

Article

## Responding to Crop Failure: Understanding Farmers' Coping Strategies in Southern Malawi

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**Abstract:** Malawi is a country in southern Africa facing high climate variability and many agricultural challenges. This paper examines farmers' coping strategies for crop failure and the determinants of their choices using household level data from rural southern Malawi. The results highlight that farmers are not responding directly to climate variability, but to crop failure, which is influenced by climate stress, as well as other constraints, such as poor soil fertility and lack of agricultural inputs and technologies. The coping strategies adopted by households are mostly *ex-post* measures, including engaging in casual labor, small businesses and the sale of forest products. The main determinants of the adoption of these coping options are education, gender of the head of household, soil fertility and frequency of crop failure. This study concludes by recommending, among other things, that policies for the more efficient communication of climate change threats should emphasize the risk of crop failure. Furthermore, initiatives to assist households to better cope with climate change should take into consideration the local context of decision-making which is shaped by multiple stressors.

**Keywords:** climate variability; coping strategies; multiple stressors; crop failure; agriculture

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## 1. Introduction

It has become apparent that Africa is undergoing significant climate change. Climate models presented by IPCC [1] predicted increased climate uncertainty for Malawi and most countries in southern Africa. The majority of these models predict higher temperatures and possibly higher rainfall for Malawi [2]. Following these predictions, rainfall and temperature are expected to increase in frequency and magnitude for Malawi.

Evidence suggests that the climate in Malawi made a significant shift in the early 1990s [3]. The frequency and severity of disasters has increased in Malawi since the southern African drought in 1991/1992. From this date, disasters have escalated with a serious drought in 2002 causing an unprecedented food crisis in Malawian history. Another major drought occurred in 2004/2005, and since then, the country has been affected by recurrent food crises caused by erratic rain and regular flooding.

High climate variability will adversely affect agricultural production in Malawi and severely challenge the livelihood of rural communities, already undermined by a range of economic and development issues. About 65% of Malawi's population lives below the poverty line, the majority in rural areas, with more than 90% relying on rain-fed subsistence farming to survive. Agriculture and economic development face also numerous constraints, including a shortage of land, poor soil fertility, high variability of maize prices and an underdeveloped credit market [4]. These challenges, coupled with increased droughts and floods, are likely to exacerbate existing gaps, making the poor more vulnerable and leaving many rural farmers in a cycle of poverty.

Vulnerability is largely determined by adaptive capacity. Indeed, the extent to which climate variability or change impacts are felt depends in large part on the capacity of the affected communities to adapt. Over time, Malawian farmers have developed a variety of coping mechanisms that help them buffer against climatic variability and other agricultural stressors, such as poor agricultural practices, lack of access to inputs and technology, poor soil fertility, which cause crop failure and food insecurity. It is important to document such strategies, to understand the determinants of farmers' choices and to identify policies that can promote sustainable coping strategies as a first step in the adoption of more robust adaptation strategies for future climate change.

Most research on adaptation to climate change has considered farmers' adaptation strategies as responses to the single climatic stimulus without paying attention to the other stressors. While our paper identifies and focuses on climate as the main stimulus of farmers' coping responses, it does not ignore the other livelihood disturbances that can impact local communities' coping strategies. In fact, farmers are dealing with a number of agricultural stresses that affect agricultural production and lead to crop failure. Climate plays undoubtedly a determinant role in explaining crop failure in the rain-fed crop system, but it is only one of many factors that influence local decision processes and outcomes [5]. There is an increasing number of scholars across Africa that recognize that the impact of climate stress is felt in a complex system shaped by the interaction of multiple stressors. Ziergovel *et al.* [6] in South Africa underscored that farmers respond to climate and multiple stresses in their local context. They therefore

called for the need for policies that support a heterogeneous response to a wide range of stresses. Further, Tschakert [7] in central Senegal indicated that farmers adapt to climate change in an environment subject to multiple stresses, and often, their adaptive capacity to the climate is undermined by poor health, rural employment and inadequate village infrastructure. In the same country, Mertz *et al.* [8] acknowledged that beyond climate, other factors, including market conditions, seed availability and labor supply, may play a greater role in shaping farmers' responses to environmental shocks. In Tanzania, Trærup and Mertz [9] emphasized the need to target policies for the local conditions that households face when experiencing climate-related shocks. The complex human-environment interaction in which rural communities are making their decisions needs to be acknowledged and taken into account for effective policy interventions. As pointed out by O'Brien *et al.* [10] and relayed by Wilk *et al.* [11], external interventions to enable adaptation are likely to be successful if they take into account farmers' local context influenced by multiple stressors' interactions, including climate.

