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Full Paper

Vulnerability analysis of rice value chain actors to climate variability in Benue State, Nigeria

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Abstract

The focal objective of this study was to examine vulnerability of rice value chain actors (RVCAs) to climate variability in Benue State, Nigeria. Multistage sampling was used to select the respondents (input suppliers, producers, processors, and marketers) based on their dominant activities. Vulnerability index (VI) of each RVCA was analyzed using three indicators: exposure, sensitivity, and adaptive capacity. Since the respondents of this study had overlapping roles and completed the same instrument, then the results would indicate vulnerabilities in the RVCAs' dominant activities. Results based on exposure show that rice producers were highly vulnerable to extreme weather conditions (VI = 0.84) while rice marketers were moderately vulnerable (VI = 0.50). Results based on sensitivity indicate that processors (VI = 0.67) and producers (VI = 0.60) were highly vulnerable. Results based on adaptive capacity show that processors (VI = 0.68) and marketers (VI = 0.63) were highly vulnerable. The overall result indicated that rice producers (VI = 0.65) were most vulnerable to climate variability among other RVCAs, and that their vulnerability was largely influenced by their very high vulnerability to exposure (VI = 0.84). There is need for climate stakeholders and the government to build capacity of RVCAs in exposure, sensitivity, and adaptive capacity to withstand extreme weather and climate change and alleviate their vulnerability. Government and NGOs should prioritize subsidy disbursement to rice farmers due to their high VI among RVCAs.

Keywords - adaptive capacity, exposure, sensitivity, vulnerability index analysis

Introduction

Variation in climate is defined as any change in climate elements (such as temperature, pressure, or winds) sustained over several decades (American Meteorological Society [AMS], 2017). Climate does not change instantly like weather, but it does change over time. As the climate continues to change, associated risks assume greater importance (Easterling et al., 2016). Tung and Hugano (2016) asserted that extreme weather conditions are offshoots of climate change. This affects food production both in quality and quantity. It may also expose people to problems of food insufficiency, food insecurity and poverty. According to the Food and Agriculture Organization [FAO] (2015), no other sector is more sensitive to climate events and extreme weather activities than the agricultural sector. It was observed that variation in climate affects agriculture (Otitoju, 2013; Otitoju & Enete, 2014; Otitoju & Enete, 2016).

Asikhai and Igbafen (2012) posited that variations in climatic factors such as rainfall and temperature correlate with crop yield in Nigeria. This is due to perpetual dependence on rainfed agricultural practices in Nigeria. Terdoo and Feola (2016) stated that the frequent change in rainfall, temperatures and droughts affect productivity of crops. Also infestation by pest and diseases as a consequence of different climatic conditions has compounded these challenges resulting in rice yield reductions and grain quality. Tiamiyu et al. (2015) emphasized that extreme rainfall leads to environmental problems such as floods, gully erosions, etc. and affects rice yield with serious consequences.

Vulnerability is a feeling of helplessness towards natural hazards like storms, flood, droughts and social hazards like poverty, etc. The Intergovernmental Panel on Climate Change [IPCC] (2007) defined vulnerability as the level of damage or harm to a

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system or people occasioned by climate change. Vulnerability depends on a system's sensitivity and the coping ability of people in a system and their level of exposure to the negative impacts of climate change. It is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (McCarthy et al., 2001). Exposure is meant to be the direct danger, shocks, and stressors, and the nature and extent of changes in climate parameters (temperature, precipitation, flood, drought, etc) (McCarthy et al., 2001). Sensitivity has to do with human-environmental conditions that aggravate the hazard, reduce the hazard, or induce an impact. Adaptive capacity refers to planned strategies including all the structural changes that have to be adopted to overcome adversities caused by climate change.

The first two components of vulnerability (exposure and sensitivity) represent potential impact, while the third component (adaptive capacity) is the potential of an actor to cope with these impacts (Füssel & Klein, 2006). This framework is mathematically expressed in Equation 1 (Kim & Kwon, 2022), which shows that vulnerability (*V*) is a function of potential impact (*I*) and adaptive capacity (*AC*).

$$V = f\,(I, AC) = I - AC \qquad \text{Equation 1}$$

Small-scale farmers are highly vulnerable because their incomes and food security are directly dependent on agricultural production (Daze & Dekens, 2016). Vulnerability of agricultural sector should be of particular interest to Nigerian government and policy makers because agriculture is a key sector of the economy accommodating 60-70% of the labor force and contributing between 30-40% of the country's Gross Domestic Product (GDP) (Ajetomobi et al., 2011). Many of the staple crops in Nigeria like rice and maize are actually affected by climate variability; however, rice farms are most likely to be affected because rice production is affected by many abiotic factors (drought, flood, extreme temperature, salinity and low soil fertility) and biotic constraints (weeds, diseases and pests) which hinder Africa's rice production (Onyegbula & Oladeji, 2017).

