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INCREASED CLIMATIC VARIABILITY AND ADAPTIVE CAPACITY OF CROP FARMERS IN BENUE STATE

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Abstract

Agriculture as a source of food and fibre and contributor to sustenance of rural livelihoods is becoming continually exposed to threats coming with increased anomalies brought by the changing climate. Farmers find themselves having to respond to the vagaries of climate change in order to maintain food security and their livelihoods. This study utilised climatic data and socioeconomic data. Statistical methods were used to measure the status, trends, level for dispersion, anomalies and relationships between variables. The adaptive capacity index was calculated using scholarly methods. The daily rainfall average was 133.8mm. The annual average rainfall amount was 1194.1mm. The average annual temperature calculated was 27.84^{o}C. Relative humidity was an annual average of 67.8%. The average daily solar radiation was 20.1 MJ m^{-2} day^{-1}. The average vapour pressure deficit was 1.3 kPa. The ideal period for rain-fed crop cultivation was 168 days annually. The adaptive capacity index for the study area was 50.83% (moderate). The most vulnerable determinant was farm technology (18.75%). The least vulnerable determinant was networking (68.75%). Other determinants such as equity, farm management, and agricultural economic base revealed a percentage score of about 60% (moderate). The infrastructure determinant had a low percentage score of 36.25% (low). The adaptive capacity index of farmers in the Benue state is marginally moderate and needs to be improved upon by addressing the underlying gaps revealed through the determinant indices.

Key Word: *Adaptive capacity, Vulnerability, Nigeria, Vapour pressure deficit, Climate change, Anomaly index*

Introduction

Climate is influenced by geographic location and elevation, and is the sum total of weather conditions for periods up to twenty years or more (Olukoye and Adebiyi, 2007). Climate is the primary determinant of agricultural productivity. Given the fundamental role of agriculture in human welfare, concerns have been expressed about the potential effects of climate change on agricultural productivity (Adams *et al*., 1998; Tiwari,

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2000). Agriculture can be affected by climate change and could suffer important adverse impacts (Mendelsohn, 2000). Though there will be gains in some crops in some regions of the world, the overall impacts of climate change on agriculture are expected to be negative and pose threats to global food security (Nelson *et al*., 2009).

In Nigeria, agriculture is the main source of food (Manyong *et al*., 2005) and the source of raw materials used in the processing industries as well as a source of foreign exchange earnings for the country (Mohammed-Lawal and Atte, 2006). Agriculture in Nigeria is mostly rain-fed (Rilwani and Gbakeji, 2009; Ayinde *et al*., 2011) and any change in climate is bound to impact its productivity in particular and other socioeconomic activities in the country. Odjugo (2011) assessed climate change and global warming in Nigeria over two climatic periods 1901-1938 and 1971-2008. Odjugo (2011) found that temperature in Nigeria increased by 1.78^{o}C between the two climatic periods. This is above the global temperature average rise of 0.74^{o}C for 100 years (IPCC, 2007). Rainfall decreased by 91 millimetres in Nigeria between the two climatic periods with major shifts in double and single rainfall peaks. The study also highlighted an increase in rainfall in the coastal areas. Another study by Olusina and Odumade (2012) looked at future weather, temperature and rainfall, conditions in Nigeria for the next 50 years (2000-2050). Olusina and Odumade (2012) found that climatic variability is likely to increase and intensify leading to more droughts, floods and storms.

Climatic factors such as temperature, soil temperature, rainfall, humidity, sunshine, are important climatic factors that influence agricultural production (Ayoade, 2004; Cicek and Turkogu, 2005; Tyubee, 2006; Adamgbe and Ujoh, 2012). Ayinde *et al*., (2011) assessed the effect of climate change on agricultural productivity in Nigeria using climatic data from 1975 – 2005. Ayinde *et al*. (2011) found an occurrence of rainfall variability and unreliability. There were sharp reductions in annual temperature with unsteady trends and variations. In Nigeria, intensive rainfall has increased due to a reduction in the onset and cessation periods of rainfall, and an increase in drought in the northern parts due to desertification (Anuforom, 2013). The current evidence presented suggests that Nigeria, like most parts of the world, is experiencing the basic features of climate variability which will significantly affect agricultural production in the country. This requires studies to ascertain the extent of variability and inherent implications for rain-fed crop production and for adaption.Conscious efforts towards adaptation to climate change has become necessary as various countries of the world have begun to put in place mitigation measures. This will ensure long term mechanisms to deal with impacts of climate change deemed to be unacceptable (IPCC, 2007).

Climate change has a global coverage, and countries less responsible for climate change are significantly more vulnerable (Bondeau *et al*., 2007). This has necessitated developed countries to assist developing countries that are "particularly vulnerable" to climate change in meeting costs of adaptation to its adverse effects (IPCC, 2007). The simple reason for this is the perception that those countries that are least responsible for climate change are said to have the highest social vulnerability indices. These poor social vulnerability indices cover issues such as human health, and food security which are critical to survival. Agriculture is adjudged as one of the most vulnerable economic activities to be affected by climate change especially in developing countries (Fussel, 2009).

Adaptation to climate change has received attention from several scholars (Smit *et al*., 2000; Tubiello *et al*., 2000; Kelly and Adger, 2000; Dessai *et al*., 2003; Adger *et al*., 2004). Adaptation could refer to a process of achieving a set of actions or outcomes in a system (household, community, group, sector, region, country) so as to equip the system to cope better with, manage or adjust to some changing condition, stress, hazard, risk or opportunity (Smith and Wandel, 2006). The parameters considered for planning adaptation strategies can vary in scale from the organism or individual to the population of a single species or an entire ecosystem (Krimbas, 2004).