Furthermore, in southern Africa, most studies on adaptive capacity have focused on South Africa [11,12–14]. Malawi, despite being well known as a hotspot of vulnerability to climate change, has drawn less attention in this literature. The few papers from Malawi include the work of Oyekale and Gideon [15], who analyzed rural households' vulnerability to climate-related income shocks and adaptation options in central Malawi. This paper zooms in on southern Malawi and contributes to filling the existing gaps in the literature on adaptive capacity by investigating several research questions: How do farm households in southern Malawi cope with multiple stressors, including climate, that result in crop failure? What types of households respond to crop failure by adopting specific coping options available in their geographical areas?

In this paper, we focus on coping responses rather than adaptation strategies and make a clear distinction between them based on the time scale. Coping strategies are short-term measures used by households when confronted with unexpected events [12], while adaptation strategies are of a long-term nature [16]. Adaptation mechanisms refer to adjustments or interventions, which take place in order to manage the losses or take advantage of the opportunities presented by a changing climate [17]. Following Kelly and Adger [18], this paper argues that long-term climate change adaptation depends on the same factors governing coping with other social and environmental stresses to which society has been and is continually responding.

To address the research questions, this study uses household data from southern Malawi to examine farmers' coping responses to crop failure and their determinants.

The paper is organized as follows. The next section describes the study area, the data used in the analysis and the empirical framework. Section 3 presents and discusses the results. The first part of these results analyzes farmers' experience with crop failure and the causes of crop failure. The second part discusses households' coping strategies and the determinants of their choices. The last section, Section 4, presents the conclusions and policy implications for this study.

## 2. Research Methods

### 2.1. Description of the Study Area

The study sites are located in the Shire River Basin, which represents about 16 percent of Malawi's total geographical area. It is the largest water resource area in Malawi, covers 18,945 km<sup>2</sup> and consists of the upper, middle and lower sections. The river originates from Lake Malawi, flowing south and southeast to the confluence with the Zambezi River. The Shire River Basin is traversed by a dense network of river systems, some of which are being exploited for irrigation, particularly in the lower reach of the basin.

According to scientific evidence, the Shire River Basin is vulnerable to climate variability and change. The El Niño phenomenon, responsible for the alteration in weather patterns in many countries, also impacts Malawi, including the Shire River Basin [19]. There is evidence of a shift in the weather pattern of the Shire River Basin towards more extreme climate events, drought, flood, erratic rainfall and higher temperature. Over the last 20 years, the Shire River Basin has experienced some of the worst changes in weather patterns, characterized by severe droughts (1991/1992, 2004, 2005) and intense floods (2000/2001) [20]. These events caused a significant decrease in production, crop failure and food insecurity.

Approximately 5.5 million people live in the basin and depend on natural resources for their livelihood [21]. Agriculture in the Shire River Basin is characterized by subsistence farming on customary land tenure, an extensive system of livestock production and fishing practiced on a small scale. Maize is the main food crop and cotton the main cash crop grown in the Shire River Basin. However, many farmers have stopped growing cotton because of the fluctuating cotton prices [22].

Crop production is based on the limited use of agricultural inputs, such as fertilizer and credit, due to some constraints accessing these inputs. As a result, farmers experience low crop yield and agricultural production, leading them to rely heavily on casual labor, the sale of charcoal and firewood and petty trade for cash income to purchase food. Farmers also face marketing problems, including fluctuation in food crop prices, a lack of farmers' associations to negotiate selling prices, a poor road infrastructure and a long distance to market.

The Shire River Basin passes through three Agricultural Development Divisions (ADDs), specifically the ADDs of Ngabu, Machinga and Blantyre. The survey took place in five districts of these ADDs, namely Chikwawa, Machinga, Zomba, Mwanza and Blantyre. Machinga and Zomba districts are part of Machinga ADD. Blantyre and Mwanza districts are included in Blantyre ADD. The rainfall pattern, temperature, soil characteristics and population growth rate in each of these districts are described in Table 1 below.

