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Determinants of adaptive capacities and coping strategies to climate change related extreme events by forest dependent communities in Malawi

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ABSTRACT

Climate change related extreme events present significant threats against the sustainability of forest-based livelihoods. Adaptive capacities and coping strategies of forest residents in Malawi towards climate change and extreme weather events were analyzed. Purposive sampling was used to select key informants while random sampling was employed to sample household heads or older member of the household ($n = 422$) involved in the household survey. Questionnaire administration, interviews and focus group discussions were used to collect the primary data. Cross tabulation of frequencies, Pearson Chi-square tests, and Binary logistic regression tests were used for the data analysis. Results showed that forest residents have always employed different adaptation and coping strategies during different climate extreme events over the years. Winter cropping (*Dimba*) around streams and wells, scored 66 % in Mchinji whilst the shifting of crop planting periods to coincide with rainy seasons topped the list in Mangochi (55 %) against droughts and erratic rainfall, respectively. Household satisfaction with water supply facilities and communication services dictated the respondents' choice of the coping strategies employed. Furthermore, household human capital enhanced the adaptive capacity of forest residents. In conclusion, institutional services, social networks and human capital resources are important in devising climate coping and adaptation strategies hence recommending for more sustainable and transformative adaptation and coping strategies that can withstand projected climate change and weather-related events.

1. Introduction

Historically, forests have played important roles in supplying goods and services for the peoples' livelihoods in most developing countries. Rural communities rely on forest resources through various products such as fuel wood, construction materials, medicine and food (Langat et al., 2016)). The Global forest goal reports that nearly 1.6 billion people globally rely on forest resources for their livelihoods for food, shelter, energy, medicine and income (UNDESA, 2021). Recently, forest ecosystems have been faced with pressure due to unsustainable management practices, lack of clarity on tenure and access rights and the persistent pressure for the land-use change through agriculture and development (Oranu et al., 2022; Rochmayanto et al., 2023). The advent of climate change in the ecological scene has exacerbated the impacts of these stresses on both forest ecosystems and forest dependent people (IPCC, 2018). In Africa and other developing regions of the world, rural communities are on the frontline of adverse impacts of climate change due to their remote location and direct dependence on climate sensitive livelihoods such as forests and rain-fed agriculture (Koli A., 2013).

Studies have established that forest dependent residents and small holder farmers have used forest and forest products as coping strategies in dealing with natural disasters such as flooding and droughts (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Ofoegbu et al., 2016; Robledo et al., 2012; Senganimalunje et al., 2022; Sonwa et al., 2012). Robledo et al. (2012) argued that one way to reduce climate change impacts on rural communities is by strengthening the community's local adaptive capacity. They suggest that through enhanced community adaptive capacity, the rural communities will be able to adjust, moderate, or take advantage of the climate induced changes in their locality (Robledo et al., 2012). This observation requires community level projects which could be designed with explicit consideration of climate change and variability to address people's livelihood and enhance their adaptive

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capacity. On the other hand, Basu (2017) asserts that there is need to understand the factors that affect the forest dependent rural community's adaptive capacity in the quest to enhance them. Recently, van Valkengoed and Steg (2019) opined that it is important to identify the household determinants of climate adaptive capacities to enhance the adoption of the climate coping and adaptation strategies amongst among various communities.

Adaptation refers to the adjustments in the natural or human systems in response to the actual or expected climatic effects (IPCC, 2014; Nunes, 2016; Nursey-Bray et al., 2013). On the other hand, Nyashilu et al. (2023) define coping strategies as specific activities employed by people to master, tolerate, reduce or minimize or minimize stressful events such as droughts and floods in a short-term period of time. Basu (2017) postulates that climate adaptation is dependent on adaptive capacity, which represents the way of reducing vulnerability. Literature has revealed that perception of climate change and taking adaptive measures are influenced by different socio-economic and environmental factors (Hassan and Nhemachena, 2008; Maddison, 2006). Van Valkengoed and Steg (2019) observed that the level of interest in climate change adaptation is influenced by such factors as climate education, and access to climate technology, expertise, and information.

Literature has revealed that different socio-economic profiles lead to different vulnerabilities thereby affecting the community's ability to adapt to the impact of climate change (Devkota et al., 2018; Ofoegbu et al., 2016; van Valkengoed and Steg, 2019). Meijer et al. (2015) reported that poverty is a significant barrier to tree planting as a key coping strategy in Malawi. This was affirmed by Asfaw et al. (2014) who argued that wealthier households are more likely to adopt both modern and sustainable land management (SLM) inputs; and are more likely to adopt SLM inputs on plots under more secure tenure. In Ghana, for instance, Antwi-Agyei and Nyantakyi-Frimpong (2021) reported inadequate credit facility and market access for the farmers' agriculture products as key challenges in adopting climate change coping strategies. Pardoe et al. (2020) added that the inability of countries to redefine the role of additional donor funding resources is a key barrier to climate adaptation in Malawi, Zambia, and Tanzania. Highlighting the link between types of vulnerability and social economic factors, a study by Devkota et al. (2018) revealed that per capita income, income distribution inequalities, universal health care coverage, and good rates of information access were valuable determinants of adaptive capacity.

The generic determinants of adaptive capacity in a social system at both household and community level comprise of non-climate factors such as economic resources, technology, information and skills, infrastructure, institutions, and equity (Devkota et al., 2018). These factors have also been referred to as livelihood assets by other schools of thought which consist of human, physical, financial, social and natural capital (Nunes, 2016). Wongbusarakum and Loper (2011) highlighted that socio-economic factors such as institutional availability, governance, and management, play vital roles in enhancing a community's adaptive capacity to climate change. On the other hand, Ofoegbu et al. (2016) opined that improving institutional facilities of a community positively influences the adoption of effective coping strategies amongst the poor communities. In support of this assertion, Rosati and Faria (2019) reported that the provision of improved institutional facilities such as communication facilities enhances the realization of the Sustainable Development Goals. In addition, the provision of institutional resources reduces the migration potential of the rural communities to cities and contribute to the attainment of the Sustainable Development Goal number ten (10) (McManus and Irazábal, 2023; Piper, 2017).

Basu (2017) established that age of the household head, farm income, forestry income, temperature and family size are key determinants of household adaptive capacity of forest residents in India. Their results showed that elder people have more experience than young ones which gave them better access to non-timber forest products from the forests. In regards to household size, Basu (2017) opined that households with many family members were forced to collect more forest products for income due to consumption pressure imposed by the large family size. In addition, it has been argued that the dependency on

