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Assessing the Effects of Extreme Weather Events on Farmers' Income in the Rural Areas of Nsanje District, Malawi

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Abstract

In Malawi, rural households that rely on rain-fed agriculture for livelihood face income loss due to frequent extreme weather events as a result of the changing climate. This study examines the impact of extreme weather events on farmers' income, followed by the evaluation of their perceptions and coping strategies in the rural areas of Nsanje district, Malawi. Primary data was collected through a structured questionnaire survey of 385 randomly selected farmers and was analyzed through descriptive statistics and regression techniques. The results revealed that farmers perceived increased frequency of floods, droughts, and heavy rains. Furthermore, droughts and floods frequency negatively affect farm income, while the age, educational level, off-farm employment, farm size, access to credit, and the use of irrigation positively impact farm income. Farmers adopted to doing *ganyu* labour, crop diversification, planting crops early, planting drought-tolerant varieties, and planting crops adapted to waterlogging as key ex-ante adaptation strategies to reduce the negative effects of extreme weather events. Farmers adopted doing *ganyu* labour, borrowing money, crop diversification, changing eating patterns, receiving remittances, and planting early as key ex-post climatic risks coping strategies. We recommend the improvement of early warning systems, implementation of income diversification activities, and an increase in access to rural credit in order to boost household capacity to cope with extreme weather events.

Subject Areas

Agricultural Productivity, Climate Change Adaptation

Keywords

Extreme Weather, Perception, Coping Strategies, Farmers, Malawi

1. Introduction

Rain-fed agriculture remains the main source for food production and livelihoods in rural Malawi, where approximately 85% of the population resides [1]. The high dependence on rain-fed agriculture for food security and income exposes the farming households to extreme weather events such as floods, droughts, storms, and heavy rains [2]-[5]. Extreme weather events often result in agricultural losses through poor harvests and crop failures with ensuing effects on agricultural productivity, food security, and livelihoods in affected areas [6]-[10]. Over the past two decades, Malawi has witnessed several extreme weather events such as floods, heavy rains, and droughts as a result of a changing climate [10] [11]. As variations in rainfall and temperature continue, annual rainfall is anticipated to increase by more than 45 - 60 mm by 2050 in Malawi [12]. Similarly, the country's annual average temperatures are projected to increase by 1˚C - 3˚C by 2060, and with a likely increase in drought risks [13]. This vulnerability to extreme weather events is partly due to the country's location around the Great African Rift Valley, bourgeoning population, environmental degradation, rapid deforestation, underdeveloped farming technologies, and unsustainable urbanization patterns [14]. Generally, the most common extreme weather events affecting the country include floods, heavy rains, and droughts. For instance, in March of 2023, Tropical Cyclone Freddy hit the southern part of Malawi. This led to heavy rains and severe flooding, which destroyed over 200,000 hectares of agricultural land [15]. Also, in March of 2019, Tropical Cyclone Idai hit the Mozambican city of Beira and moved across to neighboring countries (Malawi and Zimbabwe). This led to severe flooding along the southern and central regions of Malawi. This cyclone destroyed an estimated 71,000 hectares of cropped land [16] [17]. The frequency and severity of extreme weather events are pushing rural households, especially smallholder farmers, into poverty in Sub-Saharan Africa [18]. Therefore, in the absence of measures to lower the vulnerability of the rural households to extreme weather events, agricultural productivity is likely to have huge long-term adverse effects [19]. However, the extent to which extreme weather events could affect a farming household's food and income needs is dependent on its adaptive capability. This adaptive capacity involves the interventions and adjustments that occur in order to take advantage of the opportunities or to manage the losses that result from extreme weather events [20] [21]. As such, households that may diversify income sources could have a better survival measure when there is crop failure due to extreme weather events.

