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Assessing Vulnerability of Smallholder Farmers to Climate Variability for Enhanced Adaptive Capacity and Resilience in Karonga District, Malawi

Chakufwa Kaulanda Munthali[1]*, Victor Kasulo[2], Mavuto Tembo[3]

[1]*Plan International Malawi, Northern Region of Malawi, Malawi*
[2]*Department of Agri-sciences, Mzuzu University, Mzuzu, Malawi*
[3]*Department of Forestry, Mzuzu University, Mzuzu, Malawi*

Abstract

This study covers a comprehensive undertaking in order to determine vulnerability to climate variability of smallholder farmers in Karonga District according to gender of the household head, in selected Traditional Authorities (TA) and Group village headmen (GVH) areas. The study aimed to unravel vulnerability in its totality but wrapped in four specific objectives: to determine biophysical, socio-economic and composite vulnerability of smallholder farmers to climate variability and to examine adaptation mechanisms employed in the study area. Mixed methods were used in order to exploit both quantitative and qualitative data and stratified random sampling was employed. Data was collected through face to face interviews, focus group discussions and key informant interviews. Semi structured questionnaires were used for collecting information. Data analysis was done using SPSS and excel. A total of 39 indicators taken from literature and observations in the study area were loaded and analyzed in SPSS. In order to reduce the dimension of the indicators and thus generate vulnerability indices, principal component analysis was used with varimax rotation and using the Kaizser criterion (Eigen value >1). In all the analyses both the Kaiser-Meyer-Olkin test and the Bartlett's test requirements were fully satisfied before proceeding with dimension reduction. Positive (+) values showed increased vulnerability, while negative (-) values showed reduced vulnerability. The magnitude of vulnerability was determined based on the index's proximity to zero (0) or 1. Results for objectives 1, 2 and 3 indicate that female headed households are highly vulnerable to climate variability while male headed households have reduced vulnerability to climate variability. In terms of the area, GVH Mwaulambo area is the most vulnerable (1.90240) to climate variability, while GVH Mwenitete is the least vulnerable among the six sampled GVHs. Socio-economically, GVH Mwangulukulu is very highly vulnerable (3.18534) and GVH Zindi is the least vulnerable. The study therefore concludes that, indeed, Karonga District is vulnerable to climate variability effect. However, we also acknowledge through the findings show that the vulnerability levels differ depending on gender as well as the area (specifically, group village head areas). On adaptation, the study reveals that smallholder farmers have low adaptive capacity. The study therefore recommends that interventions to either prevent vulnerability or address post disaster challenges need to factor in the element of gender and locality in which smallholder farmers are. Special emphasis needs to be given to female headed households as they have shown very high vulnerability levels both biophysically and socio-economically as compared to male headed households.

Key words: Biophysical vulnerability; Socio-economic vulnerability; Principal component analysis; Small holder farmers; Adaptation; Karonga district; Malawi

Introduction

In this century, global climate change and variability is challenging and threatening the future of humanity (IPCC) [1]. Climate variability as an environmental issue affects all aspects of human life, as suggested, including the environment and social communities [2]. The agricultural sector is most sensitive to changing climatic conditions which affect agricultural production and farming communities [3]. Smallholder farmers are one of the most vulnerable social groups to climate variability especially in developing countries like Malawi [4]. Climate variability is expected to increase the frequency and severity of droughts and floods, leading to poor yields, crop failure and livestock mortality [5]. Considering the close relationship between agricultural production and household income of smallholder farmers, the negative impact of climate variability on crop yield increases the vulnerability of smallholder farmers. Therefore, climate variability not only has an impact on agriculture production of smallholder farmers but it also puts their household well-being and food security at risk [6].

In Malawi, one of the persistent problems is the way in which people at community level can secure their livelihoods under changing climatic conditions. The effort to maintain and enhance livelihoods systems by smallholder farmers in rural areas of the country is complicated by the fact that it is not only climate variability that is driving persistent livelihoods tendencies and outcomes [7]. A combination of factors such as economic decline, high levels of poverty, gender inequality and patriarchy, weak institutions, and natural resources depletion deriving from the broader context in the country are therefore contributing to the livelihoods challenges of smallholder farmers [8]. Natural disasters are serious threats to the country of Malawi and Karonga district in particular [7]. The socio-economic development of Malawi has been substantially affected by climate variability, whose effects have cost Malawi a significant percentage of its GDP and have reduced the quality of life of its residents. This increases the vulnerability of smallholder farmers to climate variability in Malawi.

***Corresponding author:** Chakufwa Kaulanda Munthali, Programme Area Manager, Plan International Malawi; Northern Region of Malawi, Malawi, Tel: + 265 992343494; E-mail: kasulov@gmail.com

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Furthermore, Karonga district in Malawi is one of the most vulnerable district to disasters that are associated with climate variability; it is located within the Great Rift Valley plain, which is the most geologically active to natural disasters. The environmental and geological conditions in Karonga are sensitive and vulnerable to such disasters [7].

Vulnerability is defined as the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes. 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 [9] (Figure 1).

Therefore, the vulnerability of a system depends on internal characteristics (sensitivity and adaptive capacity) of the system or population and the external factors as natural hazards (exposure). Natural hazard is defined as "a natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption or environmental damage"

The level of vulnerability of different villages to climate variability in the study area is determined by both socioeconomic and environmental factors. 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) [11]. The integrated assessment approach combines both the socioeconomic and the biophysical attributes in vulnerability analysis [12]. This study employed integrated farmers' vulnerability assessment approach which corrects the limitations in both socioeconomic and biophysical approaches.

A better understanding of vulnerability assessment of smallholders' agricultural systems, which constitute approximately 80% of all farms with livelihoods directly threatened by weather extremes is paramount. Agricultural livelihoods are considered most sensitive to climate variability impacts contributing to smallholder farmers to be socio-economically disadvantaged hence inherently vulnerable [13,14]. Malawi is a low-income country characterized by a high population growth rate (about 3.06%) and high poverty levels. The current population is estimated at 18 million people, of which 83% live in rural areas. Approximately 51% live below the national poverty line of USD $1 / day [15].

The high exposure of Malawi to environmental stresses has sparked the interest of development agencies and research institutions to report evidences of the occurrence of these environmental challenges and explore their impact on smallholder farmers. Climate variability impact studies in Malawi to date have predominantly been focused on biophysical aspects with attention been given on the crop yield and livestock production impact and are done at national level and not at local level. This creates a situation where the government lack information on vulnerability of smallholder farmers in relation to specific locations at community level resulting into failure to develop local specific adaptation strategies. Furthermore, the current knowledge showing that smallholder farmers in developing countries including Malawi are vulnerable to climate variability is primarily based on the biophysical responses to climate change using global climate models. For instance, studies by [15,16]. Furthermore, other studies have focused on social economic vulnerability in assessing vulnerability of small holder farmers to climate variability and few employed integrated approach [12,17,18]. This creates a gap in knowledge in understanding vulnerability comprehensively since integrated approach provides better information on vulnerability of smallholder farmers than when each approach is done separately [19]. Furthermore, the integrated approach provides a holistic view of vulnerability, whose results requires more evidence based to just the significance of the combination of the two [19]. This gap in knowledge on smallholder farmer's vulnerability to climate variability in the study areas calls for a more comprehensive and holistic assessment approach that integrate both biophysical and socio-economic aspects.

A deeper dive into socio economic vulnerability by, few studies revealed that gender plays an important role determining vulnerability of smallholder farmers to climate variability adaptation [12,22,21].

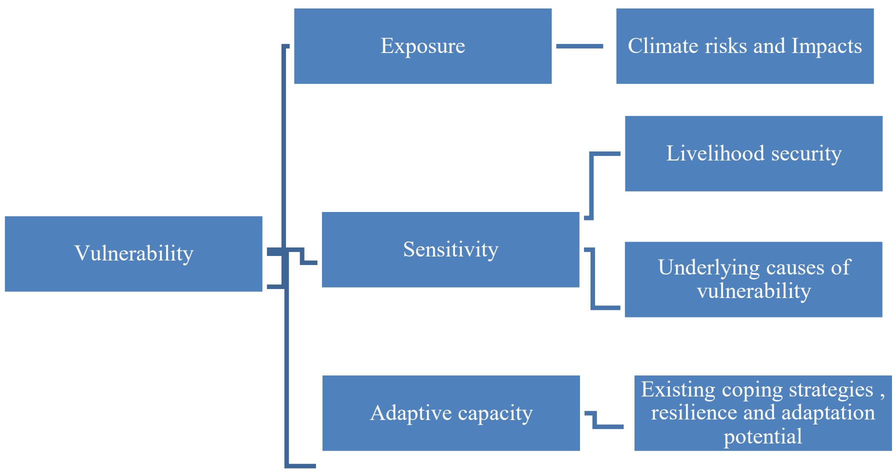

Figure 1: Key components of Vulnerability.

Women play an important role in agriculture. They constitute 70% of full time farmers, carry out 70% of the agricultural work, and produce more than 80% of subsistence crops. Smallholder farmers disproportionately produce crops for domestic consumption and they produce approximately 80% of all food consumed in Malawi [15]. In Malawi, smallholder production accounts for nearly 70% of the agricultural GDP [15]. Though both male-headed and female-headed farming households within the same geographical location are exposed to the same climatic conditions, the extent of effect of the climatic stresses varies between men and women, because of differences in their levels of adaptive capacities and sensitivity. Thus, vulnerability to climate change is worsened by gender disparity [22]. Female farmers' agricultural activities lack the needed resources relative to male farmers [23]. Despite the important roles that women play in agriculture, gender issues in particular, have received a cursory attention in climate variability studies in Malawi. Clearly, in order to address this gap, there is a need to investigate gender vulnerabilities to climate variability at a household level and explore opportunities and challenges for effective implementation of adaptation strategies.

Fundamentally, the need to understand and analyses the vulnerability of smallholder farmers in Karonga District, Malawi to changing climate variability for enhanced adaptive capacity is what ultimately driven this research study. In essence, the researcher's greatest concern was to first comprehend how smallholder farmers problematize their circumstances, the specific circumstance being climate variability, and then subsequently analyze their socio economic and biophysical vulnerability linking to adaptive strategies.

It is against this background that this research carried out an in-depth analysis of the local level vulnerabilities by integrating quantitative analysis with qualitative information obtained from primary field survey and secondary data to determine the magnitudes and patterns of rural households' vulnerability to climate variability and then identified the important determinants for adaptation at household level in Karonga District, Malawi.

It is believed that this study provides valuable information to policy makers as well as implementers in terms of ensuring disaster management preparedness, targeting the right population, specificity of help required to target population and enhancement of the population's adaptive capacity and coping mechanisms. As the area is a designated potentially disaster prone area annually especially during and after the rainy season (spanning between November to April), its impacts linger on well into the year.

Study objectives

Main objective of the study: My main objective was to contribute to enhancement of adaptive capacity through analysis of the biophysical and socio-economic vulnerability of small holder farmers to climate variability.

Specific objectives:

To examine biophysical vulnerability of smallholder farmers to climate variability by gender.

To analyze the socio-economic vulnerability of smallholder farmers to climate variability by gender.

To analyze the composite vulnerability levels of smallholder farmers by gender to climate variability.

To examine the adaptive capacity to climate variability of smallholder farmers and how by gender.

Methodological Approach

Study area

This study was conducted in Karonga district which is in the Northern region of Malawi. It is bordered by Chitipa District in the West, Rumphi District in the South, and Tanzania in the North and East. The district head quarter (known as Karonga Boma) is found about 50 km south of the Tanzanian border, 226 km north of Mzuzu City and 585 km north of the capital city of Malawi, Lilongwe (Figure 2).

The total land area of the District is 3,355 square kilometres making up 3.5% of the total land area of Malawi (94276 sq. km). Karonga is the 5th largest district in the northern region and is on 12th position in the nation (in terms of total land area). Karonga is a disaster-prone district. In 2009, there was an earth quake which left a lot of people homeless.

The District is subdivided into Traditional Authorities (TA). TAs act as custodians of the cultural and traditional values of the community. They have the control of customary land ensuring that authority over land is passed in succession from one generation to another. There are six Traditional Authorities (TAs) in the district. The study isolated 3 TAs out of the 6. The area under TA is considerably large and it is further subdivided into Group Village Headmen (GVH). The Group Village Headmen are chairpersons of Village Development Committees (VDCs). The GVHs are responsible for overseeing an average of about eight village headmen although this varies considerably. The study isolated 6 GVHs from which data was collected.

