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Research Article

Assessment of Vulnerability of Rice farmers to Climate Variability in Kogi State, North Central Nigeria: A Vulnerability Composite Index Approach

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Abstract
Vulnerability assessments to climate change are a possible criterion for adaptation and have a long history on multidisciplinary research. Identification and assessing the degree of vulnerability as a result of climate change is an essential pre-requisite for reducing climate change impacts. The study focuses on vulnerability of rice farmers to climate change in Kogi State, Nigeria. Data for the study were obtained from primary and secondary sources with the aid of structured questionnaire administered to 123 rice farmers from across the four agricultural zones in the State. A total of 15 environmental and socio-economic indicators were identified and analyzed to measure vulnerability status in the agricultural zones. Composite Climate Change Vulnerability Index computed from the hazards, sensitivity and adaptive capacity components revealed that all the rice farmers' were vulnerable to climate change but vary in the degrees of vulnerability. Scores of Exposure-Sensitivity Index (ESI) suggest that rice farmers in Owolikpa and Igalaogba were most prone and susceptible to climate change whereas, Baganna, Ikande, Odoepe, and Iluke were least exposed and sensitive to climate change. Kpancehe, Kakanda, Girinya, Eggan,and Aiyetoro were categorized under very high to high degree of vulnerability while Iya, Baganna and Echa were rated low vulnerable to climate change. These prioritized areas, based on rank and degree of vulnerability, should be given immediate consideration, and measures should be taken by internalizing region specific needs to address the growing challenge of climate change.

Keywords: *Adaptive capacity, Climate change, Composite index, Sensitivity, Vulnerability*

Introduction

Climate change has become one of the most intervening global issues facing humankind and the earth's natural system. Intergovernmental Panel on Climate Change (IPCC) (2007) refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change has already begun to transform life on earth and around the globe as seasons are shifting, temperatures are climbing and sea levels are rising (FAO, 2011). In the past decades, issues related to climate change has shifted from being the concern of a small number of environmental activities and specialized scientists to being the focus of broad scientific, political and community interest (Lefroy *et al.*, 2010). This is because climate change will influence crop production, hydrologic balances and food systems.

Consequently, the effects of climate change on food and water resources are critical for livelihood in Africa where most of the population especially farmers rely on agriculture, which is sensitive to climate variation (Ayinde *et al.*, 2011). Thus, African countries which have economies largely based on rain-fed agriculture are vulnerable to climate change. Moreover, rural farmers in Sub-Sahara African are likely to be more vulnerable to

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climate change because of the compounding challenges of poverty, low infrastructural and technological development and high dependence on rain-fed agriculture (Lipper *et al.*, 2014).

In Nigeria, about 90% of the total population depends on rain-fed agriculture for food production (Nmadu *et al.,* 2017). Therefore, climate change will have an impact on productivity and their socio-economic activities in the country, which can be measured in term of its effects on crop growth, soil erosion, incidence of pests and diseases and availability of soil water (Nmadu *et al.,* 2017). Moreover, the adverse impacts of climate change are already having their toll on the livelihood of people as farmland are being destroyed by floods, due to heavy rain falls in some parts and drought the other parts of the country. Consequently, the extreme weather event increases occurrence of pest, diseases and decreasing crop yields, which eventually impacts negatively on the agricultural sector, and other sectors of the economy, thus increasing the vulnerability farmers in Nigeria (Eze *et al.,* 2018). Nigeria is vulnerable to climate change because large segment of the population are poor and depend on agriculture which is highly sensitive to rainfall variability for income and sustenance. Most farmers have low access to education, information, technology and basic social and support services, and as a result, have low adaptive capacity to deal with the consequences of climate change (Seid, 2014).

However, the Intergovernmental Panel on Climate Change (IPCC) describes vulnerability to climate change as a function of sensitivity, exposure, and adaptive capacity (IPCC, 2014). Vulnerability analysis involves various approaches, which include socioeconomic vulnerability assessment approach, biophysical approach and integrated assessment approach. Socioeconomic vulnerability approach focuses on the socioeconomic and political status of individuals or social groups. Individuals in a community often vary in terms of education, gender, wealth, and health status, access to credit, access to information and technology, formal and informal capital and political power. In this regard, vulnerability is constructed by society as a result of institutional and economic changes. This explains why the socioeconomic approach focuses on identifying the adaptive capacity of individuals/ communities based on their inner characteristics. One major drawback of the socio-economic approach is that it focuses only on variations within society. But in reality, societies vary not only due to socio-political factors but also due to environmental factors. It does not also account for the availability of natural resource bases to potentially counteract the negative impacts of these environmental shocks.