The high population growth rates in all districts mentioned above are associated with declining land holding, decreasing soil fertility and increased poverty. High population growth puts pressure on land use, pushing smallholder farmers to marginal and less fertile areas not suitable for crop production. The extreme pressure on natural resource by the community has translated into severe land degradation in some parts of the basin. This environmental pressure leads to more drought and flood and exacerbates the impact of climate change in this region.

**Table 1.** Environmental characteristics and population growth rate in the three main Agricultural Development Divisions (ADDs) of the Shire River Basin.

Variable	Ngabu ADD	Machinga ADD	Blantyre ADD
Mean Annual Rainfall	700–1000 mm in the lowlands to over 1400 mm in the western hills	800–1100 mm	Varies from less than 700 mm to well over 2000 mm
Temperature	26 °C at low altitudes to 21 °C at high altitudes	22.5–17.5 °C	24–13 °C
Dominant soils (FAO classification)	Cambisols, Luvisols, Fluvisols, Vertisols and Gleysols	Cambisols, Luvisols and Phaeozems	Luvisols, Cambisols and Phaeozems
Population grow rate from 1998–2008	2.1% from 1998–2008	2.0%–2.9%	Between 1.0% in rural Blantyre and 4.1% in Mwanza

Sources: [23,24]

## 2.2. Data Collection

This study is based on primary data collected through household surveys during the agricultural season of 2009. A multistage sampling design was used for data collection. All three ADDs, Ngabu, Machinga and Blantyre, were first selected to represent the Shire River Basin region. In the second stage, five districts were purposely selected to capture different agro-ecological zones and major environmental problems in the Shire River Basin. These districts are Chikwawa, Machinga, Zomba, Mwanza and Blantyre. Then, the third stage was based on the selection of one random Enumeration Planning Area (EPA) in each district.

Villages from these EPAs were listed and one (1) to two (2) villages were randomly selected. In the final selection stage, fifteen (15) to thirty (30) households per village were chosen using random procedures. Hence, a total of 150 households were selected to participate in the interviews. The household survey collected information on basic household status, food and farm practices, sources of income, household assets, technical assistance, crop failure, coping strategies and climate issues. Secondary data were also collected from key informants, including village headmen, traditional authorities, government personnel, community-based organizations (CBOs) and NGOs, on the most important environmental problems in the districts.

## 2.3. Empirical Model Specification

To model households' decision to cope with climate variability and other stressors, we followed the methodology provided by Di Falco et al. [25] and Bryan et al. [26]. A farm household  $i$  will adopt coping strategies to adjust to climate variability and other stressors ( $A_i = 1$ ) if the expected net benefit ( $A_i^*$ ) is greater than zero, and zero otherwise:

$$A_i^* = Z_i + \varepsilon_i \text{ with } A_i = \begin{cases} 1 & \text{if } A_i^* > 0 \\ 0 & \text{otherwise} \end{cases}$$

$A_i^*$  is the unobserved latent variable that captures the net benefit associated with adopting coping strategies.  $\varepsilon_i$  represents the error term, and  $Z_i$  stands for the explanatory variables that influence the expected benefits of coping.

The independent variables are selected based on the literature on adoption and adaptation [26,27–29,30], which identifies a number of independent variables that are expected to influence adaptation decisions. These variables include generally household socio-economic characteristics, the physical characteristics of the farm and access to formal institutions. The selected variables are: (i) the age of the head of household; (ii) the gender of the head of household; (iii) education; (iv) family size; (v) the area cultivated; (vi) soil fertility; (vii) farmers' experience of crop failure due to climatic and other stressors; (viii) access to extension services; and (ix) a dummy variable for geographical location. For most of these independent variables, the expected sign cannot be *a priori* defined. It will depend on the choice of coping strategy. For example, the age of the head of household is generally associated with farm experience and will positively influence the coping option, such as irrigation, but on the other hand, may be negatively related to *ex-post* coping strategies, such as providing off-farm *Ganyu* labor (casual labor) or sales of forest products.

Many other studies used a multinomial logit (MNL) to analyze households' adaptation options [13,14]. In our research and similar to Bryan *et al.* [26], households reported adopting several coping options simultaneously, which precludes us from using the multinomial logit (MNL) for the analysis. Indeed, one main assumption for using the MNL is the independence of the categories. This means that the choices must be mutually exclusive; one household cannot choose more than one coping strategy.