Adaptation potential is assessed through indicators of adaptive capacity which allows for the determination of the robustness of response strategies over time, and to better understand the underlying processes (Adger *et al*., 2004). Adaptive capacity indicators can be derived from six determinants which include economic resources; technology; infrastructure; information, skills and management; institutions and networks; and equity (Smit *et al.,* 2001). Other methodologies have been proposed (Folke *et al*., 2003; Wall and Marzall, 2004).

It is possible to compare the adaptive capacity of individuals and communities across time and space at different scales. Adger *et al*. (2004) advised against aggregating indices of adaptation across scales because they differ at various scales. The occurrence of adaptation is not instantaneous but requires time for adaptive capacity to translate to adaptation. Adaptive capacity therefore represents potential to realise actual adaptation, and as such, a high degree of adaptive capacity only reduces a system's vulnerability to future hazards (Adger *et al*., 2004).

Adaptive capacity is easily influenced by economic and natural resources, social networks, entitlements, institutions and governance, human resources, and technology. Therefore adaptation to climate change and risk of exposure to climate risk can be exacerbated through multiple stresses. Studies on the assessment of adaptive capacity are limited in Nigeria (Adger *et al*., 2007).

The issue of climate variability in the study area is addressed in this paper. In addition, the adaptive capacity index of farmers in the study area to climate variability was calculated to demonstrate significance in development considerations.

Materials and Methods

Study Area

The study area is located in the Lower River Benue Basin, Nigeria between Latitudes 7^{o} 13'N and 8^{o} 00'N and Longitudes 8^{o} 00'E and 9^{o} 00'E. The study area falls within the boundaries of Benue State. The study is concentrated in three Local Government Areas (Makurdi, Gboko and Tarka), however, the findings have implications for the remaining parts of Benue State which is an agricultural based economy (Figure 1).

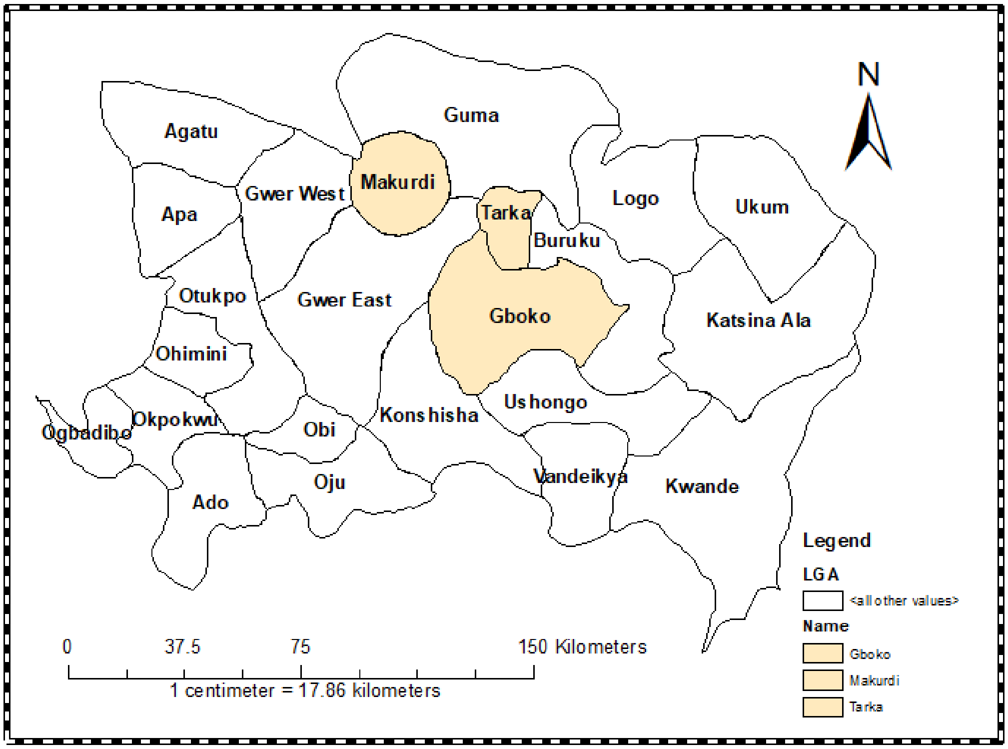

Figure 1: Study Location

Climatic Data

Over 40 years (1973-2013) climatic data was obtained from the Nigerian Meteorological Agency Abuja (NIMET) on climatic factors for Makurdi meteorological station. Available data obtained from NIMET included rainfall (1973-2013), minimum and maximum temperature (1973-2014), solar radiation (1973-2014), and relative humidity (1974-2008). Climatic data (rainfall, temperature, humidity, and solar radiation) was analysed for trends, variations, possible future scenarios and suitability for crop production. The standardised anomaly index and the reoccurrence interval were used as elsewhere in Ologunorisa and Tor (2006). Variability was calculated using the standardised anomaly index (SAI) which is presented as Equation1.

$$SAI = \frac{X-\bar{X}}{SD} \quad \text{............... 1}$$

Where X is the annual total or average, and $\bar{X}$ is the mean of sum of annual totals for years investigated. SD is the standard deviation of the variables.