Biophysical approach attempts to evaluate the level of harm that a given environmental stress causes on both social and biological systems. It is sometimes identified as an impact assessment. The emphasis is on the vulnerability or degradation of biophysical conditions (Tesso *et al*., 2012). Biophysical variables include flood, storms, episode of heavy rainfall and long term change in the mean value of climate variables. It is a main approach employed in studies of vulnerability to natural hazards and climate change. Füssel *et al.* (2006) identified this approach as a risk-hazard approach. The biophysical approach, although very informative, has its limitations. A major drawback is that the evaluation of bio-physical factors is not a sufficient condition for understanding the complex dynamics of vulnerability (Tesso *et al*., 2012). It also ignores structural factors and human agency both in producing vulnerability and adapting to it. The approach overemphasizes extreme events while neglecting root causes and everyday social processes that influence differential vulnerability (Pulwarty and Riebsame, 1997).

The third approach is called integrated assessment approach. This is the combination of both socioeconomic and bio-physical approaches to establish vulnerability. The IPCC definition which conceptualizes vulnerability to climate as a function of adaptive capacity, sensitivity, and exposure accommodates the integrated approach to vulnerability analysis (Tesso *et al*., 2012). The limitation of this approach is that it does not account for the dynamism in vulnerability. Regardless of its limitation, the approach has much to offer in terms of policy decisions. For the analysis of vulnerability in the study area both physical and social vulnerability perspectives have been integrated.

A number of climate change vulnerability studies have been conducted in many countries on specific sectors such as health, forestry and agriculture. Researches on vulnerability to climate change have also been carried out by Eze *et al.*, 2018; Tesso *et al*., 2012; Opiyo *et al*., 2014. on socio-economic vulnerability assessment, biophysical vulnerability assessment and integrated assessment. Also, Zarafshani *et al*. (2016) analysed vulnerability assessment models to drought to bring out empirical evidence on proper adaptation strategies. However, little or no work has been carried out to quantify and determine the degree of rice farmer's vulnerability to climate change in Kogi State, North central Nigeria. Thus, an integrated vulnerability assessment approach was applied to identify and determine the degree of vulnerability of rice farmers to climate change in the North central Nigeria.

Materials and Methods

Study area

The study was carried out in Niger and Kogi States in North Central Nigeria. Niger State is located between latitudes 3^0, 20^1 and 7^0, 20^1N and between longitudes 8^0, 35^1 and 11^0 30^1 While Kogi State is between latitude 6^021^1N and 8^045^1N and longitude 6^0E and 8^0E). The Land area covers 74, 244km^2 (Niger State) and 28,313.53km^2 (Kogi State). The study area has a total population of 4,412,037 (Niger State) and 3,595,789 (Kogi State)(National Population Commission (NPC), 2006). However, the study area experiences distinct dry and wet seasons with annual rainfall ranging from 1,100mm to 1,600mm depending on the location, with a temperature of about 32°C (maximum) and 25^{o}C (minimum).

Sampling techniques and data collection

In order to select a representative sample of the respondents for this study, multistage and random sampling techniques were adopted. The North Central Nigeria comprises six states but Niger and Kogi States were purposively selected in the first stage considering their greater production of rice and stratified into agricultural zones. Niger State is made up of three (3) agricultural Zones A, B and C, while Kogi State is made up of four (4) agricultural zones (A, B, C and D). The second stage involves random selection of two local government area each from all the agricultural zones (7 agricultural zones) giving a total of 14 Local government areas. Thirdly, two (2) villages were randomly selected based on the National Population Census enumeration areas making a total of twenty eight (28) villages in all. Sampling frame of households was generated using the 2006 population census enumeration area list. However, Taro Yamane's (1967) formula was used to generate the sampled size at 8% and 9% precision respectively for Niger and Kogi States respectively. Lastly, one hundred and fifty six (156) respondents from Niger State and one hundred and twenty three (123) respondents from Kogi State were computed proportionately to the total population of rice farmers in each of the selected communities(Tables 1 and 2).

