MPRI-EDIR | INTERNATIONAL JOURNAL OF EARTH DESIGN AND INNOVATION RESEARCH
VOL. 02 NO. 1 OCT-2023 ISSN: 1116 - 2759

MAPPING CLIMATE CHANGE VULNERABILITY IN NORTHWESTERN NIGERIA

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Abstract

Climate change vulnerability mapping is normally carried out with the aim of pinpointing areas with the conjunction of the highest adverse effects of climate change and people with the lowest capacity to adapt to the effects. Identification of such areas provides ample opportunities for planning climate change adaptation and resilience. The focus of this study is to map climate change vulnerability among the 7 states that comprise the northwest zone of Nigeria. Data on eleven environmental, socio-demographic and economic parameters were collected and used under three vulnerability indicators; exposure, sensitivity and adaptive capacity. GIS was used in creating the maps that portray the indicators and overall vulnerability. Jigawa, Kebbi and Sokoto were the states with the highest exposure, Jigawa, Katsina and Kano had the highest sensitivity and Sokoto, Zamfara and Kebbi had the lowest adaptive capacity. A conjuncture of these indicates Katsina, Jigawa and Sokoto as the most vulnerable Kebbi and Zamfara as the medium and Kaduna and Kano as the least vulnerable states to climate change in the area. Climate change vulnerability factors are spatially variable in the area, which calls for state-based adaptation and resilience measures in the area. It is recommended that there is a need for early warning systems for extreme climate events as well as solutions to the socio-demographic and economic indicators in the area.

Keywords:
Adaptive capacity, climate change, exposure, vulnerability mapping, northwestern Nigeria, sensitivity

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VOL. 02 NO. 1 OCT-2023 ISSN: 1116 - 2759

Introduction

Human activities which involve the emission of gases that are changing the chemistry of the atmosphere are believed to be causing global warming through the greenhouse effect. Consequently, this is producing changes in the global climate pattern known as climate change (Intergovernmental Panel on Climate Change [IPCC], 2023). No country or region in the world is immune from the adverse effects of climate change. However, as the effects differ from one region or country to another in terms of frequency and intensity, so also the vulnerability of people to these effects. In short, the vulnerability of people to climate change effects varies across the globe depending on the nature of the changes in the climate, the nature of the physical environment and the technological as well as socio-demographic and economic conditions of the people.

IPCC defined vulnerability to climate change as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007). 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. Mapping vulnerability to climate change involves determining the interplay of three factors within a given geographical area. These are; exposure to climate stressors, sensitivity to the stressors and adaptive capability to withstand or absorb the shock of the stressors. It is an integral part of effective planning for climate change.

In a survey conducted by the Commonwealth, Nigeria with a score of 1.12 on the Universal Vulnerability Index, is ranked 31 among the 138 countries covered by the survey (The Commonwealth, 2021). In another survey, on the Global Climate Risk Index, Nigeria is ranked number 70 in the world. However, the same survey also revealed that in terms of climate fatalities, it is ranked number 27, with loss of properties worth 47 million US Dollars (Eckstein et al., 2021). If these figures are to be disaggregated based on geopolitical zones of Nigeria, those in the north are most likely to be the most adversely affected.

NIMET (2021) reported that the climate of northern Nigeria is tending toward wetter and hotter conditions than what was obtained in the 1970s and 1980s with increases in rainfall and maximum temperature of 8.8% and 4.8% per year respectively. In 2018, a flood in the Hadejia-Jama'are river basin affected 22 local government areas (LGAs) in Kano and Jigawa States, covering 538.48 km^2 (Odewole et al., 2020). In 2020, floods inundated vast farmlands in Kebbi State,

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while in Jigawa and Sokoto States, 18 and 14 LGAs were affected respectively (International Federation of Red Cross and Red Crescent Societies, 2020). In addition, rainfall variability is also increasing. For instance, in 2021, northwestern Nigeria including some other parts of northern Nigeria experienced late onset and early cessation of the rainy season, which is evidence of rainfall variability.