Nigeria is the largest producer (power house) of rice production in Africa and has the capacity to increase its production (Africa Rice, 2011; Oyinbo et al., 2013). Rice is the most common and important cereal crop used as staple food in Nigeria (National Cereal Research Institute [NCRI], 2004). It is always in high demand because of its consumption rate and popularity among most households in Nigeria.

Agricultural value chains involve a sequence of value adding activities that bring products from the farm to the final consumer. It links input providers, farmers, processors, retailers and consumers, creating relationships that enable the effective functioning of the value chain (Miller & Da Silva, 2007). According to Tinsley (2012), the rice value chain (RVC) could be conveniently divided between production (farmers and support services), processing (parboiling, milling, etc.) and marketing. It also extends to the final consumers of rice. Extreme weather and climate variability are potential risks factors among rice value chain actors (RVCAs) due to their interdependent and ripple effect on the entire rice chain. By extension, this interdependency also means that sustainable and profitable rice value chain can only be achieved if all actors in RVC collaborate to manage climate risks (Dekens & Bagamba, 2014). If not properly handled, there will be less rice produce available for milling, trading and sale to consumers and what is available may be of poor quality, resulting in more breakage during processing (Daze & Dekens, 2016).

Adaptation strategies adopted by farmers against extreme climate variabilities in Nigeria include mixed/multiple cropping, early planting, planting of crop variety tolerant to new climate regime, early planting, changing of planting dates, use of chemical and organic fertilizers, cultivating different types of crops, and planting cover crops among others (Idoma et al., 2017; Mohammed et al., 2013; Okpe & Aye, 2015). This study examined the vulnerability of RVCAs to extreme weather conditions in Benue State, Nigeria. Specifically, the RVCAs' exposure, sensitivity and adaptive capacity were investigated. This study aimed to provide information to help ameliorate RVCAs vulnerability and strengthen their resilience to further improve their production method and scope, leading to better return on investment.

Methodology

Location

The study was situated in Benue State, Nigeria. It has a population estimate of about 5,741,815 (National Bureau of Statistics, [NBS], 2017).

The State lies in the Southern Guinea Savannah between latitudes 6°25'N and 8°8'N and longitudes 7°47'E and 10°E'. It experiences both dry and rainy season during the year; its climate is tropical in nature. Farming is the major occupation of Benue residents. The crops grown mostly include rice (*Oryza* spp.), maize (*Zea mays*), cowpea (*Vigna unguiculata*), soybeans (*Glycine max*) and yam (*Dioscorea* spp.) with lots of fruits and vegetables. The State is named the 'Food Basket of Nigeria' due to the assorted crops grown in the State.

Respondents

Multistage sampling technique was used in selecting the respondents. Guma and Agatu Local Government Areas (LGAs) were deliberately selected because of intensification of rice farming. Secondly, three communities were intentionally selected from the two LGAs. The communities selected were Daudu, Gbayange and Mbagbaave from Guma LGA, and Obagaji, Aila and Ocholonya from Agatu LGA. Finally, 36 RVCAs were randomly selected from the said communities making a total of 216 RVCAs.

Tinsley (2012) identified producers, processors and marketers as the actors in the RVC. These RVCAs, together with input suppliers, were investigated in this study. Consumers who are also part of the RVC were beyond the scope of this study. Given that there could be overlapping functions in chain, the boundary of the RVCAs was established based on the dominance of their activities in the rice value chain. Input suppliers are those who specialize in selling production inputs such as fertilizers, rice seeds, herbicides, implements, etc. Producers are the rice farmers. Processors are those who are involved in changing the original form of the produce to a more acceptable form. Marketers are those whose action is predominantly marketing of rice. Of the 216 selected RVCAs, only 205 (9 input suppliers, 125 producers, 35 processors, and 36 marketers) of the filled questionnaires met the requirement for the analysis, and were included in the results.