A way out to use the MNL model in our study, as highlighted by Bryan *et al.* [26], would have been to group the strategies into major categories, such as crop and land management, forest product sales and livelihood diversification. However, this will not allow for policy recommendations to be made on a specific coping strategy that can foster households' resilience to climate variability.

Another alternative to the MNL could have been to use the multivariate probit, but the limited sample size did not allow us to take such an analytical approach. Therefore, we employed a parsimonious approach, the univariate probit model specified above, to analyze the determinants of individual households' coping strategies. However, given the large number of coping options, we focus on those that are adopted by at least 7% of households.

### 3. Results and Discussion

#### 3.1. Crop Failure and Its Causes

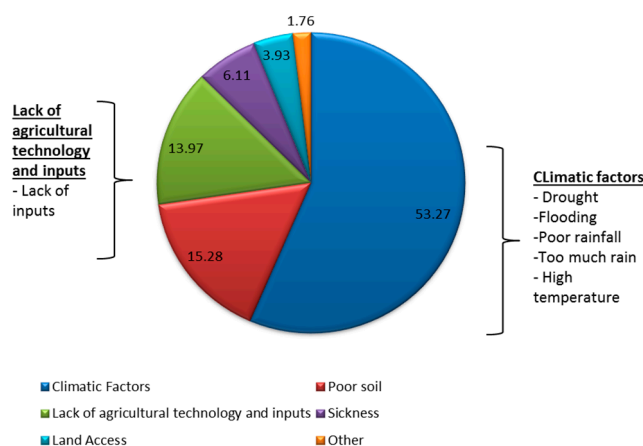
Before analyzing the determinants of coping strategies for crop failure, this section summarizes farmers' experience with crop failure and highlights the causes of crop failure.

Table 2 outlays farmers' experiences with crop failure in the past five years preceding 2009. Participants in the districts surveyed had an extensive experience with crop failure. Mwanza is the only district where almost all households surveyed had no experience with crop failure during the years of investigation. With regards to the frequency of occurrence of crop failure, the districts of Blantyre, Chikwawa and Machinga have the largest record of crop failure, higher than two-times over the five years.

**Table 2.** Households’ experience with crop failure other the past five years preceding 2009.

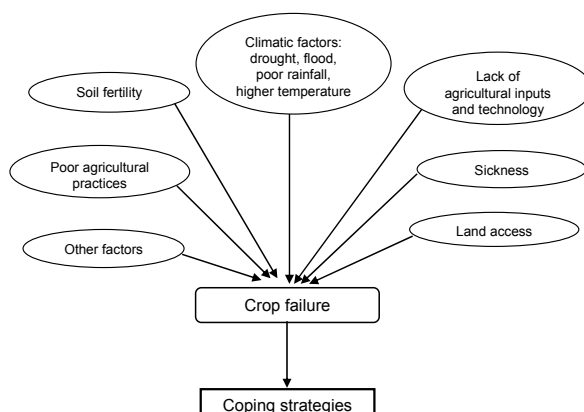
Variable	Ngabu ADD		Machinga ADD		Blantyre ADD		Total
	Chikwawa n = 30	Machinga n = 30	Zomba n = 30	Blantyre n = 30	Mwanza n = 30		
Crop failure experience							
Experience of crop failure	no	3%	3%	37%	0%	90%	27%
	yes	97%	97%	63%	100%	10%	73%
Number of times crops failed	Average	2.5	2	0.6	2.7	0.1	1.58

When farmers were interviewed about the causes of crop failure, more than half of the households (53%) listed climatic factors as the major causes (Table 2). Drought, flood, poor distribution of rainfall and high temperature cause poor yields by reducing the amount of organic matter in the soil, draining out soil nutrients or limiting the accessibility to soil nutrients during critical stages of plant growth. Next, poor soil fertility is the second most important cause of crop failure and has been reported by 15% of households interviewed. Other stressors reported as causes of crop failure include lack of agricultural inputs and technology, illness, poor agricultural practices and land access.



**Figure 1.** Main causes of crop failure reported by households.

These results suggest that crop failure is the result of the interactions of myriad factors, with the most important hindrances being climate, then soil fertility, access to agricultural technology and inputs. Farmers’ coping strategies are thus determined by all of these factors (Figure 2).