The fact that the largest proportion of the Nigerian adult population is engaged in agricultural production as the primary occupation makes climate change a serious challenge to development in the country. In the northwestern part of the country, the proportion of people engaged in agricultural production is higher than the national average of 70%. For instance, in Jigawa and Katsina states, agricultural production (crop and livestock production) is the primary occupation of about 90% and 95% of the adult population respectively (Sanusi et al., 2013; Katsina State Government, 2018). Therefore, the prevalence of agriculture, especially on a smallholder basis as the primary occupation of the majority of the inhabitants of the area predisposes the area to the adverse effects of climate change. Because agriculture is one of the foremost climate-sensitive activities.

Assessing vulnerability to climate change is vital to planning for climate change resilience and adaptation at almost every level of human society. According to Busby (2018), the basic goal of vulnerability mapping is to provide decision-makers with a visually intuitive snapshot of likely priority areas in the short to medium term. That is why it is mapped at various scales ranging from the global level (Edmonds et al., 2020), continental level, for instance, Latin America (Development Bank for Latin America (2014), regional level, for instance, West Africa (Ayodotun et al., 2019), country level (Ferrazi et al., 2021) for instance Nigeria (Busby, 2018), towns and city level, for instance, Addis Ababa (Feyissa et al., 2018) and San Diego (ICF, 2020), community level (UN-Habitat, 2020) to even institution level like universities, for instance, University of Berkeley, California (deBoer et al., 2017). It is also mapped based on sectors such as the agricultural sector (Gbetibouo & Ringler, 2009), transport sector (United Nations Conference on Trade and Development [UNCTAD], 2017), tourism sector (Moghal, 2015) and health sector (Berry et al., 2018). The specific objectives of this study are to identify and map the (i) sensitivity, (ii) exposure, and (iii) adaptive capacity and vulnerability of people to climate change in each of the states that comprise the study area.

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Materials and Methods

The Study Area

Northwestern Nigeria is located between latitudes 08°59'58.5"N to 13°52'39.5"N and 03°28'25.6"E to 10°36'10.2"E (Figure 1). It comprises Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto, and Zamfara states. It covers 212,350 km^2 (National Bureau of Statistics, 2017), representing 23.338% of Nigeria's total land area. The estimated combined population of these states as of 2019 was 54,839,886 (National Bureau of Statistics, 2020a), representing 27.265% of the total population of Nigeria. The major occupation of the adult population is subsistence agricultural (crop and livestock) production. The proportion of the population engaged in agriculture ranges from 70% in Kano state (Rigaud et al., 2021), to 95% in Katsina state (Katsina State Government, 2016). Zamfara and Katsina states are the foremost in the country in terms of cattle and sheep as well as goat production respectively (National Agricultural Extension and Research Liaison Services [NAERLS] & Federal Ministry of Agriculture and Rural Development [FMARD], 2020). The presence of rivers such as the Niger River (in Kebbi State) and its tributaries like Rima, Sokoto and Kaduna Rivers (in Sokoto, Zamfara and Kaduna states), Kano River (in Kano State) as well as Hadejia and Jama'are rivers (in Jigawa State) allow for extensive irrigation agriculture and fishing in the area. Two states (Jigawa and Kano) fall within the Lake Chad Basin while the other states (Kaduna, Katsina, Kebbi, Sokoto and Zamfara) fall within the Niger River Basin. The area has a tropical continental (Aw) type of climate characterized by wet (June – September) and dry (October – May) seasons. It is also characterised by a severe rate of desertification (Olagunju, 2015). Vegetation of the area ranges from Sudan to Sahel savanna types.

