Status (IVS) of Sorghum farmers to climate change, the adoption of the Normalized Rainfall Index (NRI) values from 1971-2010 was used as propounded by Turkes (1996). The NRI uses annual or seasonal rainfall totals and the standard deviation to indicate the water level of any given season. The NRI for a given station as defined by Turkes (1996) is computed thus;

$$\mathbf{NRI = \frac{Rsy - LM}{SD}}$$

Where Rsy = the rainfall total for the station during a year (or season)

LM = the long term mean (of the period specified for the station) and

SD = Standard deviation of the annual (or seasonal) rainfall total for that station

The table below is a modified version of classification of the index as defined by Turkes (1996).

Table 1.1

Index	Character of Rainfall	Maize farmers' vulnerability status
1.31 or more	Very wet	Highly vulnerable
0.86 to 1.30	Moderately wet	Vulnerable
0.51 to 0.85	Mildly wet	Slightly vulnerable
0.50 to -0.50	Near normal	Not vulnerable
-0.51 to -0.85	Mild drought	Slightly vulnerable
-0.86 to -1.30	Moderate drought	Vulnerable
-1.31 or less	Severe drought	Highly vulnerable

RESULTS AND DISCUSSION

General Statistics of Annual Rainfall for Gusau station, Zamfara state (1971 – 2010)

The annual rainfall series for Zamfara state was subjected to the normality test using Coefficients of Skewness (Z_1) and Kurtosis (Z_2) as described by Brazel and Balling (1986) as explained in Table 1.2. The coefficient of Skewness and Kurtosis both indicated that rainfall series had no significant deviation from the normal curve (1.96) at 95% confidence level. Hence, it was normally distributed. The Standard Deviation (SD) decreased below the Mean while the Coefficient of Variation (CV) was appreciable.

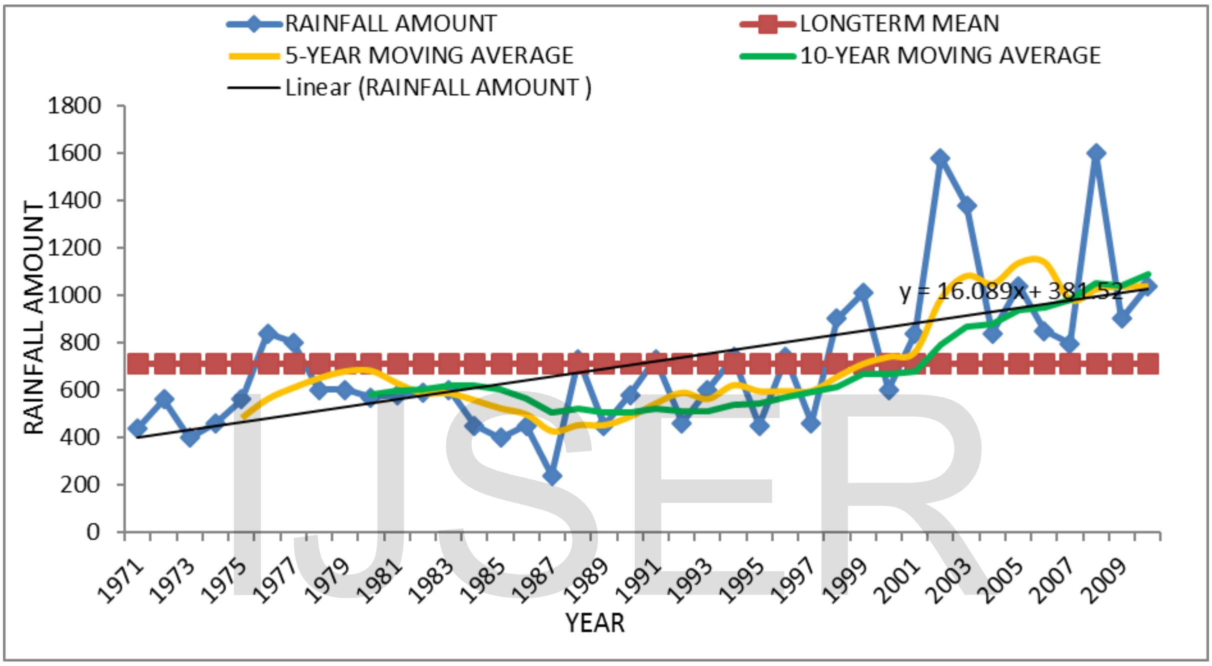
Table 1.2- Summarized Rainfall Statistics for Gusau station, Zamfara state, Nigeria.