**Figure 2.** Multiple stressors influencing coping strategies.

As climatic factors have been reported and appeared to be the main drivers of crop failure, farmers' perception of climate variability over the 10 past years from 2009 will be analyzed. The definition of climate variability in this study goes beyond the concepts of the total amount of rainfall and extreme events, such as flooding and drought, to capture the spatial distribution, including the timing of rainfall onset and intra-seasonal rainfall variation. Further, the assessment over the 10-year time period put more emphasis on the short-term climate variability and extreme events, rather than on climate change, which is assessed over a longer time scale. Table 3 reports the climate variability changes that have been observed by households in the districts surveyed over the past 10 years.

**Table 3.** Farmers' perception of climate variability over the 10 past years preceding 2009.

Climate variable	Change	Total n = 150	Chikwawa n = 30	Blantyre n = 30	Mwanza n = 30	Zomba n = 30	Machinga n = 30
Frequency of drought	Decrease	33%	0%	27%	3%	83%	50%
	No change	5%	0%	7%	0%	13%	7%
	Increase	62%	100%	67%	97%	3%	43%
Frequency of flood	Decrease	20%	7%	17%	7%	23%	47%
	No change	25%	0%	10%	90%	20%	7%
	Increase	55%	93%	73%	3%	57%	47%
Frequency of mid-drought	Decrease	18%	0%	40%	0%	13%	37%
	No change	5%	0%	3%	0%	10%	10%
	Increase	77%	100%	57%	100%	77%	53%
Onset of the rainfall season	Early	20%	3%	43%	7%	7%	40%
	Late	75%	97%	50%	93%	73%	60%
	No change	5%	0%	7%	0%	20%	0%
Rainfall during growing season	Decrease	51%	80%	37%	100%	10%	27%
	No change	5%	0%	3%	0%	17%	3%
	Increase	45%	20%	60%	0%	73%	70%

Overall, farmers noticed variability in climate pertaining to the frequency of extreme events, such as flood and drought, and the distribution of rainfall, including mid-season rainfall and onset of rainfall. Respondents opined that the frequencies of drought and floods have increased over the past 10 years, as reported by, respectively, 62% and 55% of households. This is also in line with the report from Khamis [3] stating that occurrences of floods and drought have increased substantially in the 2000s compared to the preceding years. Moreover, at least 75% of households reported more frequent mid-drought and late onset of rainfall. Farmers also observed a shortening of the rainfall growing season (51%), although this percentage is not significantly higher than the proportion of farmers who attested to be aware of a longer growing season over the 10 past years.

These perceptions are more or less consistent across districts. In Chikwawa, farmers reported changes in all climate variability parameters. Indeed, a vast majority clearly observed an increase in the frequencies of flooding, drought and mid-drought, as well as the late onset of the rainfall followed by a shortening of the rainfall growing season. The same changes tend to be observed by farmers in the districts of Blantyre and Machinga. However, in these districts, farmers do not unanimously agree on the direction of changes of the extreme climate events and the timing of the rainfall season. For example,



in Machinga, the perception of the increase and the decrease in the frequency of floods and drought are almost equally shared among farmers. The same observation holds for Blantyre concerning the onset of rainfall. These diverse perceptions may be explained by the variety of agricultural systems (low lands, uplands) in which they operate and the agricultural challenges that they face. For example, while all farmers within a given area may face the same climatic stress, some may be more exposed to floods than others, because they cultivate on low lands instead of uplands or they are confronted with more agricultural challenges (a lack of improved seeds, inputs) that increase their sensitivity to the climatic stimulus. This suggests that other factors beyond climate play a role in influencing the perceptions of climate variability.

In Mwanza and Zomba, the noticeable changes are the spatial distribution of rainfall (mid-drought and onset of the rainfall) and the length of the growing season. With regards to the climate extremes, there is a sharp contrast in perceptions with the other districts. In Mwanza, 90% of households revealed no change in flooding, while 83% of farmers in Zomba noticed a decrease in the frequency of drought.