The onset and cessation of rainfall was calculated following the method described in Adamgbe and Ujoh (2012). The reoccurrence interval (RI) of extreme rainfall events was calculated using the annual series analyses method (Equation 2).

$$RI = \frac{N+1}{M} \quad \text{............... 2}$$

Where RI is the return period in years, N is total number of extreme events, and M is the rank of individual extreme event.

The atmospheric vapour calculations were carried out using the method described in FAO (1998). The saturation vapour pressure was calculated using Equation 3.

$$eo(T) = 0.6108\exp[\frac{17.27T}{T+237.3}] \text{ ....3}$$

Where e°(T) is saturation vapour pressure at the air temperature measured in kilo Paschal (kPa), T is for both minimum and maximum air temperature [°C], and exp[..] is 2.7183 (base of natural logarithm) raised to the power [..].

The mean saturation vapour pressure was calculated with e°(Tmin) and e°(Tmax) using Equation 4.

$$Es = e°(Tmax) + e°(Tmin)/2 \text{ ......4}$$

Where Es is the mean saturation, and e°(T) values from Formula 3.

In order to arrive at the actual vapour pressure for the period 1973-2013, Equation 5 was used.

$$Ea = \frac{RHmean}{100xEs} \text{ .... 5}$$

Where Ea is the actual vapour pressure, RH mean is the mean daily relative humidity, and Es is the value of mean saturation vapour pressure.

The vapour pressure deficit was calculated using Equation 6.

$$\text{Vapour pressure deficit} = Es - Ea \text{....6}$$

Where Es is the mean saturation and Ea is the actual vapour pressure.

Analysis was conducted using Microsoft Excel and Statistical Package for Social Sciences (SPSS version 17) software environment.

Socioeconomic Data

Socioeconomic data collection was done through focused group discussions, questionnaire administration, and rapid rural appraisals. Questionnaires were administered randomly to members of farming cooperative societies in Makurdi, Tarka, and Gboko during focused group discussions. A total of 300 questionnaires were administered in Makurdi, Tarka and Gboko. However, only 281 were recovered as some members failed to return them. Data analysis such as descriptive statistics was mainly performed in the Microsoft Excel. The detailed results of the socioeconomic analysis is published elsewhere (Abah and Petja, 2015; 2016).

Adaptive Capacity Analysis

The methodology for adaptive capacity analysis was adapted from Smit *et al*. (2001), Smit and Pilifosova (2003), and the processes followed in Swanson et al; (2007). Smit *et al*. (2001) provided six determinants of adaptive capacity related to climate change. Each of these determinants has rationales which provide guidance for the development of indicators to measure degree of vulnerability (Table 1). These determinants and rationale were used to identify indicators that suit the agricultural focus of this study.

After the adaptation of the determinants to suit the purpose of this study, four features relating to agricultural adaptive capacity were identified for each determinant framework from the socioeconomic survey result summaries. These features were used in identifying indicators that were measureable using percentages (Table 2).

The indicator percentages were grouped in brackets based on intervals of five from 0-5% to 95-100%, and ranked in ascending order from 0-20 for 'higher is better indicators', and in descending order from 20-0 for 'lower is better indicators'. The total possible score for each indicator was 20 and the total possible score for each determinant was 80. The determinant score was arrived at using Equation 7:

Determinant percentage score = (Total indicator ranking scores/80) x 100....... 7

The adaptive capacity index for the study area was therefore calculated by computing the percentages for each determinant and the cumulative percentage of determinants (Equation 8)
.

Adaptive capacity index = (Total determinants scores/600) x 100......... 8

Five category classes were used to measure the adaptive capacity index of the study area.
The category classes used were 0% - 20% (Very low); 20% - 40% (Low); 40% - 60% (Moderate); 60% - 80% (High); and 80% - 100% (Very high).

Table 1: Adaptive capacity determinants

Determinants	Rationales
Economic resource base	Adaptive capacity is enhanced by greater economic resources
	Adaption options are limited by inadequate financial resources
Technological advancement	The range of adaptation options is limited by inadequate technology
	Technologically challenged regions are less likely to develop and/or implement technological adaptations
Availability of information and skills	Limited access to information, skilled and trained personnel reduces adaptive capacity
	Greater access to information increases likelihood of timely and appropriate adaptation
Available infrastructure	Adaptive capacity is enhanced by greater variety of infrastructure
	Spatial attributes and quality of infrastructure also affect adaptive capacity
Institutional capacity	Social institutional strengthening helps to reduce impacts of climate related risks
	Policies and regulations influence adaptive capacity
Equity	The equitable distribution of resources enhances adaptive capacity
	Availability of and level of entitlement to resources are important to adaptive capacity

Source: Smit *et al*. (2001).

Table 2: The determinants, features and indicators used to calculate adaptive capacity index