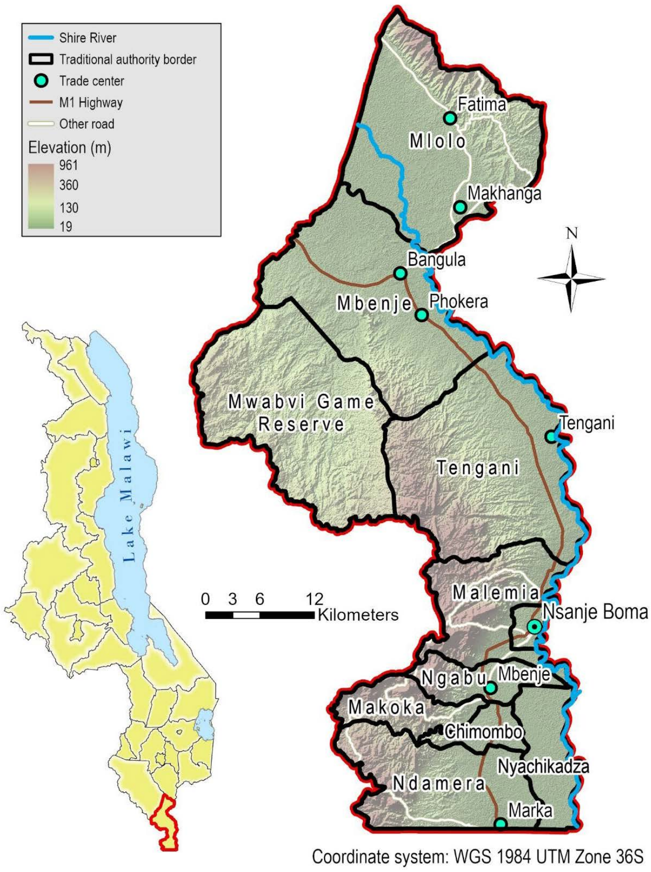
Globally, studies have shown the negative effects of extreme weather events on farmers' income. For example, in Zambia, [22] found that farming households affected by drought had a decrease in farm income by 37%. The observed household strategies included livestock diversification, income diversification, and the adoption of agroforestry. Meanwhile, in Kenya, [23] indicated that droughts reduced farm income per capita by 29%. Household and community characteristics such as access to credit, membership in a savings group, and diverse income sources enable the household to be resilient. Elsewhere in Pakistan, [24] showed that flood and drought decreased farm income by 33.1% and 10.6%, respectively. Selling assets, relying on aid, reducing expenditures, changing occupation, consuming savings, relying on loans, improving facilities, changing crop varieties, and changing working timings were the observed households' coping strategies. In rural Ethiopia, [25] found that drought had a severe effect on crop income. Relatedly, in the Semi-arid zone of Benin, [26] observed that floods reduced household agricultural income by 1.44%. The study proposed the introduction of water-resistant species as a household adaptation strategy against floods. [27] revealed that drought reduces farm income amongst men in rural Tanzania.

In Malawi, studies have addressed the impacts of extreme weather events on agricultural income. For instance, [28] observed that farming households who experienced drought had a large decline in agricultural income per hectare by 17.6%. The study suggested that farmers can safeguard farm income loss by diversifying crops and planting more drought-resistant crops. Similarly, [4] found that drought led to between 42 and 44% reductions in the value of agricultural income per hectare. Meanwhile, the flood reduced the value of agricultural income per hectare by 58%. Coping strategies such as legume intercropping provided protection against both floods and droughts, while green belts provided protection against floods. Likewise, [29] indicated that severe flooding reduced the value of agricultural income per hectare by 52%. Also, [30] observed that the majority of households had a decline in incomes in the Shire River Basin due to extreme weather events. Furthermore, [5] found that 1% increase in the exposure to drought decreased the value of agricultural income by 24.1%. However, previous studies did not assess the impact of extreme weather events on farmers' income, perception, and adaptation strategies, considering the rural areas of Nsanje district in Malawi. This study bridges that knowledge gap as it examines the impacts of extreme weather events on farmers' income, followed by assessing the perceptions and identifying the coping strategies used by farmers to safeguard income loss. This baseline information could help improve and support agricultural policies, which may increase the resilience of smallholder farmers to extreme weather events. It may also enhance effective collaboration between the government, the private sector, international research organizations, and development partners in creating special adaptation measures that would boost smallholder farmers' resilience to extreme weather events.