The analysis of actual climate data for the period of 1972 to 2009 for the districts' weather stations showed no significant trend for the average yearly rainfall observations, but a significant upward trend in minimum average temperature for the districts of Machinga, Blantyre and Chikwawa. For the latter district, Chikwawa, an increase in maximum temperature is also found to be significant. The increase in temperature and changes in the total quantity and pattern of rainfall could have a detrimental effect on yield and actually lead to crop failure. Furthermore, when the frequency of crop failure reported in Table 2 is cross-checked with actual temperature data, it is noticed that the districts with the highest frequencies of crop failure are associated with a significant increase in minimum temperature. Thereby, farmers' perceptions of climate variability could actually be based on their experience with crop failure. Hence, the perception of climate variability seems to not be the main direct stimulus of coping responses, but experience with crop failure is the primary driver of farmers' coping decisions. Direct and prolonged experience with crop failure both have a major influence on the perception of climate variability and actually determine the farmers' decisions to take action to adjust to the adverse consequences of climate and other stressors. This analysis has also been corroborated by Meze-Hausken [31], who stressed in his study in northern Ethiopia that it is the impact of the climatic stress that counts, rather than the cause, from the viewpoint of local people. The author demonstrated that farmers, pastoralists and humanitarian organizations have reported changes in climate in the form of abnormal rainfall and drought, although the long-term rainfall pattern did not show any specific change. He argued that the interaction between temperatures, evapotranspiration and other physical factors, such as soil fertility, vegetation cover and water availability, resulted in communities' belief that rainfall had declined without any validation from the actual measurement. In contrast, other studies have found coherence between observed rainfall data and local communities' perceptions. This is the case of Ovuka and Lindqvist [32], who found that Kenyan farmers' perceptions of a decreasing trend in rainfall were in coherence with meteorology rainfall observations. Such a finding has further been supported by a number of studies across Africa, including Thomas *et al.* [12] in South Africa, West *et al.* [33] in Burkina Faso and Mertz *et al.* [8] in Senegal.

### 3.2. Coping Strategies for Climate Variability and Other Agricultural Stressors

#### 3.2.1. Farmers Coping Responses and Their Determinants

Several options for coping strategies (16) were presented to households during the field survey. Every household that experienced a crop failure adopted at least one coping option. Based on Cooper *et al.* [34] classification, we grouped the coping strategies into two major categories; the *ex-ante* risk management strategies and the *ex-post* risk management options. The *ex-ante* options include farm irrigation, change of crop type/variety and crop diversification, while the *ex-post* strategies include off-farm labor, sales of forest products and other non-farm livelihood diversification.

The results from Table 4 showed that in the study area, the key coping strategies used by households to deal with short-term climate variability and the other stressors are the *ex-post* risk management strategies, such as off-farm *Ganyu* labor (28%), small businesses (16%) and the sale of charcoal and firewood (7%, each) (Table 3). These strategies are adopted to mitigate the adverse impact of crop failure on farmers' livelihood. For the *ex-ante* options, only farm irrigation (10%) is a main strategy adopted by households. Changing crop type/variety and diversifying crop production are adopted by a negligible proportion of farmers (less than 5%) to adjust to crop failure. Findings that the *ex-post* risk management strategies are the dominant coping alternative used by households is in line with some other study findings in the rest of Africa. In Tanzania, for example, Trærup and Mertz (2011) [9] showed that reduced consumption (meaning doing nothing) is the most important strategy, and casual employment is the second most reported strategy. This also validates the hypothesis that households are not responding specifically to changes in climate parameters, but to a number of disturbances that affect their crop production and livelihood.

Bryceson [35] highlighted that casual labor is the major coping mechanism used by the rural poor in Malawi to fight food insecurity. Casual labor, commonly named *Ganyu* labor in Malawi, is a short duration casual labor contract for unskilled labor paid in cash or kind [36]. Reliance on casual labor is considered as a food insecurity safety net to respond to low income due to poor maize yield. Some studies confirmed that *Ganyu* labor is used as an *ex-post* coping strategy in the event of a shock [37] and closely related to chronic and deteriorating food security conditions [38,39].

Micro-enterprise activities are important resilience strategies that households use to maintain or diversify their farm income in the face of declining maize yield and poor soil fertility [40]. Findings from Orr and Mwale [40] identified income from small business as the second most important source of cash income after crop sales. Small business in the districts surveyed occurs in the form of petty trade, including beer brewing, basket weaving, brick making and the sale of alcoholic drinks. The rapid development of these micro-enterprises has followed market liberalization, creating new opportunities for farmers in southern Malawi to earn cash income [41,42].

The sale of timber and charcoal forest products represent substantial income input for the households. A study by Fisher [43] highlighted also the high level of dependence on forest products by households in southern Malawi. Survey results from this study revealed that sales of charcoal and timber are high return activities that may contribute to reducing income inequality across households.