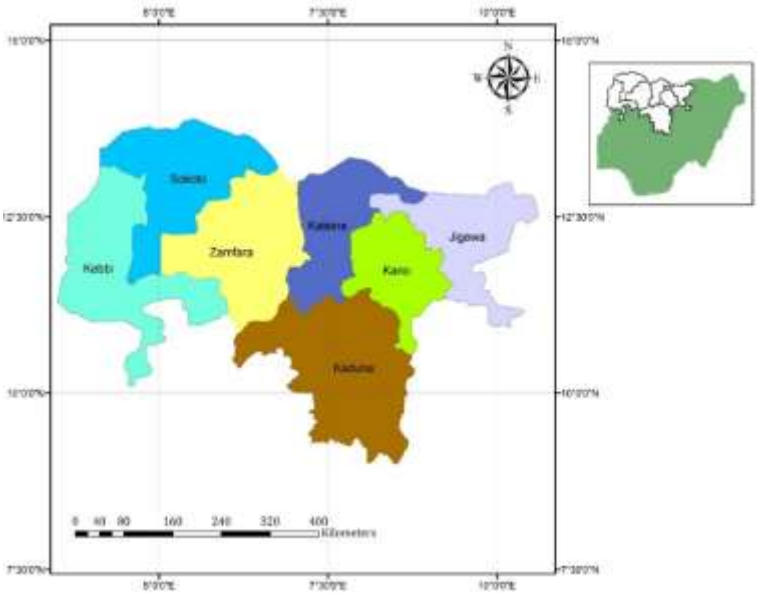

Figure 1: States of the Nigerian Northwest Zone

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Methods

There are many methods of determining climate change vulnerability index however, this study adopted the one based on the IPCC (2001) definition. This method represented vulnerability to climate change as a function of three components; exposure, which portrays the risks as a result of changes in climate variables. Sensitivity, which portrays the human and environmental conditions that can lead to escalation of a climate hazard or trigger an impact. Adaptation capacity, which portrays the potential to adapt to climate change impacts. Each of these components is assigned a value of 1, which is shared equally among the 11 parameters selected for this study as the indicators of the components following Yusuf and Francisco (2009) method. Exposure indicators (drought frequency, rainfall variability, changes in temperature and flood frequency) for the last 30 years (1993 to 2022) were assessed. The types of data used in this study and their sources are summarised in Table 1.

Table 1: Climate change vulnerability indicators and sources of data

Indicator	Source of Data
Exposure indicators	
Drought frequency Rainfall variability Change in temperature	World Bank Group Climate Change Knowledge Portal (https://climateknowledgeportal.worldbank.org/download-data) rainfall and temperature data from 1993 to 2022
Flood frequency	www.emdat.be flood occurrence data 1993 to 2022
Sensitivity indicators	
Population density	NBS (2020a) & NBS (2017)
Proportion of people living in mud houses	NBS (2020b)
Proportion of farmlands	Sedano et al (2020)

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People without registered nonfarm enterprise	NBS (2020b)
Adaptive capacity indicators	
Inaccessibility to clean water	NBS (2022)
Multidimensional Poverty Index	NBS (2022)
Proportion of LGAs in conflict	Famine Early Warning Systems Network (2019)

Since data on the various indicators were in different units of measurement, they were converted to unitless scales ranging from 0-0.25 in the case of exposure and sensitivity and from 0-0.33 in the case of adaptive capacity (lowest to highest in all the cases). These were used in computing the vulnerability to climate index using the following equations:

$$E = \frac{\sum_{i=1}^{n} E_i}{N} \quad (1)$$

$$S = \frac{\sum_{i=1}^{n} S_i}{N} \quad (2)$$

$$A = \frac{\sum_{i=1}^{n} A_i}{N} \quad (3)$$

$$V = \frac{E+S+A}{3} \quad (4)$$

Where E is the exposure, S is the sensitivity, A is the adaptive capacity, V is the vulnerability E_i are the indicators of exposure from the first to the last, S_i is the indicator of sensitivity from the first to the last, A_i is the indicator of adaptive capacity from the first to the last and N is the number of observations. From the

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values obtained, GIS was used in producing the maps as shown schematically in Figure 2.