2. Materials and Methods

2.1. Description of Study Area

Nsanje is the southmost district of Malawi and lies in the Lower Shire River Valley, which is the most disaster-prone area of the country. The Valley, almost entirely, lies below 100 m above sea level on the Great East African Rift Valley floor. The district is adjacent to Chikwawa district and Thyolo district in the east, while it is surrounded by Mozambique state in the west, south, and east. The district is spread over a total area of about 1942 km^2, and the population is estimated at over 299,168 inhabitants [31]. Nsanje district is home to two Traditional Authorities (TA). The TA of Nyachikadza, a lowland community (wetland), and TA Ndamera, an upland community (dry-land) [32]. The majority of the population in the district is rural, with over 90% involved in agricultural activities, growing food crops (maize, millet, sorghum, rice, groundnuts, chili pepper, and cash crop (cotton) production [33]. Local communities are also engaged in other livelihood activities such as capture fishing from the Shire River, animal husbandry, petty trading, charcoal production, firewood, and grass (thatch) harvesting for sale. The cropping season runs from November to April. The district exhibits a subtropical climate with three distinct seasons: a cool and dry winter, which runs from May to August, a hot and dry season from September to October, and a warm and wet season from November to April. Mean annual temperatures range between $-3^\circ C$ and $-27^\circ C$. Annual precipitation ranges between 600 mm and 1200 mm.



Source: Sundqvist (2023).

Figure 1. Overview map of the study area.

2.2. Data Collection

Using a participatory research approach, data were collected between October and December 2023. The approach involved administering individual semi-structured questionnaires. The household was the basic unit for research within each of the villages. This was through a door-to-door survey; no criteria were set for the selection of households to be assessed in each village. As such, the interviews were conducted individually; participation was random, regardless of the participants' level of education or occupation. The individuals were interviewed by research assistants, who had prior knowledge of the study area. In instances where potential participants were unable to read and understand English, the Chichewa and Sena dialects were used by the research assistant to ensure proper understanding. Chichewa and Sena are the widely spoken languages in the study area. Traditional leaders, government, NGOs staff, and other opinion leaders working in the study area were purposively selected and interviewed. The information from this group (key informants) was primarily used to clarify areas that needed some explanation. For this reason, the questionnaires for farmers and key informants were similar. Before interviewing the farmers, the research team had to consult government officials in the area for official permission. A total of 385 interviews were conducted in the TA of Ndamera and Nyachikadza villages (a total of ten villages were visited). The survey collects information on household characteristics, value of agricultural output, agricultural assets, non-farm income-generating activities, access to credit, livestock owned, and use of irrigation. The dataset also contains information on climate shocks experienced by households and the coping strategies.

2.3. Analytical Methods

Descriptive statistics and multiple regression models were used to analyze the data. The *Stata* statistical package was used for the multiple regression models to estimate the impact of extreme weather events on farmers' income. The multiple regression models were employed because they consider the linear relationship between one dependent and two or more independent variables, Equation (1), [34].

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_k X_{ki} + \varepsilon_i \tag{1}$$

where, Y_i is the dependent variable and X_i is the set of independent variables. The parameter β_1 gives the log odds of the dependent variable and β_0 is a constant. ε_i is the error term. Here, the dependent variable is the farm income. As defined by [24], it is the sum of all incomes from agricultural activities, encompassing revenue from selling crops, livestock, and rent from agricultural land, farm machinery, and agricultural wages. In Equation (1), endogeneity may be a problem due to the endogenous nature of some of the explanatory variables. ε_i is the error term for which a strict exogeneity condition is assumed to hold. Errors are independently and normally distributed with zero mean and constant variance. The value of one variable is not affected by any other variable in this model at any time. Therefore, for this study, the multiple regression model used for estimation is given in Equation (2).

$$Y_i = \beta_0 + \beta_1 \text{AGE} + \beta_2 \text{EDUC} + \beta_3 \text{HS} + \beta_4 \text{NFA} + \beta_5 \text{FS} + \beta_6 \text{FM} + \beta_7 \text{AC} + \beta_8 \text{ES} + \beta_9 \text{IRG} + \beta_{10} \text{TLU} + \beta_{11} \text{HR} + \beta_{12} \text{DD} + \beta_{13} \text{FF} + \varepsilon_i \quad (2)$$