The mean annual rainfall for the study areas is about 2200 mm. The highest rainfall in the district is experienced around GVH Mwangulukulu and Mwakaboko in Traditional Authority Mwakaboko which are part of the study areas where normally annual rainfall amount of around 3000 mm is experienced due to the topography. This triggers high intense rainfall that results in floods in the low lying areas of the study areas. However, the Arabian ridge from the east stretches into the district and dry spells or droughts in extreme cases are induced over Karonga district (Figure 3).

Research design

Designing is the initial step of a study in which the research topics and research issues are identified and presented in a systematic manner. The research objectives were set along with the activities and methodology for data collection. This study was carried out to investigate the biophysical and socio-economic vulnerability of smallholder farmers to climate variability.

This study employed mixed methods which included integration of quantitative and qualitative data collection through both quantitative and qualitative methods. Broadly defines the mixed method approach as "research in which the investigator collects and analyses data, integrates the findings and draws inferences by collecting numerical data that are analysed using mathematically based methods (in particular statistics)" and also qualitative data to gain an understanding of underlying reasons, opinions and motivations by providing insights into the problem [24].

Further to the benefits highlighted above, a mixed research method produces a better research quality by eliminating the biases inherent to either quantitative or qualitative methods alone.

Sampling framework

Sampling according to Strydom is taking any portion of a population or universe as representative of that population. For this

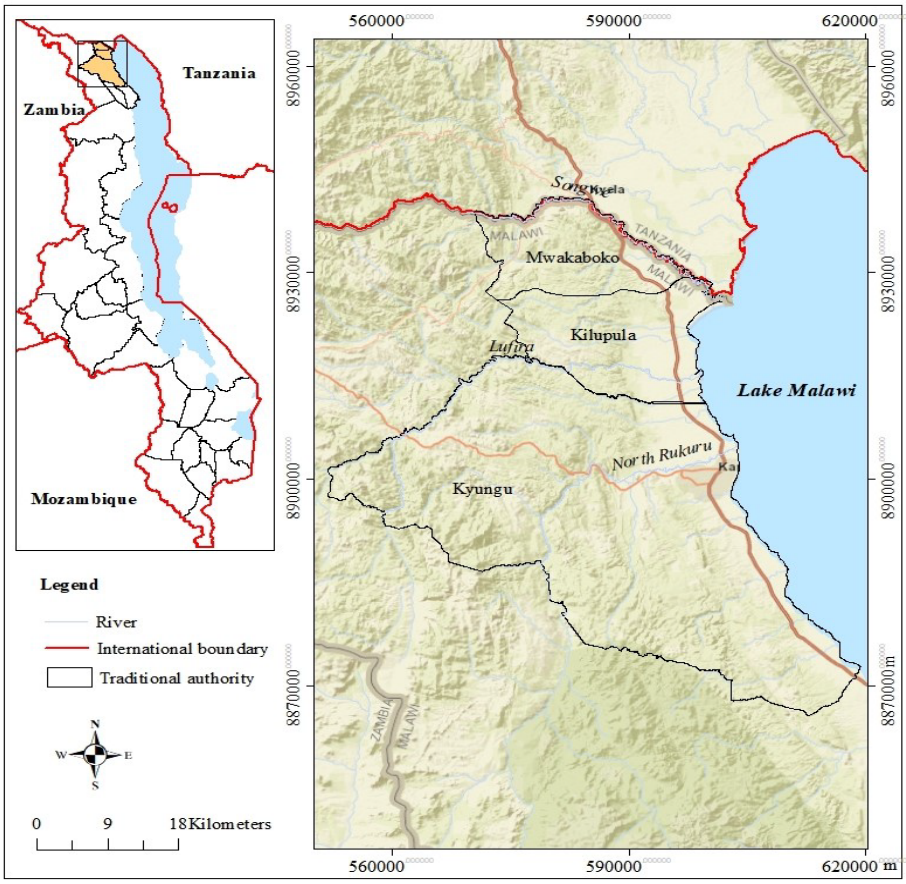

Figure 2: Location of Karonga District within Malawi, Malawi Geo-Data Land Survey Department in 2010.

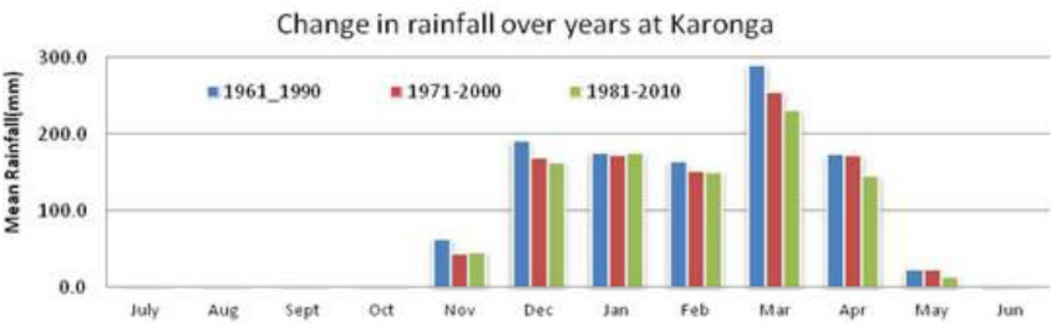

Figure 3: Monthly Rainfall for study area Karonga Meteorological Office in 2010.

study, a multi-staged sampling technique was employed, where a combination of sampling techniques were employed (purposeful and cluster sampling technique for T/As and GVHs) thusly: the sampling procedure employed both probability and non-probability sampling methods, to enhance robustness of the data collected. The following probability sampling methods were employed: cluster sampling, systematic random sampling. One non-probability method which was used is purposive sampling.

Purposive sampling method was used to identify Key Informants. Cluster sampling was used to categorize areas and was done at three levels: first at District level, second at TA level, third at GVH level. Of the six TAs in the District, 3 were chosen and of the 39 GVHs distributed among the TAs, 6 GVHs were chosen.

Within each GVH the study sought to capture information from a balance gender perspective. Stratification served to provide an opportunity for equitable representation of all the villages under study. Lastly, systematic random sampling was used to select individual respondents within each stratum.

Sample size was determined from the selected village using probability proportional to size (PPS) method to make equal representation of households in each village [25]. Thus, sample size was determined using Slovin's mathematical formula for determining sample size:

$$n = \frac{N}{(1+Ne2)}$$ Eqn 1

Where: n is sample size, N is the population, e is acceptable margin of error.

Given a total population for the 6 villages of 2645 farming households, the mathematical formula provided 345 with a 5% margin of error. The sample was proportionally distributed to the 6 villages. For doing so, sampling frames were obtained for each village by taking the list of all farm household heads. A certain sampling interval $'K'$ that was determined by dividing the total number of households by the predetermined sample size of each village.

Next, a number was selected between one and the sampling interval $'K'$ using lottery method, which is called the random start and was used as the first number included in the sample. Then, every Kth household head was selected until reaching the desired sample size for each village. Systematic sampling was applied because the population is logically homogeneous within the respective villages, as described by that systematic sample units are uniformly distributed over the population [26]. In this case, sampling units are smallholder farmers' households who are uniformly distributed in the respective villages. According to the formula, the sample size for the four villages is 345 (Table 1).

Table 1 below is a summary of the population and derived sample sizes.

Data collection

Data for this study was collected through key informant interviews (KII), household interviews, focus group discussions (FGD), field observations and secondary data from relevant literature. This study used questionnaires to collect information. The tools, were designed to be semi-structured in nature. This is in agreement with who described a semi-structured data collection tool as both allowing the researcher to focus on the topic and remain on track with study objectives and the same time allow him/her to follow up in-depth on any important emerging issues during the interview.

A pre-test of the questions and specific parts of the questionnaire were conducted on the smallholder farmers in another area outside the study area. The survey questions were prepared in English and then translated into local language (Kyangonde) to guide the data collectors during interviews. A pre-test was necessary to assess whether the instruments were appropriate and suited to the study. Necessary amendments were made through deleting and modifying questions having confusing and sensitive ideas based on the comments from experts and observations of households' responses.

Key Informant Interviews: Participants for KIIs were sampled purposively, and sampling was done up to point of information saturation. A total of 54 KIIs were conducted, all of which ensured a balance in terms of gender. Twenty KIIs were done with chiefs, 9 with government extension workers, 15 with local development agents, 5 with agricultural climate and development experts, 2 with District Agricultural Development Officers and 3 with Climate and meteorological experts. Some of the vital information collected from KIIs included; climate change patterns, biophysical and socio economic impacts of climate variability at local level, policy and institutional responses to the problem as applicable to the scope of their responsibilities, role of institutions both informal and formal that help in times of disasters, soil fertility, weather information just to mention some.

Household surveys: Findings from these KIIs, fed into the sampling design for the rest of the research and clarified on many areas regarding the study area. A household questionnaire was the main data source of the study so as to determine the vulnerability of smallholder farmers' households to climate variability. The questionnaire was divided into the following: demographic and economic household characteristics, livestock and crops production, access to extension services, credit access, hazards/ disaster occurrence, different coping strategies, land size, farmland location, soil erosion rate, land fertility level, land exposure to flood, crop productivity on temporal scale, distance to agricultural input markets, and input utilization, just to highlight some.

Focus group discussions: A total of 6 focus group discussions (FGDs) were conducted separately with a gender parity (of five men and five women) from the sampled villages to cross-check and validate answers from household respondents. The participants in FGD were selected based on gender with the help of the local leaders. Representatives from various interested groups that have been working on drought management with humanitarian agencies and development organizations were selected to be part of the groups. FGDs were guided by the interview guide which was facilitated by a skilled moderator

Field observations: Direct field observations were conducted to validate data gathered through household survey. Vulnerable areas were documented through photographs by using digital camera.

Field observations focused on bio-physical characteristics, land degradation, flood affected areas, water resources and vegetation cover and land management practices.

Data analysis

The study generated both quantitative and qualitative data. The quantitative data was coded and entered into the Statistical Package for Social Sciences (SPSS) version 22, where it was explored and managed accordingly. The qualitative data was entered, organized and summarized into themes, in accordance with the study objectives. In order to calculate the biophysical and socio-economic vulnerability indices, Principal Component Analysis (in SPSS) was used. Using literature coupled with an understanding of the study area, 39 indicator variables were identified which were used as proxies for the PCA. Twenty of which were for Biophysical vulnerability and 19 were for Socio-economic vulnerability. The table below is a summary of the variables (Table 2).

Input variables range from a few to numerous (i.e. from a handful up to more than 50) in studies on vulnerability. The majority of

Table 1: Designated sample sizes for the different strata.

No	Traditional Authority (TA)	Group Village Head	Total populatio of farming families	Total sample size
1	Kyungu	Mwahimba	679	89
		Zindi	364	48
2	Kilupula	Mwenitete	234	30
		Mwawulambo	148	20
3	Mwakaboko	Mwakaboko	563	73
		Mwangulukulu	657	85

the indicators are selected subjectively by authors who base their choice on reviews of related literature. The selected indicators have to be contextual and relevant to the local communities in which the investigation is being conducted [27]. Therefore, in this study, the researcher has chosen indicators that are contextual and relevant to the local communities in which the study was conducted. The most important aspect in the selection of indicators is to ensure that the indicators address the research question and test the concepts under operationalization [28].

How PCA was conducted: PCA was used to generate composite indices by using the "Eigenvalue-greater-than-one" rule proposed by Kaiser. After retaining all the components with eigenvalues greater than one, factor analysis in SPSS generated factor loadings for all indicators, which were used as weights. PCA is a multi-stage kind of analysis. The diagram below shows a summary of how the analysis was conducted to finally arrive at the composite Biophysical and Socio-economic Vulnerability Indices (Figure 4).