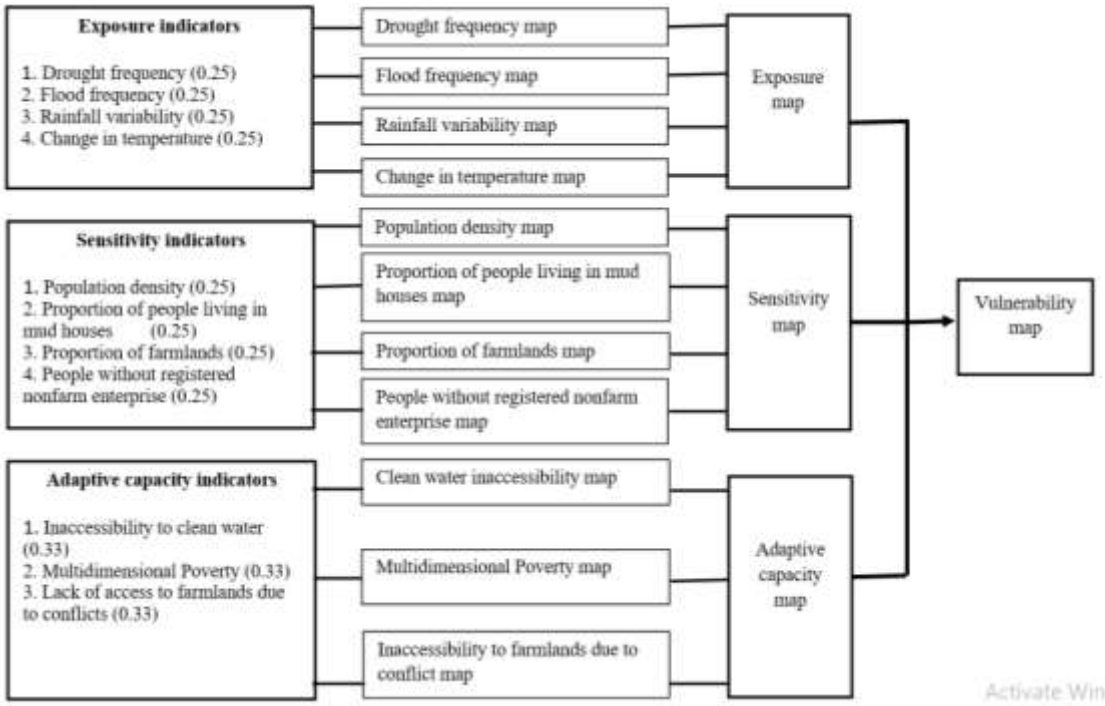

Figure 2: Climate Change Vulnerability Assessment Framework using GIS

Result and Discussion

Exposure

Result of assessment of exposure indicators and overall exposure is presented in Figure 3. In terms of drought frequency within the last 30 years, Kebbi State has the highest followed by Sokoto and Zamfara states. Jigawa, Kano and Katsina have low frequencies while Kaduna State has the lowest. High drought frequency is detrimental to the people in the study area because the majority are engaged in rainfed agriculture therefore, it implies a significant reduction in agricultural productivity. High drought frequency is also detrimental to water resources as it results in a serious reduction in surface and groundwater recharge. The Figure also reveals that Jigawa State has the highest flood frequency followed by Kano, Katsina, Kebbi and Zamfara States. Sokoto has a comparatively low frequency while Kaduna State has the lowest. People experiencing high flood frequency are bound to be adversely impacted by climate change because it entails the loss of lives and livelihoods (loss of crops, livestock and other properties). Kano State has the highest rainfall variability followed by Jigawa State then Sokoto State. Katsina