**Table 4.** Household coping strategies.

Coping strategies	Percentage
Casual labor	27.99
Wild food	0.68
Farm irrigation	10.24
Small business	15.7
Fishing	0.34
Charcoal selling	7.17
Firewood selling	6.83
Government aid	2.39
Buying	3.75
Upland yield	4.44
Loan/debt	1.02
Selling assets	4.1
Drought resistant varieties	0.68
Crop diversification	0.34
Skip meal	0.34
Barter system	0.34
No coping	13.65
Total	100

### 3.2.2. Determinants of Coping Responses

The results of the probit regression analysis of the determinants of farmers' main coping strategies are reported in Table 5.

**Table 5.** Determinants of adaptation, marginal effects.

Variable	<i>Ganyu</i> labor	Farm irrigation	Small business	Charcoal sales	Firewood sales
Education of household head	-0.1819 **	0.0008	0.0288	-0.0248	-0.0250
Gender of the household head	0.2367 **	-0.0054	-0.0646	-0.0452	-0.1345 *
Age	-0.0035	0.0000	-0.0029	-0.0010	0.0022
Access to technical assistance	-0.1176	0.0023	-0.1338	-0.2689 ***	-0.1869 **
Family size	0.0022	-0.0009	-0.0071	0.0214 *	0.0017
Asset index	-0.0091	0.0003	0.0099	-0.0060	0.0007
Area cultivated	-0.0379	-0.0009	-0.0518	0.0031	0.0103
Soil fertility	-0.1924 **	-0.0019	-0.1780 **	-0.0201	-0.0695
Experience of crop failure during the past five years	0.1519 ***	0.0013	0.1136 ***	0.0445 **	0.0431 **
Machinga ADD	-0.0140	0.6695 **	-0.1503 *		
Ngabu ADD	0.1938	0.9425 **	-0.3324 ***		
N	150	150	150	150	150

Notes: \* Significant at the 10% level of confidence; \*\* significant at the 5% level of confidence; \*\*\* significant at the 1% level of confidence. The ADDs were dropped from the sales of forest products (firewood and charcoal) regressions, because the dependent variables did not vary with the ADD independent variables. Therefore, the observations were predicted perfectly.

The key variables influencing the decision to participate in *Ganyu* labor are the education of the head of household, the gender of the head of household, soil fertility and experience of crop failure during the last five years from 2009.

The key variables driving farmers' coping mechanism are the number of times they experienced crop failure during the last five years from 2009, soil fertility, access to extension services and the gender and education level of the head of household.

Taking each specific coping strategy, the variables, education of the head of household, gender of the head of household, soil fertility and experience of crop failure during the last five years from 2009, are the most important determinants of the decision to participate in *Ganyu* labor. Households headed by men are 24% more likely to be involved in *Ganyu* labor than their female counterpart, as expected. *Ganyu* labor is a male-dominated activity, because in the traditional division of labor, men often work on plantations inside or outside their villages, while women allocate their labor in the production of subsistence food to meet the household needs [35]. This result implies that women cannot participate as much as men in this off-farm labor supply, because the household chores and their work on the subsistence farming plots will be very vulnerable to the impact of climate variability and the agricultural disturbances. Furthermore, *Ganyu* labor may reduce the impact of income shock in the short term, but it may create more exposure of the agricultural production systems to climate change in the long term. This is because farmers often engage in *Ganyu* labor to earn additional income after a bad crop year and during farming periods where their labor is most needed on their own farms, increasing, therefore, the likelihood of crop failure due to poor management.

Households with good soil fertility are 20% less likely to participate in *Ganyu* labor. This is understandable, because when farmers perceive that their soils' quality is not good, they will look for other employment to sustain their livelihoods. Similarly, less educated households and those who experience crop failures have a higher likelihood to be engaged in *Ganyu* labor, as they view it as an economic opportunity to cope with food insecurity and poverty.

Households' socio-economic characteristics and the frequency of crop failure do not influence their decisions to adopt farm irrigation techniques. The only significant variable is the geographical location (ADDs). This is a striking result, but not surprising, since farm irrigation technologies are often promoted under government projects with subsidies to facilitate uptake. Therefore, the adoption of farm irrigation techniques depends more on the access and availability of this technology at the farmers' geographical locations than on their own socio-economic characteristics. The significance of the Machinga and Ngabu ADDs suggests that farmers in these districts are more likely to have access to and benefit from water conservation techniques, compared to those in Chikwawa ADD.

