

Analysis of Farmers' Vulnerability to Climate Change in Niger State, Nigeria

Jude Nwafor Eze^{a*}, Umar Aliyu^b, Abdulmalik Alhaji-Baba^c
and Muhammad Alfa^d

Farming System Research Programme, National Cereals Research Institute,
Badeggi, Niger State, Nigeria

zejude12@gmail.com^{a*}, aliuma77@yahoo.com^b, abdulmalikbabaalhaji@yahoo.com^c,
alfanma63@yahoo.com^d

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Abstract. This research evaluates the farmers' vulnerability to climate change in Niger State. Strategies for reducing the effect of climate change have regularly been made without experimental foundations and adequate information on farmers' vulnerability to climate change in the study area. Thus, integrated farmers' vulnerability assessment approach was employed by classifying socioeconomic and biophysical indicators of vulnerability into adaptive capacity, sensitivity and exposure to determine the farmers' vulnerability to climate change. This is based on the Intergovernmental Panel on Climate Change's definition of vulnerability. The study adopted a survey design and the method utilized for the study was questionnaire administered to 400 households in the study area. The results indicate that the farmers' vulnerability was low in zone A with a mean index of 2.86, very low in zone B with a mean index of 3.74, and high in zone C with a mean index of 1.95 (the higher the value of the index the lower the vulnerability of farmers). It is recommended that measures should be taken to integrate climate change adaptation into Niger State development process. These measures should include improvement in adoption of good agricultural practices (GAP).

Introduction

Studies have shown that climate change has become a major threat to agriculture, particularly in developing countries [1-3]. Farmers in African countries have been identified as most vulnerable to climate change due to their low adaptive capacities [4-6]. In Nigeria, the climate change impacts cut across various sectors, but agriculture is the most vulnerable due to their dependent on rain-fed agriculture [7]. Consequently, agriculture is the dominant sector in the Niger State economy. About 85% of Niger State population are farmers [8]. The contribution of the agricultural sector to the economy of Niger State is challenged by its vulnerability to climate change. Moreover, strategies for reducing the effect of climate change have regularly been made without experimental foundations and adequate information on farmers' vulnerability to climate change in the study area. Thus the assessment of farmer's vulnerability to climate change is an important factor in determining where there are likely to be high impacts of climate change on farmers and why they are exposed to such impact [9]. The level of vulnerability of different zones to climate change in the study area is determined by both socioeconomic and environmental factors. The variations of these socioeconomic and environmental factors across different agro-ecological zones are responsible for the differences in their levels of vulnerability to climate change. Given the different disciplines involved in vulnerability study, there are many conceptual and methodological approaches to vulnerability analysis. The major conceptual approaches include the socioeconomic, biophysical, and integrated approaches. The socioeconomic approach is mainly concerned with the social, economic, and political aspects of society [10]. The view of vulnerability as a state (i.e. as a variable describing the internal state of a system prior to the occurrence of a hazard) has arisen from studies of the structural factors that make human societies and communities susceptible to damage from external hazards [10]. In this formulation, vulnerability is something that exists within systems

independently of external hazards. The biophysical approach views the vulnerability of a human system as determined by the nature of the physical hazard(s) to which it is exposed, the likelihood or frequency of occurrence of the hazard(s), the extent of human exposure to hazard, and the system's sensitivity to the impacts of the hazard(s) [2]. The biophysical approach is mainly concerned with the physical impact of climate change on different attributes, such as yield and income [11]. The integrated assessment approach combines both the socioeconomic and the biophysical attributes in vulnerability analysis [12]. The study employed integrated farmers' vulnerability assessment approach which corrects the limitations in both socioeconomic and biophysical approaches. This approach classifies socioeconomic and biophysical indicators of vulnerability to adaptive capacity, sensitivity, and exposure. This is to determine the level of farmer's vulnerability in the 3 agro-ecological zones of Niger State, based on the IPCC [13] definition of vulnerability. Quantifying vulnerability using indicator method is based on choosing appropriate indicators and then combining the selected indicators to determine the levels of vulnerability [14-16]. Knowledge of farmer's level of vulnerability in each zone to climate change can assist in identifying zones with the most vulnerable farmers and in determining investments for adaptation to future impacts of climate change in the study area.

Materials and Methods

The study area is located between latitude 8° 22'N and 11° 30'N and Longitude 3° 30'E and 7° 20'E in Nigeria. Niger State experiences two distinct seasons, the dry and wet seasons, with annual rainfall varying from 1,100 mm in the northern part to 1,600mm in the southern parts [17]. Mean maximum temperature remains relatively high throughout the year, averaging about 32°C, particularly in March and June. The mean minimum temperature of 25°C occurs usually between December and January [18].