The Yamane, (1967) formula is $n = \frac{N}{1+N(e)^2}$

Where n = Sample size required; N = Number of people in the population; e = allowable error (%)

Vulnerability indicators

Brooks (2003) identified exposure, sensitivity and adaptive capacity as the three main components of vulnerability. Exposure is the degree to which a system is exposed to climatic variability like rainfall, temperature, precipitation and drought (Table 3). Sensitivity is the degree to which a system is modified or is affected by an internal or external disturbance or set of disturbances (IPCC, 2007). Sensitivity can also be seen as the degree to which a system is affected either negatively or favorably by the climate variability. They are mainly environmental and demographic factors which may include net shown area, percentage of degraded land, availability of water holding capacity, rural population, and reduction in nutrition, crop diversity index and insufficient water supply. It measures responsiveness of a system/region to climatic influences which is shaped by both socioeconomic and ecological conditions of region (Kumar *et al*., 2016; Loitonjam *et al*., 2018). Every system is unique and thus presents different conditions for any kind of approach for assessment after careful examination. A set of indicators were selected for the three components (exposure, sensitivity and adaptive capacity) of vulnerability in the sampled areas. These indicators were selected based on data availability and personal judgment and literature as shown in (Table 3).

Data analysis

For this study, Composite Climate Change Vulnerability Index (CCCV) has been used to measure the development of composite index of vulnerability to climate change in the zones. In order to construct the vulnerability indicator we aggregate the exposure and sensitivity and adaptive capacity indicators following Hiremath (2013) and Iyengar *et al.* (1982).

The model is given implicitly as
Vulnerability = [Adaptive capacity – [Exposure + Sensitivity]

It can thus be written mathematically as
V = f(I – AC) …………………………..(1)

Where
V = Vulnerability, I = Impact (exposure + sensitivity), AC = Adaptive capacity

In this case vulnerability is the difference between adaptive capacity of a household and its sensitivity and exposure to the climate change induced hazards. Each set (adaptive capacity, sensitivity and exposure) composed different variables/indicators.
However, vulnerability indicators will be normalized in order to obtain indicator which are free from units and scales. The indicators/variables have different units and have different functional relationship with vulnerability. The Mini-Max Method normalization equations for an upward and downward functional relationship are;
The upward functional relationship is

$$X_{ij} = \frac{\underset{i}{X_{ij-Min\langle Xij\rangle}}}{\underset{ii}{Max\{X_{ij}\}-Min\langle X_{ij}\rangle}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

While the downward normalization functions stated that

$$y_{ij} = \frac{Max\{X_{ij}\}-X_{ij}}{\underset{ii}{Max\{X_{ij}\}-Min\langle X_{ij}\rangle}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Where Xi represents the value of the *i*-th variable (variables of adaptive capacity, exposure and sensitivity) and is either positive or otherwise with the vulnerability of the zone. The choice of weights in this matter would ensure that larger variation in any one of the indicators would not unduly dominate the contribution of the rest of the indicators and distort inter regional comparisons. However, we opted for a simple average of the scores to construct the vulnerability index.

The vulnerability index so computed lies between 0 and 1. For classification purposes, a simple ranking of the region based on mean would be enough. However, for a meaningful categorization of the different stages of vulnerability, quartiles was calculated and used to classify the zones.

Results and Discussion

The score of exposure and sensitivity index and districts under various degrees of exposure and sensitivity in the study area are shown in Table 3. The scores of exposure index (EI) and classification of the various districts under different degrees of exposure revealed that Owolikpa (2.412), Igalaogba (2.309), Eggan (2.178), Kakanda (2.169), Aya (2.008) and Odoepe (2.007) emerged as highly exposed area to climate variability. Key determinant indicators which accounted for this very high exposure to climate variability vary from district to district. A high extent of projected change in mean rainfall and very high variability in maximum and minimum temperatures were the dominant factors responsible for the exposure. However, on the contrary, some districts like Baganna (1.698), Koton-Karfi (1.651), Iluke (1.542), Aiyetoro (1.517) and Ikande (1.466) were categorized under low degree of exposure on account of high annual rainfall and low fluctuations in temperatures during the year. This result agrees with the finding of Kumar et al. (2016) which noted that human population and other climatic factors were responsible for high degree of vulnerability in northern Karnataka, India.