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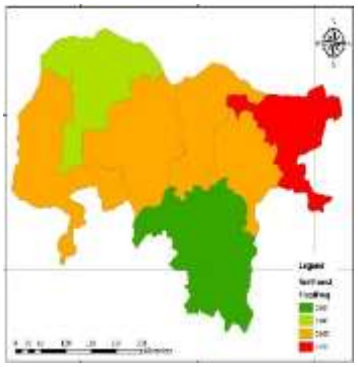
has a moderate rainfall variability, Zamfara State has low followed by Kebbi State while Kaduna has the lowest. Kebbi State has the highest change (increase) in temperature followed by Sokoto then Zamfara states. Katsina experienced a moderate change, Kano State low while Jigawa and Kaduna the lowest. A combination of these indicators gives the composite map of exposure. This shows Jigawa State as the one with the highest exposure in the zone, which is predicated on the fact that it is ranked first and second in terms of frequency of floods and rainfall variability respectively and third in terms of drought frequency. Kebbi and Sokoto states come second and third while Kaduna has the least exposure. With the projected increases in rainfall (9-14.2% by 2050 under RCP 8.5) and temperature (3.08°C under RCP 8.5) for the area (Federal Republic of Nigeria, 2020) this situation is a serious cause for concern.


(a) Drought frequency


(b) Flood frequency


(c) Rainfall variability


(d) Change in temperature


(e) Exposure

Figure 3: Exposure indicators and Exposure Maps

Sensitivity

Result of sensitivity indicators is presented in Figure 4, which shows Kano as the state with the highest population density followed by Katsina State. Jigawa State

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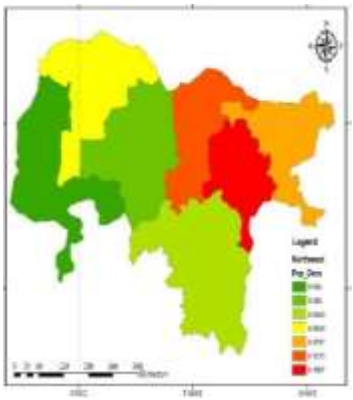
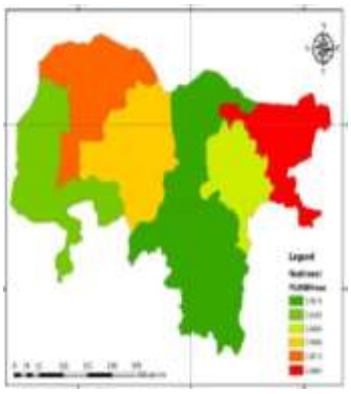
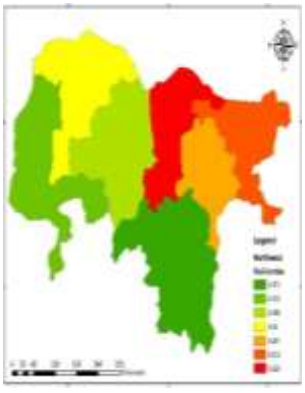
is ranked third while Sokoto, Kaduna and Zamfara states have moderate population density and Kebbi State has the lowest. The higher the population density of a state the higher the number of people that are likely to be affected by a climate extreme event. The Figure (b) also indicates that Jigawa State has the highest proportion of people living in mud houses in the study area while Kaduna and Katsina have the lowest. This indicator portrays the susceptibility of the people to extreme climatic events, especially floods and rainstorms. Because mud houses have less ability to withstand floods and rainstorms in contrast to cement or concrete ones. In terms of the proportion of farmlands, Katsina State is ranked the highest, which corroborates what the state government reported that 95% of the adult population in Katsina State are farmers (Katsina State Government, 2016). Jigawa State is the next while Kebbi and Kaduna States are ranked the lowest. The rest of the states have moderate proportions. Proportion of farmlands indicates the level of involvement of the people in crop production thus, the vulnerability of the state to extreme climate events such as drought, rainfall variability and floods. In the case of the proportion of people without registered non-farm enterprises, Jigawa State comes first, followed by Kaduna and Sokoto states while Katsina and Zamfara have the least. This indicator portrays the level of dependence of people on agriculture as their source of livelihood, which also indicates the vulnerability of the people to climate shocks. The overall sensitivity map of the area shows that Jigawa State is the most sensitive to climate change followed by Katsina State. Kano and Kaduna states have high, Sokoto and Zamfara states have low while Kebbi State has the lowest sensitivity in the area.