The study population consists of 752,309 households in the state. According to [19], the sampling size of any population that is more than 100,000 persons are 400 using:

$$n = N / (1 + N(e)^2) \quad (1)$$

at 0.05 level of precision: where n is the sample size; N is the population, that is, census population figure; and e is the level of precision/sampling error. Since the household population of the study area is more than 100,000, therefore, 400 households were proportionally selected and interviewed based on the relative population of each agro-ecological zone in the study. The household population of zone A, B and C are 249159, 268994 and 234156 respectively. Thus, the questionnaires administered per zone were calculated using

$$N1/N2 \times 400, \quad (2)$$

where $N1$ is the household population of the zone, $N2$ is the household population of the study area and 400 is the sample size for the study area. Purposive sampling technique was employed to select the communities and farm households. Integrated farmers' vulnerability assessment approach was employed by classifying socioeconomic and biophysical indicators of vulnerability into adaptive capacity, sensitivity, and exposure to determine the pattern of the vulnerability of each agro-ecological zone to climate change in Niger State, Nigeria based on household data.

Vulnerability to climate change variables

Adaptive capacity indicators were selected from social, economic and physical factors that influence the ability of farmers to adjust to climate change and to moderate its potential or actual damages, in order to adapt to the problems. Wealth enables farmers to absorb and recover from losses more quickly due to insurance, social safety nets [14, 9]. In this study, we used Membership of cooperative, Income from non-farm activity and others as a measure of wealth. Use of fertilizer, improved crop varieties and irrigation were identified as an indicator of technology and infrastructure (Table 1). These variables enhance adaptation to climate change

Sensitivity is described as the extent a system is affected either negatively or positively, by climate variability, for example, the frequency of drought [13]. The agricultural sector's sensitivity to climate change is represented by the frequency of climate extremes. In our study, it is argued that in places with a greater frequency of droughts, floods etc. the agricultural sector responds negatively (i.e., the yield is reduced). Thus, agriculture in drought, flood and soil erosion-prone areas is more sensitive in terms of yield reduction. Sensitivity could best be measured by a change in income or livelihood attributed only to climatic factors. However, it was not possible to find this type of data. Instead, we were obliged to make the simple assumption that those areas with higher frequencies of climatic and environmental problems (e.g., drought, flood, soil erosion etc.) were subjected to higher sensitivity due to loss in yield and thus loss of livelihood, given that the main source of livelihood in the study area is agriculture.

Exposure is seen as nature and degree to which a system/people is/are exposed to significant climate extremes (soil erosion/drought/flood) [13]. In addition, exposure could best be represented by both futures of gradual changes in climate and the forecasted values of the probabilities of extreme events and other climate-related and environmental problems (e.g., drought, erosion, etc.).

Table 1. Vulnerability indicators, its units of measurement and direction.

The element of vulnerability	Vulnerability indicators	Unit of measurement	Direction as it relates to indicators and vulnerability
Adaptive capacity	1. Access to loan 2. Livelihood diversification 3. Formal education 4. Application of manure 5. Use of improved seed varieties 6. Agroforestry practices	% of the total population who have access to loan, diversified livelihood, have formal education, applied manure, use improved seed, adopt agroforestry	The higher the % of the total population with more wealth, technology and literacy rate the lesser the vulnerability
Sensitivity	1. Crop failure due to increasing flood 2. Crop failure due to increasing drought 3. Reduction in crop Yield	% of the total population who feel the impact of crop failure due to flood, drought and reduction in crop yield	The higher the % of the total population who feel the impact of crop failure due to flood, drought and reduction in crop yield, the higher the vulnerability
Exposure	1. Experiencing flooding 2. Experiencing drought 3. Experiencing erosion	% of the total population who experiences flood, drought and erosion	The higher the % of the total population who experiences a flood, drought and erosion the higher the vulnerability

Source: chosen by the author

Data on the forecasted probabilities of future climate extremes were not found; thus, we had to make the very simple assumption that areas experiencing drought, floods, soil erosion, communal clashes, etc. due to higher changes in temperature, precipitation and other climatic/environmental variables were more exposed.