The required underlying assumptions for PCA were fully met. To check the robustness of the model, two statistical tests, the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy and the Bartlett's Test of Sphericity, were used. Components that increased vulnerability were considered positive, and those that reduced vulnerability were viewed as negative [29]. View the PCA as a multivariate statistical technique that is used as a data reductionist method. The technique condenses

Biophysical vulnerability	Socio-economic vulnerability
X_1: How house was affected by disaster	
X_2: how radio was affected by disaster	X_1: Age of household head
X_3: How drinking water was affected by disaster	X_2: Level of education of respondent
X_4: Importance of frequent occurrence of floods	X_3: Total educated people in the family
X_5: Importance of frequent occurrence of drought	X_4: Gross income
X_6: Drought challenge faced	X_5: Kind of house
X_7: Flood challenge faced	X_6: controller/owner of household assets
X_8: Dry spells challenge faced	X_7: Importance of agriculture occupation
X_9: Soil erosion challenge faced	X_8: importance of low use of fertilizer
X_{10}: Drought disaster frequency	X_9: Importance of lack of land
X_{11}: Flooding disaster frequency	X_{10}: Distance to input markets
X_{12}: Erratic rains disaster frequency	X_{11}: Distance to output markets
X_{13}: Strong winds disaster frequency	X_{12}: Area irrigated in acres
X_{14}: Evaluation of the trend of climatic variability	X_{13}: Size of land holding
X_{15}: Food scarcity year from 1990-2000	X_{14}: sloppiness of farmland
X_{16}: Food scarcity year from 2000-2010	X_{15}: soil category based on fertility
X_{17}: Food scarcity year from 2010-2017	X_{16}: Productivity of land without fertilizer
X_{18}: Water scarcity year from 1990-2000	X_{17}: Agriculture type being practiced
X_{19}: Water scarcity year from 2000-2010	X_{18}: Importance of wage labour occupation
X_{20}: Water scarcity year from 2010-2017	

Table 2: Biophysical and Socio-economic indicators used as proxies for PCA.

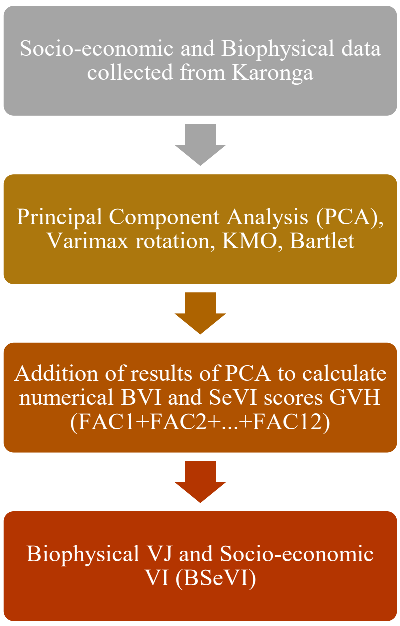

Figure 4: Flow chart for constructing Biophysical and Socio-economic vulnerability indices using PCA Adopted from Mavhura et al for 2017.

an original set of variables into a smaller number of linear varieties by identifying patterns in high-dimensional data and revealing the underlying factors (principal factors) that best describe variations in the data. The use of this reductionist technique allowed for a robust and consistent set of variables that can be monitored over time to assess any changes in overall vulnerability [30].

Varimax rotation was used to simplify the structure of the underlying dimensions and produce more independence among the factors. The varimax rotation also minimised the number of variables that loaded high on a single factor, thereby increasing the percentage variation between each factor [31]. The Kaiser criterion (Eigenvalues > 1) was applied for the component selection. This stepwise exclusion approach was carried out and iterated until the variables and components were stable and statistically robust [28].

Results

Biophysical vulnerability and perception of smallholder farmers to climate variability and its impacts on livelihoods by gender

This section covers objective 1 where results for biophysical vulnerability of smallholder farmers to climate variability and its impact on livelihoods by gender are presented. Furthermore, the results for perceptions of smallholder farmers to climate change and variability are also presented.

Biophysical vulnerability of smallholder farmers to climate variability and its impacts on livelihoods by gender: Under this objective, two PCAs were conducted using the same indicators. The first one was to establish the farmers' biophysical vulnerability to climate variability depending on gender. The second PCA served to examine vulnerability of farmers in Karonga in relation to location, using the variable GVH as the selection variable.

In order to ensure that the variables were suitable for PCA, KMO test of sampling adquancy and Bartlett's test of sphericity were carried out. To be suitable, the KMO test must yield values which satisfy the condition KMO≥0.6. In this study, all the indicators were suitable for PCA because KMO tests for both Biophysical analysis (covering both gender and GVH area) and Socio-economic analysis satisfied the condition.

The Bartlet's test of sphericity must be significant at $p<0.05$ for the data to be suitable for PCA. In this study, both for the Biophysical analysis and Socio-economic analysis, Bartlet's tests of sphericity were highly significant at $p=0.000$ implying that the data were appropriate for PCA. Taken together, both the KMO test of sampling adquancy and the Bartlett's test of sphericity provided a minimum standard which was passed before conducting a PCA for this study. Results of the tests for sampling adequacy and model robustness (Tables 3 and 4).

In terms of total variance explained, the analysis for Biophysical vulnerability by gender isolated 6 principal components while that for GVH area isolated 7 principal components. SPSS output always arranges variances in a way that the first principle component accounts for the highest variance explained, and the next component accounts for the second largest variance explained, and proceeds in a descending order, such that the last component accounts for the least variance explained of all the components.

After having passed the KMO and Bartlett's Test of Sphericity, the PCA was then conducted. The PCA extracted six (6) components out of twenty-one (21) variables where variance was explained representing biophysical vulnerability by gender variables, and also seven (7) components out of twenty (20) variables where variance was explained representing biophysical vulnerability by GVH which were both then used in the analysis. The six components explained 61 percent of the total cumulative variance in biophysical vulnerability by gender (Table 5) and seven components explained 67 percent of the total cumulative variance in biophysical vulnerability by GVH (Table 6). The initial eigenvalues shown in the same tables (Tables 3 and 4) are the variances of the principal components. Because the PCA was conducted on the correlation matrix, the variables were standardized, which means that each variable had a variance of 1, and the total variance was equal to the number of variables used in the analysis; of the 21 and 20 variables respectively. The total column under the eigenvalues section contains the eigenvalues. The first component always accounts for the most variance (and hence has the highest eigenvalue) and the second component accounts for as much of the left-over variance as it can, and so on. Hence each successive component will account for less and less variance. The percentage of variance column simply contains the percent of variance accounted for by each principal component. The cumulative % column contains the cumulative percent of variance accounted for by the current and all the preceding principal components. In this study the first component (with the highest eigenvalue of 4.658 and 4.658) accounted for the most variance, 22.179 % and 23.292 % respectively, and the second component accounted for as much as 11 % and 10% respectively. Thus, each successive component accounted for less and less variance. The extraction sum of squared loadings has three columns which exactly reproduced the values given on the same row of the left side of the tables. The number of principal components 6 and 7 whose eigenvalues were 1.094 and 1.07 or greater respectively determined the four rows reproduced in this study.

KMO and Bartlett's Test (Biophysical)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.750
Bartlett's Test of Sphericity	Approx. Chi-Square	3217.807
	df	210
	Sig.	.000

Table 3: KMO and Bartlett's test for Biophysical Vulnerability by gender.

KMO and Bartlett's Test (Biophysical)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.746
Bartlett's Test of Sphericity	Approx. Chi-Square	3152.763
	df	190
	Sig.	.000

Table 4: KMO and Bartlett's test for Biophysical Vulnerability by GVH area.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*
1	4.658	22.179	22.179	4.658	22.179	22.179
2	2.302	10.963	33.142	2.302	10.963	33.142
3	1.944	9.258	42.400	1.944	9.258	42.400
4	1.423	6.775	49.175	1.423	6.775	49.175
5	1.376	6.553	55.729	1.376	6.553	55.729
6	1.094	5.210	60.938	1.094	5.210	60.938
7	.979	4.662	65.600	-	-	-
8	.917	4.638	69.968	-	-	-
9	.831	3.958	73.926	-	-	-
10	.775	3.690	77.616	-	-	-
11	.703	3.345	80.962	-	-	-
12	.679	3.233	84.194	-	-	-
13	.649	3.089	87.283	-	-	-
14	.570	2.713	89.996	-	-	-
15	.527	2.507	92.503	-	-	-
16	.474	2.258	94.761	-	-	-
17	.420	2.002	96.763	-	-	-
18	.392	1.865	98.628	-	-	-
19	.190	.902	99.531	-	-	-
20	.078	.371	99.902	-	-	-
21	.021	.098	100.00	-	-	-

Table 5: Total variance explained representing Biophysical vulnerability by gender.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	*%of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*
1	4.658	23.292	23.292	4.658	23.292	23.292
2	2.261	11.306	34.598	2.261	11.306	34.598
3	1.811	9.053	43.651	1.811	9.053	43.651
4	1.360	6.799	50.450	1.360	6.799	50.450
5	1.293	6.464	56.914	1.293	6.464	56.914
6	1.075	5.376	62.290	1.075	5.376	62.290
7	1.017	5.084	67.374	1.017	5.084	67.374
8	.894	4.469	71.843	-	-	-
9	.866	4.302	76.145	-	-	-
10	.736	3.681	79.827	-	-	-
11	.685	3.426	83.252	-	-	-
12	.638	3.190	86.442	-	-	-
13	.609	3.043	89.486	-	-	-
14	.523	2.615	92.101	-	-	-
15	.472	2.359	94.460	-	-	-
16	.419	2.095	96.554	-	-	-
17	.402	2.008	98.562	-	-	-
18	.189	.944	99.507	-	-	-
19	.078	.390	99.896	-	-	-
20	.021	.104	100.000	-	-	-

Table 6: Total variance explained representing Biophysical vulnerability by GVH area.

The 6 principal components that explained 61% of cumulative variance of biophysical vulnerability by gender are: How house was affected by disaster X1, Impact of Frequency occurrence of droughts X2, how crops were affected by droughts X3, how tap water was affected by disaster X4, impact of frequent occurrence of floods X5, and floods challenge faced X6.

The 7 principal components that explained 67% of cumulative variance of biophysical vulnerability by GVH area are: How house was affected by disaster X1, Impact of frequency occurrence of droughts X2, how crops were affected by droughts X3, how tap water was affected by disaster X4, impact of frequent occurrence of floods X5, floods challenge faced X6, and droughts challenge faced X7.

It represents extracted communalities which is the proportion of each variable's variance that can be explained by the principal components. The extracted communalities allow for the researcher to determine how much each of the indicators have been adequately represented by the isolated principal components (Table 7).

The output from both analyses were summarised into a single table (Table 7). For a communality to be accepted to have been explained by the principle components, it must satisfy the following condition: $h \geq 0.5$. From the results, this means that under the column for Extraction subscript GVH area, all of the indicators have been adequately represented by the 7 principal components except one, representing the variable "soil erosion challenge faced" (h=0.471). As for gender, represented by the column Extraction subscript gender, all except these 6 indicators: How tap water was affected by disaster, Drought challenge faced, Flood challenge faced, Soil erosion challenge faced, Drought disaster frequency, Evaluation of the trend of climatic variability have been well represented by the isolated 6 principal components (Table 7).

Now coming to the issue of biophysical vulnerability indices, the study results are presented in Tables 12 and 13 Where Table 12 shows biophysical vulnerability indices based on gender of household head and Table 13 shows biophysical vulnerability indices based on GVH areas. Vulnerability is measured using an index which spans the range from -1 to +1. A positive vulnerability index score implies increased vulnerability for a said variable. On the other hand, a negative vulnerability index score implies reduced vulnerability. This is also in agreement with [29]. Who stated that components that increased vulnerability were considered positive, and those that reduced vulnerability were viewed as negative.

To assess the level or magnitude of vulnerability (whether increased (+) or decreased (-)), the index's proximity to either 0 or 1 is considered. Thus, for positive values, the closer the index is to 1, the greater the vulnerability, and the closer the number is to 0, the lesser the vulnerability. On the other hand, for negative vulnerability values, the closer the index is to 0, the greater the vulnerability as compared to when the value is further away from zero; that implies very low vulnerability.

(Table 8) shows that with regards to biophysical vulnerability in relation to gender, male headed households have reduced vulnerability. This is evidenced by the index which is less than 1 and it bears a negative sign. On the other hand, female headed households have high vulnerability, given by the value greater than one and the positive sign influenced by factor 6 which is floods occurrence. (Table 9) also shows that with regard to biophysical vulnerability in relation to GVH, there are various degrees of vulnerability. GVH Mwaulambo has the highest biophysical vulnerability followed by GVH Mwangulukulu.

