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Smallholder Farmers' Drought Contextual VulnerabilityAssessment in the Drylands of Northwestern Nigeria

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Abstract— This paper assessed smallholder farmers' vulnerability to drought in Bungudu, Dange, Dawakin-Tofa and Rimi areas of Northwestern Nigeria. Rainfall data of four stations was subjected to analysis. Standardized Precipitation Index was generated and intensities and duration of drought computed. Eighty smallholder farmers aged 40 years and above with appreciable years of farming experience were interviewed to determine their sensitivity and adaptive capacity to drought. Vulnerability Assessment Model developed by UNDP was employed to assess communities' vulnerability to drought. Also Focus Group Discussion (FGD) was conducted in the four localities to complement numeric information with communities' value judgments. The findings reveal that the most exposed area to drought is however not the most sensitive one. And the most adaptive area is not the least vulnerable. This is due to the high susceptibility to soil erosion observed in the most adaptive (Dawakin-Tofa) that raises its sensitivity.The FGD also expounded the impacts of droughts on livelihoods and environmental resources. It is concluded that farmers' drought adaptive strategies in the study areas such as: having economic trees in their farms and domestication of small ruminants in their houses and adjusting feeding habit may probably be their sources of high resilience to drought. It is therefore recommended that these strategies should be enhanced and be blended with other strategies that are not common in the communities of the areas such as getting information from meteorological office on what and when to plant and setting up of a community based storage facility of farm produce.

Index Terms— Adaptive capacity, Contextual, Drought, Exposure, Farmers, Northwestern, Nigeria, Sensitivity, Smallholder, Vulnerability assessment

1 Introduction

According to Zarafshani, et al [1], Drought is a slow-onset natural hazard that causes damage to farming livelihood. The hazard occurs in virtually all climatic zones, but its characteristics vary significantly from one region to another [2],[3]. The Sudano-Sahelian Zone (SSZ) of Nigeria has been documented to have experienced frequent drought and famine from 1883 to the beginning of the 21st century essentially the droughts of 1970s, 1980s and 1990s decades that impacted heavily on the livelihoods of smallholder farming communities [4]. These droughts occurred at a time the northern agro-ecological zones were experiencing ecological degradation and slow changes into the drier conditions and altered vegetation composition and structure while the coping and adaptive strategies to drought and its related ecological degradation of smallholder farmers are being constrained by bio-physical and social factors such as declining rainfall, and poverty [5].

Ecological situations, land use and adaptive strategies of farming communities play important role in triggering impacts, worsening, or ameliorating drought situations [6] and enhancing the resilience of vulnerable communities to the impacts of climate change through adaptation is becoming increasingly important [7]. Vulnerability expresses the degree to which a person, group or human-environment system is likely to be exposed to, adversely affected by, and unable to cope with, and recover from the impact of a hazard [6]. Communities' vulnerability to drought is determined by natural factors like the duration, intensity or magnitude of drought that lead to exposure (to short term dry spells or long term desiccations), nature of sensitivity or susceptibility of the communityin terms of its ecological situations and the adaptive (response) strategies of its inhabitants [8].

Turner, et al, [9] are of the view that social and ecological context in which climatic event occurs is likely to be as important if not more important than the climatic shock itself. It is asserted that in the light of increasing frequency of disasters and continuing environmental degradation, measuring vulnerability is a crucial task if science is to help support the transition to a more sustainable world [10]. The need for such information in the study area constitutes the problem or research interest to this study as it has been acknowledge that there is the need for research to explain ''varied sensitivities'' to climate change exhibited by different groups of actors and the consequences of these for adaptation at the local level as noted by Brooks &Adger[11].

1.2 Aim and Objectives

This research was aimed at assessing vulnerability of the smallholder farmers to drought. The objectives set for this work are to:

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a) Determine the exposure to droughts and how it varies from place to place in the study area
b) Establish the extent of sensitivity of farmers' population, assets, land use and ecological situations
c) Assess the vulnerability to drought of the various localities of the study area;
d) Identify the key variables determining vulnerability to drought.