Data analysis

The data collected were analysed using Percentages, Principal Component Analysis, Correspondence Analysis and the farmers' Vulnerability Index. Principal Component Analysis (PCA) is mainly used primarily as a data reduction technique in the determination of the underlying common factors [20]. The technique is derived from correlation analysis and analysis of variance. It allows the replacement of an original set of variables by a new set of orthogonal variables called

principal components [21]. PCA is a geographic science that attempts to understand most phenomena that involve investigation of a series of causally related variables. According to Anyadike [20], PCA leads to a more deterministic approach that is used more in geographic studies. It assumes that all the explanation in a given population is contained within the variables used to define the population. Principal Component Analysis (PCA) was performed to obtain the component scores which were used to weight the variables. The reason is to attach weights to the vulnerability indices using the component scores of the first principal component. On the other hand, Correspondence analysis (CA) is a multivariate statistical technique that is conceptually similar to Principal Component Analysis but applies to categorical rather than continuous data [22]. In the same way as principal component analysis, CA provides a means of showing or summarising a dataset in the two-dimensional graphical form [20]. Correspondence Analysis of the data set on vulnerability indicators (adaptive capacity, sensitivity and exposure (Tables 4, 5 and 6) were run on the variables to transform the non-metric data to a metric level and perform the dimensional reduction. In essence, Correspondence Analysis was used to quantify the qualitative data obtained from a questionnaire on adaptive capacity, sensitivity and exposure. The results of both PCA and CA were used to compute the Vulnerability Index (VI) using the equations below.

Firstly, farmers' vulnerability was calculated using the equation put forward by Deressa, Hassan, and Ringler [9] as follows:

$$\text{Vulnerability} = (\text{adaptive capacity}) - (\text{sensitivity} + \text{exposure}). \quad (3)$$

Secondly, Equation (1) was operationalised using the equation put forward by Madu [23] as follows:

$$HVI = (w_1A_1 + w_2A_2 \dots w_nA_n) - [(w_1S_1 + w_2S_2 \dots w_nS_n) + (w_1E_1 + w_2E_2 \dots w_nE_n)], \quad (4)$$

where HVI is household vulnerability index, w_1 - w_n are the weights obtained from first principal component scores, A_1 - A_n are the adaptive variables, S_1 - S_n sensitivity variables and E_1 - E_n exposure variables. Thus, a higher net value indicates lesser farmers' vulnerability and vice versa. Ranking and classification were performed on the farmer's vulnerability indices to group the agro-ecological zones according to their degree of farmers' vulnerability. The ranking and classification enhanced understanding of the variations in the vulnerability levels of the farmers to climate change in the study area

Results and Discussion

Assessment of famers' vulnerability to climate change in the study area

The results of the adaptive capacity indicators revealed that majority of the farmers did not, diversify their livelihood (57%), have access to loan (64.3%), have formal education (60.3%), use improved crop varieties (56.3%) practice agro-forestry (56.3%) except in use of manure where majority of farmers adopted manure application (63%), in the study area (Table 2). Thus, predominant farmers in Niger State have the low adaptive capacity to cope with climate change. The above results show that the ability of the farmers to cope with the consequences of climate change was low due to poor access to loan, low-income diversification, high illiteracy rate, poor adoption of agroforestry, and poor adoption of improved crop varieties. The results on sensitivity indicators show that the majority of the respondents have experienced crop failure due to flood (56.7%), crop failure due to drought (55.7%) and reduction in crop yield (58.3%) in the study area (Table 3). The high sensitivity of the households to the above-mentioned indicators could be attributed to the farmer's low adaptive capacity and high exposure to hazards. Results of exposure indicators reveal that majority of the respondents have experienced the impact of drought on farmland (57.3%), farmlands affected by floods (60.3%), and soil erosion (64.3%) as given in Table 4. The high exposure of the farmers to climate change mentioned above could be attributed to the farmers' low adaptive capacity and high sensitivity.

Table 2. Adaptive capacity indicators of the respondents.

Indicator	Zone A (%)	Zone B (%)	Zone C (%)	Mean
Access to loan	32	57	18	35.7
Diversification of livelihood	51	57	34	47.3
Formal education	52	58	31	47
Application of manure	62	74	53	63
Use of improved seed varieties	66	57	23	48.7
Agroforestry practices	52	43	36	43.7
Mean	52.5	58.5	33	

Source: Fieldwork 2017

Table 3. Sensitivity indicators of the respondents.

Indicator	Zone A (%)	Zone B (%)	Zone C (%)	Mean
Crop failure due to flood	62	41	67	56.7
Crop failure due to drought	58	57	52	55.7
Reduction in crop Yield	59	48	68	58.3
Mean	59.7	48.7	62.3	

Source: Fieldwork 2017

Table 4. Exposure indicators of the respondents.