Total amount (mm)	Long term Mean (mm)	SD (mm)	CV (%)	Max (mm)	Min (mm)	Range (mm)	Z_1	Z_2
28454.00	711.35	303.11	64.02	1600.00	240.00	1360	1.358	1.861

Source: Data Analysis for Gusau station, Zamfara state (2012)

Trends in the Annual Rainfall pattern

The annual rainfall series for 40 years (1971-2010) as observed from Figure 1.2 indicates that the 5-year running mean generally showed annual rainfall amounts below the long-term mean from 1971 to 1998. However, after then, there was a rise in the rainfall above the long-term mean until the end of the data (1999-2010). The 10-year moving average also followed the same pattern as the former. However, from 1971- 2001, it was below the long-term mean, and from 2002 until the end of the period, there was a rise above the mean. Both means revealed that from the early 1970s to the early millennium, the study area experienced rainfall amounts below normal. However, from the early millennium (2002) until the end of the study period, annual rainfall were significant and steadily increased above normal as seen in the linear trend line equation (y =16.089x + 381.52), thereby showing a significant pattern.

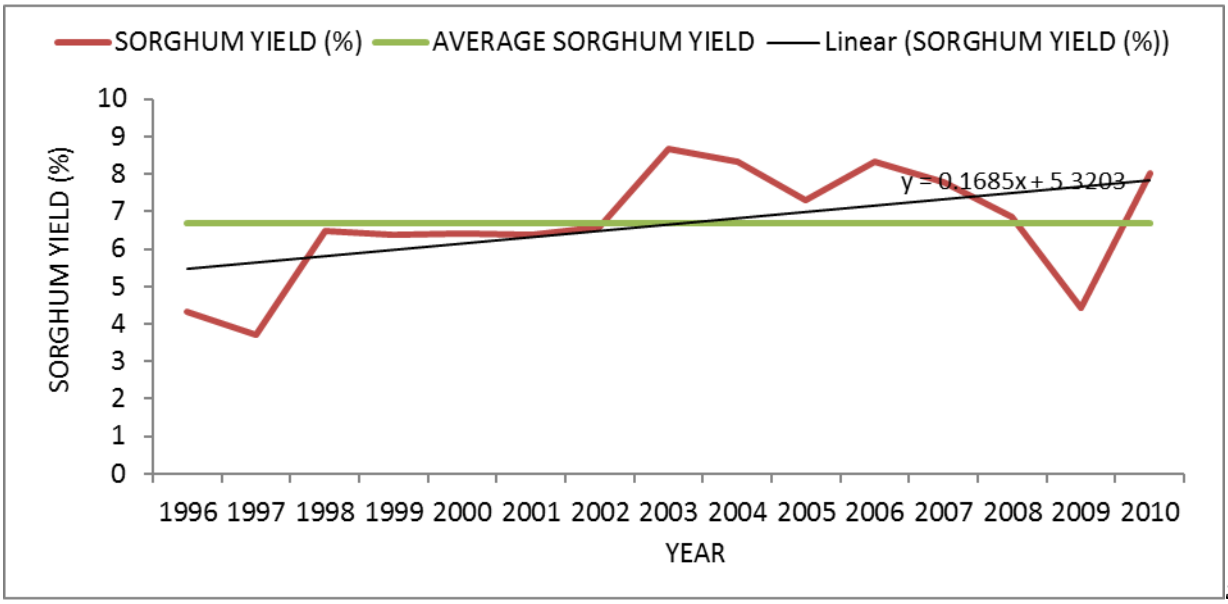


Source: Data Analysis for Gusau station, Zamfara state (2012)

Figure 1.2 – Trends in Annual Rainfall in Gusau station, Zamfara state (1971-2010)

Trends in sorghum yield pattern

In Figure 1.3, the Sorghum yield was below normal in 1996 and steadily increased in 1997 until it became near normal between 1998 and 2002. Yield pattern then rose above normal between 2003 and 2008, sharply dropped in 2009 and rose above normal in 2010. The trend line equation shows that sorghum production has tendencies of increasing in future provided that rainfall attributes increasingly normalize. The figure illustrates that sorghum also did very well even when rainfall was below 900 mm because production was still significant between 1997 and 2001.



Source: Data Analysis for Gusau station, Zamfara state (2012)

Figure 1.3 – Trends in Sorghum yield pattern for Gusau station, Zamfara state (1996-2010)

Crop-climate relationship test

The Pearson's Product moment Correlation coefficient ***(r)*** was used to determine if there was any relationship between sorghum yield (Kilogram per hectares) and annual rainfall (centimetres) from 1996 to 2010. Oladipo (1993a) opined that the independent variable (**X**) is annual rainfall since its total amount, intensity, duration, variability, reliability and its spatial and temporal distribution influences the quality and quantity of sorghum yield (**Y**) phenomena especially in the tropical regions where the prevailing economic activity is simply agro-based.