(a) Population density



(b) Proportion of mud houses



(c) Proportion of farmlands

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(d) Lack of non-farm enterprises



(e) Sensitivity

Figure 4: Sensitivity indicators and Sensitivity Maps

Adaptive capacity

Adaptive capacity indicators are presented in Figure 5, in which Kebbi State has the highest proportion of people who do not have access to clean water and those categorized as multi-dimensionally poor in the study area. Sokoto and Zamfara states are ranked second and fourth in the inaccessibility to clean water and multidimensional poverty indicators while Jigawa and Katsina states are ranked third in multidimensional poverty and inaccessibility to clean water respectively. Jigawa State has the least proportion of people experiencing inaccessibility to clean water and Kaduna has the least proportion of people experiencing multidimensional poverty. In the case of the inaccessibility of farmlands, Zamfara State has the largest number of Local Government Areas (LGAs) experiencing armed conflicts locally known as banditry. It is followed by Katsina State then Sokoto and Kaduna States. Jigawa and Kano are the only states in the study area in which there is no LGA where a substantial number of the inhabitants are barred from farming by the activities of the bandits. The overall adaptive capacity map shows that Sokoto is the state with the least capacity to adapt to climate change, which is attributable to the prevalence of multidimensional poverty, inaccessibility to clean water as well as inaccessibility to farmlands due to conflicts. It is followed by Zamfara, Kebbi and Katsina States. Kaduna State has a medium capacity while Kano and Jigawa States have the highest, which could be attributed to the fact that they are relatively free from the atrocities of the bandits and they have fewer multidimensionally poor people. Desert encroachment at the rate of 0.6 km per year (Federal Ministry of Environment, 2001) as well as an increase in rainfall

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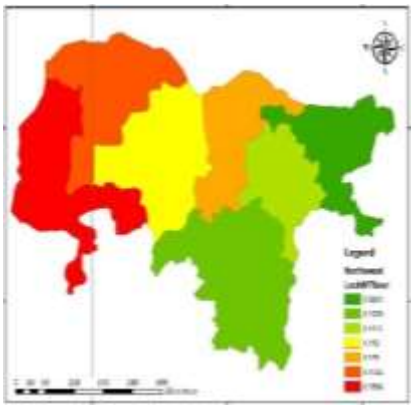
variability, which reduces agricultural productivity area bound to reduce the people's adaptive capacity the area.



(a) Inaccessibility to clean water



(b) Multidimensional poverty



(d) Inaccessibility to farmlands due to conflicts



(e) Adaptive capacity

Figure 5: Adaptive Capacity indicators and Adaptive Capacity Maps

Climate Change Vulnerability

The composite map of vulnerability is presented as Figure 6. Katsina State is the most vulnerable to climate change, which is attributable to its high sensitivity, especially the high proportion of farmlands, high population density and inaccessibility to the farmlands due to armed conflicts. This means any adverse effect of climate change is bound to affect more people in Katsina State than in any other state. Research has shown that the coincidence of population exposure (population density) and other indicators are strong determinants of climate change vulnerability (UNESCO 2022; Young et al., 2023). Jigawa State is second due to its position as the state with the highest frequency of floods, the highest proportion of people living in mud houses and the highest number of people without registered non-farm enterprises. Sokoto, Kebbi and Zamfara are next to

