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 Ri Valley plain, which is the most geologically active to natural disasters. e environmental and geological conditions in Karonga are sensitive and vulnerable to such disasters [7].

Vulnerability is de ned as the degree to which a system is susceptible to, or unable to cope with the adverse e ects 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).

erefore, 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 de ned 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”

e level of vulnerability of di erent villages to climate variability in the study area is determined by both socioeconomic and environmental factors. Given the di erent disciplines involved in vulnerability study, there are many conceptual and methodological approaches to vulnerability analysis. e major conceptual approaches include the socioeconomic, biophysical, and integrated approaches. e socioeconomic approach is mainly concerned with the social, economic, and political aspects of society [10]. e 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. e 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]. e integrated assessment approach combines both the socioeconomic and the biophysical attributes in vulnerability analysis [12]. is 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. e 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].

e 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. is creates a situation where the government lack information on vulnerability of smallholder farmers in relation to speci c locations at community level resulting into failure to develop local speci c 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]. is 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 signi cance of the combination of the two [19]. is 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 importantes including

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

'K' Next, a number was selected between one and the sampling interval using lottery method, which is called the random start and was used as the rst number included in the sample. en, 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.

D

Data for this study was collected through key informant interviews (KII), household interviews, focus group discussions (FGD), eld observations and secondary data from relevant literature. is study used questionnaires to collect information. e tools, were designed to be semi-structured in nature. is 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 speci c parts of the questionnaire were conducted on the smallholder farmers in another area outside the study area. e 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.

: 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 O cers 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.

: Findings from these KIIs, fed into the sampling design for the rest of the research and clari ed 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. e questionnaire was divided into the following: demographic and economic household characteristics, livestock and crops production, access to extension services, credit access, hazards/ disaster occurrence, di erent coping strategies, land size, farmland location, soil erosion rate, land fertility level, land exposure to ood, crop productivity on temporal scale, distance to agricultural input markets, and input utilization, just to highlight some.

F : A total of 6 focus group discussions (FGDs) were conducted separately with a gender parity (of ve men and ve women) from the sampled villages to cross-check and validate answers from household respondents. e 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

F : Direct eld 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, ood a ected areas, water resources and vegetation cover and land management practices.

D

e study generated both quantitative and qualitative data. e quantitative data was coded and entered into the Statistical Package for Social Sciences (SPSS) version 22, where it was explored and managed accordingly. e 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 identi ed which were used as proxies for the PCA. Twenty of which were for Biophysical vulnerability and 19 were for Socio-economic vulnerability. e 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. e majority of

No	Traditional Authority (TA)	Group Village Head	Total populatio of farming families	Total sample size
1	Kyungu	Mwahimba	679	89
		Zindi	364	48
2]TJ20. Asbil(lcayp1)]TJ9.8 -0.8aKil(lcayp1)]48 7CSused as16 m3l(l.88CS38.15 0 TD[48)]TJ307.15 -1.9 -1.[2]TJ20)]Tw.8 mbo as16 m9Direct 1-64.84 -TD[48)]TJ204.84 -1.62 TD[				

Citation:

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: *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

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							
	-0.0109 **1**	-0.0174 **2**	0.2006 **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**
Mwai257.561707.50290 4D[3)]TJ40080 TD[-0.0109)]TJ7.62020 TD[-0.2936)]TJ7.760 0 TD[0.2006)]TJ3589 0 TD[0.1531)]TJ708720 TD[-0.5194)]TJ8179 0 TD[0.2435)]TJ/								

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

[illegible]

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

GenderGender								

of the le side of the table. e number of principal components (7) whose eigenvalues were 5.981 or greater determined the seven rows reproduced in table 13. A er these important tests were passed, the PCA was carried out with varimax rotation. e isolated principal components managed to explain approximately 60% of the total variance in the sample (Table 12). e 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. ese 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. e 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.

e study results show that all the variables have been adequately represented except four indicators; gross income, kind of house, 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. e 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 signi cance levels were also the same.

A er 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

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

e PCA for calculating overall (encompassing biophysical and socio-economic) vulnerability isolated 13 principal components. ese 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 varans th8 proxy ihat each ves wece var swiach[(Accorpas3 Tce)valikcep innan,i

KMO and Bartlett's Test (Socio-economic)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.606

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Indicators	Initial	Extraction

Citation:

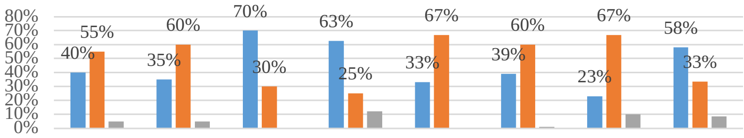

Figure 8: Smallholder farmers' adaptation practices to climate variability in the study area.

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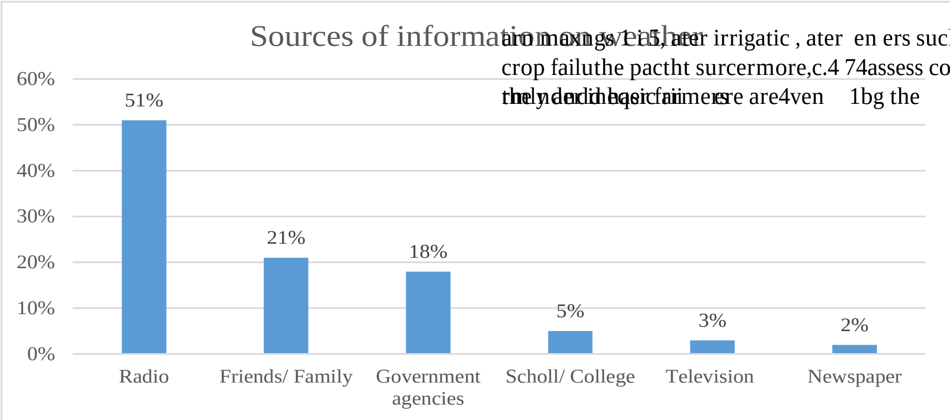

Figure 13: Sources of climate related information.

climate variability in the study areas. eir biophysical vulnerability was exacerbated by frequent occurrence of disasters such as oods 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. is agrees with the ndings of [32]. Who reported that women tend to su er more from the e ects 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 diversi cation is an important strategy to withstand climatic shock [33]. However, inadequate access to non-farm and o - 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.

e 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. is 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 di ers a little, where Mwangulukulu is more vulnerable than the other two followed by Zindi and last of all, Mwakaboko. is is not surprising considering that Mwawulambo is near the upper part of Lu lya River where it experiences a lot of oods and as the water comes down to Mwenitete the strength is lowered down causing less oods. ere is need to do more in sensitizing the communities to stop cutting down of trees at the source of the Lu lya liver but also to plant more trees and bananas along the river banks. ere is also need to sensitive the communities from stopping cultivating along the river banks. ere are also frequent droughts occurrence. Mwangulukulu also experiences frequent oods as compared to the other GVHs. is results into crop failure and land degradation. Mwahimba is close to town and experiences less oods 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 di cult for them agriculturally. It is important there for the government to subsidise the prices of fertilizers so that all smallholder farmers could bene t rather than focusing on targeting a few farmers. In other words there is need to have universal fertilizer subsidy. ere 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. mplm Furthermore,w 0 -1 1.2 TD[(i of programmes that would empower women economically so that they can have the capacity to be able to support their families. is implies that when disasters strike women are more vulnerable to the e ects of 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

Citation:

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 e ort 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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