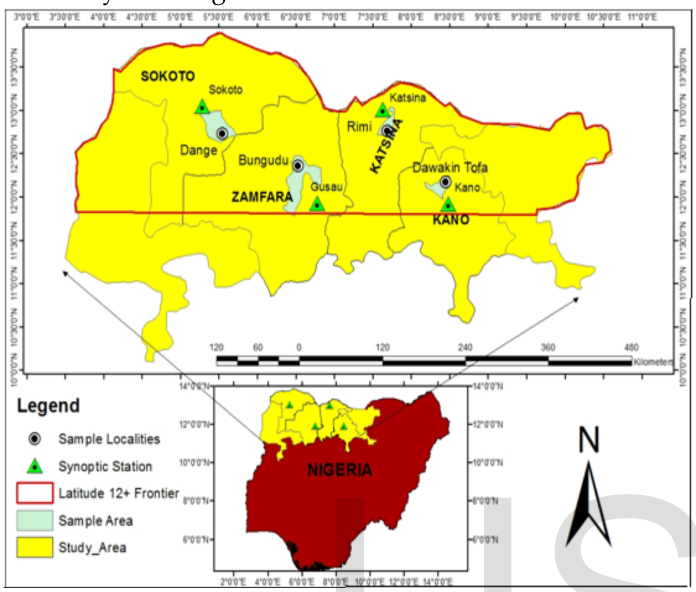

Fig. 1. Map of Study Area

1.1 Study Area

Fig. 1 shows the study area which is located between lat 12^{0} 00^{i}N to 13^{0} 45^{i} N and Longitude 3^{0} 30^{i} E to 11^{0} 35^{i} E. The climate of area is tropical wet and dry and semi-arid steppe types coded A_W and B_S by W. Koppen [12]. The vegetation comprises of tropical grasslands of the Sudan and Sahel Savanna. Agriculture, the predominant economic activity in the study area, is mostly rain fed. Crops produced include millet, sorghum, rice, cowpea, soy beans, wheat, groundnut, maize, cotton, sesame and vegetables [13].

2 DROUGHT CONTEXTUAL VULNERABILITY

Vulnerability relates to the degree to which a human and/or ecological system is likely to experience harm as a result of changes in climate [14], [9]. Vulnerability to drought is influenced by a range of biophysical and socio-economic factors [15], [16], [17]. It is an aggregate measure of human welfare that expresses the degree to which a person, group or human-environment system is likely to be exposed to, adversely affected by, and unable to cope with, and recover from the impact of a hazard [6]. It is a function of the character, magnitude and rate of climate change variation to which a system is exposed, its sensitivity and adaptive capacity [16].

The three components of vulnerability that is: exposure, sensitivity, and adaptive capacity as well as their determinants are context-specific to place and system and they can vary over time, by type and by climatic stimuli [18], [19], [20]. Schröter et al [21] and Challinor, et al [22] observe that factors that make farmers in semi-arid Africa vulnerable to drought will usually not be identical to those that make farmers in Northern Europe vulnerable to the extreme weather event. A vulnerability assessment is the process of identifying, quantifying, and prioritizing (or scoring) the vulnerabilities in a system.

Contextual approach to vulnerability assessment uses a method that emphasizes current climate vulnerability and relaxes the "nature" and "society" dichotomy. This approach views vulnerability as the present inability of a system to cope with changing climate conditions, whereby vulnerability is seen to be influenced by changing biophysical conditions as well as dynamic social, economic, institutional as well as technological structures and processes [23]. In our perspective, vulnerability is considered a characteristic of ecological and social systems that is determined by multiple factors and processes [24], [25], [23] and is interpreted as current inability to withstand external changes including but not limited to climate change [24].

3 MATERIALS AND METHODS

Research tools and materials used include: an open ended questionnaire; Microsoft Excel 2007, Arc GIS9.3 and National Drought Mitigation Centre (NDMC) University of Nebraska Lincoln (USA) Drought Calculator. The NDMC Drought Calculator was downloaded from the website of the Centre. A 61 years rainfall data of the 4 Synoptic weather stations with largest historical records in terms of temporal resolution across North-West of Nigeria namely: Kano, Katsina, Gusau and Sokoto was collected. Socioeconomic and ecological data were generated from survey and Focus Group Discussion. The research has been designed and organized in these stages: Pre-field preparation, Reconnaissance Survey, Field Data Collection / Fieldwork, Focus Group Discussion (FGD).

