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Impact of extreme weather events on agricultural production and household livelihoods in rural Malawi

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Abstract

Due to the high dependence of Malawians on rain-fed agriculture, frequent extreme weather events expose their rural farming households to droughts, floods, low agricultural production, and food insecurity. This study used fixed-effects regressions and panel data from the Malawi Integrated Household Panel Surveys (2010–2017) to assess the impact of extreme weather events on maize yield and value of agricultural output. Furthermore, the study adopted a Probit model to analyze the determinants of the households' choice of coping strategies. Using drought shock as an indicator for extreme weather events, results showed that 1% increase in the exposure to drought decreased the maize yield by 12.6% and the value of agricultural output by 24.1%. The results from the Probit analysis indicated that the age of the household head, level of education, increase in the dependency ratio, and access to extension services were the different determinants of the households' choice of coping strategies. Undertaking *ganyu* labor, receiving remittances, obtaining credit, selling household assets, and relying on own savings were the coping and effective coping strategies employed by households to offset potential income loss. The study recommends the implementation of income diversification activities, application of irrigation systems, improvement in livestock production, and increase in access to rural credit in order to improve household capacity to cope with extreme weather events.

Keywords: *extreme weather, rural households, agricultural production, adaptation strategies, Malawi*

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1. Introduction

Agricultural productivity remains the main source of livelihoods for rural households across Malawi, where approximately 85% of the population resides [1]. However, agricultural productivity faces the challenges of changing climate and small landholdings [2]. As most of the farming households highly rely on rain-fed agriculture for food security and incomes, these households are highly vulnerable to extreme weather events such as droughts and floods [3, 4].

Over the past two decades, Malawi, as other countries across southern Africa, has witnessed extreme weather events, especially variations in rainfall and temperature, which cause frequent droughts and floods [5, 6]. In addition, as variations in climate continue, the country will experience an estimated 20% increase in rainfall by 2090. Similarly, annual temperatures are expected to increase by 1.9°C in 2060 and with a likely increase in drought risks [7]. These extreme weather events partly result from the country being located in the great African Rift Valley, bourgeoning population, rapid deforestation, underdeveloped farming technologies, environmental degradation, and unsustainable urbanization patterns [6, 8].

Furthermore, the country has experienced 19 major floods and seven droughts. For instance, 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 [9, 10]. The Malawi Vulnerability Assessment Committee (MVAC) forecasted that over 2.8 million people (17% of the population) in 17 flood-affected districts were not able to meet their food requirements between April 2015 and March 2016. Meanwhile, approximately 6.5 million people (39% of the population) in 24 drought-affected districts could not meet their food needs during the April 2016–March 2017 period [11, 12].

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 is further determined by the households' socio-demographic characteristics including gender, age, educational level, access to extension services, and access to credit. This may likely be due to the fact that these

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characteristics often determine the households' access to appropriate adaptation strategies aimed at managing risks and adapting, before, during, and after extreme weather events [13]. According to Beckline et al. [14] and Ngoe et al. [15], 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. As such, households that may diversify income sources could have a better survival measure when there is crop failure due to extreme weather events.

Worldwide, studies have shown the negative effects of extreme weather events on agricultural productivity, farm income, and the adaptation strategies undertaken. For example, in Zambia, Alfani et al. [16] found that households affected by drought had a decrease in maize yields and income by 20% and 37%, respectively. The observed household adaptation strategies included livestock diversification, income diversification, and the adoption of agro-forestry. Meanwhile, Micheler et al. [17] espoused that drought reduced maize yields by 50%–80% in Zimbabwe. Conservation agriculture practices such as minimum tillage, mulching with crop residues, and crop rotation were the adaptation strategies employed by the studied households to lessen the negative effects of drought. In Kenya, Wineman et al. [18] indicated that droughts reduced crop income per capita by 29%. Household and community characteristics such as access to credit, membership of a savings group, and diverse income sources enable households to be resilient. Elsewhere in Pakistan, Hussain et al. [19] showed that the frequency of drought decreased the farm income by 10.6%. 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 adaptation strategies. In Nigeria, Amare et al. [20] found drought to have decreased agricultural productivity by 38% and with a severe impact on millet and maize productivity across the country.

In Malawi, studies have assessed the impacts of extreme weather events on agricultural productivity and incomes. For instance, Moylan [21] observed that farming households who experienced drought obtained a large decline in maize yields per hectare by 21%. This was accompanied by 17.6% loss in the value of the agricultural output per hectare. The study proposed that farmers can safeguard from farm income loss by diversifying crops and planting more drought-resistant crops. Relatedly, McCarthy et al. [4] found that drought led to 32–34% lower maize yields and between 42 and 44% reductions in the value of agricultural output per hectare. Meanwhile, flood reduced maize yields by 54% and the value of agricultural output per hectare by 58%. Adaptation strategies such as legume intercropping provided protection against both floods and droughts, while green belts provided protection against floods. Similarly, McCarthy et al. [22] indicated that severe flooding reduced the value of agricultural productivity per hectare by 52%. Furthermore, Coulibaly et al. [13] observed that the majority of households had a decline in agricultural productivity and incomes in the Shire River Basin due to extreme weather events.