Consistent with expectations, farmers who perceived that their soils are of good quality are 18% less likely to be involved in small businesses. Furthermore, numerous experiences of crop failure over the past five years increase the probability of choosing small businesses as an adaptation strategy. Farmers in the ADDs of Machinga and Ngabu have a lower likelihood to be involved in small businesses relative to those in the Blantyre ADD. As outlined above, in Blantyre ADD, being a poor ADD with low soil fertility and, thereby, having weak farming opportunities, alternative employment in small businesses will appear as a promising prospect to earn income.

The main drivers of charcoal sales are access to technical assistance, family size and the number of times crops failed during the past five years. Concerning the firewood sales coping strategy, male heads

of households and households that receive technical assistance have less probability to adopt this coping strategy. However, families who experienced numerous crop failures during the past years have a higher likelihood to sell firewood. Crop failure leads to food insecurity and forces farmers to hire out and embrace non-farm activities as coping strategies. These strategies help households to cope with income shocks, but actually may increase the pressure on forest resources and the incidence of deforestation, further increasing the vulnerability to climate variability.

In all regression results, experience with crop failure consistently appears to be a significant determinant of farmers' coping decisions, except for the adoption of farm irrigation. Such a finding confirms the initial hypothesis that the main driver of farmers' coping strategies is their experience with crop failure, which is influenced by numerous stimuli, including climate.

#### 4. Conclusions and Policy Implications

This paper examines farmers' coping responses to crop failure due to multiple stressors and the drivers of these coping options in southern Malawi. The agricultural sector in Malawi is influenced by more than climate variability. Other stressors, including poor soil fertility, lack of agricultural inputs and technology and poor agricultural practices, also affect crop production and lead to crop failure when inappropriately addressed.

Results from this research highlight that climate-related challenges are the main causes of crop failure, as reported by farmers, but the other agricultural stressors are also sources of concern. The threat of climate variability and change does not directly motivate coping responses; conversely, experience with the impact of climate variability and other stressors trigger actions. No wonder very few farmers adopt pro-active, preventive actions, and most of them are taking *ex-post* reactive measures. Hence, strategies adopted by farmers to cope with the impact of the interaction of these stressors are largely dominated by *ex-post* reactive coping measures. A common denominator to these coping mechanisms is that they require little investment in human, physical and financial capital and are driven by farmers' experience with crop failure. Indeed, the characteristics of households most dependent on these options are being less educated, having male-headed households, having poor soil fertility and experiencing a high number of crop failure.

These strategies can be considered as informal safety nets that provide short-term benefits to households with poor farm assets and endowments, but may actually be very limited to sustain livelihood and enable households to adapt to long-term changes in climate. Therefore, there is a need for policies to assist farmers to move beyond these daily adjustments and to adopt more sustainable adaptation strategies to climate change. Several policy implications for adaptation to climate change can be drawn from these research findings.

First, since experience with the impact of climate risk influences perception, communicating climate change risks with reference to crop failure is likely to be an effective strategy to stimulate *ex-ante* adaptation responses. This is particularly true when farmers operate in a complex setting influenced by the dynamism of multiple stressors.

Second, there is a need for policies to assist farmers to move beyond the daily coping adjustments and adopt more sustainable adaptation strategies to climate change. These can include the development of sustainable farming systems through climate-resilient varieties, improved soil fertility and soil

conservation practices and agro-forestry technologies. Investment in these strategies should go along with the necessary institutions to facilitate their uptake by farm households. It is important for the government to facilitate access to extension services that will provide information and training on improved farm management and climate information, which are very essential to adapting to long-term climate change. More education of farm households is also necessary to increase awareness of the adaptation opportunities, to enhance their ability to implement strategies for drought/flood preparedness and to apply new technologies effectively for climate change mitigation and adaptation.

Third, initiatives to assist households to better cope with climate change should be embedded in the local context of farmers' decision making. Adaptation to changing climate should not be considered in isolation, but in a context shaped by socio-economic and political factors.

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### Author Contributions

Jeanne Y. Coulibaly is the lead author. She designed the research, performed the analysis and wrote the paper. Glwadys A. Gbetibouo provided very constructive technical advice in the research design and the analysis. Godfrey Kundhlande compiled the data for the analysis. Gudeta Sileshi and Tracy Beedy provided information on the environmental characteristics of the study area and contributed to the data collection process.

### Conflicts of Interest

The authors declare no conflict of interest.

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