Vulnerability Index (VI) Indicators

The VI of RVCAs in Benue State, Nigeria was based on the three vulnerability indicators: exposure, sensitivity and adaptive capacity which were measured using a research instrument containing 14 indicators of vulnerability (2 under exposure, 3 under sensitivity, and 9 under adaptive capacity). The indicators were selected from Ludena et al. (2015), Jana et al.(2017), Ludena and Yoon (2015), and Žurovec et al. (2017). Similar to the approach of Žurovec et al. (2017), the indicators in this study were selected based on prior peer-reviewed studies which examined the quantitative assessment of agricultural vulnerability (e.g., Gbetibouo et al. (2010); Jana et al. (2017); Luden et al. (2015); Ludena and Yoon (2015); O'Brien et al. (2004); Ravindranath et al. (2011); Wiréhn et al. (2015)). The application of the same 14 indicators to all rice value chain actors was based on the overlapping roles played by the actors.

The 14 indicators used in this study are shown in Table 1. Exposure was measured through intensity of flood and drought. The exposure indicators have positive functional relationship with vulnerability (i..e, vulnerability increases (↑) with an increase in the value of the indicator). Sensitivity is the degree to which a given operation or ecosystem is affected by extreme weather conditions and climatic stresses, and were measured through livelihood sensitivity (annual income generated from RVC) and human sensitivity (e.g. dependency ratio and enterprise diversification). Sensitivity indicators have a negative functional relationship with vulnerability (i..e, vulnerability decreases (↓) with an increase in the value of the indicator). The adaptive capacity indicators used in this study include years of education, social capital (i.e. number of persons the household can ask for financial help), household member working, farm-based/value chain based organizations, farm holding (in hectares), literacy ratio, access to credit, access to market, number of extension visit and land ownership. Adaptive capacity indicators also have a negative functional relationship with vulnerability. It was hypothesized that increase in adaptive capacity indicators result to increased adaptability and coping capacity of RVCAs which consequently reduce their vulnerability.

Data Analysis

The data were arranged in the form of a rectangular matrix with rows representing the four RVC actions (input supply, farming/production, processing, and marketing) and the columns representing the 14 indicators (listed in Table 1). To allow comparisons across rice value chain actions, the values obtained from all the estimated vulnerability indicators (adaptive strategies) were normalized using the functional relationship to be free

Table 1. Indicators of vulnerability to climate variability by RCVA.

Vulnerability Components	Indicators	Description of the indicator	Functional Relationship	Applicable Equation
Exposure	Flood	Number of flood events in the last 10 years	↑	Equation 2
	Drought	Number of droughts experienced in the last 10 years		
Sensitivity	Human sensitivity	Number of dependent persons in the household	↓	Equation 3
	Livelihood sensitivity	Annual income generated from your value chain operations (i.e. farming, processing and marketing		
	Crop diversification	Area under major crop (in hectares)		
Adaptive capacity	Social capital	Number of contacts the household can ask for financial help	↓	Equation 3
	Human development	Number of working household members		
		Level of education: Years of schooling of the household head		
	Farm-based/ Value chain-based organization	Number of farmers organization/ association		
	Farm holding	Average farm size (hectares)		
	Literacy rate	Number of persons aged 15 years or older who are able to read and write in the households		
	Access to credit	Amount of credit received (in naira)		
	Access to market/ processing site	Distance travelled to market to sell the produce or processing site (in kilometres)		
	Number of extension visit	Number of contacts per cropping year/season		
	Land ownership (Asset Ownership)	Average size of land own by the household (in hectares)		

Note: Indicators adapted from Luden et al. (2015), Jana et al. (2017), Ludena and Yoon (2015), Žurovec et al. (2017).

from their respective units so that they all lie between 0 and 1, where higher values correspond to high vulnerability and vice versa. The normalization was achieved with formulas (equations 2 - 5) developed by the United Nations Human Development Report (2004) (cited by Žurovec et al., 2017). The formulas depended on whether an increase in the indicator corresponds with an increase (↑) or a decrease (↓) in vulnerability. The functional relationship is provided in Table 1. If the functional relationship shows that vulnerability increases (↑) with increase in the value of the indicator, then for each rice value chain action i, and for each indicator j, the normalized score X_{ij} was computed as

$$X_{ij} = \frac{X_i - \min X_j}{\max X_j - \min X_j} \qquad \text{Equation 2}$$

where X_{ij} represents the value of the indicator j corresponding to the rice value chain action i; and max X_j and min X_j represent maximum and minimum values of indicator j, respectively, across all rice value chain actions.