In Malawi, rural households who rely on rain-fed agriculture for livelihood face persistent income loss due to extreme weather events. There is a lack of studies in Malawi that assessed the effect of extreme weather event vulnerability on rural households' agricultural productivity as well as the coping strategies. Most studies have not estimated the effectiveness of the coping strategies employed by the rural households using a panel data in Malawi. This article, therefore, aims at filling this gap in knowledge. In particular, the article not only analyzes the impact of extreme weather events on rural households' agricultural productivity but also explores the coping strategies that households employed, as well as evaluates the effectiveness of the coping strategies. More research studies are needed to identify the current coping strategies and to assess the effectiveness of these coping strategies to help determine how resilience can be improved before, during, and after a weather shock both at the national and community levels. The article demonstrates that rural households' coping strategies such as *ganyu* labor, receiving remittances, obtaining credit, selling assets, and relying on own savings were the most effective measures needed to safeguard them from agricultural productivity decline (as well as income loss) in rural Malawi. Therefore, this article attempts to identify the main effective coping measures, which can increase the farming households' resilience to the threats arising from extreme weather events both at the national and community levels in Malawi. Therefore, this baseline information could help improve and support agricultural policies which may increase the resilience of farmers to extreme weather events. It may also enhance an effective collaboration between government, the private sector, international research organizations, and development partners in enhancing the coping strategies that would boost farmers' resilience to extreme weather events.

2. Materials and methods

2.1. Description of study area

Malawi is a landlocked country located in southern Africa and lies between 13°30′ South and 34°00′ East. The country borders Zambia to the West, Mozambique to the Southeast, and Tanzania to the Northeast. The country is spread over a total area of approximately 118,484 km^2, and the population is estimated at over 18,143,217 inhabitants, made up of 28 districts and three regions. The capital and largest city is Lilongwe, while other cities include Blantyre, Mzuzu, and Zomba. The agricultural sector is the mainstay of the economy, employing over 80% of the country's total labor primarily dominated by smallholder farmers. The sector also accounts for approximately 40% of the country's Gross Domestic Product (GDP) and 83% of foreign exchange earnings [2, 23]. Moreover, smallholder farmers account for an estimated 78% of the cultivated land and generate approximately 75% of Malawi's total agricultural output [24]. Maize is the country's staple food, where over 60% of the arable land is allocated to its production, accounting for nearly 60% of national caloric intake [24, 25]. The country exhibits a subtropical climate with three seasons: a cool dry winter which runs from May to August, a hot and dry season from September to October, and the rainy season from November to April. The mean temperature ranges from 8°C in the northern highlands to 38°C in the lowlands of Lake Malawi and the Lower Shire Valley in the southern region and a humidity of approximately 50–80% (**Figure 1**).

With a humidity of approximately 50–80%, the annual precipitation ranges between 750 mm in the predominant savanna woodland vegetation and 1,630 mm along Lake Malawi [1]. The landscape varies throughout the country with the Great Rift Valley running from North to South and containing peaks as high as 3,000 m. This diverse landscape includes tropical and subtropical grasslands, savannas, and Miombo woodland, the Zambezian, mopane woodlands, and flooded grasslands (made of grasslands and swamp vegetation). To the east of the valley lies Lake Malawi (covering 29,600 km² and making up over 75% of the country's eastern boundary). By volume, Lake Malawi is the world's fourth largest freshwater lake and is endemic to more fish species than any other lake in the world. The country's biodiversity is diverse and includes several large mammal species (elephants, rhinos, hippos, big cats), bird species (parrots, owls, falcons, waterfowls), and various plant species (grass, shrubs, herbs, bamboo) [1, 8].