A multi-stage sampling procedure adopted by this study led to the selection of four synoptic stations, four localities close to the stations and eighty smallholder farmers household. In the first stage four synoptic stations that have the best historical records in terms of temporal resolution and most consistent data were chosen. The second stage involves sampling of communities. A total of four prominent smallholder farming communities close to the four synoptic stations were selected using purposive sampling. Finally, twenty smallholder far-

mers of not less than forty years and twenty years farming experience were selected through availability sampling.
SPI developed by [26] has been used to quantify the degree of dryness of study area at 6 and 12 months timescales. The computation was done with the National Drought Mitigation Centre's (NDMC) Program for Calculating SPI. Indicators have been identified to build and index whose components comprise exposure, sensitivity and adaptive capacity. The exposure component has three (3) indicators that represented moderate, severe and extreme droughts across the four stations. In constructing Drought Sensitivity Index, variables measured by the index include: farmers characterizations, ecological conditions, as well as land use. And indicators used to construct Adaptive Capacity index include: percentage of farmers who are: having more than 1 income sources; practicing mixed cropping; benefiting economic trees; with small ruminants and or adjusting feeding habit. The values of the indicators are normalized using the following procedures:
(i) When the observed values are related positively to the vulnerability (as for instance exposure and sensitivity) the normalization is done using the formula in eqn (1).

$$P_{ij} = [(X_{ij} - Min)*100]/ (Max. Value - Min. value) \quad eqn (1).$$

(ii) But when the observed values are related negatively to the vulnerability, the normalized score is computed using the formula in eqn (2)

$$N_{ij} = -1[(X_{ij} - Min)*100]/ (Max. Value - Min. value) \quad eqn (2)$$

All the normalized scores for the two types of functional relationship will lie between 0 and 1. After computing the normalized scores, the Vulnerability Index (VI) is constructed by giving equal weights to all indicators using single average of all the scores using the formula in eqn (3).

$$Vulnerability = \frac{\sum Pij + \sum Nij}{K} \quad eqn (3)$$

Determinants of Vulnerability were obtained using correlation matrix and Principal Component Analysis (PCA).a technique for extracting from a set of variables those few orthogonal linear combinations of variables that most successfully capture the common information [27]. The procedure of Principal Component Analysis was employed to identify the scores from the first component of PCA, which accounts for the largest variability in the data set considered from the weight for the indicators.

4 RESULTS AND DISCUSSIONS

Fig.2 .depicts the drought exposure index of the four areas which reveals that Katsina with index of 0.33 is the most exposed area to drought and the least exposed is Kano. The commonest crops cultivated by farmers are: millet (5-65%) and surghum (15-30%) and that cultivation of maize is restricted to two areas of Dawakin-Tofa (30%) and Bungudu (25%). farmers have varying considerations or reasons for choosing to cultivate certain crops which range from rainfal (55% in Rimi), soil fertility improvement (30% in Dange), weeds control to yields. There is also almost a uniform distribution of proportion of farmer having access to economic trees and small ruminants across the study area. The most susceptible or sensitive to droght area is Dawakin Tofa. Here 30% farmers cultivate maize and 95% of farmers in both Dawakin Tofa and Dange suffered farm trees and shrubs depletion. Seventy percent (70%) of farmers in Dawakin-Tofa experience soil erosion.

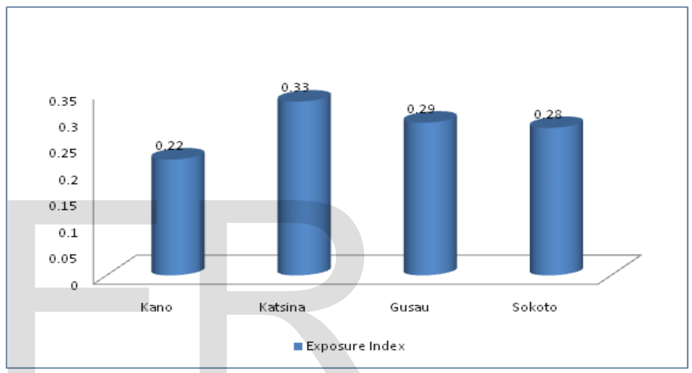

Fig. 2. Exposure to Drought Index

The drought sensitivity index was computed and the index is presented in table 1 where four sensitivity indicators where load weighted using PCA. Dawakin-Tofa (with index of 12.25) emerged the most sensitive to drought followed by Dange (coefficient=7.8) and the least is Rimi (0.88). Soil erosion in and around farm lands and farmers cultivation of maize account for the area's highest sensitivity as the two factor scoring scored high (9.5 and 2.75 respectively).