If the functional relationship shows that vulnerability decreases (↓) with an increase in the value of the indicator, then the normalized score Y_{ij} was computed using the formula

$$Y_{ij} = \frac{\max X_j - X_i}{\max X_j - \min X_j} \qquad \text{Equation 3}$$

When equal weights were obtained for the vulnerability indicators, simple average of all the normalized scores was computed to construct the average vulnerability index AVI using

$$\text{AVI} = \frac{\sum X_{ij} + \sum Y_{ij}}{K} \qquad \text{Equation 4}$$

where: K represents the number of indicators used (K =14).

After normalization, the average vulnerability index (AVI) for each source of vulnerability was worked out and then the overall vulnerability index VI was computed by employing the following formula.

$$\left[\sum_{i=1}^{n} (\text{AVI})^{\infty}\right]^{1/\infty} \qquad \text{Equation 5}$$

where: n is the number of sources of vulnerability, and α is the number of the indicators in each rice value chain action; in this case, n = α = 14. The criteria for the classification of vulnerability index are shown in Table 2.

Table 2: Criteria for classification of vulnerability index.

Vulnerability Index	Categorization
< 0.20	Very Low (VL)
0.20 - 0.40	Low (L)
0.41 - 0.60	Medium/Moderate (M)
0.61 - 0.80	High (H)
0.81 - 1.00	Very High (VH)

Source: Sugiarto et al. (2017).

Results and Discussion

Table 3 presents the results of the VI analysis. Since the respondents of this study had overlapping roles and completed the same instrument, then the results would indicate vulnerabilities in the RVCAs' dominant activities. Results indicate that rice producers were highly vulnerable to extreme weather conditions (VI = 0.84) while rice marketers were moderately vulnerable (VI = 0.50). Rice processors (VI = 0.40) and input suppliers (VI = 0.38) were less vulnerable. This result of high vulnerability index recorded among rice producers (farmers) is expected since rice farmers were more exposed to flood, drought and other vagaries of weather condition as a result of their predominantly field based activities than all other RVCAs. Munyai et al. (2019) asserted that high vulnerability indicates that there is high potential for damage to properties and loss of life. This is the predicament of rice farmers. This result of high vulnerability of rice producers (VI = 0.84) corresponds with Akanbi et al. (2022) where vulnerability index (based on exposure) of 0.689 was recorded.

With respect to sensitivity indicators, the result shows that processors (VI = 0.67) and producers (VI = 0.60) were highly vulnerable and recorded higher VI among RVCAs. The marketers (VI = 0.46) and input suppliers (VI = 0.33) in RVC were less vulnerable. These results could be attributed to low income available to rice processors and producers making them to be more vulnerable. This result confirmed Molua et al. (2020) who noted that climate change and vulnerability (damages) are higher at lower income levels as higher income people apparently take measures to reduce their vulnerability. Households or actors often attempt to diversify their sources of economic activities in order to have multiple sources of income to cope with vulnerability even before the occurrence of climate shocks (Dercon, 2005; Fafchamps, 2003). Again, acquisition of household assets has a crucial role in climate resilience. These assets include natural assets (e.g. land), physical assets (e.g. infrastructure), financial assets (e.g. insurance, savings), human assets (e.g. know-how, health) and social assets (e.g. networks).

Vulnerability was also analyzed through adaptive capacity indicators. Processors (VI = 0.68) and marketers (VI = 0.63) highly vulnerable; rice producers (VI = 0.50) and input suppliers (VI = 0.48)

Table 3. Vulnerability level analysis of rice value chain actors.