The description of the variables used in the regression model, along with their expected signs, is given in Table 1. The explanatory variables have been selected on the basis of insights from the relevant literature and the ground realities of the study area. The use of irrigation was included in the regression model because it enhances agricultural productivity, thus crop income. Furthermore, it can serve as a coping strategy against drought impacts by increasing crop yields and resilience in the face of changing conditions. However, in this article, we considered the variable as one of the determinants of the value of agricultural output, not as a coping strategy. Extreme weather events reduce the income of farming households; as such, we do not include the variable as a coping strategy. This is because most farming households lack the financial resources and knowledge to apply irrigation systems [35] [36]. For the variable of weather shock, the study relied on subjective reports of measures of extreme weather events experienced by households. The study considered whether a household experienced flood, drought, and heavy rains during the 2022/2023 cropping season as indicators of climate risks. Therefore, households that reported having been affected by floods, droughts, and heavy rains during that period were considered for analysis, as described by [37] and [38].

Table 1. Description of variables and expected sign with the response variable.

Variable	Description	Expected Signs
Y_i	Total annual farm income of the farming household in Malawian Kwacha	
AGE	Age of household head in years	+
EDUC	Number of years of schooling of the farmer	±
HS	Size of household—total number of household members	±
NFA	Dummy takes the value 1 if the farmer engaged in any non-farm employment and 0 otherwise	±
FS	The farm size in hectares	+
FM	Dummy takes the value 1 if the farmer uses any farm machinery and 0 otherwise	+
AC	Dummy takes the value 1 if the farmer had access to credit and 0 otherwise	+
ES	Dummy takes the value 1 if the farmer accesses agricultural extension services and 0 otherwise	+
IRG	Dummy takes the value 1 if the farmer uses irrigation and 0 otherwise	+
TLU	Total livestock units owned by the farmer	+
FF	Dummy takes the value 1 if the farmer experienced floods and 0 otherwise	−
DD	Dummy takes the value 1 if the farmer experienced drought and 0 otherwise	−
HR	Dummy takes the value 1 if the farmer experienced heavy rains and 0 otherwise	−

3. Results

3.1. Descriptive Statistics of Variables

Table 2 presents descriptive statistics for socioeconomic variables, with an average age of 38.22 years and an average household size of 4.28 members. Meanwhile, farmers had on average 3.72 years of education and a farm size of 0.89 hectares. Also, the average farm income was 11576.16 Malawi Kwacha (MWK), and 13% of the farmers used irrigation. Further analysis found 37% engaged in non-farm employment and 18% had access to agricultural extension services.

Table 2. Descriptive statistics of socioeconomic and shock variables.

Variable	Mean	Std. Deviation
Farm income (Malawian Kwacha)	11576.16	26741.82
Gender of the farmer	0.57	0.50
Age of the farmer	38.22	16.48
Years of schooling	3.72	5.50
Size of household	4.29	1.92
Non-farm employment	0.37	0.48
Farm size	0.89	0.19
Use farm machinery	0.20	0.40
Access to credit	0.08	0.27
Access extension service	0.18	0.39
Irrigation application	0.13	0.50
Number of livestock owned	4.17	1.26
Experienced floods	0.83	0.38
Experienced drought	0.17	0.38

Note: 2019 exchange rate was 1 USD = 789 MWK.

3.2. Farmers' Perceptions about Extreme Weather Events

About 88.3%, 8.1% and 3.6% of the farmers had perceived an increase, a decrease, and no changes in flood frequency. Similarly, 76.1%, 19.1% and 9.8% had perceived an increase, decrease, and no change in drought frequency, respectively. Also, 20.5%, 68.3%, and 11.2% thought the frequency of heavy rains had decreased, increased, or remained unchanged (Table 3).