Table 1.3: Computation of Relationship between Annual Rainfall total and Sorghum yield

Year	Sorghum yield (**Y**) ('00) (kg/hectares)	Annual Rainfall (**X**)(cm)	**X** - x	**Y**– y	(**X** – x) (**Y** – y)	$(\mathbf{X} - x)^2$	$(\mathbf{Y} - y)^2$
1996	8.90	4.60	-5.69	-4.79	+27.26	32.38	22.94
1997	7.60	9.00	-1.29	-6.09	+7.86	1.66	37.09
1998	13.30	10.10	-0.19	-0.39	+0.07	0.04	0.15
1999	13.10	6.00	-4.29	-0.59	+2.53	18.40	0.35
2000	13.20	8.40	-1.89	-0.49	+0.93	3.57	0.24
2001	13.10	15.80	+5.51	-0.59	-3.25	30.36	0.35
2002	13.50	13.80	+3.51	-0.19	-0.67	12.32	0.04
2003	17.80	8.40	-1.89	+4.11	-7.77	3.57	16.89
2004	17.10	10.40	+0.11	+3.41	+0.38	0.01	11.63

2005	15.00	8.50	-1.79	+1.31	-2.35	3.20	1.72
2006	17.10	7.95	-2.34	+3.41	-7.98	5.48	11.63
2007	16.00	16.00	+5.71	+2.31	+13.19	32.60	5.34
2008	14.10	9.00	-1.29	+0.41	-0.53	1.66	0.17
2009	9.10	10.40	+0.11	-4.59	-0.51	0.01	21.07
2010	16.50	16.00	+5.71	+2.81	+16.05	32.60	7.90
Total	**205.40**	**154.35**			**45.21**	**177.86**	**137.51**

Source: Computed by Author at95% confidence level

$\sum \mathbf{X} = 154.35$
$\sum \mathbf{Y} = 205.40$
$x = {}^{\sum X}/_{n} = {}^{154.35}/_{15} = 10.29$
$y = {}^{\sum Y}/_{n} = {}^{205.40}/_{15} = 13.69$
$\sum (\mathbf{X} - x)(Y - y) = +45.21$
$\sum (\mathbf{X} - x)^2 = 177.86$
$\sum (\mathbf{Y} - y)^2 = 137.51$
$\boldsymbol{r} = {}^{+45.21}/_{\sqrt{177.86 \times 137.51}} = +0.289$
$\boldsymbol{r = +0.289}$

In the case of Sorghum yield, the Pearson's Product Moment Correlation coefficient (***r***) indicates that there was a positive relationship though not also perfect, between the yield and annual rainfall from 1996 to 2010. About 93% of annual rainfall from 1996 to 2010 was above 600mm and 87% of sorghum yield was also recorded to be above 900 kilogram per hectare of arable land. Increases in annual rainfall amounts led to increases in Sorghum yields. This showed an increase in yield as a result of increase in rainfall.

Normalized Rainfall Index *(NRI)*

The Normalized Rainfall Index (NRI) has been computed to cover for each year from 1971 to 2010. The Annual rainfall amount (***Rsy***) expressed in millimetres, Long term mean (***LM***) and the Standard deviation (***SD***) as recorded in Table 1.2 has been used in calculating the ***NRI***. A summarized version of the Impact Vulnerability Status (IVS) for Gusau station, Zamfara state has been computed below as propounded by Turkes (1996).

Table 1.4: Computation of Normalized Rainfall Index and Vulnerability Status

Year	Annual Rainfall amount (mm)	$NRI = \frac{Rsy - LM}{SD}$	Character of Rainfall	Sorghum farmers'Impact Vulnerability Status
1971	440	-0.90	Moderate drought	Vulnerable
1972	560	-0.50	Near normal	Not vulnerable
1973	400	-1.03	Moderate drought	Vulnerable
1974	460	-0.81	Moderate drought	

1975	560	-0.50	Near normal	Not Vulnerable
1976	840	+0.42	Near normal	
1977	800	+0.29	Near normal	
1978	600	-0.37	Near normal	
1979	600	-0.37	Near normal	
1980	570	-0.47	Near normal	
1981	580	-0.43	Near normal	
1982	590	-0.40	Near normal	
1983	600	-0.37	Near normal	
1984	450	-0.86	Moderate drought	Vulnerable
1985	400	-1.03	Moderate drought	
1986	450	-0.86	Moderate drought	
1987	240	-1.56	Severe drought	Highly vulnerable
1988	730	+0.06	Near normal	Not vulnerable
1989	450	-0.86	Moderate drought	Vulnerable
1990	580	-0.43	Near normal	Not vulnerable
1991	731	+0.07	Near normal	
1992	460	-0.83	Mild drought	Slightly Vulnerable
1993	600	-0.37	Near normal	Not vulnerable
1994	740	+0.09	Near normal	
1995	450	-0.86	Moderate drought	Vulnerable
1996	738	+0.09	Near normal	Not vulnerable
1997	460	-0.83	Mild drought	Slightly Vulnerable
1998	900	+0.62	Mildly wet	
1999	1010	+0.99	Moderately wet	Vulnerable
2000	600	-0.37	Near normal	Not vulnerable
2001	840	+0.42	Near normal	
2002	1580	+2.87	Very wet	Highly Vulnerable
2003	1380	+2.21	Very wet	
2004	840	+0.42	Near normal	Not vulnerable
2005	1040	+1.08	Moderately wet	Vulnerable
2006	850	+0.46	Near normal	Not vulnerable
2007	795	+0.28	Near normal	
2008	1600	+2.93	Very wet	Highly vulnerable
2009	900	+0.62	Mildly wet	Slightly Vulnerable
2010	1040	+1.08	Moderately wet	Vulnerable