A biophysical vulnerability index (BioVI) score for gender and GVH were developed by adding all six component scores and seven component scores respectively (factor loadings) for each gender and GVH. The results are shown in (Table 8 and Table 9). The positive numbers in the last column of (Table 10 and Table 11) represent increased potential of biophysical vulnerability to hazards, while the negative numbers show reduced potential of the same. Depending on the numbers, the extent of vulnerability could be very high or very low. In this analysis, the BioVI scores ranged from 1, 9024 (most vulnerable) to -0.34920 least vulnerable).

Benchmarking the Vulnerability Indicator (VI) scores, color coded is important in identifying GVHs with relatively high and low social vulnerability to hazards. Therefore, the VI scores were classified into five categories. These ranged from 1.5000 (highly vulnerable) to -1.5000 (very low vulnerability). (Table 12) describes the final benchmarks for the VI scores and their associated GVHs based on the five levels.

(Table 13) shows that GVH Mwaulambo is very highly vulnerable biophysically to climate vulnerability among the rest of the GVHs, given by a positive vulnerability index which is greater than.

1.This is influenced by the factor of droughts effect on crop production.

Mwenitete GVH is the least vulnerable among the GVHs. This is evidenced by the vulnerability index which is negative and further placed from zero (-1.2495). The rest of the GVHs fall in between, as presented in (Table 13). is a map showing biophysical vulnerability of the farmers in the study area differentiated by the GVH area (Figure 5).

From the map in figure 5, six GVHs were sampled for the study. GVH Mwabulambo is highly vulnerable to Biophysical vulnerability followed by GVHs Mwangulukulu, Mwakaboko and Zindi. GVH Mwenitete is the least vulnerable followed by GVH Mwahimba as

Variables	Initial	Extraction $_{GVH}$	Extraction $_{Gender}$
How house was affected by disaster	1.000	.615	.544
Impact of frequency occurrence of droughts	1.000	.649	.746
How crops were affected by droughts	1.000	.802	.725
How tap water was affected by disaster Impact of frequent occurrence of floods	1.000 1.00	.727 .761	.438 .756
Floods challenge faced	1.000	.520	.486
Droughts challenge faced	1.000	.565	.432
Dry spells challenge faced	1.000	.571	.583
Soil erosion challenge faced	1.000	.471	.470
Drought disaster frequency	1.000	.512	.480
Flooding disaster frequency	1.000	.721	.667
Erratic rains disaster frequency	1.000	.525	.501
Strong winds disaster frequency	1.000	.608	.581
Evaluation of the trend of climatic variability	1.000	.570	.481
Food scarcity year from 1990-2000	1.000	.657	.590
Food scarcity year from 2000-2010	1.000	.688	.678
Food scarcity year from 2010-2017	1.000	.658	.583
Water scarcity year from 1990-2000	1.000	.936	.934
Water scarcity year from 2000-2010	1.000	.978	.975
Water scarcity year from 2010-2017	1.000	.940	.935

Table 7: Extracted communalities for Biophysical vulnerability by gender and GVH area.

Gender	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	BioVI
Male	-0.00997	-0.04737	-0.07452	0.07976	0.07012	-0.36722	**-0.34920**
Female	0.02967	0.14099	0.22182	-0.23741	-0.20871	1.09301	**1.03937**

Table 8: Biophysical vulnerability indices based on gender of household head

GVHs	Isolated Principal Components							
	1	2	3	4	5	6	7	BioVI
Mwaulambo	-0.0174	0.4626	1.2932	0.9600	-0.5773	-0.1943	-0.0244	**1.9024**
Mwenitete	-0.2936	0.0957	0.2904	-0.8669	-0.0109	-0.5194	0.0552	**-1.2495**
Mwahimba	0.2006	0.1531	-0.6876	-0.2632	-0.7118	0.3990	0.2435	**-0.6665**
Zindi	-0.1703	-0.4008	-0.6202	0.0760	0.3589	-0.0872	0.8179	**-0.0257**
Mwakaboko	0.0781	-0.2398	-0.5884	0.4870	0.4473	0.0157	-0.3854	**-0.1856**
Mwangulukulu	0.1751	-0.1465	0.0939	-0.4519	0.5080	0.3772	-0.5320	**0.0239**

Table 9: Biophysical vulnerability indices based on GVH areas.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.642	14.679	14.679	2.642	14.679	14.679
2	1.726	9.589	24.269	1.726	9.589	24.269
3	1.638	9.102	33.370	1.638	9.102	33.370
4	1.404	7.801	41.172	1.404	7.801	41.172
5	1.222	6.787	47.958	1.222	6.787	47.958
6	1.081	6.007	53.966	1.081	6.007	53.966
7	1.077	5.981	59.947	1.077	5.981	59.947
8	.972	5.399	65.346	-	-	-
9	.920	5.112	70.458	-	-	-
10	.856	4.755	75.213	-	-	-
11	.761	4.229	79.441	-	-	-
12	.708	3.935	83.376	-	-	-
13	.633	3.518	86.894	-	-	-
14	.607	3.370	90.264	-	-	-
15	.558	3.099	93.363	-	-	-
16	.471	2.616	95.980	-	-	-
17	.416	2.312	98.291	-	-	-
18	.308	1.709	100.000	-	-	-

Table 10: Total variance explained representing socio-economic vulnerability by gender and GVH area.

Variables	Initial	Extraction
Age of household head	1.000	.653
Level of education of respondent	1.000	.628
Total educated people in the family	1.000	.738
Source of income	1.000	.439
Kind of house	1.000	.451
Controller/owner of household assets	1.000	.514
Importance of agriculture occupation	1.000	.550
Importance of wage labour occupation	1.000	.443
Importance of lack of land	1.000	.563
Importance of low use of fertilizer	1.000	.630
Distance to input markets	1.000	.749
Distance to output markets	1.000	.657
Area irrigated in acres	1.000	.709
Size of land holding	1.000	.428
Sloppiness of farmland	1.000	.616
Soil category based on fertility	1.000	.688
Productivity of land without fertilizer	1.000	.714
Agriculture type being practiced	1.000	.620

Table 11: Extracted communalities representing socio-economic vulnerability by gender and GVH area.

in (Table 11). Areas which were not sampled in the study have no vulnerability indices and thus have not been coloured.

Socio-economic vulnerability of smallholder farmers by gender to climate variability

Under this second specific objective, the aim was to determine socio-economic vulnerability in terms of gender of household head and in terms of GVH area. To conduct PCA, 18 indicators were identified using literature and observation. To check the robustness of the model, two statistical tests, the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy and the Bartlett's Test of Sphericity, were used. The results of the tests were identical for both gender and GVH areas hence one (Table 14) is presented.

According to the results, the data passed both tests, and the results were identical; the KMO value was 0.606 and the significance levels were also the same.

After having passed the KMO and Bartlett's Test of Sphericity, the PCA was then conducted. The PCA extracted seven (7) components out of eighteen (18) variables, which were then used in the analysis. The seven components explained 60 percent of the total cumulative variance in social vulnerability (Table 10). The initial eigenvalues shown in Table 16 are the variances of the principal components. Because the PCA was conducted on the correlation matrix, the variables were standardized, which means that each variable had a variance of 1, and the total variance was equal to the number of variables used in the analysis; 18. The total column under the eigenvalues section contains the eigenvalues. The first component always accounts for the most variance (and hence has the highest eigenvalue) and the second component accounts for as much of the left-over variance as it can, and so on. Hence each successive component will account for less and less variance. The percentage of variance column simply contains the percent of variance accounted for by each principal component. The cumulative % column contains the cumulative percent of variance accounted for by the current and all the preceding principal components. In this study the first component (with the highest eigenvalue of 2.642 accounted for the most variance, 14.679 percent, and the second component accounted for as much as 9.589 percent. Thus, each successive component accounted for less and less variance. The extraction sum of squared loadings has three columns which exactly reproduced the values given on the same row

Gender	Isolated Principal Components							
	1	2	3	4	5	6	7	SoVI
Male	-0.06491	0.02857	-0.48799	0.01493	-0.03812	0.01436	-0.05900	**-0.58316**
Female	0.20265	-0.08921	1.49538	-0.04661	0.11900	-0.04482	0.18421	**1.82060**

Table 12: Vulnerability index scores for socio-economic vulnerability by gender.

Vulnerability Index	Rating (Colour code) GVH
< -1.5000	Blue (Very low vulnerability)
-1.5000 to -0.5000	Green (Low vulnerability)
-0.5001 to 0.5000	Yellow (Medium vulnerability)
0.5001 to 1.5000	Orange (High vulnerability)
>1.5000	Red (Very high vulnerability)

Table13: Benchmarking of vulnerability levels, colour coded and GVH.

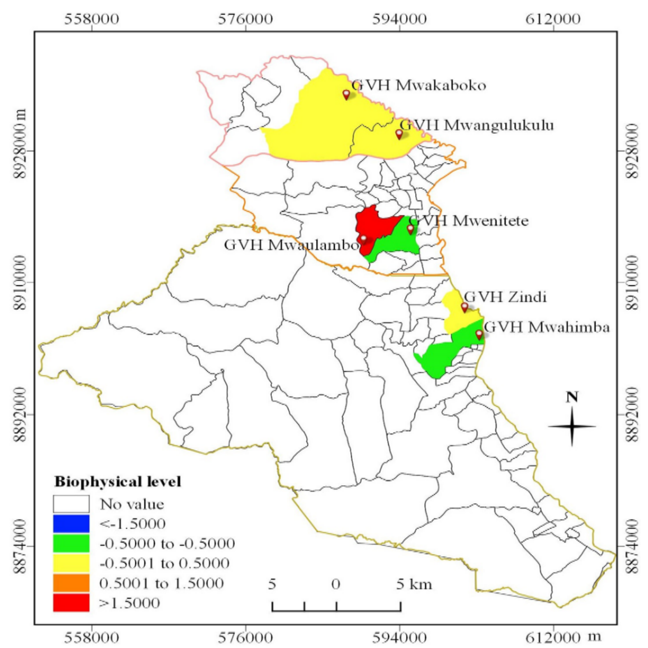

Figure 5: Map showing biophysical vulnerability of the 6 GVHs selected for the study.

of the left side of the table. The number of principal components (7) whose eigenvalues were 5.981 or greater determined the seven rows reproduced in table 13. After these important tests were passed, the PCA was carried out with varimax rotation. The isolated principal components managed to explain approximately 60% of the total variance in the sample (Table 12). The seven principle components are: Sex of household head X1, Age of household head X2, Level of education of respondent X3, Total educated people in the family X4, Gross income X5, Kind of house X6, Ccontroller/owner of household assets X7. These were the same in terms of gender and GVH areas as a result one table was used.

(Table 10) represents the total variance explained given the isolated principal components and the representing indicators. Table 13 is for communalities, showing how well each of the indicators have been adequately represented by the 7 principal components. The extracted commonalities were similar for both gender and GVH areas as a result the same indicators were employed in assessing vulnerability in terms of gender and GVH areas.

The study results show that all the variables have been adequately represented except four indicators; gross income, kind of house, importance of lack of land and size of land holding. For the Socio-economic vulnerability, the variables with the highest communalities in descending order are distance to input markets, total number of family members who can read and write, productivity of land without fertilizer and area irrigated (in acres), their communalities are 0.749, 0.738, 0.714 and 0.709, respectively. This implies more than 70% of their total variance being explained by the isolated principle components. The rest of the variables have satisfied the requirement: $h \geq 0.5$.

Vulnerability indices were generated with gender of household head and GVH area as grouping variables. The results are presented in (Tables 12 and 15).

A social vulnerability index (SoVI) score was developed by adding all seven component scores (factor loadings) for each GVH and gender of household head. The results are shown in (Tables 15 and 16). The positive numbers in the last column of (Tables 15 and 16) represent increased potential of social vulnerability to hazards, while the negative numbers show reduced potential of the same. Depending on the numbers, the extent of vulnerability could be very high or very low. In this analysis, the SoVI scores ranged from 3.1853 (most vulnerable) to -0.58316 (least vulnerable).