3.3. Household Adaptation Strategies

Here, the household adaptation strategies included measures adopted before (ex-ante) and after (ex-post) the occurrence of the different extreme weather events. As seen in Figure 2, farmers adopted a number of measures before the occurrence of extreme weather events. However, about 30% of the farmers did not take any actions in advance to cope with climatic risks. The majority of the farmers did more *ganyu* labour.

Table 3. Perceptions of the farmers on weather shocks in the past ten years.

Variables	Variability	Frequency	Percentage
Flood frequency	Increase	340	88.3
	Decrease	31	8.1
	No change	14	3.6
Drought frequency	Increase	293	76.1
	Decrease	58	19.1
	No change	34	9.8
Frequency of heavy rains	Increase	263	68.3
	Decrease	79	20.5
	No change	43	11.2

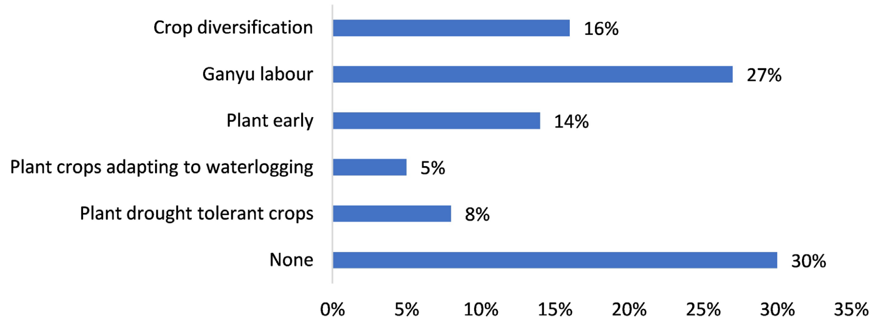


Figure 2. Ex-ante coping strategies.

The adoption of coping strategies to climatic risks after the occurrence of extreme weather events (ex-post adaptation) is presented in Figure 3. The main farming household ex-post measures included *ganyu* labour, borrowing money, crop diversification, changing eating patterns, receiving remittances from friends/family, and planting early.

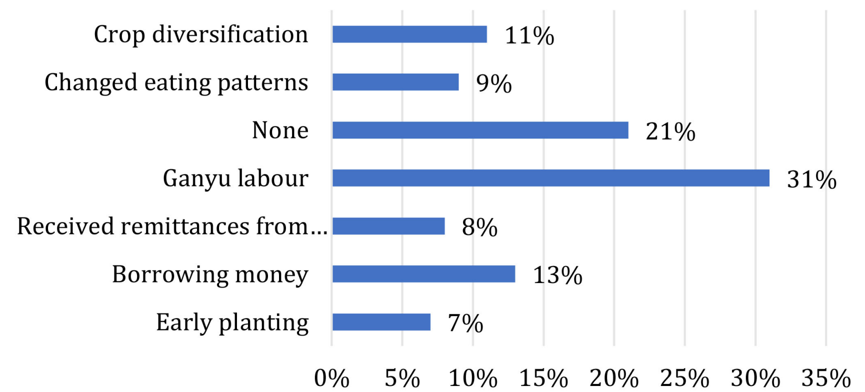


Figure 3. Ex-post adaptation strategies.

Ganyu labour is a kind of off -farm work done by individuals on a casual basis [39]. The key ex-ante adaptation mechanisms adopted by farming households in the study area were *ganyu* labour, crop diversification, planting crops early, planting drought-tolerant varieties, and planting crops adapted to waterlogging.

3.4. The Impact of Extreme Weather Events on Farm Income

In Table 4, the findings indicate that the occurrence of droughts and floods has a significant and negative impact on farm income. This study also found a significant and negative relationship between household size and farm income. Furthermore, results show that there is a positive and statistically significant relationship between farm income and non-farm employment. Non-farm employment is economic activities not related to agriculture. Additionally, applying irrigation, years of schooling, access to credit, and farm size have a significant positive impact on the farm income.

Table 4. Regression results of the determinants of farm income.