TABLE 1
SENSITIVITY INDEX

COMMUNITY	DANGE	RIMI	BUNGUDU	DAWAKIN-TOFA
60yrs and above farmers	2.25	0	0	0
Extra large family	1.75	0.875	0.875	0
Maize cultivators	0	0	0	2.75
Erosion around farm	3.8	0	1.9	9.5
	7.8	0.875	2.775	12.25

Table 2 shows the vulnerability index generated after nonalization of indicators values. The first collumn are the normalized values which are from 0 – 1. The second collumn p*w is scoring or weighted value obtained by assigning the same value (mean) of the observations and multiplied by the normalized value [28].

TABLE 2
VULNERABILITY INDEX

Communities	Dange		Rimi		Bungudu		Dawakin-Tofa	
Indicators	X	X*W	X	X*W	X	X*W	X	X*W
60yrs and above farmers	1	2.25	0	0	0	0	0	0
Extralarge family	1	1.75	0.5	0.88	0.5	0.875	0	0
Maize cultivators	0	0	0	0	0	0	1	2.8
Drought intensity	1	9.3	1	9.3	0.63	5.9	0	0
Erosion around farm	0.4	3.8	0	0	0.2	1.9	1	9.5
Mixed cropping	-0.2	-0.06	0	0	-0.83	-4.98	-1	-6
Economic tree	0	0	0	0	-1	-10	-1	-10
Small ruminants	-1	-14.5	0	0	-1	-14.5	-1	-14.5
> 1 sources of income	-1	-3.5	-1	-2.31	-0.33	-1.16	0	0
Adjusting feeding	-0.7	-7.2	0	-1.83	0	0	-1	-10.8
Aggregate	-0.2	-8.17	-0.5	4.21	-0.5	-19.6	-2	-29

First principal component, expressed in terms of the variables, is an index for each area based on the following expression in eqn (4).

$$V = (W_{a1}X_1 + W_{a2}X_2 + W_{a3}X_3....W_{an}X_n) - (W_{s1}Y_1 + W_{s2}Ys + W_{e1}Z_1 + W_{e2}Z_2) \quad \text{eqn(4)}$$

Where: V stands for vulnerability, while X, Y and Z are adaptive capacity, exposure, and sensitivity.

TABLE 3
CORRELATION MATRIX

Indicators	1	2	3	4	5	6	7	8	9	10
60yrs + farmers (1)	1									
Extra-large family (2)	0.82	1								
Maize cultivators (3)	-0.3	-0.8	1							
Drought intensity (4)	0.48	0.87	-0.9	1						
Erosion in farm (5)	0	-0.6	0.9	-0.9	1					
Mixed cropping (6)	0.46	0.7	-0.7	0.9	-0.7	1				
Economic tree (7)	0.58	0.71	-0.6	0.84	-0.5	0.98	1			
Small ruminants (8)	-0.3	0	-0.3	0.48	-0.6	0.67	0.577	1		
> 1 sources of income	-0.8	-1	0.8	-0.9	0.59	-0.9	-0.89	-0.25	1	
Adjusting feeding (10)	-0.31	0.29	-0.8	0.57	-0.9	0.28	0.101	0.421	-0.2	1

Correlation matrix (table 3) has been used to identify the determinants of vulnerability. As can be seen in the matrix ten (10) indicators cross correlate. The determinants of drought vulnerability that shows associations are drought intensity which strongly (r=0.82) correlates with extra-large family size (in Dange, Rimi and Bungudu) also correlates with erosion (in Dawakin-Tofa, Bungudu and Dange). With regards to adaptation the indicators that are the major drivers include mixed cropping, economic trees and small ruminants which are employed as response measure to drought. Mixed cropping has very strongly correlates (r=0.9) with intensity of drought and strongly (r=0.7) with extra-large family (in Dawakin Tofa, Bungudu and Dange) as well as with economic trees and small ruminants.

There is much difference between drought potential impact (exposure + sensitivity) with the communities' adaptive capacity with values of adaptive capacity being high above those of potential impacts. The range of the values of adaptive capacity is between -41.25 (highest in Dawakin-Tofa) to -4.128(lowest at Rimi), the potential impact values range from 17.1 (highest at Dange) and 8.675 (least in Bungudu). Note that because potential impact relate to vulnerability its values are written in positive signs while Adaptive capacity has related negatively with vulnerability hence its signs are also negative. But the absolute values of the two measure apply in the sense that -41.25 is the same as 41.25 and is higherthan - 4.128.