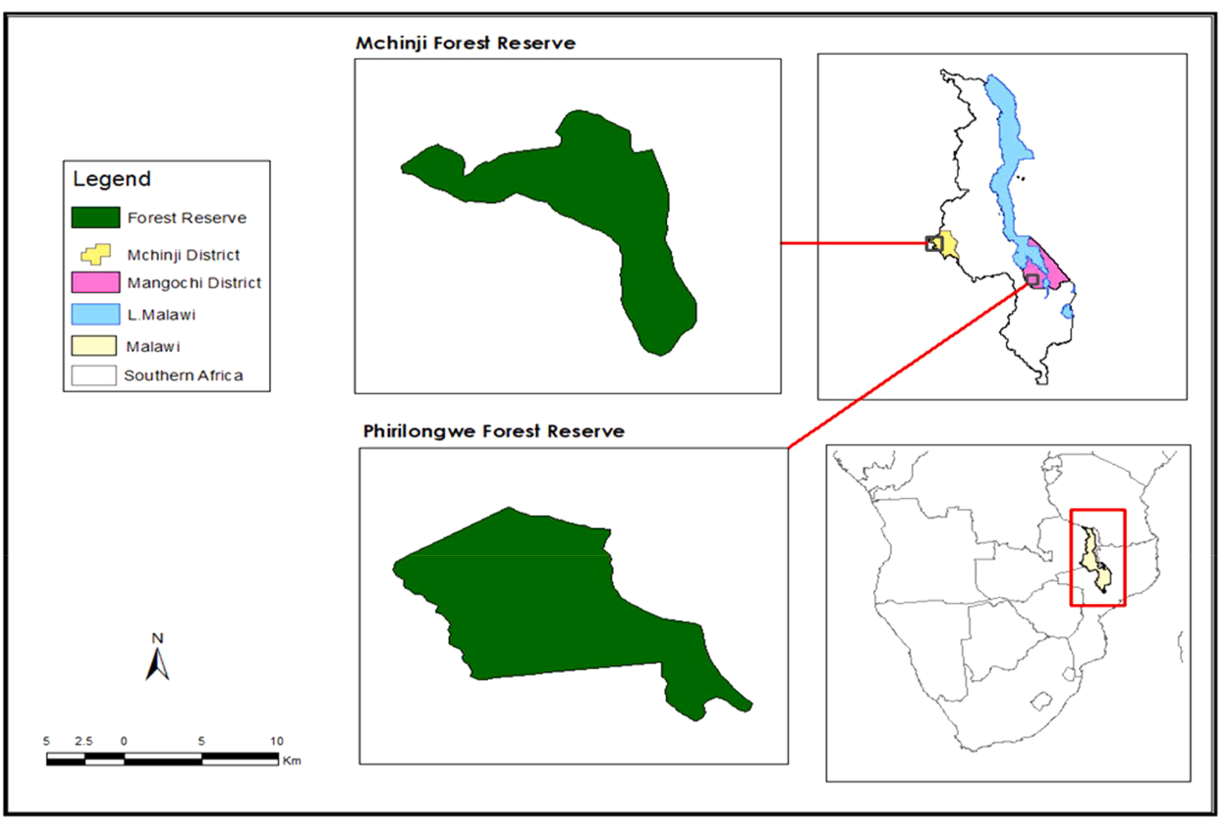

Fig. 2.1. Map of the location of Mchinji and Phirilongwe forest reserves in Malawi.

forests for livelihoods due to climate change increases with increase in temperature (Basu, 2017). Senganimalunje et al. (2022) postulate that extreme weather events adversely affect agriculture consequently increasing the food insecurity forcing forest communities to turn into alternative adaptation options including forest products. Furthermore, adaptive capacity of forest communities is influenced by the income from forestry which brings positive impacts (Basu, 2017; Chilongo, 2014; Clar and Steurer, 2019). Increased income from forestry enhanced the possibility to boost adaptation to reduce climate change risk. Contrary to the agriculture sector, a negative relationship of low land holding size and climate adaptive capacity of forest communities was recorded in India (Basu, 2017). This means that low farm holding size has greater adaptation compared to large farm holding size.

Studies focusing on the determinants of adaptive capacity and coping strategies of forest dependent communities during extreme weather events have received little attention. Thus, this study focused on the adaptive capacity that combines the traditional asset-based adaptive capacity to include other factors such as institutional services and the social networks among forest dependent communities. Furthermore, the study analyzed education as a household attribute to the choices of the coping strategies or enhancing household adaptive capacity. The novelty in the analytical approach in this objective is that we depart from the traditional asset-based determinants of adaptive capacity which has its roots from the studies of Sen (1984).

This study aimed to examine the forest-based determinants of adaptive capacity and their adaptation and coping strategies towards climate change related extreme weather events in Malawi. Specifically, the study focused on (1) identifying various coping strategies used by forest dependent households to respond to the impacts of climate variability and change in their areas, (2) establishing household perceived barriers or challenges to the adoption of various coping and adaptation strategies in the study area, and finally, (3) exploring the attributes of household adaptive capacity influencing the household choices of the coping strategy in the study area.

2. Materials and methods

2.1. The study site

The study focused on two sites in Malawi (Fig. 2.1): Mchinji district targeting 12 villages in three Traditional Authorities (TAs) surrounding Mchinji forest reserve in the central region and Mangochi district where 20 villages were targeted in three Traditional Authorities (TAs) surrounding Phirilongwe forest reserve in the southern region. The Government of Malawi (2018) reports that Mchinji district has a total land area of 3131 km^2 with a total population of 602,305 people and a population density of 192 persons per square kilometer. On the other hand, Mangochi district has a total land area of 6729 km^2 with a total population of 1,148,611 people and a population density of 171 persons per square kilometer (Government of Malawi, 2018). In terms of climate, Mchinji district experiences a warm tropical climate which is greatly influenced by its location and topography. On the other hand, Mangochi district which lies largely on the southern end of the Lake Malawi lift valley experiences warm tropical climate with mean annual temperatures ranging from 18 to 32 °C.

Mchinji forest reserve was gazetted in 1924 with a total forest area of 20,885 ha whereas Phirilongwe forest reserve, situated on the western side of Mangochi district was gazetted in the year 1924 with a total forest area of 16,129 ha. Vegetatively, both Mchinji and Phirilongwe forest reserves and the surrounding customary forest are covered with Miombo woodland with Brachystegia as a dominant tree species. The common tree species in these reserves are Brachystegia/Julbernadia species such as *Julbernadia paniculata* (Benth) Troupin, *Julbernadia globiflora* (Benth), *Uapaca kirkiana* (Müll.Arg), *Pericopsis angolensis* (Baker) Meeuwen, and *Pterocarpus angolensis* DC. On the other hand, a major available non-timber forest product being harvested in the Phirilongwe forest reserve is the *Oxytenanthera abys-sinica* (A. Rich) Munro (local bamboo) which commonly grows naturally on the escarpment of the Phirilongwe Mountain.

2.2. Sampling frame and sample size

We employed a multistage sampling technique approach, which ensures that all responses were represented in the study (Kelley et al., 2003). The study targeted two (2) regions out of the four Malawian regions and purposively selected two (2) districts, one in each region and the two forest reserves, one in each district thus Mchinji and Phirilongwe forest reserves. In these two reserves, no government intervention or project is being implemented. We randomly selected the Traditional Authorities (TAs) and their respective villages falling within 5-kilometer radius of the selected reserves to collect a representative sample. Lastly, purposive sampling was used to select the households and key informants in this study. To qualify as a respondent of the household in this study, the member of the household ought to have lived in the study area for over 10 years during the time of data collection and aged 21 years and above. Studies have shown that the probability of recalling

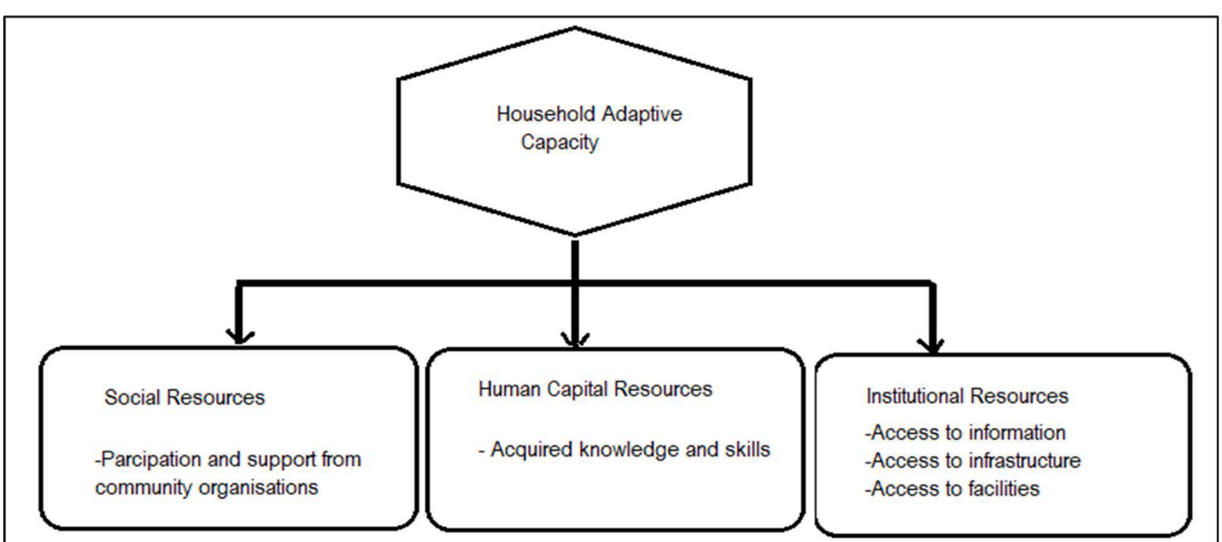

Fig. 2.2. Household adaptive capacity analysis framework.

Table 2.1
Explanatory variables used in the binary logistic regression model.