Variables	Coefficients	Standard Error	t-Values	P Value
Age of the farmer	0.003*	0.006	0.42	0.093
Number of years of schooling	0.106***	0.093	1.14	0.007
Household size	−0.166*	0.552	−0.30	0.064
Non-farm employment	0.453**	0.221	2.05	0.042
Farm size	0.016**	0.067	0.24	0.039
Use of any farm machinery	0.034	0.191	0.18	0.333
Access to credit	0.063***	0.020	3.09	0.002
Access to extension services	0.121	0.278	0.44	0.663
Use of irrigation	0.232***	0.230	1.33	0.005
Total livestock units (TLU)	0.097	0.176	0.55	0.541
Heavy rains	−0.117	0.211	−0.55	0.582
Flood	−0.196*	0.205	−0.96	0.067
Drought	−0.406***	0.580	−0.70	0.000
Number of observations	385			
R-squared	0.660			
Adjusted R-squared	0.198			
Constant	12.455***	2.637	4.72	0.000

Note: ***, **, *indicate significance of estimated coefficient at 1%, 5%, and 10% levels of probability, respectively.

4. Discussion

4.1. Household Coping Strategies

Majority of the farmers did not adopt any strategy before the occurrence of the climate risks. The reason behind this was that they had limited information about the occurrence of specific types of extreme weather events. In addition, farmers lack financial resources that restrict them from adopting adaptation measures in advance. These findings are in line with the findings by [8], who observed that a lack of finance and limited warning information on the occurrence of specific extreme weather events restricted farmers from taking action in advance. The major *ex-ante* adaptation strategies included doing *ganyu* labour, crop diversification, planting crops early, and planting drought-tolerant varieties. However, farmers adapted to crop diversification, doing *ganyu* labour, and planting crops early as both ex-ante and ex-post adaptation measures. Crop diversification provides the farming households with a broader choice of growing a variety of crops within a given farmland. [40] also found that crop diversification expands production-related activities on various crops, reduces the possible risk of climate variations, and permits farmers to change crop types that are better suited to the prevailing climate regimes. Farming households did more *ganyu* labour in order to protect and prepare their crops from the extreme weather events. *Ganyu* labour is an important household buffering mechanism in response to low farming household income, especially in the case of low crop yields. According to [40], this practice ensures a constant flow in a household's off-farm income, which buffers the impacts of climate risks on income. Furthermore, farming households that forecasted drought based on their previous experiences selected drought-tolerant crops. Many farmers who used drought-tolerant varieties posited that these varieties had a positive impact on their crop yield. This finding is in line with that of [41], who showed that farm households who were exposed to drought adopted drought-tolerant varieties. Farmers who have access to weather forecasting information often adjust to early planting of crops according to the occurrence of extreme events. [42] also reported similar findings. Another important *ex-post* measure was borrowing money, changing eating patterns, and receiving remittances from friends/family. Receiving remittances was able to minimize the negative effects on farming household income after the occurrence of weather events. Remittances are usually made by family members and other acquaintances who have temporarily or permanently migrated abroad or to a bigger town, or who live in the same location. According to [43], farming households that received remittances were able to offset the impacts of extreme weather events on agricultural income in the rural areas of Ghana. Farming households explained changing eating habits through either reducing the frequency of mealtimes a day. Some attest to reducing the quantity of each meal and skipping meals. Similar findings were reported by [44], who revealed that farm households changed their eating patterns as a coping strategy against climate risks in Southwestern Ethiopia. Also, borrowing money was found to be another strategy adopted by farmers to cope with extreme weather events. The source of borrowing money is mostly informal and entails relying on family members and friends during an emergency. The use of informal credit is common due to limited access to formal credit facilities at the local level. [37] also found that borrowing money was a household adaptation measure to buffer the effects of climate risks.