TABLE 4
DROUGHT POTENTIAL IMPACT

COMMUNITY	DANGE	RIMI	BUNGUDU	DAWAKIN-TOFA
60yrs and above farmers	2.25	0	0	0
Extra-large family	1.75	0.875	0.875	0
Maize cultivators	0	0	0	2.75
Drought intensity	9.3	9.3	5.9	0
Erosion around farm	3.8	0	1.9	9.5
	17.1	10.175	8.675	12.25

The potential impact is highest at Dange (17.1) and least at Bungudu (8.675). This is due to the fact that Dawakin-Tofa is the most sensitive (12.25) while Rimi is the most exposed (9.3) to drought. Determinant factors that make Dawakin-Tofa the highest in drought sensitivity include existence of soil erosion in and around farm land and high preponderance of maize cultivators more than in any other place (table 4).

TABLE 5
DROUGHT ADAPTIVE CAPACITY INDEX

COMMUNITY	DANGE	RIMI	BUNGUDU	DAWAKIN-TOFA
Mixed cropping	-0.06	0	-4.98	-6
Economic tree	0	0	-10	-10
Small ruminants	-14.5	0	-14.5	-14.5
> 1 sources of income	-3.5	-2.31	-1.155	0
Adjusting feeding	-7.2025	-1.8275	0	-10.75
	-25.263	-4.128	-30.64	-41.25

The vulnerability of Rimi is the highest and as explained the determinant factors for its vulnerability include drought intensity which strongly (r=0.82) correlated with extra-large family size. This relationship is also observed in Dange. Also in Dange the preponderance of elderly farmers correlated sharply with extra-large family size and intensity of drought. Factors that a little bit ameliorated the situations in Dange (-25.263) was its adaptive capacity that is relatively higher than that of Rimi (-4.128) refer to table 5. The vulnerability of the areas is represented in fig. 3

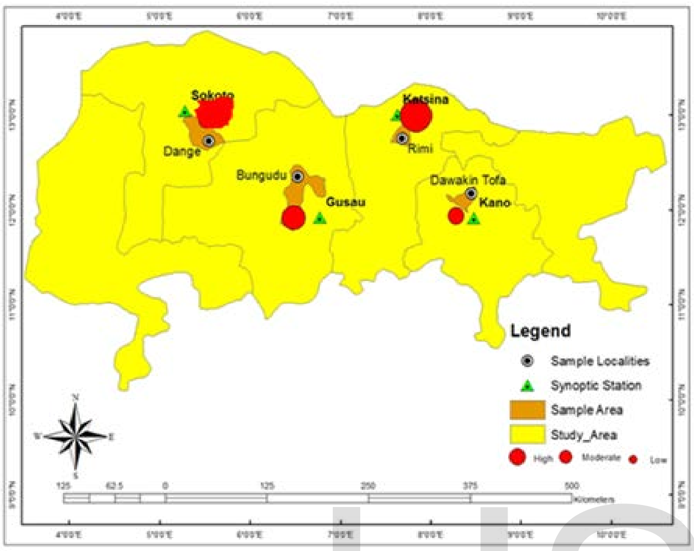

Fig. 3. Drought Vulnerability Map

The aggregate of the result from FGD in all the four communities shows that the decades 1970s and 1980s were time of droughts and famines that created a lot of havoc. The time witnessed failure in rainfall, scarcity in food, human and animal mortality and morbidity intensified. There was also influx of migrants from North (Niger republic and other far northern areas). These compounded drought vulnerability of the communities. People sold their livestock, lands and precious assets to survive while so many heads of household migrated to humid areas to provide labour in farms, markets and houses.

5 CONCLUSION AND RECOMMENDATIONS

The most exposed area is hoever not the most senstive one to drought. And the most adaptive area is not the least vulnerable. This is due to the high susceptivility to erosion of the most Adaptive (Dawakin-Tofa) that raises its sensitivity. The farmers around Dawakin-Tofa, Dange, Bungudu and Rimi as arranged according to descending order, their drought adaptive strategies such as mixed cropping, benefiting economic trees, adjusting feeding habit, getting gift of replanting seeds after drought, among other strategies may probably be the sources of their resilience to precarious drought that ravage them. In view of the foregoing, it is therefore recommended as follows:

- ✓ That the foregoing adaptive strategies should be enhanced and be blended with other adaptive strategies that are not common in the communities of the study areas such as getting information from NIMET on what and when to plant;
- ✓ Also ecological problem of vegetal resources depletion should be given utmost priority as the farmers resort to consumption of wild fruits and vegetables during drought so as not to make these vital resources extinct.
- ✓ Community Based Storage facility for smallholder farmers should be evolved so as to help farmers store their surplus produce's effectively and retrieve it when they so wish minimal or zero spoilage or loss.

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