No.	Explanatory variable	Possible responses 1 0
1.	Employment status	Employed not employed
2.	Household size	>6 <6
3.	Education qualification	Formal Informal
4.	Farming skills	Yes No
5.	Livestock keeping skills	Yes No
6.	Culture and language skills	Yes No
7.	Carpentry Skills	Yes No
8.	Hunting skills	Yes No
9.	Art and crafts skills	Yes No
10	Age of respondent	>35 <35
11.	Gender of respondent	Male Female

major climate events in an area is increased by the age and experience of individuals (Chakufwa et al., 2016; Limuwa et al., 2018; Mittal et al., 2021). The surveys targeted the household head or any older member of the household in the absence of the household head. Sample size determination was adopted from Krejcie and Morgan (1970). The list of households surrounding Mchinji and Phirilongwe forest reserves was accessed from the respective district councils. The total population of the forest-dependent communities was used at a 95 % confidence level, thus a 5 % confidence interval to arrive at the sample size. Since the population size of the forest-dependent communities was provided, we used the following formula to capture a representative sample proportion required in this study;

$$S = \frac{\left(X^2NP(1-P)\right)}{\left[\left(d^2(N-1) + X^2(P(1-P)\right)\right]} \quad \text{(Equation 1)}$$

where, S = required sample size, $X = Z$ value at the desired confidence level in this case 1.96 for 95 %, N = is the population size, P = Population proportion expressed as decimal and assumed to be 50 %, thus 0.5. Thus, 50 % prevalence was given and d = degree of accuracy (5 %) expressed as proportion thus 0.05.

From this model, we interviewed 422 households from the two forest reserves in Mchinji and Mangochi districts. The study sampled 227 households in Mchinji (N = 134,799) distributed across three Traditional Authority (TA) jurisdictions surrounding Mchinji forest reserve (TA Mlonyeni, TA Nyoka, TA Mkanda) and 195 households in Mangochi district (N = 152,879) distributed in three traditional authorities around Phirilongwe forest reserve (TA Mponda, TA Chilipa, TA Mtonda). The difference in the number of households sampled in these sites is based on the size of the forest reserve. In this case, the Mchinji Forest Reserve is large as compared to the Phirilongwe Forest Reserve. In addition, differences in size of the Traditional Authorities also affected the number of households sampled.

2.2.1. Demographic characteristics of the sampled respondents

The demographic characteristics of the sampled households reveal that there were more men (53 %) than women in the Mchinji sample while there were 56 % women in the Mangochi sample. This demographic difference might be attributed to the fact that men in Mangochi are mostly not at home, often at the lake fishing, as compared to their male counterparts in Mchinji, who are mostly farmers. As regards age, Mangochi respondents comprised of 76.92 % older than 35 years compared with the respondents in Mchinji at 68.3 %. In terms of household size, 45.7 % of the households in Mangochi had the household size greater than six (6) compared to 32.6 % in Mchinji. This might be attributed to the communal and extended family traits among the Yao ethnic group which is common in Mangochi. The study also indicates that 84 % of the sampled respondents in Mangochi were married compared to only 75 % in Mchinji. This also supports the revelation of common early marriages reported in Mangochi district (Government of Malawi, 2018). In terms of education, 33 % of the samplein Mchinji had accessed secondary education compared to only 10 % in Mangochi. Furthermore, 24 % of the respondents in Mangochi had no formal education compared to only 8 % in Mchinji. This is consistent with the most recent Malawi Population and Housing Census report (Government of Malawi, 2018) which revealed that Mangochi district still has the lowest literacy rate in Malawi at 53 %. In Mchinji, 63 % of the respondents were self-employed compared to 55 % in Mangochi.

2.3. Data collection

Data collection was held between April and November 2019. We employed three data collection methods which are household survey interviews, focus group discussions (FDGs) and key informant interviews (KIIs). Household survey interviews involved the household head or any adult member of the selected household in the absence of the household head. A single semi-structured household questionnaire which comprised of closed questions to collect both qualitative and quantitative data that responded to the study objectives systematically was used in household surveys. In addition, eight (8) focus group discussions (FGDs) were conducted using a checklist. Participants in these

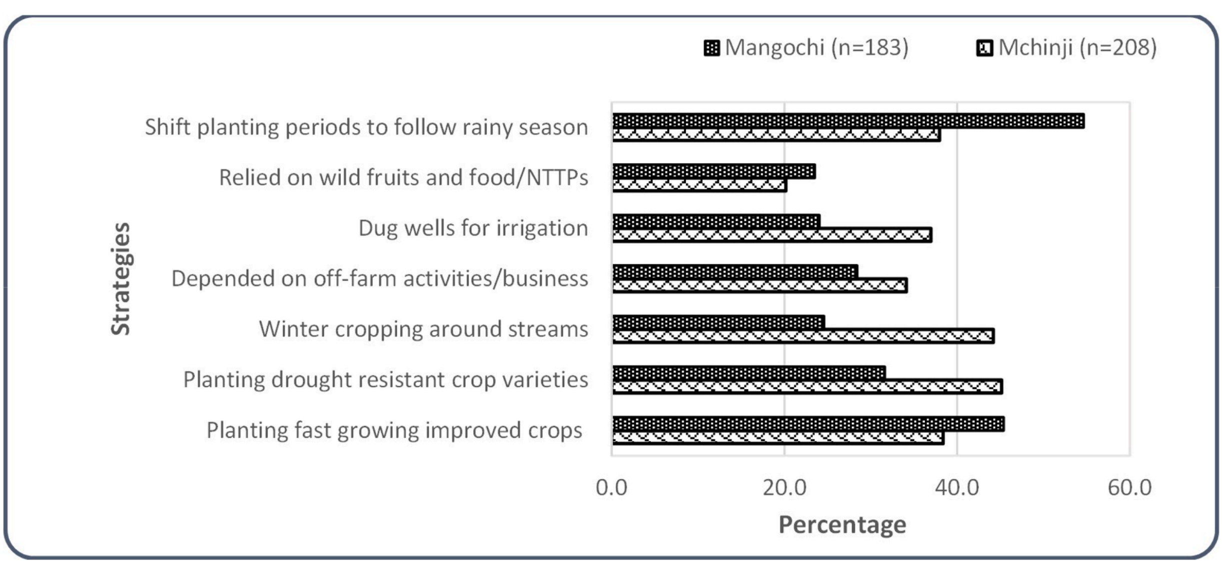

Fig. 3.2. Coping strategies dealing with erratic rainfall.

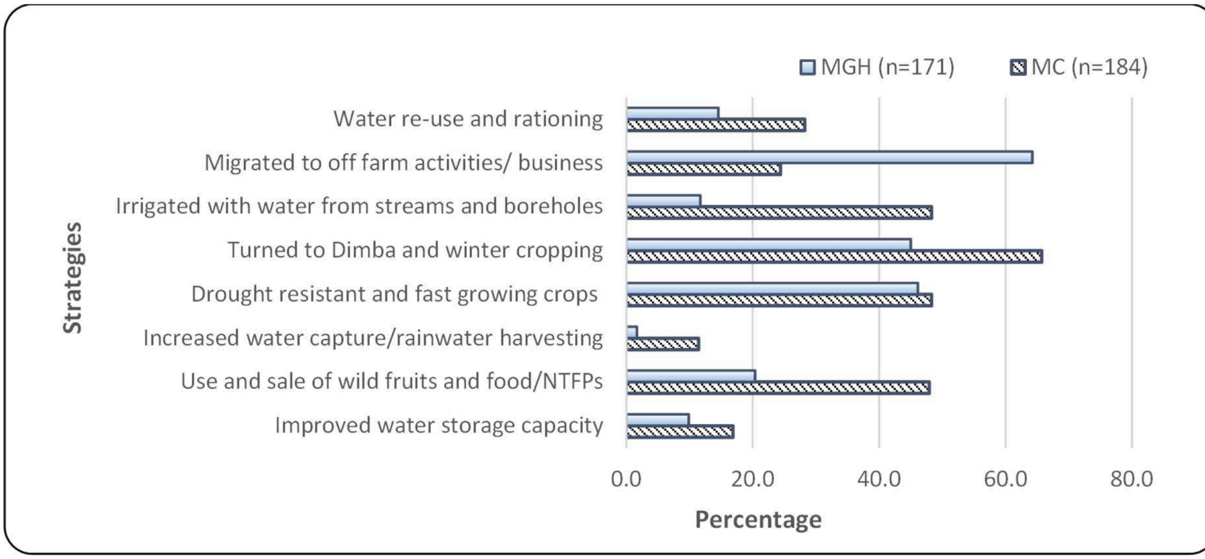

Fig. 3.3. Coping strategies dealing with serious droughts.