Indicators	Rice Value Chain Actors							
	Input Suppliers		Producers		Processors		Marketers	
	Actual Value	**Vul. Index**	**Actual Value**	**Vul. Index**	**Actual Value**	**Vul. Index**	**Actual Value**	**Vul. Index**
Exposure Indicators:								
Drought	0.34	0.00	0.98	0.68	0.86	0.34	0.79	1.00
Flood	0.98	0.78	0.89	1.00	0.67	0.46	0.78	0.00
Mean VI (Exposure Indicator)		**0.38**		**0.84**		**0.40**		**0.50**
Sensitivity Indicators:								
Annual Income from Value Chain Operation	102482.3	**1.00**	258110.5	**0.85**	303345.9	**0.00**	213405.1	**0.61**
Dependency Ratio	0.452	**0.00**	0.34	**0.31**	1.01	**1.00**	0.98	**0.29**
Enterprise Diversification	0.98	**0.00**	1.02	**0.63**	0.43	**1.00**	0.56	**0.47**
Mean VI (Sensitivity Indicators		**0.33**		**0.60**		**0.67**		**0.46**
Adaptive Capacity Indicators:								
Education	8.08	**0.00**	9.01	**1.00**	11.05	**0.92**	6.09	**0.31**
Social Capital	1.02	**0.82**	0.98	**0.00**	1.89	**0.51**	2.01	**1.00**
Working Household members	2.08	**0.71**	0.98	**1.00**	4.02	**0.91**	0.67	**0.00**
RVC Organization	0.98	**1.00**	2.03	**0.89**	0.46	**0.00**	0.77	**0.86**
Farm holding	0.23	**0.00**	1.05	**1.00**	0.75	**0.89**	0.01	**0.83**
Literacy rate	0.78	**0.41**	0.55	**0.00**	0.34	**0.84**	0.45	**1.00**
Access to credit	0.45	**0.00**	0.65	**0.54**	0.12	**1.00**	0.56	**0.50**
Access to market	0.78	**0.61**	0.66	**0.00**	1.22	**1.00**	0.89	**0.79**
Number of extension visit	0.10	**0.27**	4.34	**0.00**	2.01	**0.48**	1.35	**1.00**
Land ownership (Asset ownership)	2.01	**1.00**	2.90	**0.58**	0.78	**0.29**	1.02	**0.00**
Mean VI Based on Adaptive Capacity		**0.48**		**0.50**		**0.68**		**0.63**
Overall Vulnerability Index		**0.40**		**0.65**		**0.58**		**0.53**
Rank		**4th**		**1st**		**2nd**		**3rd**

Source: Computed from field data, 2019.

were moderately vulnerable. These results could be because rice processors and marketers had not developed their resilience and adaptive capacity through education, access to credit and membership of RVC based organizations. Bakkensen and Mendelsohn (2016) posited that evidence of adaptation being important in most of the world by examining the effects of income, population density and storm frequency on damage and fatalities. Rice producers and input suppliers recorded lower VI among RVCAs in the study area. The result of input suppliers with vulnerability index of 0.48 coincide with Suryanto and Rahman (2019) where the social network score (vulnerability index) in Sonorejo was 0.482.

The overall result which was used to rank RVCAs further revealed that rice producers (VI = 0.65) were most vulnerable to climate variability among other RVCAs, and that their vulnerability was largely influenced by their very high vulnerability to exposure (VI = 0.84). This was followed by processors (VI = 0.58), marketers (VI = 0.53) and input suppliers (VI = 0.40) in Benue State, Nigeria. These results may be due to over dependence on rainfed agriculture, small-scale of operation and scattered land holding. Input suppliers were least vulnerable among RVCAs. This could be traced to their operation being done in-door, hence not directly affected by weather.

Conclusion and Recommendations

This study examined the vulnerability of RVCAs to extreme weather conditions in Benue State, Nigeria. Specifically, the RVCAs exposure, sensitivity and adaptive capacity were investigated. Ultimately, this study aimed at ameliorating RVCAs vulnerability and developing their resilience for better return on investment. Based on the results of this study, the following recommendations were made for policy consideration. First, since the rice producers were most affected by climate variability as a result of their exposure to drought and flood, it is expected that adaptable drought and flood tolerant rice varieties at subsidised rate are to be promoted for adoption by the agricultural extension and advisory services providers to reduce their vulnerability to drought and flood. The effect will trickle down to other value chain actors. This will encourage more investment and boost value chain activities. Second, government at all levels should ensure capacity building and other non-financial supports of the RVCAs by providing access to credit/grants to rice value chain actors. This will help to increase their adaptive capacity to weather extreme shocks and climate variability. Finally, rice processors are more vulnerable to climate variability due to their weak sensitivity and adaptive capacity levels. It is therefore advised that they are to diversify their activities to more relevant enterprises that are less prone to climate variability along the value chain. In addition, it is equally expected that ensuring processors have more access to credit and markets, and quality education through interventions by the governments and other stakeholders will reduce their level of vulnerability.

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