Determinants	Features	Indicators
Agricultural economic base	Monthly income	Percentage of population earning high (above 1 dollar a day X 30 days) a month. Higher is better.
	Farm expenditure	Percentage of population spending above series average on farming. Higher is better.
	Crop yield	Percentage of population recording high crop yields. Higher is better.
	Agricultural diversity	Percentage difference between agricultural types. Lower is better.
Farm Technology	Irrigation	Percentage of population engaged in irrigation farming. Higher is better.
	Mechanisation	Percentage of population engaged in mechanised farming. Higher is better.
	Processing equipment	Percentage of population utilising modern processing equipment. Higher is better.
	Storage facilities	Percentage of population utilising appropriate storage facilities. Higher is better.
Farm management	Farm ownership	Percentage of population that own their own farmlands. Higher is better.
	Farm inputs	Percentage of population that have access to fertilisers. Higher is better
	Farm labour	Percentage of population heavily dependent on farm labour. Lower is better.
	Farming season	Percentage of population that have good knowledge on farming season. Higher is better.
Infrastructure	Dependence on agriculture	Percentage of population dependent on agriculture. Lower is better.
	Water sources	Percentage of population that have access to portable water. Higher is better.
	Housing type	Percentage of population that have access to modern housing (zinc roof and brick walls). Higher is better.
	Roads	Percentage of population that have access to tarred roads. Higher is better.
Networking	Cooperative membership	Percentage of farmers that belong to farming cooperative societies. Higher is better.
	Mobile communication	Percentage of population that have access to mobile telecommunication services. Higher is better.
	Agricultural extension	Percentage of population that have regular contact with agricultural extension workers. Higher is better.
	Markets	Percentage of population that have close proximity (<5km) to markets. Higher is better.
Equity	Access to electricity	Percentage of population with access to electricity supply. Higher is better.
	Access to hospitals	Percentage of population with access to government hospitals. Higher is better.
	Access to schools	Percentage of population with access to government schools. Higher is better.
	Access to police	Percentage of population with access to police stations. Higher is better.

Results and Discussion

Climatic Conditions

Rainfall

The daily rainfall average calculated for the period 1973-2013 was 133.8mm and the median was 108.7mm. The highest daily rainfall recorded for the period was 149mm which was recorded on the 3rd of August 2000. The earliest rain recorded in the period was on January 1st 1985 when 18.6mm of rainfall was recorded, and on the 2nd of January 2008 when 3mm of rainfall was recorded. Daily rainfall began to increase significantly in the month of April and continued to increase and peaked in the months of August and September for the period 1973-2013.

The monthly total rainfall for the period (1973-2013) showed that August had the highest amount of 9220.7mm for the period and was followed by September with 9021.7mm. The lowest month was December with a monthly total of 37.6mm for the period. The months of April to October all recorded monthly totals above 3000mm, and more than 50% of the rainfall amount recorded was in four months (June-September).

The annual average rainfall amount recorded for the period 1973-2013 was 1194.1mm, and the median was 1207.9mm. The year with the highest amount of rainfall was 1999 (1617.1mm). Other years with high amounts of rainfall were 1984 (1572mm), 1998 (1537.6mm), 1975 (1508.6mm), 2012 (1466.7mm), 1980 (1425.5mm), and 2009 (1407.5mm). The year with the lowest amount of rainfall was 2003 (761.5mm).

The average months of onset and cessation for rainfall duration for the period (1973-2013) were put at April and October. This means that sustained rainfall was available for rain-fed agriculture between the months of April to October 1973-2013. However, variations were observed annually with regards to onset and cessation of rainfall. It was observed that onset of rainfall began in March in 1980, 1984, and 1985. Onset of rainfall began in April for most of the remaining years. Rainfall cessation began in October in 1973, 1983, 1985, 2001, and 2003. Cessation of rainfall began in November for the remaining years. Even though rainfall onset began in April for most of the years assessed, the threshold was either reached or surpassed late in April. This suggests that rain-fed agricultural activities should now be delayed till the penultimate or ultimate week of April each year. Adamgbe and Ujoh (2012) extensively looked at climatic variability and crop yield in Benue for 25 years (1986 – 2010). Adamgbe and Ujoh (2012) as part of their finding revealed that climatic parameters including rainfall and temperature accounted for a 48% of the variance in rice yield, 71% of variance in cassava yield, and 78% of the variance in yam yield. Therefore, interpretation of annual weather changes is important to crop cultivation.

The average number of rainy days for the period (1973-2013) was 85.7 days. The year with the highest number of rainy days was 1977 (159 days). Other years with high number of rainy days were 1978 (156 days), and 1975 (121 days). The year with the lowest number of rainy days was 1983 (56 days). The linear forecast showed that the number of total annual rainy days is decreasing.

The relationship between total number of rainy days and annual rainfall totals showed that the year 1977 which had the highest number of rainy days had produced an annual rainfall total of 1387.1mm. The year 1978 which had a total number of 156 rainy days produced an annual rainfall total of 1326.2mm, and 56 rainy days in 1983 produced an annual total of 930.3mm. A disturbing trend which supports increasing rainfall intensity as observed showed that although the total number of annual rainy days seems to be decreasing, the annual rainfall totals is not decreasing. There are several years in which less than a hundred days of rainfall produced annual rainfall totals over 1200mm which is above the annual average of 1194.1mm calculated for the period 1973-2013. Notable among these years are 1999 which produced the highest annual rainfall total of 1617.1mm in 95 rainy days. The year 1984 recorded an annual rainfall total of 1572mm in 79 days. Similarly, the year 1998 recorded annual rainfall totals of 1537.6mm in 76 days. The year 2012 which was most recently notable for rainfall intensity and severe flooding, recorded a total of 1407mm of rain in 89 days.

This study utilised daily rainfall averages of >40mm during a 24 hours period as heavy rainfall (rainstorms) as stated in FAO (1998). The year with the highest number of days of heavy rainfall was 1998. Other years with more than 10 days of heavy rainfall were 1984, 1999, and 2006.