FGDs were drawn from the Area Development Committees (ADCs) at the Traditional Authority level and the Village Natural Resource Management Committee (VNRMCs) members at the forest reserve level. The number of participants in the FGD meetings ranged between 6 and 12 people. FGDs collected qualitative data which was used to triangulate quantitative data collected through household surveys. Finally, sixteen (16) KIIs were held during the period of data collection. The KIIs involved the District Forestry Officers, District Development planners, Agricultural officers, climate and disaster management specialists at the district, the Director of forestry, the Group village heads, the Forestry assistants and forest guards and patrolmen.

2.3.1. Adaptive capacity assessment framework for the study

To examine and understand how the adaptive capacity of the rural communities varied across the study communities, an adaptive capacity framework (Fig. 2.2) was developed taking into consideration the guidelines for the sustainable livelihood assessments (SLA). Here the questions asked included assessing the socioeconomic factors that enhanced or constrained their household adaptive capacity (Senganimalunje et al., 2022).

2.4. Data analysis

We computed frequencies and conducted Pearson chi-square tests, and binary logistic regression tests in analyzing the data. The applicability of binary regression model (goodness of fit) on the data was tested using the Hosmer-Lemeshow and Pearson Chi-square tests. Qualitative data collected through FGDs and KIIs were analyzed using content analysis. We used Binary logistic regression models to analyze the influence of social economic resources, human capital, and institutional resources on the choices of the household on coping strategies and challenges faced. The predictor variables of the collected data were categorical, which satisfied the preconditions for employing Binary logistic regression analysis. To ascertain the strength of the association or

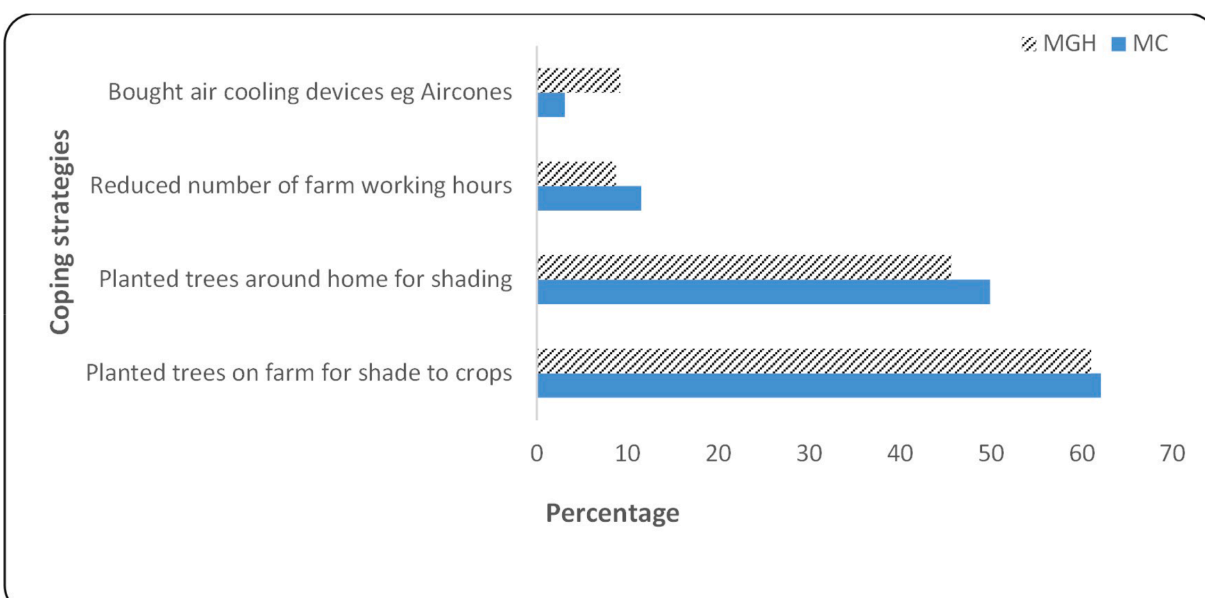

Fig. 3.4. Coping strategies dealing with serious high temperatures.

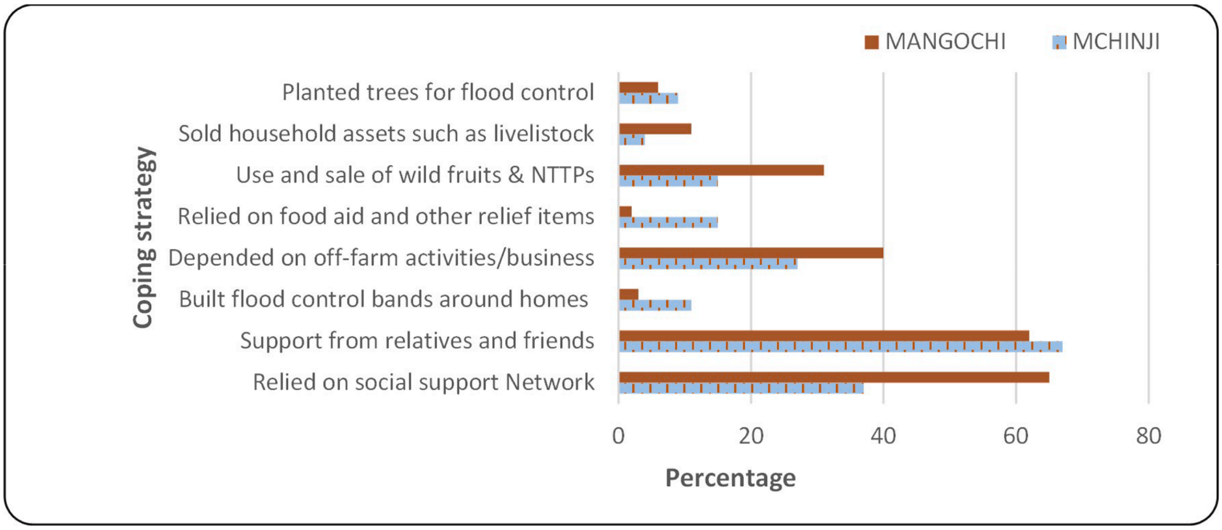

Fig. 3.5. Coping strategies dealing with floods.

non-independence between the two binary data values, odds ratios were employed. The results were deemed as statistically different at 95 % confident interval.

In the binary regression analysis, satisfaction with social and institutional resources were coded as a binary choice model with the assumption that respondents were "*satisfied*" or "*not satisfied*" with social resources in their locality. Satisfaction with social and institutional resources were dependent variables in the model. Similarly, human capital which was assessed through education level was framed as binary "*educated*" or "*not educated*" and formed the dependent variable. Explanatory variables are presented in Table 2.1.

Let Ti represent a dichotomous variable that equals 1 if respondents are satisfied with social, institutional resources, and human capital in the communities, and 0 if not satisfied. Thus, the probability of being satisfied were in each case, Pr ($Ti = 1$), which is the cumulative density function F evaluated at $X_i\,\beta$, where Xi is a vector of explanatory variables and β is a vector of unknown parameters. We modelled the cumulative density function using the following logistic probability function:

$$\Pr(Ti = 1) = \frac{\exp(Xi\ \beta)}{1 + \exp(Xi\ \beta)} \qquad \text{(Equation 2)}$$

We analyzed social resources, human capital, and institutional resources separately. In regards to social resources, community satisfaction with social support groups was employed. Institutional resources in this study considered satisfaction with water supply system and communication services. Similarly, human capital was assessed based on the level of education of the respondents.