The results, according to the key provided in Table 16, show that female headed households are highly vulnerable socio-economically given by the index 1.82060. This is influenced by the factor of education level of the household head. On the other hand, male headed households have low socio-economic vulnerability.

Table 15 shows socioeconomic vulnerability levels for the area in terms of GVH area. Mwangulukulu has the highest vulnerability index which is greater than 1.5000 (3.1853). It is therefore ranking as "very highly vulnerable. Mwakaboko GVH is next with a score of 0.7663, it is thus ranked as highly vulnerable. Zindi GVH has the lowest Socio

economic vulnerability index score. is a geographical representation of socio-economic vulnerability of the farmers in the study area differentiated by the GVH area (Figure 6).

Composite vulnerability of smallholder farmers and their resilience according to gender and GVH area

For the third objective, the aim was to determine composite (overall) vulnerability levels of smallholder farmers in Karonga district in terms of gender of household head and 6 GVH areas (Table 17).

To attain composite vulnerability indices according to gender of household head, PCA was conducted, which aimed to determine vulnerability, with "sex of household head" as the selection variable. The 20 indicators used for biophysical and the 19 indicators for socio-economic vulnerability analyses were combined. Principal component analysis was done with varimax rotation and the Kaiser criterion (Eigenvalue>1). To conduct PCA, 18 indicators were identified using

KMO and Bartlett's Test (Socio-economic)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.606
Bartlett's Test of Sphericity	Approx. Chi-Square	835.921
	df	153
	Sig.	.000

Table 14: KMO and Bartlett's tests for socio-economic vulnerability by gender and GVH area.

GVHs	Isolated Principal Components							
	1	2	3	4	5	6	7	SoVI
Mwaulambo	0.1534	0.2627	-1.4009	0.4185	0.2368	-0.4942	0.2280	**-0.5957**
Mwenitete	-0.4533	-1.0202	0.2961	0.3590	0.3155	-0.1666	-0.0174	**-0.6869**
Mwahimba	-0.3259	0.0259	0.3099	-0.1836	-1.0036	0.3653	-0.0181	**-0.8301**
Zindi 1	-0.0693	-0.2841	-0.0587	-1.0154	-0.4221	0.1279	-0.1235	**-1.8452**
Mwakaboko	0.0258	0.4373	0.2091	-0.2031	0.1584	-0.0248	0.1636	**0.7663**
Mwangulukulu	0.5536	0.4425	0.7375	0.4445	0.5505	0.2442	0.2125	**3.1853**

Table 15: Vulnerability index scores for socio-economic vulnerability by GVH area.

KMO and Bartlett's Test (Socio-economic)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.606
Bartlett's Test of Sphericity	Approx. Chi-Square	835.921
	df	153
	Sig.	.000

Table 16: KMO and Bartlett's tests for socio-economic vulnerability by gender.

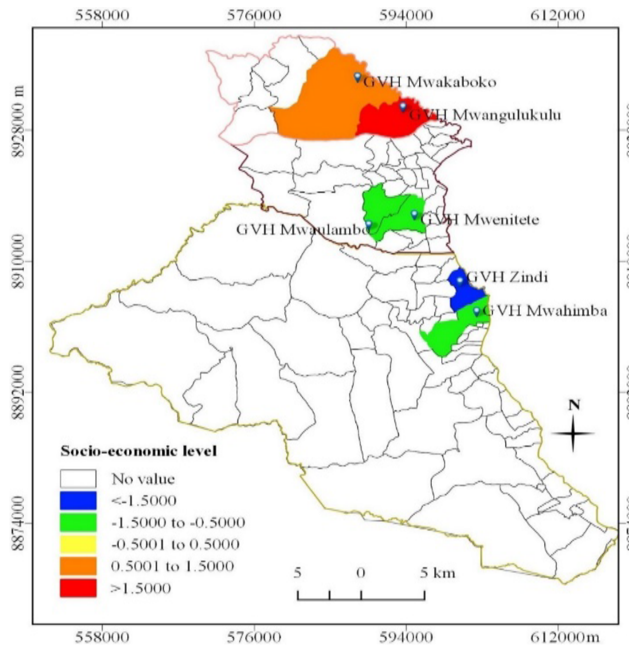

Figure 6: Socio-economic vulnerability for the 6 sampled GVHs for the study.

literature and observation. To check the robustness of the model, two statistical tests, the Kaiser-Meyer-Olkin (KMO) test of sampling adequacy and the Bartlett's Test of Sphericity, were used. The results of the tests are presented in (Table 18 and 19).

According to the results, the data passed both tests, and the results were identical; the KMO value was 0.606 and the significance levels were also the same.

After having passed the KMO and Bartlett's Test of Sphericity, the PCA was then conducted. The PCA extracted seven (7) components out of eighteen (18) variables, which were then used in the analysis. The seven components explained 60 percent of the total cumulative variance in social vulnerability (Table 10). The initial eigenvalues shown in Table 12 are the variances of the principal components. Because the PCA was conducted on the correlation matrix, the variables were standardized, which means that each variable had a variance of

The test results in Table 18 and 19 show that the conditions for PCA were fully met. The sampling adequacy was greater than 0.6 and the exact value was 0.736, and significance levels are ≤ 0.05 at 0.000 p-value.

The PCA for calculating overall (encompassing biophysical and socio-economic) vulnerability isolated 13 principal components. These 13 components extracted explained approximately 66% of the total cumulative variance in the 38 proxy indicators (Table 19).

(Table 20) displays the communalities which the proportion of total variance of each indicator variable which has been adequately represented by the isolated principal components. As a rule of thumb, for a communality to be accepted it must satisfy the condition: h≥0.5. From Table 22, out of the 38 indicators, all except 2 indicators have been fully represented.

Vulnerability indices were generated with gender as the grouping variable. The results are presented in (Table 21).

The results according to Table 21 indicate that female headed households are more vulnerable to climate variability hazards (both biophysical and socio-economic) than male headed households. This is evidence by the vulnerability index for female headed households of 1.22582 which is influenced by factor of control over household assets which represents high vulnerability. On the other hand, male headed households according to the key, have medium vulnerability.

A composite vulnerability index (CoVI) score was developed by adding all Biophysical and Socio economic component scores (factor loadings) for each GVH. The positive numbers in the last column of (Table 22) represent increased potential of vulnerability to hazards, while the negative numbers show reduced potential of the same. Depending on the numbers, the extent of vulnerability could be very high or very low. In this analysis, the CoVI scores ranged from 3.20920 (most vulnerable) to -1.87091 (least vulnerable). In order to determine the composite vulnerability indices for GVH area, output from biophysical and socio-economic vulnerability were summed. This was adopted from and the results have been presented in [28] (Table 22).

GVHs Mwangulukulu and Mwaulambo have the highest composite vulnerability. They both have indices greater than one, therefore they are highly vulnerable (Figure 7).

The GVHs with the lowest composite vulnerabilities are Mwenitete and Zindi GVH. Furthermore, GVH Mwahimba has low vulnerability. The GVHs vulnerability levels were influenced by frequency occurrence of droughts and floods on the biophysical part and also level of education of the household head, control of household assets, distance to input and output markets among others.

Adaptation strategies of smallholder farmers

These are results for the specific objective 4 which looks at adaptation strategies which contributes to the adaptive capacity of smallholder farmers. Small holder farmers in the study areas have always adapted to climate variability through a variety of means including, for example, planting late-transplant rice or switching to other crops like bananas,

KMO and Bartlett's Test (Socio-economic)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.606
Bartlett's Test of Sphericity	Approx. Chi-Square	835.921
	df	153
	Sig.	.000

Table 17: KMO and Bartlett's tests for socio-economic vulnerability by GVH area.

KMO and Bartlett's Test (Biophysical and socio-economic)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.736
Bartlett's Test of Sphericity	Approx. Chi-Square	4948.849
	df	703
	Sig.	.000

Table 18: KMO and Bartlett's test for composite vulnerability in study areas.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.403	14.219	14.219	5.403	14.219	14.219
2	3.549	9.339	23.558	3.549	9.339	23.558
3	2.355	6.197	29.754	2.355	6.197	29.754
4	2.092	5.505	35.260	2.092	5.505	35.260
5	1.981	5.213	40.473	1.981	5.213	40.473
6	1.635	4.304	44.777	1.635	4.304	44.777
7	1.433	3.771	48.548	1.433	3.771	48.548
8	1.297	3.314	51.961	1.297	3.314	51.961
9	1.188	3.126	55.087	1.188	3.126	55.087
10	1.146	3.017	58.103	1.146	3.017	58.103
11	1.077	2.834	60.938	1.077	2.834	60.938
12	1.024	2.696	63.634	1.024	2.696	63.634
13	1.012	2.664	66.298	1.012	2.664	66.298
14	.969	2.550	68.848	-	-	-
15	.908	2.390	71.237	-	-	-
16	.803	2.112	73.349	-	-	-
17	.787	2.070	75.419	-	-	-
18	.757	1.992	77.412	-	-	-
19	.723	1.903	79.314	-	-	-
20	.683	1.798	81.112	-	-	-
21	.652	1.716	82.828	-	-	-
22	.632	1.663	84.491	-	-	-
23	.622	1.636	86.127	-	-	-
24	.584	1.538	87.665	-	-	-
25	.537	1.413	89.078	-	-	-
26	.506	1.331	90.408	-	-	-
27	.503	1.323	91.731	-	-	-
28	.457	1.203	92.934	-	-	-
29	.425	1.119	94.054	-	-	-
30	.409	1.075	95.129	-	-	-
31	.386	1.016	96.144	-	-	-
32	.343	.903	97.047	-	-	-
33	.336	.884	97.931	-	-	-
34	.277	.728	98.659	-	-	-
35	.257	.676	99.335	-	-	-
36	.173	.455	99.790	-	-	-
37	.060	.159	99.949	-	-	-
38	.020	.051	100.000	-	-	-

Table 19: Total variance explained representing composite vulnerability in study area.

Indicators	Initial	Extraction
Age of household head	1.000	.616
Level of education of respondent	1.000	.728
Total educated people in the family	1.000	.710
Source of income	1.000	.701
How house was affected by disaster	1.000	.624
How crops were affected by drought	1.000	.574
How tap water was affected by disaster	1.000	.612
Kind of house	1.000	.619
Controller/owner of household assets	1.000	.646
Importance of agriculture occupation	1.000	.582
Importance of wage labour occupation	1.000	.593
Indicators	**Initial**	**Extraction**
Importance of lack of land	1.000	.463
Importance of low use of fertilizer	1.000	.574
Impact of frequent occurrence of floods	1.000	.766
Impact of frequent occurrence of drought	1.000	.781
Distance to input markets (km)	1.000	.776
Distance to output markets(km)	1.000	.659
Area irrigated in acres	1.000	.768
Size of land holding	1.000	.602
Sloppiness of farmland	1.000	.507
Soil category based on fertility	1.000	.669
Productivity of land without fertilizer	1.000	.692
Agriculture type being practiced	1.000	.686
Drought challenge faced	1.000	.583
Flood challenge faced	1.000	.447
Dry spells challenge faced	1.000	.610
Soil erosion challenge faced	1.000	.524
Drought disaster frequency	1.000	.627
Flooding disaster frequency	1.000	.715
Erratic rains disaster frequency	1.000	.555
Strong winds disaster frequency	1.000	.729
Evaluation of the trend of climatic variability	1.000	.610
Food scarcity year from 1990-2000	1.000	.638
Food scarcity year from 2000-2010	1.000	.715
Food scarcity year from 2010-2017	1.000	.676
Water scarcity year from 1990-2000	1.000	.927
Water scarcity year from 2000-2010	1.000	.960
Water scarcity year from 2010-2017	1.000	.931

Table 20: Extracted communalities for composite vulnerability.

1	2	3	4	5	6	7	8	9	10	11	12	V. Index
-0.0271	-0.0378	0.047	0.0743	0.039	-0.0528	0.0032	0.0296	-0.4764	-0.0242	-0.0086	0.035	-0.3989
0.0833	0.1164	-0.1444	-0.2282	-0.1198	0.1623	-0.0098	-0.0911	1.4639	0.0743	0.0264	-0.1076	1.2258

Table 21: Composite vulnerability index for Karonga District according to gender**.**

GVH	Biophysical vulnerability	Socio-economic vulnerability	Composite vulnerability
Mwaulambo	1.90240	-0.59570	**1.30670**
Mwenitete	-1,24954	-0.68686	**-1.93640**
Mwahimba	-0.66651	-0.83011	**-1.49661**
Zindi	-0.02566	-1.84525	**-1.87091**
Mwakaboko	-0.18556	0.76630	**0.58075**
Mwangulukulu	0.02386	3.18534	**3.20920**

Table 22: Composite vulnerability indices for Karonga District according to GVH areas.