Extreme daily rainfall causes flooding. The highest daily amounts of rainfall for the each year (Julian day) was adopted as extreme daily rainfall (Table 3). The reoccurrence interval showed that the extreme rainfall event ranked number one (149mm) may occur again in 42 years (Table 3). The second ranked event of 125.3mm may occur in 21 years. Extreme daily rainfall events below 100mm have shorter intervals between 1-5 years and are likely to occur more often. Extreme daily rainfall events cause flooding in Makurdi annually and this is well documented in the media and several literature (Ologunorisa and Tor, 2006; Ocheri and Okele, 2012; Abah, 2012; Shabu and Tyonum, 2013).

Rainfall fluctuation was assessed in five year brackets. There were two consecutive periods of deviation from the annual mean (1983-1992, and 2003-2007). The standardised rainfall anomaly index (SAI) for the period 1973-2013 showed that there were slightly more wet years (22) than drier ones (19). The year brackets of 1982-1995 and 2000-2011 witnessed more negative deviations. The period 1975-1978 and 1996-1999 were the most consistent wet periods. The standardised rainfall index revealed that rainfall for the period 1973-2013 witnessed very high variation and inconsistency. Even though Makurdi experiences spells of high rainfall intensity, the progressive consistency of rainfall in Makurdi is decreasing.

Table 3: Extreme daily rainfall events and reoccurrence intervals (1973-2013)

Date	Amount (mm)	Rank	Reoccurrence interval (years)
Aug 3, 2000	149.30	1	42
Jun 30, 1986	125.30	2	21
Jul 20, 1981	123.70	3	14
Jun 25, 1999	119.30	4	10.5
Sep 2, 1973	110.20	5	8.4
Sep 2, 1975	110.20	6	7
Jul 28, 1974	110.00	7	6
May 5, 2009	105.40	8	5.25
Sep 6, 1990	100.70	9	4.67
Aug 16, 2012	98.40	10	4.2
Aug 11, 2002	96.80	11	3.82
Aug 4, 1984	95.00	12	3.5
Jul 24, 2006	94.70	13	3.23
Jun 13, 1998	92.90	14	3
Sep 7, 1997	89.50	15	2.8
Aug 29, 1996	86.30	16	2.63
Aug 22, 1987	85.30	17	2.47
Sep 18, 1989	83.30	18	2.33
Jul 10, 1993	80.30	19	2.21
Sep 18, 2011	79.80	20	2.1
Sep 21, 2013	77.10	21	2
Jul 15, 1985	76.80	22	1.91
Aug 13, 2007	76.30	23	1.83
Jul 16, 1980	76.20	24	1.75
Jun 5, 1983	74.00	25	1.68
Sep 5, 2010	73.50	26	1.62
Aug 20, 1979	71.90	27	1.56
Jul 15, 1982	71.70	28	1.5
Oct 17, 1976	71.10	29	1.45
Aug 13, 1995	70.60	30	1.4
Jun10, 2005	70.60	31	1.35
Sep 11, 1992	70.50	32	1.31
May 14, 2008	66.40	33	1.27
Aug 30, 2004	65.80	34	1.24
Aug 22, 1994	61.70	35	1.2
Aug 27, 1991	56.60	36	1.17
Sep 2, 1977	55.10	37	1.14
Jun 7, 2003	54.70	38	1.11
Oct 17, 1978	53.30	39	1.08
Aug 2, 2001	51.30	40	1.05
Oct 27, 1988	45.20	41	1.02

Temperature

The average annual temperature calculated for the period January 1973 to December 2014 was 27.84^{o}C. The highest annual temperature averages were recorded in 2005 (28.6^{o}C), 1998 (28.55^{o}C), 2010 (28.5^{o}C), and 2003 (28.43^{o}C). The lowest temperature values were recorded in 2012 (26.8^{o}C) and 1974 (27.2^{o}C).

The average maximum and minimum daily temperatures for the period 1973-

2014 showed that temperature is highest between the first 20 to 110 days of the year. Temperature dropped and stabilised in the months with high rainfall (July, August, and September), and rises around the onset period of rainfall.

The highest maximum temperature for the period 1973-2014 was recorded on February 5 1998 (42^{o}C). A total of 186 days recorded maximum temperatures above 39^{o}C between 1973 and 2014 and were classified high discomfort days. All the high discomfort days with extreme maximum temperature (>39^{o}C) fell between the months of February and April. Most of the other days of the year between 1973 and 2014 had maximum temperature between 30^{o}C -39^{o}C. This means that atmospheric temperature in Makurdi causes some form of discomfort to humans and livestock for most parts of the year annually.

The annual average maximum temperature from 1973-2014 showed that the years with the highest maximum temperature were 1998, 1973, 2003, 2005, and 2010. The lowest minimum temperature (10^{o}C) was recorded on February 2, 1973. Minimum temperature below 12^{o}C for the period 1973-2014 was recorded in 22 days between the months of December and February. The year with the highest frequency of minimum temperature lower than 12^{o}C was 2012 which recorded 9 days of minimum temperature between 10.8^{o}C-11.8^{o}C on January13, and December 21-31. The year 2011 recorded 4 days of minimum temperature between 11^{o}C and 11.8^{o}C in December (2-9).

The result of the standardised temperature anomaly index (SAI) for the period 1973-2014 revealed several departures from the referenced annual mean. There were 20 years with positive anomalies indicating warmer temperature than the reference mean. Negative anomalies were observed in 19 years indicating cooler temperature than the reference mean. A string of negative anomalies occurred between 1974 and 1992, and a string of positive anomalies occurred between 1998 and 2010. The coolest year was 2012 and the warmest was 2005. These two temperature extremes occurred in the last 10 years. The near equal numbers of positive and negative temperature variations are similar to that of rainfall observed for the same period. This could be a glimpse into the Earth’s struggle to maintain climatic homoeostasis.