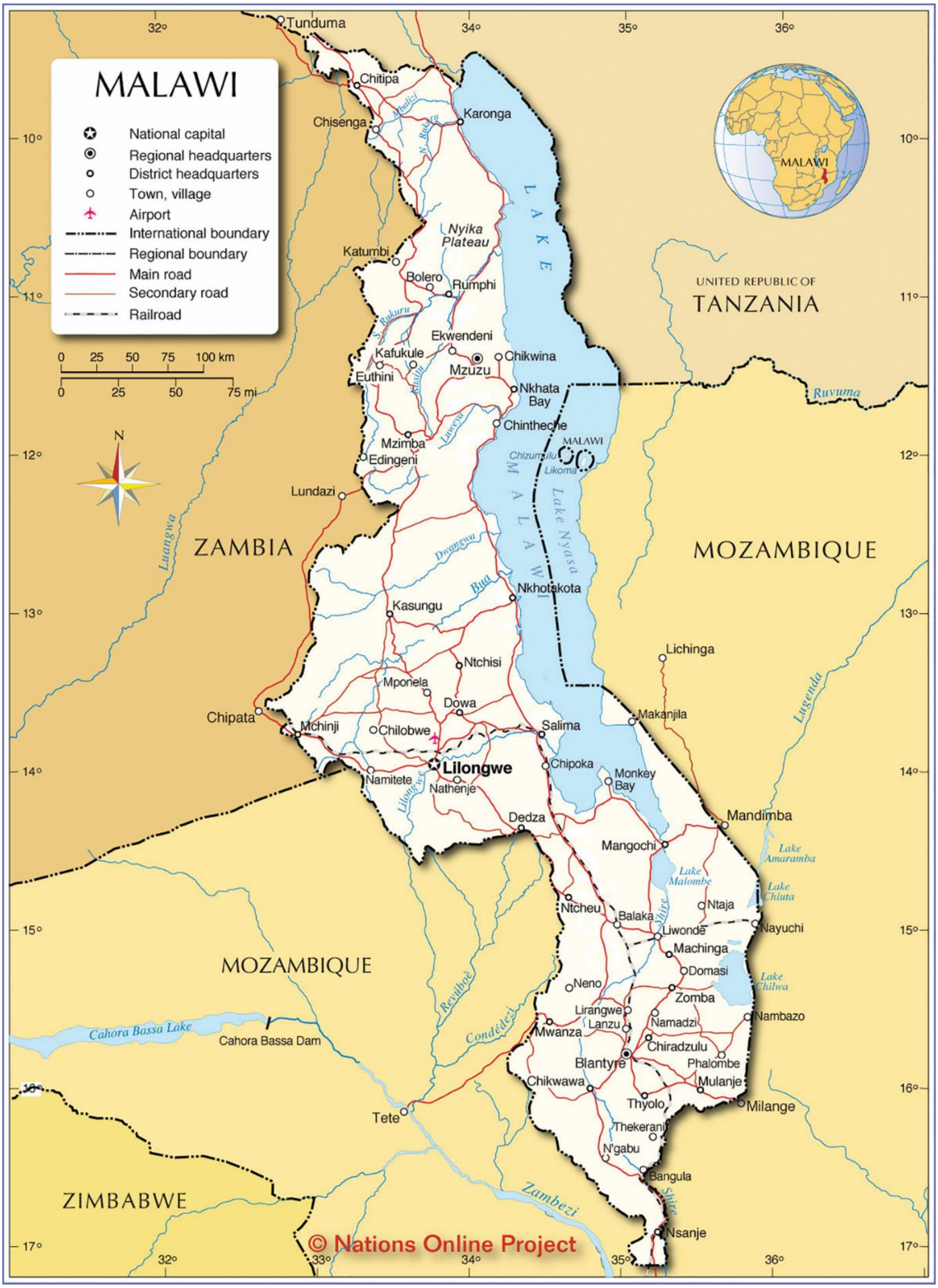

Figure 1 • Map of Malawi. Source: One World - Nations Online [26].

2.2. Data collection

This study made use of socioeconomic household data from the Malawi Integrated Household Panel Surveys (IHPS). The IHPS is a series of Integrated Household Surveys that collect information on a wide range of topics. The IHPS is supported by the World Bank Living Standards Measurement Study, the Integrated Surveys on Agriculture (LSMS-ISA) initiative. The IHPS was created by the Government of Malawi through the National Statistical Office [27] The survey collects information on household characteristics such as wage, food security, agricultural assets and production, livestock and fisheries sectors, non-farm income generating activities, and consumption expenditures. The dataset also contains information on climate and economic shocks experienced by households and the coping strategies. The IHPS used a two-stage stratified sample selection process which included the selection of sample Enumeration Areas (EAs) and the random selection of households in each EA. EA refers to the smallest operational area established for census with well-defined boundaries. This study used three waves of surveys from the Integrated Household Surveys The three waves cover the three main regions of Malawi, namely, North, Central, and South. The first wave (IHS3) was undertaken from March 2010 to March 2011 and consisted of 12,288 households located in 564 EAs. The second wave was conducted between April 2013 and December 2013 and comprised 3,247 households based in 204 EAs. The third wave (IHS4) was from April 2016 to April 2017 and sampled 12,480 households drawn from 780 EAs.

2.3. Analytical methods

2.3.1. The effects of climate shocks on agricultural production

This study adopts a production function to estimate the impact of weather-related shocks on maize yield and the value of agricultural output per hectare measured in Malawian Kwacha. There is likely existence of unobserved characteristics most probable to be correlated with the variables of interest which could make use of ordinary least squares (OLS) to be biased. To address the problem of unobserved heterogeneity and exogeneity, the fixed effects are employed in this study. As described by Dell et al. [28] and Hirvonen [29], the fixed effects control for all time-invariant unobserved household demographic and EA characteristics. Here, some assumptions and preliminary tests were carried out before the analysis. The Hausman test was conducted to test whether the FE estimator is suitable. The probability of the chi-squared in the Hausman test output was less than 0.05; thus, the fixed-effect model was chosen. The key assumption here is that the error terms in the linear regression model should be uncorrelated with the explanatory variables (exogenous explanatory variables or “no endogeneity”). In addition, the collinearity diagnostics test was carried out for the explanatory variables included in the model. According to our estimation, the mean Variance Inflation Factor (VIF) was 1.10. Therefore, there was no serious multicollinearity issue in our model. If this assumption was not met, our model would have suffered from the endogeneity problem. However, with respect to weather shocks, the study assumed strict exogeneity since by their nature, weather shocks are a kind of covariate events that may affect all households in a given geographical place rather than a single household alone. Thus, we do not expect weather shocks to be endogenous as it is not largely influenced by an individual household’s decision. For this study, the production function used for estimation is given in Eq. 1:

$$InY_{hit} = \beta_0 + \beta_1 X_{hit} + \beta_2 C_{hit} + \beta_3 P_{hit} + \mu_h + \theta_{it} + \varepsilon_{hij}\,, \tag{1}$$

where InY_{hit} is the natural logarithm of the dependent variable of household h residing in EA i in year t. C_{hit} is a vector describing self-reported climate shocks experienced by a farming household h in EA i in year t, and it takes the variable 1 if a household was affected by at least one of the extreme weather events (drought or flood). X_{hit} is a vector of control variables including agricultural household socio-demographic characteristics, and P_{it} is a vector of land characteristics for household h in EA i in year t. μ_h are the time-invariant agriculture household unobserved effects, θ_{it} represents the year and EA fixed effects, and ε_{hit} 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 value is not affected by any other variable in this model at any time. This model controlled for other land and demographic and socioeconomic characteristics that may also impact the value of agricultural output.

2.3.2. Adaptation and farmers’ choice of adaptation strategies

In the aftermath of extreme weather events, the affected households try to cope by engaging in one or a set of available adaptation strategies to offset its impacts. We assume that there is a propensity of the household to employ in a specific adaptation strategy. However, there are factors that often influence a household’s choice to an appropriate adaptation strategy. The study, therefore, adopts a Probit model to analyze the types of adaptation strategies which affected the households employed in this study. Moreover, we examine the socioeconomic factors that influence the farming household’s choice of adaptation measures:

$$AS_{hit} = \beta_0 + \beta_1 X_{hit} + \beta_2 C_{hit} + \mu_h + \theta_{it} + \varepsilon_{hij}\,, \tag{2}$$

where AS_{hit} is a binary indicator taking the value 1 if household h residing in EA i engaged in the adaptation strategy in year t. The adaptation strategies specifically examined include relying on own savings, selling household assets, receiving remittances, obtaining credit, and engaging in *ganyu* labor. *Ganyu* labor is any off-own-farm work done by individuals on a casual basis [30]. These options are mostly ex-post adaptation strategies. According to Abid et al. [31], these ex-post adaptation strategies are the measures adopted by households after being exposed to extreme climate events.

2.3.3. Effectiveness of adaptation strategies

The study indicated that a household responded to extreme climate events by employing one or a set of adaptation strategies aimed at safeguarding from potential maize yield and crop income loss. However, there is a high likelihood that even after implementing available adaptation measures, affected households may likely experience maize yield and crop income decline. To this end, we examine the effectiveness of the adaptation strategies by introducing an interaction term into Eq. 1, as shown in Eq. 3:

$$\begin{aligned} In(Y_{hit}) = {} & \beta_0 + \beta_1 X_{hit} + \beta_2 P_{hit} \\ & + \beta_3 C_{hit} + \beta_4 A_{hit} + \beta_5 \left(C_{hit} \times A_{hit}\right)\,, \\ & + \mu_h + \theta_{it} + \varepsilon_{hij} \end{aligned} \tag{3}$$

where the additional term is an interaction between the adverse weather event dummy and dummies for the adaptation strategy.

The vector of coefficients of interest β_5 measures the relative effectiveness of each adaptation mechanism. A significant and positive coefficient would mean that the adaptation measure is effective in safeguarding from potential crop income loss. Meanwhile, a significantly negative or insignificant coefficient would suggest that the adaptation strategy did not minimize crop income loss.

2.3.4. Definition of the model variable for fixed-effect model

2.3.4.1. Dependent variable

The main dependent variables include maize yield and crop value per hectare (Malawian Kwacha). The value of crop output was computed using local prices based on sales (if the household sold harvested crops as included in the surveys) when available.

2.3.4.2. Climate shock indicator

For the variable of climate shock, the study relied on subjective reports of measures of climate shock experienced by farming households. The responses were generated from questions included in shock modules used in household questionnaires. The study considered whether a household experienced drought at least once in a given year over a period of 2010–2017 as an important indicator of climate shock. Therefore, rural households that reported having been affected by droughts during the Integrated Households Surveys years were considered for analysis, as described by Akampumuza and Matsuda [32] and Quisumbing et al. [33].

2.3.4.3. Control variables

To control for potential omitted variable biases and to identify important time-invariant determinants of the agricultural production, this study included some selected explanatory variables. Therefore, the selected explanatory variables for the regression model included gender, age of the household head, the number of years of schooling, household size, household dependency ratio, access to extension services, plot size, ownership of livestock, fertilizer application, pesticide use, irrigation use, access to credit, off-farm employment, wealth index, and agricultural index. The wealth or asset index is based on the principal component analysis of whether or not the household owns their residence and durable goods (mortar, bed, table, chair, fan, tape/CD player, TV/VCR, etc.). The agricultural index is based on the principal component analysis of whether or not the household owns a number of farm implements and machinery (slasher, sprayer, panga knife, treadle pump, watering can, ox cart, etc.).