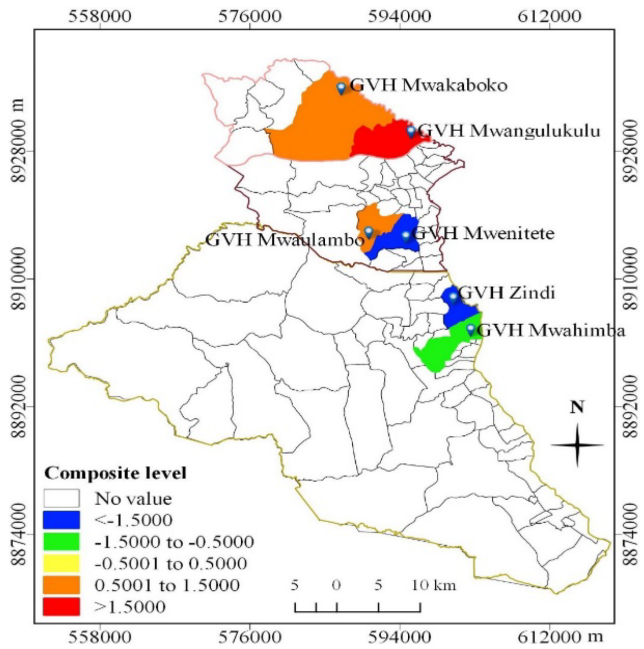

Figure 7: Composite vulnerability index for Karonga District based on GVH area.

potatoes and cassava. However, climate change is pushing at-risk smallholder farmers beyond their capacity to adapt to the changes they have traditionally dealt with, as well as making them more vulnerable due to their increased sensitivity and exposure to climate variability impacts. As an approach, climate variability adaptation is a dynamic process and not an end state, given the uncertainty in climate change impacts and the need to support at-risk populations to: address current hazards, increased variability and emerging trends; manage risk and uncertainty; and build the capacity of smallholder farmers to adapt. In order for the smallholder farmers to have resilience to climate variability, there is need for them to have the adaptive capacity which would reduce exposure and sensitivity hence reduce vulnerability.

Based on the focus group discussions and key informant feedback, the smallholder farmers in the study areas have been using different strategies to respond to climate variability. Smallholder farmers were asked about their primary adaptation strategies in the face of climate change and variability. The study investigated seven adaptation measures namely: planting different crop, diversifying crops, shifting planting dates, plant drought resistant crops planting trees, livestock rearing, and diversity from farming to non-farming activities. The results in among the adaptation strategies practiced by smallholder farmers in the study area, crop diversification was practiced by more households (70%) whereas only a few respondents practiced livestock rearing (23%). Through FGDs and KII, the majority of the smallholder farmers in GVHs which are near Karonga town practiced crop diversification due to the campaign made by agricultural extension services from government extension workers and NGOs. On the planting of trees as an adaptation strategy, the respondents indicated that this was done mainly to provide natural shade for their livestock and crops on-farm during the extended dry periods. Shifting of planting dates was also indicated as one the adaptation strategy practiced by 63% of smallholder farmers in all the GVHs (Figure 8).

summaries a number of adaptation techniques and the percent of respondent using the strategies. Planting of drought resistant crop varieties (33%), off farm activities (58%) and enhanced livestock rearing (23%), shifting planting dates (63%), diversifying crops (70%) and planting trees (39%).

(Figure 8) shows that many of the adaptation options are not implemented by smallholder farmers. For instance, 55% of smallholder farmers indicated that they do not employ change of crop variety as adaptation measure. In addition, 67% of smallholders indicated that they do not rear livestock as a means of adaptation strategy. This is therefore weakening farmers' endeavours for adaptations to climate change and variability.

Adaptive capacities of smallholder farmers to climate variability: This section looked at crop Production and use of agricultural technologies, land allocation among smallholder farmers, annual production, challenges in crop production, asset ownership, access to land holding, livestock ownership and off farm activities, access to basic services and infrastructure, access to basic services by smallholder farmers, institutional infrastructure in the study areas and sources of climate related information The degree to which smallholder farmers have access to the highlighted factors determines the level of the adaptive capacities of smallholder farmers to climate variability in the study areas.

Crop Production and Use of Agricultural technologies: Crop production and livestock raring are the major livelihood activities undertaken in the study areas. According to the survey, the dominantly grown crops in the study areas include rice, maize, cassava, sweet potatoes, vegetables, and bananas. The context of agriculture in the study areas is changing with increasing challenges of reduced soil fertility, erratic weather patterns due to climate change and changing markets.

The study further assessed the income that the smaller holder farmers gets from on farm activities annually where the household were asked a series of question on crop cultivation; the number of acres the household allocate to a particular crop, the average number

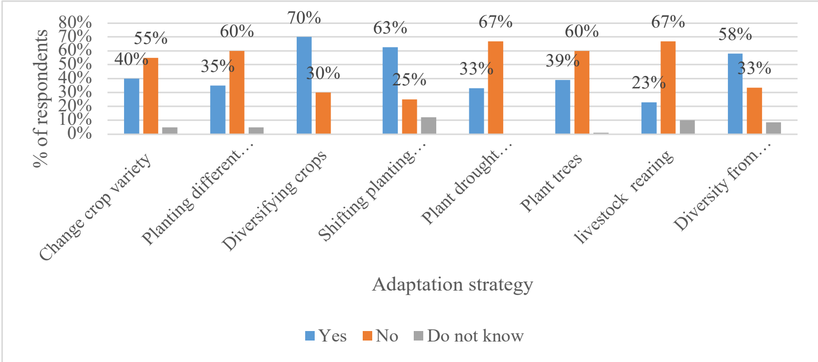

Figure 8: Smallholder farmers' adaptation practices to climate variability in the study area.

of times a particular crop is grown per year; the input and labor cost per acre of a particular crop; the production from a crop in Kilograms; the crop output cost; and also the total income realized. A range of pre-selected crop were used to get the information, (i.e. Rice, Maize, Cassava, Sweet potatoes, Vegetables, Banana, Cotton, sugar cane). On average, the land holding size in the study areas is 0.33 acres. As regards land allocation to the main crops grown in the area, the largest portion of land is located to growing rice, followed by maize and vegetable where on average, 1.14acres, 0.67acres, and 0.4 acres are allocated respectively. With male headed household having larger land allocated to rice 1.2 acres on average than female headed household at 0.9 acres (Figure 9).

On crop production, the study revealed that on average, the households produce more rice (4015 Kilograms) followed by maize (1628 kilograms) and cassava (1234 kilograms) annually. Proportionally it can be noted that on average the households also produce more vegetables (270 Kgs) (Figure 10).

Access to land holding and land use: In the study villages the majority of smallholder farm households have small plot of land commonly less than one ha. It was also revealed that there is land degradation due to charcoal burning. Field observations in the study areas showed that land resources have become highly degraded and scarce. The problem largely stems from failure to give due consideration to the importance of applying innovative and local level participatory land use planning. It was revealed through FGDs and key informant interviews that due to shortage of government extension workers more especially agricultural and forestry extension workers is contributing to failure to implement proper land use planning.

Livestock husbandry and grazing resources: The study revealed that the population of livestock in the study areas is small as indicated in the (Table 23).

The smallholder farmers were further asked to indicate the type of livestock they own. The results revealed that 46% of the sampled households own cows, 29.2% of the sample farm households own goats, 62.6 of farm households own pigs, 0.9% of farm households own rabbits, 29.5% of the respondents own chickens and 26.2% of the respondents own ducks (Figure 11).

Although small ruminants such as goats or rabbits are vital sources of income for smallholder framers, over 80% of households do not own these ruminants. During the FGDs and Key informant interviews, smallholder farmers appreciated the quality of their livestock breed because of their ability to withstand stresses such as feed shortage and disease compared with improved breeds. But admitted to the fact that productivity is low compared to improved hybrid species.

The FGDs and KII revealed that when it comes to decision making on how livestock are utilized like when to sell them in the household, 79% of the household said the decision makers are males and 21% are females. And for females they were those that were female headed households. Livestock are often regarded as producers of milk and meat, income generators, and reservoirs of wealth.

Off- farm activities: Diversification on and beyond the farm includes both non-agricultural livelihood strategies that are carried out on the farm, such as the sale of charcoal and activities that farm families undertake beyond the farm, such as petty trade or seasonal migration in order to reduce climatic risks.

In all the study villages, off farm activities by smallholder farmers are very limited and only 39.3 % of the total sampled households responded that they are engaged in off farm activities to supplement their family income from agricultural production. Of those who practice off farm activities about 17.4 % are engaged in petty trade, 40.7 % reported daily labour, 8% fishing, and on a limited scale 9.7 % in handwork production and sale (Figure 12).

Petty trade activities are largely marketing of rice, livestock and also retailing of goods in rural markets after buying from Tanzania and from town markets.

When asked about where they have got the information about climate variability, 51% have heard about the term through the radio. FGDs revealed that smallholder farmer's household's exposure to weather forecasts and using the information for farm activities was described as insignificant by most farmers. Some participants were reluctant to appreciate the value of weather forecast and tended to associate occurrence of rainfall to God's will.

When asked about the sources of information as regards weather information in their communities, the results revealed that smallholder farmers do not get enough information from print media through newspapers (2%), television (3%), school (5%) and government extension workers (18%). However, more information is received through radios (51%) and famillies or friends (22%) (Figure 13).

During the FGDs, it was further revealed that the number of these agricultural extension workers is not adequate hence there is minimal contacts.

Discussion

On biophysical vulnerability of small holder farmers in relation to gender, the study showed that male headed households have reduced vulnerability and female headed households have high vulnerability to

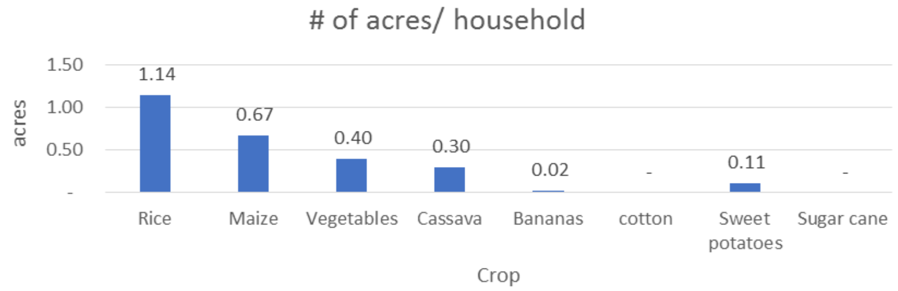

Figure 9: Land allocation in relation to crops.

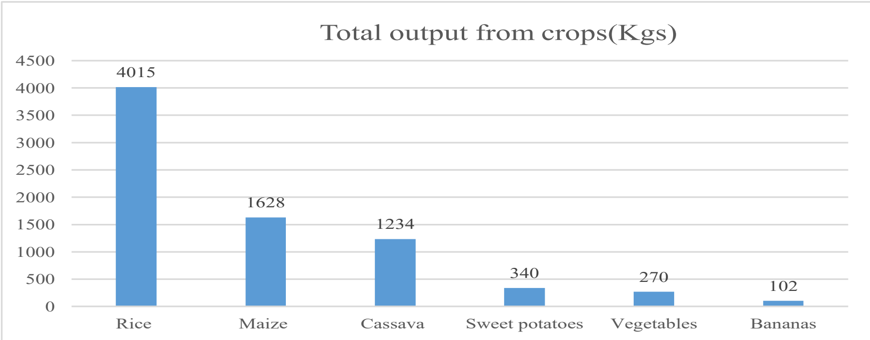

Figure 10: Average annual crop production per household.

Name of livestock	Cows owned	Pigs owned	Goats owned	Rabbits owned	Ducks owned	Chickens owned
Total	544	565	341	68	2709	3069

Table 23: Livestock population in the study area.