Relative Humidity

Relative humidity in Makurdi is quite high annually with an annual average of 67.8% calculated for the period 1974-2008. The most extreme value (99.5%) was recorded on August 13 in 1997. Relative humidity values between 96.5% and 99.5% were recorded severally in 1974, 1975, 1979, 1981, 1983, 1988, 1993, 1995, 1997, 2006, and 2007.

The year with the highest humidity average was 1975 (73.7%). The year 2008 (72.6%) and 2007 (72%) had high humidity averages. The lowest humidity average was recorded in 1977(59%). The humidity average for most of the years between 1974 and 2008 was between 60% and 70%. The relative humidity median between 1974 and 2008 ranged from 61.5% to 76.5%.

Relative humidity and temperature in Makurdi have an inverse relationship, and the months between February and April were periods of potential heat stress. The period between day 113 and day 305 had consistently high figures in the peak of the wet season while the drop in both humidity and temperature from day 321 and between day 1 and day 65 suggested drier periods.

The greatest positive deviation of relative humidity from the reference annual mean was in 1976 and the greatest negative deviation was a year later in 1977. Even though the highest relative humidity percentage was recorded in 1997 as earlier established, it had a negative deviation from the reference mean.

A five year moving average was put through the relative humidity anomaly series. The trend shows that relative humidity between 1974 and 2008 mostly had a negative deviation and this was continuous between 1984 and 2004.

Solar Radiation

The average daily and annual solar radiation obtained was 20.1 MJ m^{-2} day^{-1}. The lowest was 5.7 MJ m^{-2} day^{-1} and was recorded in July 1985 and 1987. The peak of the rainy season usually received the least solar radiation which is a function of cloud cover. The daily equivalent evaporation was calculated by multiplying the daily solar radiation with 0.408 as stated in FAO (1998). The annual total evaporation in Makurdi is 3006.8 mm day^{-1} with a daily average of 8.2 mm day^{-1}.

The year 2012 received the highest average solar radiation (21.4 MJ m^{-2} day^{-1}) and the lowest average of 19.5 MJ m^{-2} day^{-1} was recorded in 1980 and 1987. In total, nine years (1973, 1974, 1989, 1995, 2000, 2001, 2011, 2013, and 2014) had solar radiation averages above 20.3 MJ m^{-2} day^{-1}. Solar radiation in Makurdi has been extensively analysed and described as suitable for solar energy applications including farming, and solar radiation has an immense influence on evaporation and transpiration (Isikwue *et al*., 2014).

Atmospheric Vapour Deficit

The mean saturation vapour pressure (Es) calculated from daily maximum and minimum temperature series (1973-2013) was 3.9 kPa (Table 4) and the average actual vapour pressure (Ea) calculated was 2.7 kPa. The vapour pressure deficit (VPD) for the period was calculated. The average vapour pressure deficit was 1.3 kPa. The first quarter of the year had the highest vapour pressure deficit while the lowest vapour pressure deficit was experienced during the peak of the wet season in the third quarter. It is generally noted in literature that the ideal vapour pressure deficit for most crops is between 0.8 kPa to 1 kPa. The ideal period for rain-fed crop cultivation in the study area was found to be between day 141 and day 309 (about 168 days annually). Low VPD can cause plants to have mineral deficiencies, guttation, disease, and soft growth, while high VPD can cause wilting, leaf roll, and stunted growth (FAO, 1998).

Table 4: Descriptive statistics of atmospheric vapour data of Makurdi (1973-2013)

	N	Range	Min	Max	Mean	Std. Dev.	Variance	Skewness
e^o(Tmax)	366	2.57	4.05	6.62	5.1739	.75049	.563	.364
e^o (Tmin)	366	1.61	1.83	3.44	2.7227	.36810	.135	-.589
Es	366	1.61	3.40	5.01	3.9483	.43603	.190	.972
Ea	366	1.50	1.60	3.11	2.6510	.41283	.170	-1.119
Vapour deficit	366	1.94	.55	2.50	1.2973	.61985	.384	.493

Socioeconomic Conditions

Out of the total respondents, 55.3% were males and 44.7% were females. The age structure revealed that the age brackets 20-29 years (27.10%), 30-39 years (26.34%), and 40-49 years (23.66%) formed the bulk of respondents. Majority of the respondents had attained at least one form of formal education. The level of education with the highest percentage was secondary education (41.02%). Majority of the respondents practice farming as their source of livelihood. The results showed that 74.60% of respondents indicated farming as either a first or second occupation. Most of the respondents (70.27%) earned 30,000 naira and below monthly.

Cultivated crops included rice (20.44%), maize (8.64%). Beans had a frequency of 14.54% and soybeans had a frequency of 12.35%. Yam had the highest frequency of all the crops mentioned (25.24%) and cassava also had quite a high frequency (18.79%). Other crops mentioned were pepper, okra, vegetables (leaves), tomatoes, oranges and mangoes. Pepper was the most indicated vegetable.

The month of April was the most indicated as the start month, while November and December were the most indicated end months. The most popular fertiliser type among respondents is the NPK which is nitrogen, phosphorus and potassium based (52.7%), followed by Urea based fertilisers (35.4%), and then single super phosphate (SSP, 11.9%). The number of bags used ranged from 1 – 25bags. The percentage of respondents who claimed irrigation is practiced in their communities were few (30.7%) as against those who claimed irrigation is not practised in their communities (69.3%). The predominant source of water for irrigation as indicated was river/stream (56%), which was followed by hand dug wells (22%). Dams and boreholes made up 11% and 4%.