Here, the explanatory variables such as the use of irrigation, fertilizer, and pesticide for the regression model were included because they are crucial for enhancing agricultural productivity. Furthermore, they can serve as coping strategies against drought impacts by increasing crop yields and resilience in the face of changing conditions. However, in this article, we considered the variables as determinants of agricultural productivity not as coping strategies. This is because farming households lack income to purchase fertilizer and pesticide, as well as to implement irrigation systems. In addition, extreme weather events reduce the income of farming households; as such, we do not include the variables as coping strategies. This is because most farm households lack money and knowledge to purchase and sustainably apply fertilizer, pesticides, and irrigation systems [34, 35]. Furthermore, excluding the three variables from the model is not feasible because the specification used in Eq. 1 allows controlling for household resource endowments as potential determinants of agricultural productivity.

3. Results

This section presents the results from the econometric models using the *STATA* statistical package. Our first analytical step involves descriptive analysis. Second, the study identifies the correlation between maize yield, the value of agricultural output and climate shock, and the explanatory variables. Then, we evaluate the households' choice of adaptation strategies and the effectiveness of the adaptation measures.

3.1. Descriptive statistics of agricultural production variables

Table 1 illustrates descriptive statistics of agricultural production variables and where the mean plot size was 0.939 hectare, while 43.8% were the owners of the cultivated plot. Approximately 61.5% of the households applied fertilizer. The average maize yield was 252.037 kg, and the value of agricultural output was 19,324.700 Malawian Kwacha.

Table 1 • Descriptive statistics of agricultural production variables

Variables	Pooled	
	Mean	**Std. Dev.**
Value of the agricultural output per hectare	19,324.700	129,574.600
Maize yields (kg)	252.037	1,277.412
Fertilizer: 1 if the household applied inorganic fertilizer, 0 otherwise	0.615	0.487
Fertilizer quantity per hectare (kg)	36.380	230.461
Hired labor: 1 if the household hired labor, 0 otherwise	0.128	0.334
Pesticide and herbicide: 1 if a household used pesticides and herbicides, 0 otherwise	0.017	0.128
Quantity of pesticide and herbicide used per hectare (liters)	2.112	34.686
Use of irrigation: 1 if a household used irrigation, 0 otherwise	0.075	0.263
Owner of the cultivated land: 1 if a household is the owner of the land, 0 otherwise	0.438	0.768
Plot size (hectares)	0.939	0.577
Agricultural index: 1 if a household owns farm implements and machinery, 0 otherwise	0.152	0.359
Number of observations	9,675	

Notes: The value of agricultural output is in Malawian Kwacha, and the 2017 exchange rate was 1 USD ≈ 1,735 MWK.

3.2. Household socio-demographic characteristics

Approximately 68.8% and 36.6% of the households were exposed to droughts and floods during the survey period, respectively. The average age of the household head stood at 38.8 years, for an average household size of 4.7 and an average formal education of 4.2 years. Meanwhile, 20.5% had access to credit and 17.5% access to extension services, whereas only approximately 10% were engaged in one or more forms of non-farm activities. Approximately 11.6% own their residence and a number of durable goods, and 81.9% of the households reside in rural areas (**Table 2**).

Table 2 • Descriptive statistics of socio-demographic characteristics of households

Variables	Pooled	
	Mean	**Std. Dev.**
1 if household was affected by drought, 0 otherwise	0.688	0.748
1 if household was affected by flood, 0 otherwise	0.366	0.482
Gender of household: 1 if the household is female, 0 otherwise	0.487	0.500
Age of household head (years)	38.844	15.731
Household size: number of household members	4.735	2.259
Years of education of household head	4.166	5.588
Access to credit: 1 if a household had access to credit, 0 otherwise	0.205	0.404
Non-farm income: 1 if the household engaged in off-farm employment, 0 otherwise	0.100	0.300
Access to extension services: 1 if a household access extension service, 0 otherwise	0.175	0.378
Distance of household to the nearest market (km)	18.980	15.025
Dependency ratio: 1 if the number of dependents < 15, >64 years old in the household, 0 between 15 and 64 years old	0.181	0.385
Rural households: 1 if the household is rural, 0 otherwise	0.819	0.385
Southern region: 1 if a household was in the South, 0 otherwise	0.456	0.498
Northern region: 1 if the household was in the North, 0 otherwise	0.203	0.402
Central region: 1 if the household was in the Central, 0 otherwise	0.341	0.474
Wealth index: 1 if a household owns a number of durable (assets) goods, 0 otherwise	0.116	0.320
Ownership of livestock: 1 if a household own a number of livestock, 0 otherwise	0.387	0.487
Number of observations	9,675	

3.3. Effects of climate shocks on agricultural production

Results showed that 1% increase in the exposure to drought decreased the maize yield by 12.6% and the value of agricultural output by 24.1%. Furthermore, 1% increase in the total number of livestock owned increases the maize yield and the value of agricultural output by 3% and 20.9%, respectively. Similarly, 1% increase in having access to credit and engaging in off-farm employment raises the value of the agricultural output by 2.9% and 30.7% (see **Table 3**).