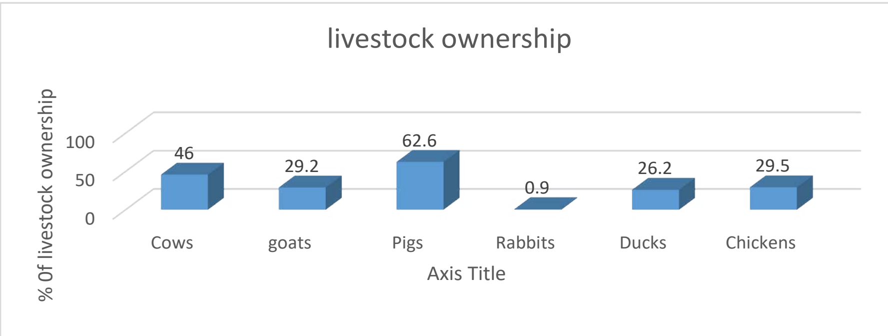

Figure 11: Livestock ownership by smallholder farmers.

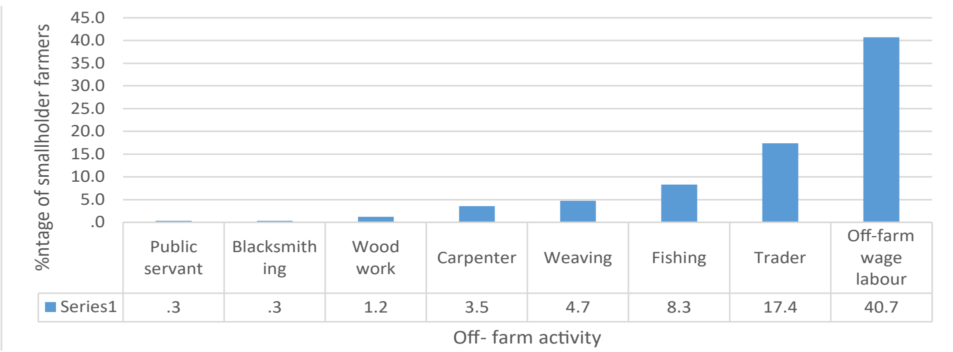

Figure 12: Off-farm activities.

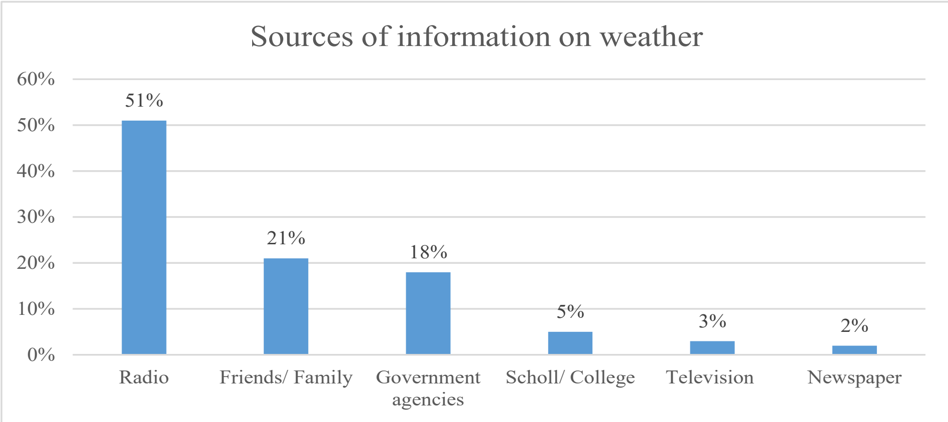

Figure 13: Sources of climate related information.

climate variability in the study areas. Their biophysical vulnerability was exacerbated by frequent occurrence of disasters such as floods resulting into crop failures and lack of control over assets among others. Furthermore, through the same FGDs it was revealed that the vulnerability of women to disasters is increased for a number of reasons. Post-disaster, women are usually at higher risk of being placed in unsafe, overcrowded shelters, due to lack of assets, such as savings, property or land. Poor women experiencing higher gender inequality appear to be at the highest risk: a direct correlation has been observed between women's status in society and their likelihood of receiving adequate health care in times of disaster and environmental stress. This agrees with the findings of [32]. Who reported that women tend to suffer more from the effects of climate variability. Even though women are more vulnerable to these climates related shocks, they are the ones who have a lot of responsibilities of taking care of children, the elderly and the sick. It is emphasized that livelihood diversification is an important strategy to withstand climatic shock [33]. However, inadequate access to non-farm and off- farm activities in the study areas constrains smallholder farmers' capacity more especially women to lead better livelihoods and also has weakened coping and adaptive capacities of smallholder farmers in times of erratic rainfall that triggers crop failure.

The biophysical vulnerability was also assessed at GVH level. According to the results provided, the Group Village Headman with the highest Biophysical vulnerability score is Mwawulambo. This is followed by Mwangulukulu, Zindi and Mwakaboko in that order. Notwithstanding that they are (all three) in the same category of being "vulnerable", the magnitude of vulnerability differs a little, where Mwangulukulu is more vulnerable than the other two followed by Zindi and last of all, Mwakaboko. This is not surprising considering that Mwawulambo is near the upper part of Lufilya River where it experiences a lot of floods and as the water comes down to Mwenitete the strength is lowered down causing less floods. There is need to do more in sensitizing the communities to stop cutting down of trees at the source of the Lufilya liver but also to plant more trees and bananas along the river banks. There is also need to sensitive the communities from stopping cultivating along the river banks. There are also frequent droughts occurrence. Mwangulukulu also experiences frequent floods as compared to the other GVHs. This results into crop failure and land degradation. Mwahimba is close to town and experiences less floods than the other GVHs because of the presence of the dyke on the upper part of the village.

Land degradation is contributing to smallholder farmers' vulnerability in that it results into poor yields as smallholder farmers need to by using fertilizer in their gardens in order to improve yield. Since most farmers are poor and fertilizer is expensive, it makes life difficult for them agriculturally. It is important there for the government to subsidise the prices of fertilizers so that all smallholder farmers could benefit rather than focusing on targeting a few farmers. In other words there is need to have universal fertilizer subsidy. There is also need to train farmers on maximizing their land use by employing new agricultural technologies like conservation agriculture which would cut most of the challenges that smallholder farmers are facing due to climate variability and shortage of land. Furthermore, where land use planning is made an integral component of rural development strategy there is high potential for the local community to be more resilient in times of climatic shocks and other adverse incidents.

Social- economic vulnerability in this study focused on the socio-economic and political status of individuals or social groups. It encompasses social inequalities, including individual income, age, gender and characteristics of communities which influence susceptibility of various groups to damage and govern their ability to respond to stresses or shocks. Under this specific objective, the household variables analysed include age, sex, education, family size, marital status and education, access to land resources, irrigation, asset endowment, access to credit services and access to markets. These variables have implications on smallholder households' perception of climate change, vulnerability to climate change, adaptation to climate change and coping to climate change but also how gender differences of smallholder farmers is impacted by climate change and variability.

The results of the study indicated that female headed households are more vulnerable to climate variability than male headed households. The PCA revealed that the principal components of socioeconomic variables that are contributing largely to the adaptive capacity index are level of education, control of assets, household income, age of household head and sex of house hold head. The findings further stressed the fact that women in the study areas, do not have ability of making decisions on issues that affects them and that that women do not own and control assets and that household assets are under the control of their husbands. The study results also showed that there is a significant number of families where fathers migrate to look for casual labour in times of disasters and hunger outbreak leaving women taking care of children and this makes these families vulnerable. As a result, women are given a lot of burden to look after children as such, there is need to come up of programmes that would empower women economically so that they can have the capacity to be able to support their families. This implies that when disasters strike women are more vulnerable to the effects of climate change. There is need to target women's socio-economic status deliberately in the study areas to improve their adaptive capacity. This is a clear indication that in patriarchy society like in the study areas men are decision makers. It was revealed during FDGs that even if the woman is the bread winner of the household as long as she is married, the head of the household is the man. This creates gender inequality as such women do not make decisions on their own on issues that affects their families in relation to climate variability. Gender of the household head of smallholder farmers is assumed to influence the decision to adopt changes in relation to climate change and variability. Even though women are disempowered, they possess distinctive knowledge and skills that should be accredited and utilized to develop resilience against climate change shocks and other development activities. A recent study in South Africa by reported that female-headed households are more likely to take up climate change adaptation methods. According to the the possible reason for this observation is that in most rural smallholder farming communities, men more often look for jobs in towns, and much of the agricultural work is done by women [34]. This is supported by who argues that women play a major role in agriculture accounting for 43 percent of the agricultural labour force in developing countries, a figure that raises up to more than 60 percent in parts of South Asia and in Africa including Malawi [35]. This is further supported by the study by which revealed that female-managed plots are, on average, 12% smaller than those of their male counterparts and 25% less productive as a result of differing levels of knowledge and access to inputs for improving farming efficiency [36]. Besides the capacity that women have generally in fighting climate change impact in the study areas, they are made vulnerable because they are not empowered and are negatively affected by harmful cultural beliefs as highlighted in the FGDs where it was revealed that women do not have authority over resources like land, children, livestock, crops including their sexual and reproductive health and rights which affects number of children to bear and this increases their vulnerability as revealed by the study. For instance, the study further revealed that the average family size of the respondents was generally high with an average of 6 persons and the average family size was greater than that of the national average of 4 [7]. This entails that women have more farming experience and empowering them would really help to reduce vulnerability of smallholder farmers to climate variability and significantly contribute to building the household resilience to climate impacts. This is supported by [37]. who states that women have more farming experience and information on various management practices and how to change them, based on available information on climatic conditions and other factors such as markets and food needs of the household.

Socio-economically, GVH Mwangulukulu has the highest vulnerability index greater than 1.5000 (3.1853). It is therefore ranking as "very highly vulnerable. Mwakaboko GVH is next with a score of 0.7663, it is thus ranked as highly vulnerable. On the other hand, Mwawulambo, Mwenitete and Mwahimba, in that order, have a ranking of Low vulnerability, with Mwawulambo having the highest magnitude on the socio-economic category and Zindi GVH has the lowest vulnerability index score. The GVHs with high socio economic vulnerability are far from Karonga town and have little access to input and output markets which makes them at a disadvantage in finding good markets for their produce. They are being abused by middle men compared to those in the GVHs which are close to Karonga town. The small holder farmers in the GVHs with high socio economic vulnerability have low access to credit facilities including financial lending institutions which is contributing to their high vulnerability socio economically as compared to those GVHs that are near Karonga town. The smallholder farmers in the GVHs with low vulnerability therefore do not only rely on farm activities alone but also on small scale business which acts as a cushion rendering them able to withstand and respond better to disaster triggers economically, as shown by the low vulnerability index. Furthermore, other GVHs with low vulnerability are close to town like GVH Mwahimba and Zindi where there are a lot of NGOs and basically the build the capacity of smallholder farmers in different forms of income generating activities (IGAs) which improves their adaptive capacities [38].

The study results showed that crop production and livestock raring are the major livelihood activities undertaken in the study areas and the dominant grown crops include rice, maize, cassava, sweet potatoes, vegetables, and banana.

On access to land holding and land use, in order to help smallholder farmers, satisfy their subsistence need and withstand any climatic shock, one of the most important way-out is maximizing land productivity per unit area and yet this is lacking among many smallholder farmers. To this effect the agricultural extension service must be structured to have adequate access to improved technologies and other physical resources so that they could lead a sustainable livelihood.

It was also revealed that most smallholder farmers are vulnerable to climate variability socioeconomically in the identified villages partly because they do not have enough livestock. Although livestock is key in supporting smallholder farmers in times of food shortages and in building their resilience to climate change related shocks in the study villages, the current livestock husbandry system is purely traditional and the livestock are not provided with adequate feed supply, veterinary services are poor and genetic improvement interventions are negligible. Almost all farm households keep local breeds of livestock which means that, the productivity is still low even when management improves. It is therefore important to encourage and support smallholder farmers to obtain improved breeds for faster growth and more milk, eggs and meat.