4.2. Effect of Extreme Weather Events on Farm Income

Being exposed to droughts has a negative and significant impact on agricultural income. This indicates that rising temperatures and changing rainfall patterns are detrimental to agricultural production, hence income. It may be due to the fact that higher temperatures and deficiencies in precipitation hamper crop growth. This usually occurs when rainfall does not meet crop moisture and soil water requirements, thereby reducing crop yields, thus the value of crop output. This result is in line with that of [45], who revealed that drought reduced crop yields due to inadequate water supply available for crop growth in the United States. With the application of irrigation systems, agricultural production losses could be reduced during a drought. Furthermore, floods had a negative influence on farm income. This is due to the fact that flood destroys and wash away crops and cropland. This finding is consistent with the work of [46], who also found that floods destroyed crop production of rural farmers in Northern Benin. The negative coefficient of heavy rains suggests that as heavy rains increase, farm income tends to decrease (an inverse correlation), which aligns with theoretical expectations that excessive rainfall can cause crop damage, soil erosion, rot of crops in the fields, extreme moisture content levels, and other problems. The positive and significant coefficient of access to credit signifies that an increase in credit improves a household's financial capacity to expand agricultural production. For instance, credit facilitates households to purchase and apply crop production inputs as well as to timely implement farm management decisions. This observation is in line with that of the study carried out by [47]. They revealed that credit availability plays an important role in agricultural production in rural Ethiopia. Still, from a financial viewpoint, farmers involved in non-farm employment had an increase in farm income per hectare. This is due to the fact that income from non-farm employment may be used to purchase farm inputs such as fertilizer and seedlings so as to augment agricultural production. This observation is related to that by [48], who postulated that income from off-farm employment assisted in the purchase of farm inputs such as fertilizer and seeds in Ghana. On the other hand, off-farm income can be used to finance irrigation systems during droughts. Implementing irrigation may boost crop yields, thus bringing higher returns to the farmer [49]. The number of years of schooling has a positive and significant correlation with farm income. This implies that an increase in the educational level enables the farmer to be more skilful in the search for information and the application of new techniques of farming [50]. An increase in the age of the farmer has a positive and significant impact on agricultural income. It may be due to the fact that older household heads have the required experience to cultivate more crops and adapt to climate change. Experienced farmers have equipped most farmers with various farm management practices and techniques that can be used to increase crop yields and, hence, farm income [51]. An increase in farm size has a positive and significant impact on farm income. This means that with an increase in farm size, revenues from crop production increase. This is due to the fact that an increase in farm size enables farmers to diversify crops. This finding is in line with [24], who found that an increase in farm size permits farmers to diversify crop systems. The increase in the household size has a negative impact on the farm income. When a household is largely composed of dependents, the production input on participating in most farming activities may be outweighed by other household expenses. This is due to the fact that the dependents do not assist in any agricultural activities. This observation is similar to that by [52], who found that household size affects its agricultural activities.

5. Conclusions and Policy Implications

In rural areas, agriculture, which is the main source of revenue for small-scale farmers in Sub-Saharan Africa, is vulnerable to extreme weather events due to climate change. This exposure to extreme weather events affects household incomes. This vulnerability is attributed to the high dependence on rain-fed agriculture for income and food security. This article examined the impact of extreme weather events such as floods, droughts, and heavy rains on farmers' income in the rural areas of Nsanje district, Malawi. The study also assessed the perceptions and the coping strategies employed by the households before and after the incidence of the extreme weather events. Using multiple regression models, the findings showed that droughts, floods, and household size have a negative impact on farm income. Further results of the study indicated that the use of irrigation, access to credit, non-farm employment, increase in the educational level, age of the farmer, and farm size have a positive impact on farm income.

According to the findings of the study, the majority of the farmers posited that the frequency of floods, droughts, and heavy rains increased over the last decade. With respect to the farming households' coping strategies, the study found that most farming households did not adopt any measures in advance. However, the main ex-ante measures include *ganyu* labour, crop diversification, planting crops early, planting drought-tolerant varieties, and planting crops adapted to waterlogging. Meanwhile, the key ex-post strategies were doing *ganyu* labour, borrowing money, crop diversification, changing eating patterns, receiving remittances from friends/family, and planting early. Based on the findings of this paper, it is necessary to encourage income diversification activities that could enhance the resilience of households. Also, the article recommends financial strengthening and increasing financing incentives at the farm and household level, such as rural credit, to assist farmers in improving productivity.

Conflicts of Interest

The authors declare no conflicts of interest.

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