3. Results

3.1. Coping strategies dealing with climate change and weather extreme events

3.1.1. Coping strategies dealing with erratic rainfall

The study has showed seven commonly adopted coping strategies to alleviate the impacts of erratic rainfall by forest dependent households in the study sites (Fig. 3.2). Shifting the planting periods to coincide with the rainy season was the most preferred coping strategies recorded which scored highest in Mangochi (54.7 %, n = 183) compared to Mchinji (38 %, n = 208) to cope with erratic rainfall effects. These results were statistically significant between the study site ($p = 0.000$, X^2= 11.4, DF=1). Although planting improved fast growing crops scored 45

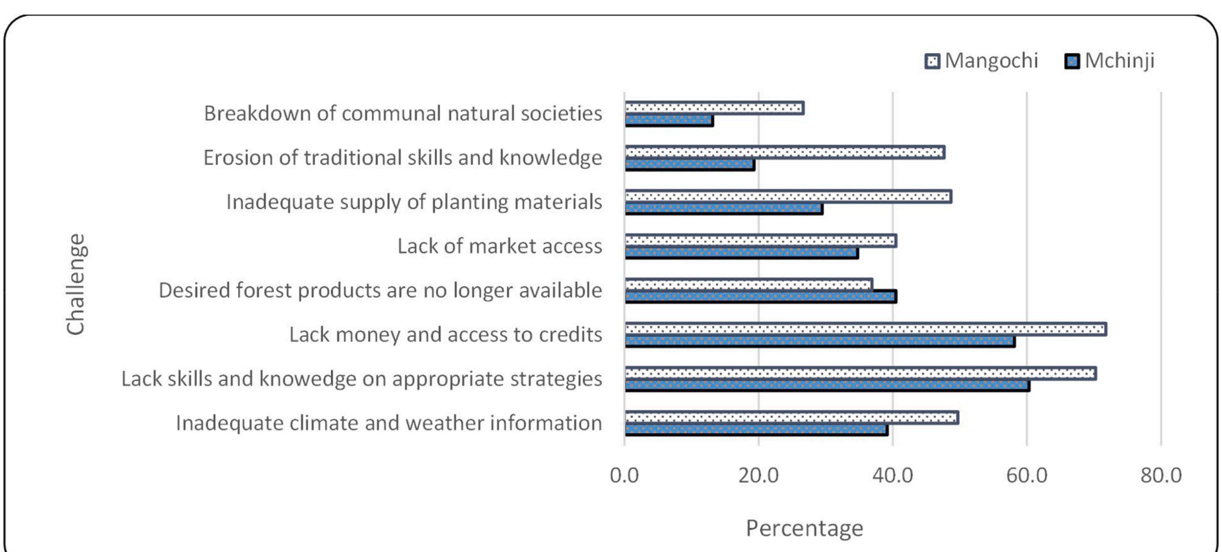

Fig. 3.6. Challenges faced by forest residents in adopting coping strategies.

Table 3.2
Social institutional factors influencing household adaptive capacity.

Attribute of adaptive capacity	Responses	Proportion of respondents%		Statistical results	
		Mchinji (n = 227)	Mangochi (n = 195)	X^2	P-value
Water supply services	Very dissatisfied	28.8	24.7	61.3	0.000
	Dissatisfied	11.5	37.6		
	Satisfied	35.4	34.0		
	Very satisfied	24.3	3.6		
Market center access	Very dissatisfied	37.1	46.4	49.35	0.000
	Dissatisfied	25.0	43.8		
	Satisfied	20.5	7.7		
	Very satisfied	17.4	2.1		
Health care center Access	Very dissatisfied	37.0	45.1	37.7	0.000
	Dissatisfied	18.1	35.9		
	Satisfied	26.4	13.8		
	Very satisfied	18.5	5.1		
Communication services	Very dissatisfied	47.5	31.9	26.45	0.000
	Dissatisfied	14.0	14.1		
	Satisfied	29.9	51.8		
	Very satisfied	8.6	2.1		
Emergency services (police)	Very dissatisfied	50.0	52.3	13.37	0.010
	Dissatisfied	30.9	35.9		
	Satisfied	15.5	7.2		
	Very satisfied	3.6	4.6		

% (n = 183) in Mangochi and 38 % (n = 208) in Mchinji, the results were not statistically significant (p = 0.075, X^2=2.371, DF=1). Through Group Discussions and key informant interviews, forest dependent households identified hybrid-maize, beans, and water-melons as the fast growing and improved crops which were commonly grown and observed in the Dimba farms during the data collection. The most adopted coping strategies against erratic rainfall in Mchinji were winter cropping around streams and wells (44 %, n = 208), and planting drought resistance crop varieties (45 %, n = 208) such as cassava, soya beans, sorghum and sweet potatoes. Results further show that only 24 % (n = 208) and 25 % (n = 183) of the forest dependent households used forest products as coping strategy to erratic rainfall in Mchinji and Mangochi, respectively.

The results also showed through both KIIS and FGDS that forest dependent household were conversant with their local climate. However, it was also revealed during KIIs with the Mchinji District Development Agriculture Officer (DADO) that the use of fast growing and resistant crops acts as safety measure to enhance household livelihood resilience. He further indicated that its effectiveness is based on the household financial capacities and access to improved planting materials.

3.1.2. *Coping strategies dealing with droughts*

Results on the adopted coping strategies dealing with serious droughts (Fig. 3.3) reveal that the majority of households in Mchinji (66 %, n = 184) turned to *dimba* for winter cropping around streams and wells but this number was fewer than half in Mangochi (45 %, n = 171). The results were statistically significant between the study sites (p = 0.003, X^2 = 8.040, DF=1). Switching to off-farm activities as a coping strategy to drought scored highly in Mangochi (64 %, n = 171) compared to Mchinji (24 %, n = 184). However, the results were not statistically significant between the study sites (p = 0.143, X^2=1.402, DF=1). It was reported during KIIS and FGDs that most youths in Mangochi have migrated from their villages to urban areas and others even to work in South Africa.

3.1.3. *Coping strategies dealing with high temperatures*

In dealing with high temperatures, 62 % (n = 227) and 61 %, (n = 195) in Mchinji and Mangochi, respectively, responded by planting trees on their farms to provide shading to crops though the results were not statistically significant between sites (p = 0.465, X^2=0.038, DF=1). Similarly, a good proportion of forest residents responded by planting trees around homes to provide shading, 46 % in Mchinji and 50 % in Mangochi (Fig. 3.4). However, these results were also not statistically significant between the study sites (p = 0.284, X^2=0.447, DF=1). The results further show that less than 10 % of the respondents had reduced number of field working hours as a strategy to cope with increased high temperatures.

3.1.4. *Coping strategies dealing with floods*

The study records three major coping strategies commonly adopted in dealing with floods (Fig. 3.5). The results show that 67 % (n = 218) in Mchinji relied on the support from relatives and friends compared to 62 % (n = 184) in Mangochi. The results were statistically significant between the study site (p = 0.032, X^2=9.082, DF=1). Secondly, 65 % in Mangochi relied on the support from the social networks as compared to

Table 3.3
Influence of satisfaction with institutional services on coping strategy adoption.

Dependent variable	Independent variable	Odd ratio (95 %CI)	S.E	P-Value
Water supply services	- Plant drought resistant crops	2.004(0.987- 4.071)	0.36	0.049
	- Improve water storage capacity	4.157(1.235–13.99)	0.62	0.021
	- Increased water capture	0.176(0.35–0.900)	0.83	0.037
	- Reduced working hour on farm	0.157(0.42–0.586)	0.67	0.006
Communication services	- Shift planting periods	2.971(1.586–5.565)	0.32	0.001
	- Dug wells for irrigation	2.038(1.070–3.883)	0.33	0.031
	- Off-farm activities	2.805(1.5815.241)	0.32	0.001
	- Winter crops around streams	3.240(1.780–5.89)	0.29	0.000
	- Plant drought resistant crops	0.0312(0.162–0.60)	0.334	0.000
	- Use sale of wild fruits and food	4.517(1.654–12.34)	0.51	0.003

only 35 % in Mchinji ($p = 0.002$, X^2=8.436, DF=1). Thirdly, 40 % of the forest dependent households in Mangochi relied on off-farm activities compared to only 27 % in Mchinji. As regards to forestry, 31 % in Mangochi turned to use and sale of forest fruits and other non-timber forest products when impacted by floods compared to only 15 % in Mchinji.

3.2. The household perceived barriers or challenges on coping strategies

Fig. 3.6 shows the results on the challenges faced by forest dependent households in coping with the impacts of climate change. Lack of money and access to credit facility scored 72 % in Mangochi compared to 58 % in Mchinji. The results were statistically significant between the study sites ($p = 0.002$, $X^2 = 8.603$, DF = 1). The other common challenge was the lack of skills and knowledge for appropriate coping strategies scoring 70 % in Mangochi and 60 % in Mchinji ($p = 0.021$, X^2=4.518, DF=1). As regards to forest related challenges, 40 % in Mchinji compared to 37 % in Mangochi reported that most desired forest products are becoming scarce. However, these results were not statistically significant between the study sites ($p = 0.256$, $X^2 = 0.574$, DF= 1).