Table 3 • Agricultural production fixed-effect regression

Variables	Ln (maize yield)	Ln (crop value per hectare)
Drought shock (yes = 1)	−0.126***	−0.241**
	(0.161)	(0.096)
Plot size (hectare)	0.078	0.068
	(0.093)	(0.093)
Irrigation use (yes = 1)	0.395**	0.381**
	(0.192)	(0.191)
Fertilizer application (yes = 1)	0.208**	0.000**
	(0.098)	(0.000)
Pesticide and herbicide applied (yes = 1)	0.014	0.001
	(0.055)	(0.002)
Livestock ownership (yes = 1)	0.030*	0.209**
	(0.018)	(0.098)
Dependency ratio	−0.032	0.026
	(0.120)	(0.100)
Agricultural index (yes = 1)	0.159	0.019
	(0.149)	(0.132)
Gender (female = 1)	0.070	0.084
	(0.096)	(0.095)
Household size	−0.008	−0.027
	(0.007)	(0.022)
Number of years of education	0.027***	0.024***
	(0.009)	(0.009)
Access to credit (yes = 1)	0.028	0.029*
	(0.100)	(0.018)
Age of household head	0.007***	0.008***
	(0.006)	(0.004)
Off-farm employment (yes = 1)	0.046	0.307**
	(0.117)	(0.129)
Access to extension service (yes = 1)	0.088	0.087
	(0.123)	(0.126)
Wealth index (yes = 1)	−0.037	0.070
	(0.041)	(0.096)
Number of observations	9,675	9,675
Constant	2.476***	2.453***
Overall r-squared	(0.241)	(0.231)
	0.013	0.014

Notes: Robust standard errors are given in parentheses. Asterisks ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

3.4. Household adaptation strategies

The various climate shock ex-post adaptation strategies included relying on own savings, selling household assets, receiving gifts and remittances, obtaining credit, and doing *ganyu* labor. Approximately 59.6%, 51.1%, and 23.1% of the households adopted to doing *ganyu* labor, received remittances, and sold household assets, respectively. Meanwhile, 14.6% and 13.3% of the households obtained credit and relied on their own savings as climate shock adaptation strategies, respectively (**Table 4**).

3.5. Households' choice of adaptation strategies

Various determinants of ex-post adaptation strategies to drought shock were identified using the Probit analysis (**Table 5**). The results revealed that exposure to drought shock increased the prospect of relying on own savings by 11.8%, doing *ganyu* labor by 71.4%, obtaining credit by 5.4%, selling household assets by 12.6%, and receiving remittances by 36.6%. Furthermore, age of the household head (i.e., experience) increased the likelihood of relying on own savings by 8.7%. Similarly, access to extension services enhances the prospect of engaging in *ganyu* labor by 6.9% and receiving remittances by 8.2%. An additional year of schooling by the household head enhances the probability of receiving remittances by 7.3%. Meanwhile, 1% increase in the total value of dependency ratio increases the likelihood of selling household assets by 5.9%.

Table 4 • Climate shock adaptation strategies

Variables	Pooled	
	Mean	**Std. Dev.**
1 if household relied on own savings, 0 otherwise	0.133	0.340
1 if the household sold household assets, 0 otherwise	0.231	0.422
1 if a household obtained credit, 0 otherwise	0.146	0.353
1 if the household received remittances from family/friends, 0 otherwise	0.511	0.500
1 if the household do *ganyu* labor, 0 otherwise	0.596	0.491
Number of observations	9,675	

Table 5 • Households' choice of adaptation strategies: Probit marginal effects

Variables	Rely on own savings	*Ganyu* labor	Obtain credit	Sell assets	Receive remittance
Drought shock (yes = 1)	0.118***	0.714***	0.054*	0.126***	0.366***
	(0.032)	(0.029)	(0.032)	(0.026)	(0.034)
Gender (female = 1)	0.000	−0.002**	−0.001	−0.004***	−0.003**
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Age of the household head	0.087*	−0.071	−0.011	0.048	0.080
	(0.052)	(0.045)	(0.049)	(0.040)	(0.054)
Household size	−0.008	0.006	0.005	−0.008	−0.008
	(0.007)	(0.006)	(0.007)	(0.006)	(0.008)
Dependency ratio	−0.011	0.009	−0.039	0.059**	−0.077**
	(0.032)	(0.029)	(0.031)	(0.026)	(0.034)
Number of years of schooling	0.008	0.025	0.037	−0.061	0.073*
	(0.043)	(0.039)	(0.041)	(0.034)	(0.045)
Access to credit (yes = 1)	−0.041	−0.003	0.024	0.024	−0.040
	(0.041)	(0.036)	(0.039)	(0.032)	(0.043)
Off-farm activities (yes = 1)	0.013	0.043	−0.008	−0.021	0.092*
	(0.055)	(0.049)	(0.053)	(0.044)	(0.056)
Access to extension services (yes = 1)	0.010	0.069*	−0.010	−0.026	0.082*
	(0.043)	(0.038)	(0.042)	(0.034)	(0.044)
Observations	9,675	9,675	9,675	9,675	9,675
Constant	−1.245***	0.338***	−1.099***	0.336***	−0.052
	0.074	(0.057)	(0.071)	(0.064)	(0.057)

Notes: Robust standard errors are given in parentheses. Asterisks ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

3.6. Effectiveness of adaptation strategies

One percent increase correlated with performing *ganyu* labor increases households' maize yield and crop income per hectare by 36.3% and 37.9%, respectively. Moreover, 1% increase in receiving remittances enhances farmers' maize yield and crop income per hectare by 7.5% and 14.7%, respectively. Similarly, 1% increase in relying on own savings improves households' ability to mitigate extreme weather events on crop income per hectare by 10.5% (**Table 6**).