The predominant farm sizes were between 1-5 hectares (37.5%). Other significant sizes include those between 5-7 hectares (21.3%) and 7-10 hectares. Most of the farms of respondents were within five kilometres from their households. Out of this majority, 13% have farms which were less than one kilometre from their households. Only 25% travel beyond 5 kilometres to carry out agricultural activities. Even though 87% of respondents have farms that were at least more than 10 kilometres from their households, 55.8% of respondents process harvest after transporting them home. Another 34.2% indicated that they process harvest in the farm with hired labour before transporting them to storages.

Most respondents claimed they spend above 30,000 naira on their farms annually. More than half of the respondents (58%) spend more than 20, 000 naira annually on their farms. Another 33.9% indicated they spend below 15,000 naira annually. Most respondents involved in farming rice (62.3%), yam (64.3%), and cassava (64.8%) spend more than 20, 000 naira annually on their farms. The percentage of respondents that sell between 10-30% of farm output was 34%. Most respondents (56.8%) indicated that they sell between 40-70% of farm output. Another 9.2% indicated that they sell between 80-100% of output. Respondents mostly source for funding from relations (58.3%). But community cooperatives have started having a growing influence on funding for farm operations (22.9%). Borrowing from community cooperatives is not as challenging as regular banks because they have very flexible payback mechanisms and very low interest rates. Going by the indications of respondents, it was clear that family labour was less available or was transforming into hired labour. This was because 50.2% of respondents indicated hired labour over family labour (30%).More than 60% of the respondents indicated an increase in yields. The increased trends mentioned by respondents were due to availability of fertilisers, improved seedling, and expansion of area cultivated.

According to respondents, 45.7% of them live in zinc roofed houses with cement blocks. Another high percentage (20.2%) live in thatched roofed and mud walled houses. Most of the respondents (61.71%) indicated hand dug wells as the main source of water supply. Most of the respondents (70.26%) claimed they have markets within a kilometre and under five kilometres to their farms or households. Most of the respondents (84.19%) have rarely seen an agricultural extension worker in their communities. Respondents (74.67%) indicated the lack of milling and storage facilities in their communities. Over 50% of respondents in this study claimed to have electricity supply. Pipe borne water is grossly inadequate as only 23.3% indicated availability in their communities. Pipe borne water here may refer to community borehole projects by government. The most available facilities were the Global Satellite Mobile communication networks (86.2%) and markets (72.7%). Government schools (66.8%), radio signals (60.1%), and hospitals (56.9%) were also appreciably indicated. Banks were the least available. Only about half of the respondents (50.6%) had police stations in the communities. Respondents indicated an inadequacy of health services including HIV and AIDS in the communities. A total of 57.7% of respondents claimed they don't know any farmer who has HIV or has died from AIDS. However, another 42.3% claimed that they know farmers who have HIV or have died from AIDS.

Many respondents (70.9%) had at least heard about climate change. The most indicated variability was rainfall irregularity. Respondents indicated that rainfall duration had become shorter. Drought was used to describe the increased number of dry days noticed by some respondents. Even though the duration of the wet season had become shorter, the intensity of rainfall has increased as indicated by some respondents. Respondents claimed that the intensity of heat had increased. Overall, irregular onset and cessation of rainfall, shorter wet season, increased rainfall intensity, increased heat intensity, drought and flooding were the summaries of weather variability indicated by respondents.

Adaptive Capacity Index

The adaptive capacity index calculated for the study area fell into the moderate adaptive capacity category (50.83%). The most vulnerable determinant was farm technology with the lowest percentage of 18.75% (very low). The least vulnerable determinant was networking with an appreciable percentage of 68.75% (high). Other determinants such as equity, farm management, and agricultural economic base had a percentage score of about 60% (moderate). Figure 2 is a graph showing the average determinant indices. The infrastructure determinant had a low percentage score of 36.25% (low).