Indicator	Zone A (%)	Zone B (%)	Zone C (%)	Mean
Farmland affected by flooding	68	58	55	60.3
Farmland affected by drought	57	54	61	57.3
Farmland affected by erosion	67	62	64	64.3
Mean	64	58	60	

Source: Fieldwork 2017

The results of PCA on adaptive capacity, sensitivity and exposure

The PCA of the data set on vulnerability indicators (adaptive capacity, sensitivity and exposure) extracted three components with eigenvalues greater than 1 (Table 5). The result reveals that these three components explained 82.27% of the total variance in the dataset. The first component has an eigenvalue of 7.12 and accounted for 40.43% of the explained variance.

Table 5. Component scores of the principal component.

Vulnerability indicators	Component		
	1	2	3
Farmlands affected by flood	0.74	0.81	0.3
Have access to loan	0.87	0.38	-0.25
Diversification of livelihood	0.67	0.35	-0.27
Experienced crop failure due to flood	0.21	0.46	0.81
Farmers that uses manure	0.88	-0.42	-0.22
Reduction in crop yield	0.38	0.54	0.67
Farmers that uses improved seed variety	0.46	-0.31	-0.35
Experienced crop failure due to drought	0.06	0.84	0.38
Affected by erosion	0.22	0.97	-0.01
Affected by drought	0.11	0.27	0.88
Farmers with Formal education	0.75	-0.37	-0.36
Agroforestry practices	0.61	0.04	0.81
Eigen Values	7.12	4.23	2.22
Percentage of explained variance	40.43	22.75	19.09
Cumulative % of explained variance	40.43	63.18	82.27

Source: Fieldwork 2017

The second component has an eigenvalue of 4.23 and accounted for 22.75% of the explained variance. The third component has an eigenvalue of 2.22 and accounted for 19.09% of the explained variance.

Correspondence analysis (CA) on adaptive capacity, sensitivity and exposure

The correspondence analysis results on adaptive capacity, sensitivity and exposure (Tables 6, 7 and 8) were used together with the component scores of the first principal component (Table 5), in the computation of the farmers' vulnerability indices of different agro-ecological zones.

Table 6. Correspondence analysis results of adaptive capacity indicators.

Adaptive Capacity Indicators	Zone A	Zone B	Zone C
Access to loan	0.51	0.79	0.37
Diversification of livelihood	0.30	0.64	0.35
Formal education	0.58	0.89	0.23
Application of manure	0.38	0.65	0.19
Use of improved seed varieties	0.39	0.54	0.31
Agroforestry practices	0.85	0.68	0.28

Source: Fieldwork 2017

Table 7. Correspondence analysis results of sensitivity indicators.

Sensitivity indicators	Zone A	Zone B	Zone C
Experienced Crop failure due to flood	0.06	0.15	0.45
Crop failure due to drought	0.22	0.49	0.56
Reduction in crop Yield	0.87	0.57	0.88

Source: Fieldwork 2017

Table 8. Correspondence analysis results of exposure indicators.

Exposure Indicators	Zone A	Zone B	Zone C
Affected by flooding	0.26	0.41	0.18
Affected by drought	0.32	0.28	0.28
Affected by erosion	0.47	0.48	0.32

Source: Fieldwork 2017

Results of the farmers' Vulnerability Indices to climate change in the study area

The first principal component (Table 5) and the correspondent analysis results (Tables 6, 7 and 8), as indicated in the research methodology were used to calculate the vulnerability indices. For instance, the farmers' vulnerability index for zone A is calculated as follows:

$$[(0.87 \times 0.51) + (0.67 \times 0.35) + (0.88 \times 0.58) + (0.46 \times 0.38) + (0.75 \times 0.39) + (0.61 \times 0.85)] - [(-0.21 \times 0.06) + (-0.06 \times 0.22) + (-0.38 \times 0.87)] + [(-0.74 \times 0.26) + (-0.11 \times 0.32) + (-0.22 \times 0.47)] = 2.86$$

The farmers' vulnerability indices calculations for the rest of the zones followed the same procedure. The values of the farmers' vulnerability indices were obtained, ranked and classified. The higher the mean index the lower the vulnerability of farmers to climate change (Table 9).

Table 9. Indices of farmers' vulnerability to climate change in niger state.