Responsiveness or sensitivity of different districts was estimated by the combining socio-economic indicators given in Table 1. Sensitivity index (SI) score for each districts on Table 2 revealed that Koton-Karfi (3.008), Ejule (2.990), Kakanda (2.995), Kpanche (2.722), Girinya (2.661) and Echa (2.610) were highly sensitive to climate change in the study area, while districts like Aiyetoro (2.541), Baganna (2.295), Ikande (3.133), Odoepe (2.014), Iluke (1.981) and Igalaogba (1.723) were rated as least sensitive to climate change in the state. High state of sensitivity could be as a result of less area under forest and low cropping intensity andwide spread problem of drinking water.

The scores of Adaptive Capacity Index of all the districts have been given in Table 4. Ejule, Echa, Eggan, Koton-Karfi, Iya, Owolikpa, Baganna,Odoepe and Aya emerged as districts having high degree of Adaptive capacity with their Adaptive capacity scores being 4.090, 3.972, 3.861, 3.844, 3.692, 3.609, 3.545, 3.425, and 3.320 respectively while Ikande, Girinya, Kpanche and Iluke with scores 2.989, 2.937, 2.929 and 2.900 respectively were rated as districts with least Adaptive capacity. The districts secured high in terms of Adaptive capacity chiefly on account of very high access to information, access to radio which was the highest among all the districts, high literacy rate, to a large extent access to good health system together with higher access to improved seed variety and lesser infant mortality rate than that other districts. Wide range of Adaptive capacity scores, ranging from 4.090 to 2.900 shows that there are perceptible inter-district disparities among the districts.

Table 4 revealed the exposure-sensitivity and vulnerability index. The result showed that Kpancehe, Kakanda, Girinya, Eggan, Igalaogba, Koton-Karfi, Ejule and Aiyetoro are the most vulnerable districts as evident by their vulnerability index score (more than 0.773) values to the tune of 0.984, 0.925, 0.924, 0.901, 0.827, 0.815, 0.780 and 0.774 respectively while districts values such as Iya, Baganna and Echa were considered least vulnerable to climate change with vulnerability index score values 0.433, 0.448 and 0.516 respectively. The wide range average score of vulnerability index (0.433) of Iya and (0.948) Kpanche suggests that there are huge disparities among the districts in terms of their level of vulnerability to climate change. The findings are in conformity with vulnerability status reported by David and Igbekele (2015) using a composite index (based on demographic, social, occupational, agricultural and climatic indicators) where they estimated that rice farmers in the tropical forest zones are more vulnerable to extremes maximum temperature and maximum rainfall than their fellow farmers in the savannah. Exposure and sensitivity positively influence vulnerability, therefore both were added to give the compounded result on vulnerability. A district having high ES and low AC will be highly vulnerable to climate change. How strength of ES and AC determine the vulnerability status of a district can be understood by taking the example of Kpanche and Kakanda district. These districts were (vulnerability rank 1 and 2, respectively) the most vulnerable districts on the account of being poor in adaptive capacity (with ACI rank of 15 and 12 respectively) and highly prone in terms of exposure-sensitivity (with their ESI rank of 1 and 2, respectively). Echa which, in spite of having poor rank in terms of ES (rank 11 and placed under high degree of ESI), but with high level of AC, the area was placed under the 'low degree' of vulnerability capacity.

Conclusion

Majority of the rice farmers' in Kogi State are vulnerable to climate change but varies in their degrees of vulnerability. To moderate the detrimental effects of exposure and reduce sensitivity, there is need for increased adaptive measures (especially in road connectivity, rural electrification, non- farm job creation, better health facilities and education. Finally, holistic measures moderating exposure level, reducing sensitivity and enhancing Adaptive capacity that can sustain agriculture and livelihood should be enhanced.