Table 6 • Effectiveness of household adaptation strategies

Variables	Ln (maize yield)	Ln (crop value per hectare)
Drought shock (yes = 1)	−0.421*** (0.025)	−0.143*** (0.052)
Adopted an adaptation strategy (yes = 1)	0.134*** (0.037)	0.178*** (0.044)
Climate shock* Rely on own savings	0.063 (0.048)	0.105* (0.058)
Climate shock* *Ganyu* labor	0.363*** (0.035)	0.379*** (0.045)
Climate shock* Borrowing money	0.054* (0.031)	0.049 (0.038)
Climate shock *Selling assets	0.079*** (0.026)	−0.007 (0.025)
Climate shock* Receiving remittances	0.075* (0.041)	0.147*** (0.033)
Gender (female = 1)	0.032 (0.025)	0.049* (0.029)
Age of household head	0.002 (0.022)	−0.038 (0.029)
Household size	0.008 (0.003)	0.000 (0.004)
Number of years of schooling	0.007*** (0.002)	0.005* (0.003)
Access to credit (yes = 1)	0.002 (0.020)	0.011 (0.024)
Off-farm employment (yes = 1)	0.009 (0.022)	0.029 (0.031)
Access to extension service	0.035** (0.015)	0.005 (0.025)
Constant	12.836***	14.804***
Observations	(0.069)	(0.669)
Overall r-squared	9,675	9,675
	0.183	0.125

Notes: Robust standard errors are given in parentheses. Asterisks ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

4. Discussion

4.1. Effect of droughts on agricultural production

Being exposed to droughts negatively and significantly affected maize yields and crop income per hectare. This implies that temperature increases and changing rainfall patterns are detrimental to agricultural production. It may be due to the fact that higher temperatures and deficiencies in precipitation hinder crop growth. This usually occurs when rainfall does not meet crop moisture and soil water requirements, thereby reducing crop yields. This finding is in line with that of Ray et al. [36], who revealed that drought reduced crop yields due to less water and soil moisture available for crop growth in the United States. With the use of irrigation and fertilizers, crop production losses could be reduced during a drought. The positive and significant coefficient of livestock ownership signifies an increase in maize yield and crop income per hectare. This is because livestock plays an important role as a basic production input in agricultural production. Livestock in a mixed crop–livestock farming system may be used to supply oxen power for plowing and threshing. Furthermore, it is a vital source of capital through which substantial income is generated through the sales of livestock products such as meat, milk, and butter.

To this end, the income might be used to purchase agricultural inputs so as to enhance production. Moreover, in case of short-term liquidity constraint, livestock can be used as a collateral to acquire credit from informal credit sources. The credit may enhance a household's financial capacity to expand production. For instance, it enables households to purchase and apply crop production inputs as well as timely implementation of farm management decisions. This result is in line with that of the study carried out by Demeke et al. [37] in Ethiopia. They found that livestock and credit availability play essential roles in agricultural production. Still from a financial perspective, farmers involving in off-farm employment had an increase in crop income per hectare. This is due to the fact that income from off-farm activities may be used to purchase farm inputs such as fertilizer and seedlings in order to augment crop yields. This observation is similar to that by Dasmani et al. [38], who posited that income from off-farm activities assisted in the purchase of farm inputs such as fertilizer and seeds in Ghana. The number of years of schooling have a positive and significant effect on agricultural production. This is because as educational level increases, it enhances the farmer to be more skillful in the search for information and the application of new techniques of cultivation [39]. The higher age of the household head had a positive and significant impact on agricultural productivity. It may be due to the fact that older household heads have the required experience to cultivate more crops. Experience has resulted in most of the household heads being skilled on the various farm management practices and techniques that could be used to augment crop yields [40].

4.2. Households' choice of adaptation strategies

There is a positive and significant relationship between exposure to droughts and the likelihood to rely on own savings, doing *ganyu* labor, obtaining credit, selling household assets, and receiving remittance as ex-post adaptation strategies. Obtaining credit or borrowing money was one of the adaptation strategies to cope with extreme weather events reported by Abid et al. [31] in rural Malawi. In another study, Chidanti-Malunga [41] indicated that rural households implemented the increased use of water resources for small-scale irrigation or wetland farming, increased management of residual moisture, and fishing and crop diversification as adaptive strategies in response to extreme weather events. Adaptation is a necessary condition to boost farmers' capacity to recover quickly from the negative effects of drought shock on agricultural productivity. The age of the household head positively influenced the choice of relying on own savings. It may be due to the fact that the older the farmer, the more experience the farmer possesses in terms of better knowledge and information on changes in weather conditions. As such, they may be able to minimize risk by saving their surplus income for an unanticipated climate shock. Relatedly, a study by Helgeson et al. [42] also found that the age of household head influenced the choice of farmers' adaptation strategies in Uganda.