Zones	Index	Rank	Class
Zone A	2.86	2	high vulnerability
Zone B	3.74	1	low vulnerability
Zone C	1.95	3	Very high vulnerability

Source: Fieldwork 2017

The result of the farmers' vulnerability indices in descending order was shown as follows zone C(1.95), zone A (2.86) and zone B (3.74) as shown in Table 9. Thus, farmers in 'zone C are the most vulnerable to climate change, while farmers in zone B are the least vulnerable to climate change (Table 9). Farmers in zone A have high vulnerability level with a mean index of 2.86 (Table 9). The high vulnerability level was due to the fact that the farmers' vulnerability indicators for adaptive capacity were very high, with the mean value of 52.5%, (Table 2). Thus, the higher the percentage of total farmers with more wealth, technology and literacy rate, the lesser the vulnerability (Table 1). The sensitivity was high with the mean value of 59.7% for zone A (Table 3). Also, the exposure value was high with the mean indicator of 64% (Table 4). Thus, the higher the percentage of the total farmers affected by climate change and extremes, the greater the vulnerability (Tables 1). Consequently, the high adaptive capacity with high sensitivity and exposure increases the vulnerability of the farmers to climate change. Moreover, the farmers in zone B have low vulnerability level with a mean index of 3.74 (Table 9). The low vulnerability level was because the farmers' adaptive capacity was very high, with the mean adaptive capacity of 58.5%, (Table 2). Thus, the higher the percentage of total farmers with more wealth, technology and literacy rate, the lesser the vulnerability (Table 1). The sensitivity was low with the mean sensitivity of 42% for zone B (Table 3). Also, the exposure was low, with the mean exposure of 47.3% as shown in Table 4. Thus, the lower the percentage of the total farmers affected by climate change and extremes, the lesser the vulnerability (Tables 1). Consequently, the high adaptive capacity with low sensitivity and exposure decreases the vulnerability of the farmers to climate change. Also, very high vulnerability level recorded in zone C was because the adaptive capacity was very low, with the mean adaptive capacity of 33% as given in Table 2. Thus, the higher the percentage of total farmers with more wealth, technology and literacy rate, the lesser the vulnerability (Table 1). Also, the farmers' sensitivity and exposure in zone C were high with the mean sensitivity and exposure of 61.3% and 60% respectively (Table 3 and 4) Thus, the higher the percentage of the total farmers affected by climate change and extremes, the higher the vulnerability (Tables 1). Therefore, the low adaptive capacity with high sensitivity and exposure made the farmers be highly vulnerable to climate change in zone C, in Niger State.

Thus, the farmers in zone C with high vulnerability level could, therefore, be described as the most vulnerable to climate change in the study area. On the other hand, the farmers in zone A and zone B with low and very low vulnerability levels could be described as the less vulnerable to climate change in Niger State.

Recommendations

Reducing climate change impact effectively requires both local management and macro policy approaches that promote sustainability of land resources [24]. In this regards, it is recommended that measures be taken to integrate climate change adaptation into the state development process. These measures should include:

Poverty reduction: Poverty can be reduced through livelihood diversification, by creating economic activities that will generate employment for the households. These could be achieved through finance and technical assistance such as loans and capacity building. When finance and technical assistance are given to the farmers, it could motivate them to venture into small and medium scale businesses such as poultry farming, fish farming, production of local briquettes (to solve the immediate farmers' problems of unaffordable fuel), trades and services, which on its own will generate employment.

Enhance food security through good agricultural practices: To enhance food security and reduce the impact of climate change through good agricultural practices, there is the need to improve on the use of improved crop varieties particularly varieties made for dry-land areas (e.g. upland rice) and adoption of agro-forestry.

Alternative sources of energy: Promotion of alternative sources of energy (use of coal stoves, local briquettes, gas cookers, biogas digesters, box-solar cookers, off-grid solar power plant) to reduce human impact on the remaining woody biodiversity resources are needed. Therefore, promotion of alternative sources of energy will contribute towards development aspirations of the study area in many important ways: (1). saving trees that would otherwise be cut down for charcoal or firewood production to increase carbon dioxide sequestration; (2). use of renewable energy technology will ease the energy demand for fossil fuels and grid electricity.

Conclusion

In conclusion, the predominant farmers in Niger State are highly vulnerable to climate change. Consequently, the interaction of climate change impacts with the socio-economic status (high illiteracy rate, dependency on farming and poor access to loan) has contributed to the high level of farmers' vulnerability to climate change in the study area. Moreover, the variations within each agro-ecological zone were considered in order to target specific areas that are highly vulnerable and to recommend appropriate interventions. Thus, there is a need for integrated rural development schemes aimed at alleviating poverty and increasing the adaptive capacity of farmers to climate change in Niger State.

Finally, the study has effectively used integrated vulnerability assessment approach to determine the degree of farmers' vulnerability to climate change, which has much to offer in terms of policy decisions. The results can be used for the reduction of potential damage of climate change and the vulnerability of farmers by integrating its outputs into spatial planning and emergency planning on reducing the impact of climate change in Niger State, Nigeria.

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