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Table 1 List of selected indicators to express the exposure, sensitivity and adaptive capacity

Exposure indicators

1. Percentage change in rainfall from the base year value (E1)
2. Change in maximum temperature (E2)
3. Change in minimum temperature (E3)

Sensitivity indicators

1. Population density (S1)
2. Rice output (S2)
3. Percentage of smallholder farmers (S3)
4. Percentage of malaria fever (S4)
5. Percentage of male households head (S5)
6. Percentage Area not cultivated (S6)

Adaptation capacity

1. Member of association (AC1)
2. Percentage of household with access to credit (AC2)
3. Percentage of household with access to health clinic (AC3)
4. Distance to the market to sell produce (AC4)
5. Average farm size (AC5)
6. Literacy rate (AC6)

Source: Field survey

Table 2: Sample distribution of respondents by zones in Kogi State

Zones	LGAs	EAs	Sample Frame	Sample size
A	Ijumu	Aiyetoro	11857	8
		Iya	8302	5
	Kabba/Bunu	Iluke	8675	5
		Odoepe	5229	3
B	Bassa	Kpanche	13202	8
		Ikande	18860	12
	Omalla	Echa/Abejukolo	20398	12
		Baganna	11656	7
C	Lokoja	Kakanda	17698	11
		Eggan	15731	10
	Kogi	Girinya	10357	6
		KotonKarfi	11510	7
D	Ibaji	Ejule	17220	11
		Aya	12054	7
	Idah	Igalaogba	9693	6
		Owolokpa	8616	5
Total			189402	123

Source; 2006 National Population Census Figures

Table 3: score of exposure and sensitivity index and districts under various degrees of exposure and sensitivity

Districts	Exposure Index	Rank	Degree of Exposure	Sensitivity Index	Rank	Degree of Sensitivity
Kpanche	1.155	1	Low	2.722	4	High
Ikande	1.466	3	Low	2.133	11	Medium
Ejule	1.880	10	High	2.990	2	Very high
Aya	2.008	12	High	1.852	15	Low
Aiyetoro	1.517	5	Moderate	2.541	9	Moderate
Iya	1.501	4	Low	2.624	6	High
Iluke	1.542	6	Moderate	1.981	13	Low
Odoepe	2.007	11	Hhigh	2.014	12	Moderate
Giriya	1.201	2	Low	2.661	5	High
K/Karfi	1.651	7	Moderate	3.008	1	Very high
Kakanda	2.169	13	High	2.955	3	Very high
Eggan	2.178	14	Very high	2.584	8	High
Igalaogba	2.309	15	Very high	1.723	16	Low
Owolikpa	2.412	16	Very high	1.933	14	Low
Echa	1.878	9	High	2.610	7	High
Bagana	1.698	8	Moderate	2.295	10	Moderate

Source; Field Survey 2018

Table 4. score of adaptive capacity, exposure-sensitivity index and vulnerability index

Districts	ACI	R	Degree of AC	ESI	R	Degree of ES	VI	R	Degree of Vulnerability
Kpanche	2.929	15	Low	3.877	12	Medium	0.948	1	Very high
Ikande	2.989	13	Low	3.599	15	Low	0.610	11	Medium
Ejule	4.090	1	Very high	4.870	1	Very high	0.780	7	High
Aya	3.320	9	Medium	3.860	14	Low	0.540	13	Medium
Aiyetoro	3.284	10	Medium	4.058	8	High	0.774	8	High
Iya	3.692	5	High	4.125	6	High	0.433	16	Low
Iluke	2.900	16	Low	3.523	16	Low	0.623	10	Medium
Odoepe	3.425	8	High	4.021	10	Medium	0.596	12	Medium
Giriya	2.937	14	Low	3.861	13	Low	0.924	3	Very high
K/Karfi	3.844	4	Very high	4.659	3	Very high	0.815	6	High
Kakanda	3.199	12	Medium	4.124	7	High	0.925	2	Very high
Eggan	3.861	3	Very high	4.762	2	Very high	0.901	4	Very high
Igalaogba	3.205	11	Medium	4.032	9	Medium	0.827	5	High
Owolikpa	3.609	6	High	4.345	5	High	0.736	9	Medium
Echa	3.972	2	Very high	4.488	4	Very high	0.516	14	Low
Bagana	3.545	7	High	3.993	11	Medium	0.448	15	Low

Note: R, AC, ACI, ESI and VI indicates rank, adaptive capacity, adaptive capacity index, exposure-sensitivity index and vulnerability index respectively