Off-farm employment and additional year of education of household head increase the probability of adapting to receiving remittances. This implies that an exposure to drought shock increases the household's likelihood of having one or more family members taking up off-farm employment. As a result, the family member may likely send financial assistance in the form of remittances. In Uganda, Akampumuza and Matsuda [32] reported that an extra year of education by the household head increased the chance of having a family member engaging in off-farm employment and receiving remittances. Furthermore, access to extension services increased the likelihood of a household to do *ganyu* labor and to receive remittances. Elsewhere in Cameroon, Beckline and Kato [43] observed accessibility to agriculture extension services to build the capacity of local farmers on weather conditions, thus escaping food security risks. Similarly, Gadédjisso-Tossou [44] also revealed that access to extension services enables households to gain more knowledge of changing climate conditions as well as agricultural production and farm management practices in Togo. The positive and significant coefficient of dependency ratio implies that households with a high dependency ratio are more likely to sell household assets after being exposed to drought shock. In Malawi, Abid et al. [31] found that social networks and capital were the important factors influencing households' adaptation decisions.

4.3. Effectiveness of adaptation strategies

Households that engage in *ganyu* labor and receive remittances were able to minimize the substantial decline in maize yield and crop income per hectare. Remittances are usually made by family members and other acquaintances who have temporarily or permanently migrated abroad or to a bigger town, or living in the same location. According to Jack and Suri [45], farming households in Kenya using M-PESA—Safaricom's mobile money platform were able to offset the impacts of extreme weather events by receiving remittances from their family members and other acquaintances. By doing *ganyu* labor, households also supplement their income through additional casual work. *Ganyu* labor is an important household buffering mechanism in response to low farm household income, especially in case of low crop yields. According to Coulibaly et al. [46] and Isaac et al. [47], *ganyu* labor is usually a short duration, seasonal casual work paid in cash or kind, and without any formal contract between the employer and the employee. This practice ensures a constant flow in a household's off-farm income, which buffers the impacts of climate shock. There exists a positive and significant interaction between exposure to drought shock, obtaining credit, and selling assets for maize yield. This indicates that households that sold assets and obtained credit were able to prevent a reduction in the maize yield per hectare after being exposed to a drought shock. Similarly, the interaction between drought exposure and relying on own savings shows that upon exposure to drought conditions, relying on own savings provides protection against crop income decline.

5. Conclusions

In rural areas, agricultural productivity, which is the main economic activity for smallholder farmers in Sub-Saharan Africa, is vulnerable to weather shocks due to climate change. The exposure to weather shocks affects household incomes. This vulnerability is attributed to the high dependence on rain-fed agriculture for incomes and food security. This article assessed the self-reported impact of exposure to drought shocks on maize yield and the value of agricultural output using the fixed-effects model and the panel data from the Malawi IHPS (2010–2017). The study also examined the coping and the effectiveness of coping strategies employed by the households to abate income loss in rural Malawi. Again, the study adopted a Probit model to analyze the determinants of the households' choice of coping strategies against extreme weather events.

5.1. Key results

1. Drought shock triggered a decrease in the maize yield by 12.6% and agricultural output by 24.1%.
2. The use of irrigation, application of fertilizer, increase in the number of livestock owned, credit accessibility, engaging in off-farm employment, increase in the level of education, and years of farming experience (the age of household head) exert positive effects on agricultural production.
3. Undertaking *ganyu* labor, receiving remittances, obtaining credit, selling household assets, and relying on own savings were the coping and effective coping measures employed by the households to safeguard against agricultural productivity decline.
4. Household characteristics such as age of the household head, level of education, increase in the dependency ratio, and access to extension services were the different determinants of the households' choice of coping strategies.

5.2. Recommendations

- The article strongly recommends policy instruments such as rural credit to assist farmers in improving productivity.
- The study suggests that implementation of a policy toward enhancing livestock production is necessary to reduce vulnerability to food insecurity.
- The study recommends income diversification activities which could enhance the resilience of households to weather shocks.
- Strategies seeking to increase household resilience to weather shocks would, therefore, be paramount, considering the ongoing climate change in the country.
- The implementation of irrigation systems should be promoted and encouraged due to its importance in agricultural productivity.

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Author contributions

Conceptualization, N.M. and M.B.; methodology, N.M.; validation, T.M.; formal analysis, N.M.; investigation, B.M.; resources, T.M.; data curation, M.B.; writing—original draft preparation, N.M.; writing—review and editing, M.B.; visualization, T.M.; supervision, M.B.; project administration, M.B. and, T.M.; funding acquisition, N.M. and M.B. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

Data supporting these findings are available within the article, at https://doi.org/10.20935/AcadEnvSci7630, or upon request.

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