3.3. Household adaptive capacity attributes and adoption of climate coping strategies

3.3.1. Institutional resources

Institutional resources have a considerable effect on the households' adaptive capacity and climate coping strategy adoption. Our study recorded that most of the respondents both in Mchinji and Mangochi were dissatisfied with market access, health care services, and emergency /police services in their locations (Table 3.2). However, the results show that whilst 61 % were dissatisfied with communication services in Mchinji, 54 % of the forest-based households in Mangochi were satisfied with communication services. Both FGDs and our exploratory field observations revealed that in some areas around Ndawambe in Mchinji, it was difficult to access both mobile and radio network. Similarly, 59 % of the respondents in Mchinji were satisfied with water supply services whilst 61 % in Mangochi were dissatisfied. The Pearson Chi-square test results reveal that all these results were statistically significant at $p = 0.05$.

We then analyzed the relationship of household satisfaction with institutional resources such as water supply and communication facilities and the household choice of the climate adaptation and coping strategies (Table 3.3). The results show that household satisfaction with water supply facilities, doubles the likelihood of planting resistant crop varieties (OR= 2.004, CI= 0.987–4.071) and increases four (4) times the likelihood of using improved water storage capacity (OR=4.157, CI=1.235–13.99) as climate coping strategies. However, forest residents' satisfaction with water services was less likely attributed to the adoption of increased water capture, reduced working hours during high temperature. On the other hand, the satisfaction with communication facilities, increases the likelihood of respondents to adopt the use and sale of wild fruits and food. Similarly, the likelihood of adopting winter cropping around streams, using water ration, shifting planting periods to coincide with rainy seasons, tripled (3 times) with the satisfaction of households with communication facilities.

3.3.2. Social support

Results on the functioning social support groups operating in the studied communities are presented in Fig. 3.7. They show that more forest-based households are benefiting from the social support groups in Mchinji compared to Mangochi district. Results indicate that over 80 % of the forest dependent households accessed support from family and friends, and local community organizations in Mchinji district when affected by climate extreme events. On the contrary, only 45 % of the respondents in Mangochi accessed their support from the neighborhood. The results further reveal that less than 10 % of the forest dependent household in both study sites access food aid and relief items from government agencies. Focus group discussions confirmed that nowadays, government food aid and relief items are politicized and are accessible to a few politically connected households.

3.3.3. Human capital resource

Results from the analysis of the human capacity resource of the forest residents as attributes that influence choices of climate coping strategies are presented in Table 3.4. Human capital resources were framed and modeled from the level of education. In this case, respondents who accessed education were treated as having human capital resource. The results record that education more likely influenced the adoption of use and sale of non-timber forest products (NTFPs) (OR=8.547, CI=1.752–41.348), planting of drought resistant crops (OR=4.248, $P = 0.020$), and use of rainwater harvesting (11.36, CI=0.77–17.61) though its standard error was greater than one (1). On the other hand, education less likely influenced the planting of trees around homes (OR=0.585, CI=0.334–1.026), engagement in off-farm activities (OR=0.246, CI= 0.062–0.975), use of water rationing (OR= 0.132, CI= 0.034–0.503), and the planting of improved crops (OR=0.242, $P = 0.002$).

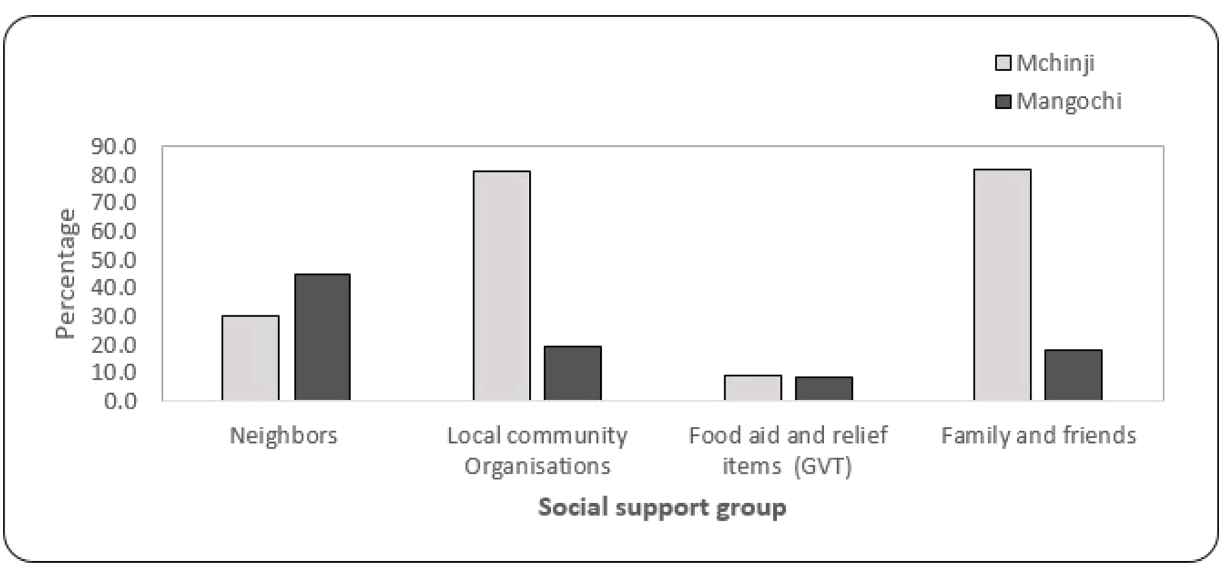

Fig. 3.7. Active social support groups in Mchinji and Mangochi.

Table 3.4
Influence of Level of education to the choice of coping strategies.

Coping strategies	Educational qualification		
	Odd ratio(95 % CI)	S.E	*P*-Value
Plant improved crops (Yes/No)	0.242(0.097–0.604)	0.44	0.002
Use water rationing (Yes/No)	0.132(0.034–0.503)	0.61	0.005
Use and sale of NTFPs (Yes/No)	8.547(1.752–41.348)	0.81	0.008
Plant drought resistant crops (Yes/No)	4.248(1.258–14.348)	0.54	0.020
Use rain-water harvesting (Yes/No)	11.36(0.77–167.61)	1.13	0.070
Engage in off-farm activities (Yes/No)	0.246(0.062–0.975)	0.70	0.046
Planted trees around homes (Yes/No)	0.585(0.334–1.026)	0.28	0.061
Irrigated crops using streams (Yes/No)	0.950(0.483–1.870)	0.35	0.883

4. Discussion

The study was set out to determine the adaptive capacity and the climate extreme coping and adaptation strategies amongst the forest-based households in Mchinji and Phirilongwe Forest Reserves in Mchinji and Mangochi districts, respectively. This section discusses the current results as they relate to the previous findings in Malawi and elsewhere.

4.1. Coping strategies dealing with climate change and weather extreme events

4.1.1. Coping strategies dealing with erratic rainfall and drought

The study has revealed several strategies employed in dealing with erratic rainfall. Winter cropping around wells and streams also referred to as 'Dimba cropping' or 'irrigation farming' was more confined in Mchinji as compared to Mangochi. This was confirmed with the observation on the ground which showed that the Phirilongwe area was so dry with little, or no rivers observed compared to Mchinji. Most fresh crops were observed growing along the streams and around wells such as fresh beans, maize, and Irish potatoes in Mchinji. These findings support the findings of (Mwase et al., 2014), and (Joshua et al., 2016) in Malawi, (Ofoegbu et al., 2016) in South Africa, and (Abid et al., 2015) in Pakistan. However, Ofoegbu et al. (2016) argued that winter cropping as a coping strategy towards climate change only works in a shorter term. If the climate change persists, all streams, rivers and wells may completely dry up rendering the strategy ineffective and not feasible. On the other hand, Joshua et al. (2016) also argued that irrigation farming triggers water conflicts amongst the communities over the control and ownership of the water resource. This calls for the proper definition of the water resources amongst the stakeholders in question although this is not a problem at present in the study site.