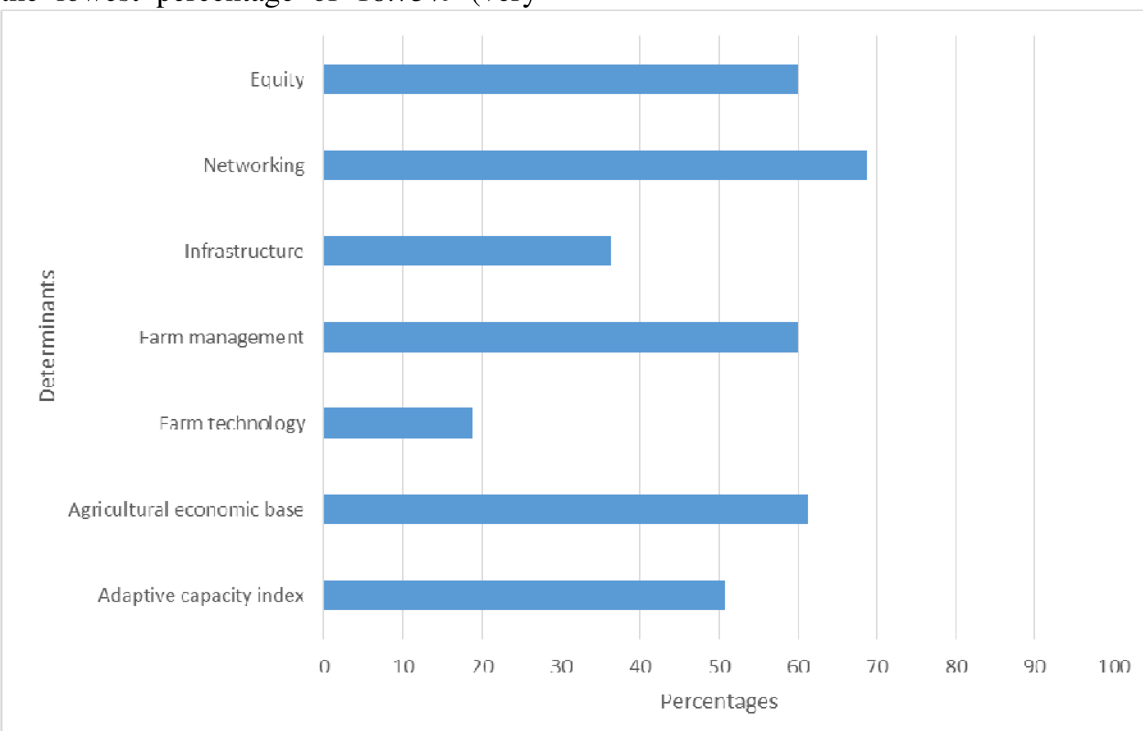

Figure 2: Determinant scores and adaptive capacity index for the study area

The moderate adaptive capacity suggested that farmers in the study area were already striving to cope with whatever climatic changes they had observed. However, this adaptive capacity category has not placed farmers in the study area in a strong resilient position especially with a lean moderate score of 50.83%. Multiple stresses related to HIV, land degradation, trends in economic globalization and violent conflicts can adversely affect the index score realised for study area. There is a need to begin to look at critical gaps exposed through this adaptive capacity analysis process with a view to finding home grown solutions that will strengthen the adaptive capacity and resilience of farmers in the Benue state to impacts of climate change.

The concept of adaptations assesses the degree to which communities moderate or minimise negative impacts of climate change, or optimise positive effects, to avoid harm (Smit and Wandel, 2006). The results demonstrate the necessity of climate change adaption strategies for communities with significant risk of livelihood loss. Communities in developing countries are mostly at the receiving end of climate change since dependence of livelihoods is primarily based on sectors influenced heavily by climate for instance agriculture; as well as infrastructure influenced by climate such as houses, amenities, and transportation; and inadequate adaptive capacity to cope with impacts of climate change (Patt *et al*., 2010; Ford *et al*., 2015). The study area has witnessed climatic variability which has affected farming practices over several seasons as alluded to by respondents. This was evident in the higher number of farmers who practiced the cultivation of cowpeas together with cereal crops not only to optimize produce but to improve low soil fertility conditions. Higher rainfall intensity over shorter periods has altered the length of the farming season as farmers tend to avoid flooding periods during the peak of the rainy season. This means farmers now retire earlier from farming seasonally as against earlier periods creating the need to engage in additional income generating activities since irrigation farming was still quite unpopular. The 2012 flood disaster in Nigeria drowned about 354,776 cattle, 2,161,607 goats/sheep, 574,020 pigs, and 4,681,936 poultry birds while crop production losses amounted to about 305.1billion Naira (Ukeje and Ujor, 2016). Early warning systems, timely climatic information made available to farmers during the farming season, and adequate standard storage systems will enhance resilience to seasonal flooding and other climatic anomalies. Farmers are already facing challenges due to current weather variability and associated shocks, necessitating the need for support to assist in building livelihood resilience to current climate-induced risk in the short term while planning for adaption to future climate change (Cooper *et al*., 2013). The gaps presented in the adaptive capacity index are significant. Bridging gaps in farm infrastructure and technology while optimising others will support farmers in the study area to build resilience and overcome immediate challenges faced with utilising mainly traditional farming methods and inadequate infrastructure. Swanson *et al*. (2007) mentioned policy interventions which can enhance the adaptive capacity of communities to climate change including improving the relationship between commodity prices and farm income, sustainable soil management practices, steering away farming from marginal areas, investment in farm technology and equipment, improving transportation, and access to agricultural education. These policy interventions should be targeted to the most challenged areas identified in the adaptive capacity indices, while continuously monitoring the dynamics of weather and climate for trends (Swanson *et al*., 2007).

Conclusion

This study has made some critical observations. The study has observed a trend of late rainfall onset and early rainfall cessation. Rainfall intensity seemed to be increasing with a gradual reduction in the number of rainy days.

The number of rainstorms is increasing, and the reoccurrence interval for most extreme rainfall events was put between 1 to 5 years. Analyses revealed that rainfall between 1973 and 2013 in the study area had a high variation. The daily maximum temperature and annual temperature averages for the study area is gradually increasing leading to increased heat stress. Solar radiation and evaporation values were found to be adequately suitable for agricultural purposes. The vapour pressure deficit results suggested that about 168 days annually (between days 141 – 309) are optimal for rain-fed crop cultivation in the study area. The study found that farmers in the region where most vulnerable in the area of farming technology and infrastructure. Farmers in the region are moderately vulnerable in the equitable distribution of amenities and available farm management skills. The agricultural economic base seemed to be the least vulnerable feature. The adaptive capacity index of farmers in the Benue state was moderate and needs to be improved upon over time by addressing the underlying gaps revealed through the determinant scores.

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