Efforts to promote modern livestock husbandry are limited, concentrate feed supplying enterprises for poultry or feed for dairy cows and beef animal's production are in most places unavailable. Interviews with key informants revealed that the livestock subsector in general lacks strategic intervention and if the current livestock husbandry system remains unimproved, the contribution of livestock to climate change adaptation will be insignificant in the study areas. The study analysis further showed that livestock holding is small and many farmers are not engaged in rearing of small ruminants and poultry husbandry which raises questions on the efficiency of the agricultural extension service delivery.

The shrinking farm land holding is counterproductive to adoption rate of adaptation strategies to climate change. In this event, it is imperative for smallholder farmers to maximize productivity per unit area through employing of improved technologies and credit services to buy improved agricultural inputs. The reality on the ground however indicates that the magnitude of improved agricultural inputs use is still at low level and provision of moisture stress tolerant crop varieties and that of early maturing varieties is not yet well organized. The secondary data collected from the District Agricultural Development Officer shows that smallholder farmers are engaged in effort to reduce and manage soil erosion through promotion of sustainable land management activities such as soil and water conservation, river bank protection and compost manure application and conservation agriculture. However, it was further revealed that the uptake of these technologies and practices has been a challenge. For example, very few smallholder farmers are practicing soil and water conservation practices and composite manure application to their farms every year while the majority are not. The challenge is that animal manure is difficult to get because of the tethering method of livestock rearing where animals are also not housed in one place each night to accumulate the dung. There is need to step up the efforts with the support of local leaders and other stakeholders in order to improve on land management for increased productivity and environmental conservation.

Smallholder farmers largely depends on one crop that is rice and the majority do not have enough land to grow other crops to improve productivity. This tends to make the efforts to improve rural livelihoods more challenging and elusive. In this regard, it can be argued that improving ecosystem productivity has to be complemented by provision of appropriate technologies and financial services that could be accessed by the majority of smallholder farmers which would really help to address challenges of climate change. An analysis of GVHs vulnerability to climate variability showed that GVH Mwangulukulu was very highly vulnerable (3.2092). Mwawulambo and Mwakaboko had high vulnerability, although according to magnitude, Mwawulambo had a higher score (1.3067) as compared to Mwakaboko (0.5808). Mwahimba GVH had a "low vulnerability rating. Lastly, Mwenitete and Zindi, had Very low vulnerability over all.

These results shows that some communities are vulnerable biophysically and not socio economically and vice versa and others are vulnerable in both. For instance, GVH Mwawulambo is biophysically the most vulnerable of the 6 GVHs, and yet socio-economically, there is a marked difference, it has low vulnerability. Mwawulambo GVH is an area which is highly affected by floods and droughts as it is very close to Lufilya River and is close to the upland part of it. Socio-economically, the results from this study shows that they have low vulnerability. This tallies well with the socio-economic status of the area. Even though, they are highly vulnerable biophysically, socio-economically, they are active. The results further reveal that Mwangulukulu GVH has the highest composite vulnerability indices. However, when we compare between Biophysical and Socio-economic vulnerability, there is a marked difference. Biophysically, they are considered just vulnerable, given by the positive but smaller vulnerability index which is falling in the third category. Socio-economically on the other hand, they are highly vulnerable. These results come as no surprise especially when we factor in the physical and socioeconomic situation on the ground in the area. Unlike most part of Karonga district which has low altitude, GVH Mwangulukulu area occurs on one part of land which has a higher altitude relative to the rest. As such it is not very much exposed to frequent floods and droughts which scourge other communities in study areas. With flooding as one of the exposure trigger of vulnerability, this feature in the area renders its inhabitants less exposure to floods than in other GVHs. This in part explains why the Biophysical vulnerability index for the area is small. Socio-economically, the results show that they are very highly vulnerable, given by the vulnerability index which is greater than 1.5000. First, this, may be as a result of the area being largely populated by smallholder farmers who are not active in other income generating activities. As a result, when they are exposed to other forms of disasters which affects crops, they have no other means of supporting themselves, as such they struggle economically. Secondly, their land holding size is smaller compared to the other GVHs areas. Furthermore, GVH Mwakaboko, is also highly vulnerable. Biophysically, it shows that they are just vulnerable but the value is closer to 0. However, socio-economically, they are highly vulnerable as the index is closer to 1 (0.76630).

GVH Zindi, is biophysically vulnerable and has very low vulnerability index on the vulnerability index score. The GVH is indeed affected by various disasters, chief of which is flooding. Like Mwakaboko, one part is situated close to the North Rukuru River and has no dyke, which tends to overflow during heavy rains rendering part of the area close to it, very compromised biophysically. The other part of the area is not hit by flooding much. This is why the area as a whole is vulnerable to a lesser extent, but not as much as other GVHs. The part which is not much exposed tends to lessen the index for the whole area. Socio-economically, they are least vulnerable. The area is strategically close to Karonga Township, making its people have access to markets, good road network, and electricity and a good number of government extension workers. In addition to this, they have access to most humanitarian non-governmental organizations which are in the main Township, which respond quickly with aid whenever disasters strike. The smallholder farmers also are involved in other occupations besides farming. All these factors, the study believes, boosts their adaptive capacity rendering them able to cope during disasters and thus, socio-economically the very least vulnerable of all the 6 areas sampled. However, the persistent occurrence of these natural disasters is reducing sustainability of their adaptive capacity. GVHs Mwahimba and Mwenitete have low vulnerabilities both biophysically and socio-economically. Even their composite indices are very low, with Mwenitete having the least overall vulnerability. First, the two GVHs are hit by disasters but not to the magnitude of the other GVHs.

Socio-economically, the two areas occur right in Karonga Township, and close to main road respectively where there is a lot of trading and this reduces overreliance on farming, much as they do engage in farming activities. These GVHs with low vulnerability, are also better served with government extension workers as such smallholder farmers have better access to information related to climate related issues. They are involved in growing bananas which is one of the lucrative crops in the District. They are also involved in small scale businesses as additional source of income. To add to the list of socio-economic advantages, the houses found in this area are of better quality, they have access to markets, electricity, information presence of International Non-Governmental Organizations (INGOs) and good road networks. All these place them at an advantage in terms of how they adapt to climate variability. The occurrence of climatic variability more especially floods, droughts, dry spells, strong winds in the study areas makes it essential for smallholder farmers and development agencies to initiate strong coping, adaptation and mitigation mechanisms.

Conclusion

This research carried out an in-depth analysis of the local level vulnerabilities by integrating quantitative analysis with qualitative information obtained from primary field survey and secondary data to determine the magnitudes and patterns of rural households' vulnerability to climate variability and then identified the important determinants for resilience at household level in Karonga District, Malawi.

The research methods employed were deemed to be adequate in covering the wider spectrum of key variables to measure climate change trends, related to biophysical and socio- economic impacts and subsequent human responses in the form of land use, livelihoods, coping and adaptation strategies among others in Karonga District.

In each of the objectives, indicators were identified to measure the vulnerability of smallholder farmers to climate change.

The study generated primary data through information gathering from a wide sector involving rural households, key informants, government and non-government staff working at local levels and through field observations. This was again complemented by gathering secondary data from relevant literature and government and non-government reports. This study therefore employed mixed method which included integration of quantitative and qualitative data collection through both quantitative and qualitative methods. The biophysical and socioeconomic data collected through household survey supplemented with observation and FGDs. The qualitative data gathered from focus group discussions and key informant interviews were summarized and coded according to themes. This data was collected under all the four specific objectives. Specific category of issues that were highlighted frequently by smallholder farmers during the discussions were given due emphasis.

The analytical tests were supported by descriptive statistics. This involved computation of percentages of single variables, the median and average outcomes. The quantitative data was coded and entered into the Statistical Package for Social Sciences (SPSS) version 22, where it was explored and managed accordingly.

Under objective 1, the study revealed that smallholder farmers are affected at different levels depending on their geographical location. For instance some GVH Mwabulambo is highly vulnerable to climate variability due to frequent occurrences of floods. While GVH Mwenitete is less vulnerable to climate variability.

Under objective 2, Socio-economically, GVHs which are far from town like GVH Mwakaboko is highly vulnerable to climate variability as they has not access to input and output markets, inadequate access to credit facilities among others. GVHs like Mwahimba is less vulnerable socio economically as they have access to credit facilities and more NGOs are close to town which renders them adequate support in improving the snmallholder farmers adaptive capacity.

Under objective 3, the study revealed that smallholder farmers, experience biophysical vulnerability and socioeconomic vulnerability depending on geographical location and their proximity to Karonga town and activities of smallholder farmers on income generating activities. For instance GVHs are vulnerable biophysically but less vulnerable socio economically. For instance GVHs Mwangulukulu and Mwaulambo have the highest vulnerability and GVHs Mwenitete, Zindi Mwahimba have low composite vulnerability to climate change. This demonstrated that integrated approach is the most ideal in assessing vulnerability of smallholder farmers to climate variability as opposed to employing biophysical and socioeconomic approaches separately. This approach showed more advantages in understanding vulnerability of smallholder farmers in the study areas in totality as opposed to employing the biophysical approach and socio-economic approach separately. The integrated approach to vulnerability assessment focused on both variations within society and also on environmental factors. It further accounted for the availability of natural resource bases to potentially counteract the negative impacts of these environmental shocks. The integration of socioeconomic and biophysical approaches to determine vulnerability therefore provided a holistic understanding of the vulnerability of smallholder farmers in its fullness as it focused on identifying both the adaptive capacity of individuals by gender and communities at GVH level based on their internal characteristics as well as their vulnerability to natural hazards and climate variability.

Under objective 4 the study revealed that smallholder farmers in the study areas exhibit vulnerability to different types of natural hazards. Furthermore, the smallholder farmers have low adaptive capacity to climate variability even though the level of vulnerability varies from community to community as evidenced by the results. Furthermore, this reduces the resilience levels of smallholder farmers in the study areas. It is undeniable fact that, the capacity to bounce forward during and after climate change induced shocks depends on a number of households' characteristics, institutional arrangements, social networks, economic capacity and natural setting. The study has reinforced the notion that Karonga district is not spared to the adverse effects of climate change and has of late experiences incidences of extreme weather events and these are to become frequent with climate change. Climate change and associated climate variability will therefore severely impact future development trajectories and thus pose a serious challenge to multi-dimensional poverty reduction efforts in the study areas, around Karonga and the country at large. Climate change and variability is real and is happening in Karonga as evident from the discussions.

Recommendations From The Study

The recommendations for this study are presented as suggestions on how initiatives on climate change could be more effective and the various stakeholders involved in climate change in Karonga District and Malawi should organize their programming to increase the adoption rate, the effectiveness and sustainability of climate change adaptation strategies. The areas that need further research will also be highlighted.

In order to address the gaps revealed by the study in order to improve the biophysical and socioeconomic vulnerability of smallholder farmers to climate variability, the study recommends the following:

- INGOs and government stakeholders need to provide these local smallholder farmers with appropriate recourses including modern agricultural technologies that would help to build their capacity to adapt to climate variability.
- There is a need to conduct intensive community sensitization and advocacy work on the causes of climate variability targeting smallholder farmers more especially women to make sure that the smallholder farmers own the adaptation strategies.
- There is need to diversify income sources including village savings and loans associations (VSLAs) in order to build their resilience to climate change impacts.
- Government and NGOs need to identify and promote technologies that are suited to changing climatic variables and at the same time understanding variables that influences smallholder farmers' motivation to climate adaptation.
- Karonga District needs to develop local adaptation and mitigation strategies that are all inclusive with all sectors that are weather and climate sensitive. This would provide local assembly with a means for adapting to the adverse impacts of climate change as such the study areas and the district at large will benefit.
- The adaptation strategies should be designed to promote livelihood diversification schemes and packages of the different options should be prepared carefully so that they could motivate smallholder farmers to adopt them.
- The extension support on livestock is still weak. In the face of these challenges there is an urgent need to seriously assess livestock

development activities that have been implemented in the context of climate change over the years and design strategies that enable farm households to manage their livestock in a very productive way so that they could adapt to the negative impacts of climate change.

It is further recommended that the government and NGOs need to make a concerted effort to work with those existing women's groups that currently meet the needs of local women in terms of credit facilities, social welfare protection and other vital community functions. Working in tandem with such existing groups, whether informal or formal, can help reach women to build their adaptive capacity, but care should be taken not to co-opt completely their original goals and objectives.

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