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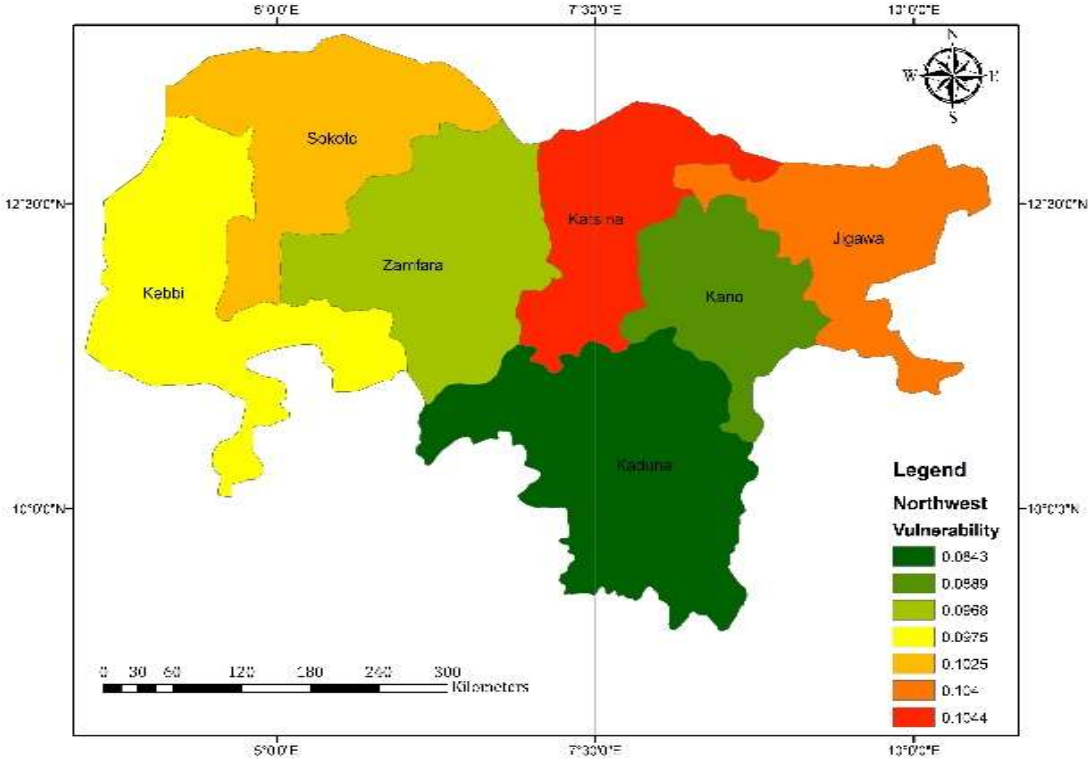
Jigawa in vulnerability to climate change. This is attributable to their high exposure and low adaptive capacity. Kano and Kaduna states have the lowest vulnerability to climate change in the area because of their low exposure, moderate sensitivity and high adaptive capacity.



Climate change vulnerability

Figure 6: Climate Change Vulnerability Map

Conclusion and Recommendation

The result of this study reveals that exposure, sensitivity and adaptive capacity are highly variable in the study area. Jigawa and Kebbi states have the highest exposure, Jigawa, Katsina and Kano states have the highest sensitivity while Sokoto, Zamfara, Kebbi and Katsina states have the lowest adaptive capacity. Katsina, Jigawa and Sokoto emerged as the most vulnerable states while Kaduna and Kano as the least vulnerable states. The most important climate change threats affecting the area are flood, drought and an increase in temperature. It also further indicates the importance of climate change vulnerability mapping. The study recommends early warning systems and widespread adoption of climate-smart agriculture throughout the area. State-specific climate change adaptation

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plan for each state should be produced to address the spatial variation of the vulnerability indicators. Adequate and effective measures of reducing people's sensitivity as well as boosting their adaptive capacity should be vigorously pursued in the area.

Acknowledgement

This research project was sponsored by Tertiary Education Trust Fund (TETFUND) using its Institution Base Research Grant (IBR) with reference number TETF/DR&D/CE/COE/KAITA/IBR/2021/VOL.II.

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