The study further supports the findings of Kalanda-Joshua et al. (2011) in Malawi and Ahmed and Shafique (2019) in Bangladesh which showed that indigenous people are familiar with their local climate and have their own ways of interpreting its changes. This helps them to detect the onset of the rainfall season hence assisting them to prepare for the crop planting activities. Our results further concur with the findings of Mwase et al. (2014), Abid et al. (2020) and Antwi-Agyei and Nyantakyi-Frimpong (2021) which revealed that adjusting the crop planting calendar is a key climate coping strategy to deal with the variation in the onset of the rainfall season. However, this strategy entails that farmers must be acquainted with the climate data to work effectively (Ofoegbu et al., 2016), which in most cases is not readily available at local level. The study findings also suggest that the use of fast-growing improved crops is key in adapting to erratic rainfall. These results corroborate the findings of the study by Mwase et al. (2014) in Chikwawa and Nsanje, Malawi, and by Ofoegbu et al. (2016) in Vhembe, South Africa. In Kenya, Ogalleh et al. (2012) also revealed that farmers were using fast growing maize in response to reduced rainfall season.

The other coping strategy that scored highly in dealing with erratic rainfall and droughts and was dominant in Mangochi was the migration to off-farm activities such as selling fish and opening hawkers to sell groceries. This was largely reported during FGDs in Mangochi that most youths have migrated from the villages to town and others even to work in South Africa. Although this strategy has worked in Mangochi, its effectiveness may be limited as the opportunity for sustaining off-farm activities in Mangochi is relatively low thus forcing many people in the district to emigrate to South Africa. Ofoegbu et al. (2016) argued that continued practice of off-farm activities may lead to rural-urban migration challenges which result in poor rural development. As such, there is need to promote social economic development of the rural communities to reduce the overreliance of the rural people on off-farm activities. However, these results contradict the findings of Suckall et al. (2017) in Malawi who reported that climate stresses typically do not change rural dwellers' aspiration to leave their homes, except for a small group of younger farmers from better off households. They further argue that climate stresses may erode human, financial, and social capital, thus reducing their migration capability. However, it has been speculatively established in some parts of Malawi such as Mzimba that most young men have emigrated to South to look for better opportunities. This has not solely been stimulated by climate stress but also other social factors.

The study suggests that forest dependent households scored badly on the use of rainwater harvesting as a strategy to curb erratic rainfall and droughts effects. This might be attributed to the level of poverty amongst the forest dependent communities. Studies have shown that rainwater harvesting is one of the most effective strategies in dealing with erratic rainfall and droughts although its effectiveness depends on the volume of storage tanks installed by the households (Abid et al., 2020; Ajani, 2013; Antwi-Agyei and Nyantakyi-Frimpong, 2021; Ofoegbu et al., 2016). However, it was observed in the current study that most of the forest dependent households relied on their large containers they owned and most of their houses were grass-thatched, thus not well-suited for harvesting rainwater. Respondents complained that the little water they do harvest only lasts for a few days, suggesting that irrigation as a coping strategy is not feasible to most of the forest dependent communities thus not effective during prolonged droughts. As observed by Tembo (2013) and Bryan et al. (2009), most African rural communities require access to credit to boost their coping and adaptation capacities. As such, for forest dependent households to fully adopt these technologies, they need external financial boost and proper trainings to enhance their technical capacities.

The use and sale of forest products as a climate coping strategy scored highly in Mchinji as compared to Mangochi in dealing with drought. Comparatively, this strategy scored low with other coping strategies assessed. However, it was observed during FGDs that their capacity to engage in sale and management of non-timber forest products is poor. These findings support the findings of Fisher et al. (2010), Chilongo (2014) and Senganimalunje et al. (2022) which revealed that forest products only act as safety nets and facilitate the resilience of forest based households towards climate shocks. Forest dependent residents claimed that they only engage in selling of non-timber forest products such as fruits, nuts, mushroom, and thatch grasses from their adjacent Forest Reserves. This contributes to their household income which assist them during and after hydro meteorological events such as droughts. However, tree planting was observed to be commonly implemented on their farms resulting in the increased tree cover outside forest in this area. Lin et al. (2019) opined that limited rural community participation in community forestry activities enhance socioeconomic benefits from community forestry by these communities.

4.1.2. Coping strategies dealing with high temperatures

Studies have established that high temperatures are perceived to pose varying consequences on the lives and the livelihoods of forest dependent residents (Chisale et al., 2021; Ofoegbu et al., 2016). As such various strategies are required to deal with the negative impacts of high temperatures. This study has shown that most of the forest dependent residents planted or retained trees around their homes and farms to provide shade against heat waves. As revealed during the data collection exercise, more trees of various species were observed outside the forest. Farmers reported that these trees provide shade which reduces soil moisture loss on farms and prevents them from heat waves during working hours. These results corroborate the findings of previous studies which established that tree planting outside forest is a common practice being employed in many developing countries (Mango and Akinifesi, 2021; Meijer et al., 2015; Ofoegbu et al., 2016; Ogalleh et al., 2012; Robledo et al., 2012; Skole et al., 2021). Robledo et al. (2012) revealed that local communities in Zambia, Mali and Tanzania employed tree planting as a way to protect the soils from drying out (sun heat) and to diversify agricultural products as additional strategy to cope with climate variability and change. Ogalleh et al. (2012) revealed that tree planting is a key strategy employed by farmers in Laikipia District of Kenya to provide shades against high temperatures.

In another study in Malawi, Meijer et al. (2015) reported that local farmers have positive attitude towards planting trees on their farms, leading to more trees outside forests. However, they further noted that farmers prioritized buying food, fertilizers and paying school fees over tree planting. This implies that these farmers consider tree planting as not a pressing issue compared to other more immediate household needs. Thus, there is need to address the farmers basic need to motivate them fully into tree planting, consistent with findings from other studies. Recently, Mango and Akinifesi (2021) assessed the perception of local communities in tree species selection to be used for on farms planting and found that fruit tree species were the most prioritized in trees for on-farm tree planting. Similarly, Skole et al. (2021) argued that trees outside forest are becoming key in forest assessment under REDD+ initiatives calling for consideration of these trees outside forest to benefit from REDD+ financing. This is another opportunity where trees outside forests can generate more financial benefit without being harvested.

4.2. Perceived challenges to coping strategies

Lack of money and access to credit facility and markets came up as the most common challenges affecting the adoption of climate coping strategies in this study. FGDs also established that most of the climate coping strategies require investment costs such as access to improved and drought resistant crop varieties and planting materials. With the lack of funds, forest dependent households could turn to credit institutions to borrow funds to be used as initial cost to implement these strategies. On the other hand, availability of markets could offer the opportunity for them to sale other available products to access these climate coping strategies (Abid et al., 2015; Antwi-Agyei and Nyantakyi-Frimpong, 2021; Nyashilu et al., 2023; Ofoegbu et al., 2016). However, credit institutions and markets access were not readily available within their localities. This was more pronounced in Mangochi compared to Mchinji. These challenges were previously reported in Malawi by Meijer et al. (2015), and Asfaw et al. (2014), in Ghana by Antwi-Agyei and Nyantakyi-Frimpong (2021), in Pakistan by Abid et al. (2015), and South Africa by Ofoegbu et al. (2016). Meijer et al. (2015) reported that poverty is a key barrier to tree planting as a key coping strategy in Malawi. This was affirmed by Asfaw et al. (2014) who reported that wealthier households were more likely to adopt both modern and sustainable land management (SLM) inputs; and are more likely to adopt SLM inputs on plots under more secure tenure. In Ghana, Antwi-Agyei and Nyantakyi-Frimpong (2021) reported inadequate credit facility and market access for the farmers' agriculture products as key challenges in adopting climate coping strategies. Recently, Pardoe et al. (2020) reported that one of the key barrier to climate adaptation planning in Malawi, Zambia and Tanzania is the ability of the countries to redefine he role of additional donor funding resources. This entails that financial resources play a vital role in planning for national adaptation programmes.

The other challenge which scored highly in this study was the inadequate knowledge and information about site-based and modern or improved coping strategies to be used to tackle the effects of extreme weather events. We established in this study that some of the strategies such as adjusting the planting dates to follow the rainfall seasons, required reliable and effective location-specific climate and weather data. It was also mentioned during FGDs that respondents lacked knowledge and skills to implement modern climate coping strategies such as switching to drought resistant and improved fast growing crop varieties. In addition, the erosion of traditional skills and knowledge in the younger generation has rendered them ignorant of the old ways detecting the weather changes and adaptation methods. This lack of knowledge to improve the coping strategies increases their vulnerability to the extreme weather effects (Ofoegbu et al., 2016). Various studies have also reported the insufficient knowledge as key issues in the implementation of climate coping strategies (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Makate et al., 2016; Nyashilu et al., 2023; Singh et al., 2018). It is therefore imperative to consider the packaging of climate information to target the forest dependent residents.