Source: Computed by Author using Microsoft Excel

From the NRI table above, there were more periods (53%) when rainfall was near normal most especially between 1975 and 1983. About 28% was influenced by drought occurrences. Severe drought was only recorded once in 1987 while moderate drought was recorded in the early 70s and middle and late 80s. About 19% was influenced by increases in the rainfall amounts which majorly occurred in the millennial periods with the highest peak recorded in 2008. It can be deduced that sorghum farming was not vulnerable when annual rainfall in the state was 600 mm to 900 mm, making it a drought resistant crop. Table 1.5 gives us a better representation of the decadal frequency in years of vulnerability status.

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Table 1.5: Decadal frequency in years of Sorghum Farmers' vulnerability

Decadal Years	Frequency in Years of Sorghum Farmers' Vulnerability Status			
	Not Vulnerable	Slightly Vulnerable	Vulnerable	Highly vulnerable
(1st period) 1971 - 1980	1972, 1975, 1976, 1977, 1978, 1979, 1980	-	1971, 1973, 1974	-
(2nd period) 1981 - 1990	1981, 1982, 1983, 1988, 1990	-	1984, 1985, 1986,1989	1987
(3rd period) 1991 - 2000	1991, 1993, 1994, 1996, 2000.	1992, 1997, 1998	1995, 1999,	-
(4th period) 2001 - 2010	2001, 2004, 2006, 2007	2009	2005, 2010	2002, 2003, 2008

The Decadal frequency of Impact Vulnerability Status (IVS) indicates that the earlier periods of the 1970s, middle and latter periods of the 1980s and 90s and the millennium were periods when sorghum farming was vulnerable with harsh conditions of drought and rainstorm rocking the study area during these periods. High vulnerability was greatly experienced in the 2nd and 4th periods in 1987, 2002, 2003 and 2008. Sorghum became a staple food crop within the periods when there was no vulnerability.

CONCLUSION AND RECOMMENDATIONS

Sorghum farmers were vulnerable to climate change in 1997 to 1999 when annual rainfall appeared to be below normal. However, yield began to increase from the early periods of the millennium. But sharp increases in rainfall amount above the long term mean from the late periods of the millennium affected Sorghum yield especially in 2009. This shows that Sorghum does not require so much amount of rainfall neither does it require very low moisture to mature and develop because it is a drought-resistant crop.

Therefore, sorghum farmers should employ certain measures in addressing impact vulnerability on Sorghum yield and boosting better productivity in the study area which include the following:

1. Planting the best short duration of sorghum-seed variety in periods of drought. The best short duration is the ICSV line which takes about 75 to 80 days to grow, mature and develop its yield.
2. Application of organic manure such as cow dungs, bird droppings, green manure, farm wastes, compost and other decayed vegetative matter; and fertilizers made up of Nitrogen, Phosphate, Potassium, Potash and Calcium are all important to soil fertility and subsequently, quality crop yield for maize in cases of drought.
3. Developing a more improved grain processing and storage facility is vital for maize grains and should be encouraged and provided for local farmers to reduce pest attacks on yield. Maize could be stored in cobs or shelled and kept in tightly closed silo or rhombus bags sprayed with acetylic dust or even dried pepper. Store houses should also be sanitized. Storehouses should be properly sanitized thoroughly by spraying insecticides, well-ventilated with louvers, lightly painted and cracks on the wall mended to avoid grain pests attack.
4. Executing the best soil conservation practices for farming such as crop rotation, shifting cultivation, terracing, use of seed-dressing fungicides and insects' treatments which would help to reduce pests attack
5. Updating and monitoring continuous rainfall data will help improve maize productivity in terms of agricultural planning. Yearly budgetary planning in the agricultural sector should involve the services of professional experts from the agricultural research institutes, Nigerian Meteorological Agency etc.
6. Large scale irrigation development schemes should be developed to intensify agriculture. Water for irrigation should be supplied from dams and reservoirs in areas underlain by crystalline rocks (igneous and metamorphic rocks), and from boreholes in areas of sedimentary rocks. Irrigation development has numerous benefits.

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