The study also established that the desired appropriate coping strategies such as planting materials, and forest products to be used as climate coping strategies are becoming scarce. People might have the knowledge and skills to implement the technology, but the inadequate supply of the materials to be used in implementing the strategy constrains its implementation. Chisale et al. (2021) reported the reduced availability of firewood, mushroom, thatch-grasses, and medicinal plants both in Mchinji and Phirilongwe forest reserves. Studies have shown that improved supply and access to forest products and planting materials are key to reducing the vulnerability of forest dependent residents (Abid et al., 2015; Antwi-Agyei and Nyantakyi-Frimpong, 2021; Mwase et al., 2014; Ofoegbu et al., 2016). This calls for improved supply of the planting materials and the domestication of the identified threatened forest products to improve the resilience of forest dependent residents.

The findings of this study also suggest that inadequate rural institutions constrained the selection decision for the coping strategies to be considered. Respondents in both study sites were observed to be more individualistic in their approach towards otherwise communal issues. For example, during data collection, we noted that there was no deliberate effort to form committees to lobby for their involvement in the management of their adjacent forest reserves. In addition, it was revealed during group discussions that the problems they used to address communally are now approached individually. Mwase et al. (2014) in Malawi, and Antwi-Agyei and Nyantakyi-Frimpong (2021) in Ghana, reported that rural communities respectively solved their financial problems by establishing Village Saving Loans (VSLs). Slowly traditional leaders were reported to have been losing control over their subject. This is dividing the people thereby increasing their exposure to climate and extreme weather events. Mwase et al. (2014) and Abid et al. (2015) reported that in Malawi, social capital, rural institutions and supply constraints are the main challenges facing the adoption of climate coping strategies. Elsewhere, Gyampoh et al. (2009) in Ghana, Robledo et al. (2012) in Mali, Tanzania and Zambia, Ofoegbu et al. (2016) in Vhembe, South Africa, and Abid et al. (2015) in Pakistan also reported that rural institutional committees are key amongst forest dependent communities to enhance their resilience against the effects of extreme weather events.

4.3. Attributes of household adaptive capacity

The study has further established that various household demographic characteristics of the forest dependent residents influenced the choice of the strategies they used. However, the variations in the adaptive capacity of the residents to respond to the adverse effects of climate and extreme weather events was found to be affected by such factors as institutional resources, social support, and household human capacity attributes as discussed below.

4.3.1. Institutional resources

Our findings suggest that household satisfaction with institutional resources such as water supply and communication facilities affected household choice of the climate adaptation and coping strategies. We recorded that household satisfaction with water supply facilities, doubles the likelihood of planting resistant crop varieties and quadruples the likelihood of using improved water storage capacity as climate coping strategies. However, forest residents' satisfaction with water services was less likely attributed to the adoption of increased water capture and reduced working hours during high temperature. The other institutional resources that dictated the choice of household coping strategy was satisfaction with communication facilities in the society. The satisfaction with communication facilities increased the likelihood of respondents to adopt the use and sale of wild fruits and food. Similarly, the likelihood of adopting winter cropping around streams, using water ration, shifting planting periods to coincide with rainy seasons increased with the satisfaction of households with communication facilities. Through both focus group discussions and exploratory field observation it was revealed that in some areas around Ndawambe in Mchinji, reception of both mobile and radio network was poor. These results support the findings of Ishaya and Abaje. (2008) and Ofoegbu et al. (2016) who opined that improving institutional facilities of a community positively influences the adoption of effective coping strategies amongst the poor. Furthermore, Rosati and Faria (2019) reported that the provision of improved institutional facilities such as communication facilities enhances the realization of the Sustainable Development Goals. In addition, Piper (2017) reported that provision of institutional resources reduces the migration potential of the rural communities to cities and contribute to the attainment of the Sustainable Development Goal number ten (10). This has recently been supported by McManus and Irazábal (2023) among the Venezuelans in Costa Rica.

4.3.2. Social support

Studies have shown that the reliance of social networks such as families and friends, neighbors and aid from government and local organizations are the common forms of social support accessed by rural communities in developing countries during natural disasters (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Juhola et al., 2016; Ofoegbu et al., 2016). Our study has shown that more forest dependent households relied on and accessed support from family and friends, and local community organizations in Mchinji district during climate extreme events. On the contrary, respondents in Mangochi accessed their support from the neighborhood. Access to food aid and relief items from government agencies was revealed to be insignificant by forest dependent household in both study sites. Our group discussion and exploratory interviews confirmed that nowadays, government food aid and relief items are politicized and are mostly accessible to a few politically connected households. These results corroborate the findings of Abman and Carney (2020) who argued that in the absence of well-defined subsidy eligibility criteria, access to government subsidized fertilizers is highly skewed towards individuals of the same ethnicity as the president as compared to areas with other predominant ethnicities in Malawi. These findings were also recorded in Ghana by Ajibade and McBean (2014). They argued that the effectiveness of social support from government and local organizations always depends on the access by all needy households which is not always the case. Otherwise, it is always attributed to raising gender and social injustice issues as they are politically influenced (Ajibade and McBean, 2014; Antwi-Agyei and Nyantakyi-Frimpong, 2021; Juhola et al., 2016). In contrast, Ajibade and McBean (2014) opined that the reliance of social networks and the selling of livestock and forest products may not address the underlying causes of climate vulnerability. As such, they argued that these practices only compromises farmers' adaptive capacities to address climate change effects.

4.3.3. Household social-economic capital resources

The results record that education more likely influenced the adoption of use and sale of non-timber forest products, planting of drought resistant crops, and use of rainwater harvesting. This might be because education capacitates people with knowledge and skills of rainwater harvesting, forest products marketing, and the use drought resistant crops to cope with climate effects. These findings corroborate the findings of David et al. (2007) and Ofoegbu et al. (2016) who opined that adequate human capital resources enhance effective adaptive capacity to climate change. The study further suggests that education less likely influenced the planting of trees around homes, engagement in off-farm activities, use of water rationing, and the planting of improved crops. It might be opined that education does not affect certain behaviors of forest dependent communities. Some behaviors are inborn such as tree planting around their farms and homes. Meijer et al. (2015) reported that forest dependent communities naturally have the positive attitude towards tree planting.

5. Conclusion

Climate change presents significant threats against the sustainability of forest-based livelihoods. This study analyzed the determinants of adaptive capacity and the coping and adaptation strategies of forest residents in Malawi in response to climate related extreme weather events. Challenges affecting the successful implementation of the climate coping strategies among forest-based residents were also explored. The study established that forest dependent households have always employed different adaptation and coping strategies during different climate extreme events over the years. Planting drought-resistant and fast-growing plant species, winter cropping around streams and wells, shifting crop planting periods to coincide with rainy seasons and switching to off-farm activities were the key adaptation and coping strategies employed by forest dependent residents against erratic rainfall and droughts. Forest dependent communities coped and adapted with high temperature effects by planting trees around farms and homes to provide shades. The lack of money and access to credit facilities and markets, inadequate knowledge and skills for appropriate adaptation strategies, inadequate effective and reliable climate and weather data, and the inadequate supply of the planting materials and forest products affected the implementation of climate coping and adaptation strategies. Community satisfaction with water supply facilities and communication services dictated the choice of the coping strategies employed in Mchinji and Mangochi. Furthermore, social supports and human capital also enhance the adaptive capacity of the forest dependent residents in Mchinji and Mangochi. We conclude that forest dependent households have used both coping and adaptation strategies against different climate extreme events. In addition, institutional services, social networks, and human capital resources dictate the choice of coping and adaptation strategies against climate related extreme events. We therefore recommend for more sustainable and transformative adaptation and coping strategies that can withstand the projected climate change for the forest dependent residents.

Ethics statement

The authors declare that the data collection protocols and all research work leading to this manuscript was approved by the University of Pretoria Ethical Committee (Reference: 180000126).

CRediT authorship contribution statement

Harold L.W. Chisale: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Writing – original draft. **Paxie W. Chirwa:** Resources, Supervision, Writing – review & editing. **Judith Francesca Mangani Kamoto:** Project administration, Resources, Supervision, Writing – review & editing. **Folaranmi D. Babalola:** Resources, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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