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Ex-ante and *ex-post* coping strategies for climatic shocks and adaptation determinants in rural Malawi

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ABSTRACT

This paper assesses farmers' experiences with different climatic shocks as well as their *ex-ante* and *ex-post* coping strategies for climatic risks and shocks in rural Malawi. The paper is based on a comprehensive data set collected in 2013 from 1582 farm households located in three regions of Malawi (northern, central, and eastern). The study uses a bivariate probit model to examine the role of farm characteristics—including physical, human, social, and financial capital—in the household's decision to adapt to climatic shocks. The results revealed that farmers in the study area experienced droughts, floods, and crop pests and diseases as key climatic shocks. Additionally, some indirect climatic shocks reported by farmers include crop damages, increases in input and output prices, and reductions in farm profit. Farmers adopted more on-farm work, drought-tolerant varieties, early planting, and intercropping as key *ex-ante* adaptation strategies to reduce the adverse impacts of extreme climate events. Farmers adopted drought and disease-tolerant crops, diversified their crops, planted earlier, did more on-farm work, and changed their eating habits as key *ex-post* climatic shock coping strategies. Furthermore, social networks and capital were found to be important factors influencing farmers' adaptation decisions. The study suggests improving access to community resources, infrastructure, and information in order to improve household capacity to cope with climatic shocks.

1. Introduction

Climate change is real, and its effects have become increasingly apparent over the past few decades (Abid et al., 2016a,b). Developing countries, especially those located in sub-Saharan Africa such as Malawi, are already facing multiple challenges related to poverty, food security, and health. They are particularly likely to be affected by the negative impacts of climate change (Deressa et al., 2009; Minot, 2010). Climate change projections suggest a mean temperature increase of 3 to 4 degrees celsius by the end of the 21st century in Afirca, which is 1.5 times higher than projections for the earth overall (Bryan et al., 2013). All of these projected changes are likely to adversely affect agriculture production in Africa, including Malawi. The yields of major African crops like maize, sorghum, millet, cassava, and groundnut are likely to be reduced by 8 to 22% by 2050 (Schlenker and Lobell, 2010).

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Malawi, a landlocked country located in southeastern Africa, faces particular challenges responding to climate change (Kachulu, 2017). The livelihoods of more than 80% of Malawi's population depend on the agriculture sector, which is particularly likely to be negatively impacted by climate change (FAO, 2015a,b). This overdependence of Malawi's population on climate-sensitive agriculture contributes to the country's high vulnerability to climate change (Kachulu, 2017). This vulnerability is aggravated by challenging socioeconomic conditions, including a high poverty rate, population pressure, food insecurity, political instability, and ethnic tensions, which lead to compromised food security and economic wellbeing in Malawi (DEA-Department of Environmetnal Affairs, 2002).

Given the abrupt changes in climate and their effects, adaptation is one of the key policy options to reduce the negative impact of climate change (Kurukulasuriya and Mendelsohn, 2008). Considering the importance of adapting to climate change, a comprehensive understanding of coping and adaptation dynamics across these regions is urgently needed. The Intergovernmental Panel on Climate Change defines coping as the use of available skills, resources, and opportunities to address, manage, and overcome adverse climatic conditions, with the aim of achieving basic functioning in the short to medium term (IPCC, 2012). On the other hand, adaptation in human systems is defined as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities" (Wiederkehr et al., 2018). Adapting agriculture to climate change, therefore, entails taking the right measures to reduce the adverse effects of climate change on agriculture by making appropriate adjustments and changes in farm management and cropping practices (Adger et al., 2003). Globally, a range of adaptation options are available and adopted by farmers (Abid et al., 2016a,b). These options range from individual adaptation measures to institutional and policy options. The individual and farm-level measures may include changes in agronomic practices, changes in cropping patterns, better utilization and management of resources like water, land, fertilizer, and pesticides, and changes in livelihood strategies like income diversification. Policy or institutional measures may include early warning systems for extreme events, disaster preparedness, improved risk management, climate risk insurance and biodiversity conservation (Abid et al., 2016a,b; Kurukulasuriya and Mendelsohn, 2008; Hassan and Nhemachena, 2008).

Decision-making vis-à-vis adaptation to climate change at the farm level is complex and dependent on socioeconomic, demographic, institutional, economic, and other factors (Rahut and Ali, 2017). The perceptions of key decision-makers also play an important role in the process of coping and adaptation (Abid et al., 2015; Wolf et al., 2010). These perceptions are shaped by several factors, including farming experience, contact with extension services, or contact with the media. They may not always reflect reality. Understanding these factors is critical for devising local adaptation policies and plans, as plans or policies may not be successful if they do not address local concerns and behaviors (Czaja et al., 2006; Pauw et al., 2010). Here, perceptual data can act as a valuable complement to climate data and might reveal important underlying drivers or processes that specific environmental parameters fail to detect (Mulwa et al., 2017).

Taking the case of Malawi, this study assesses the vulnerability and adaptation of farming communities to long-term and short-term climatic shocks. Specifically, this study has three objectives: to assess the vulnerability of farmers to climatic shocks; to examine the adoption of different risk management and coping strategies before and after the occurrence of different climatic shocks; and to determine factors affecting the adaptation decision making of farmers.

2. Methodology

2.1. Study area

The study was conducted in 16 districts across the Central, Northern, and Southern administrative regions of Malawi (Fig. 1). Malawi is geographically located in southeastern Africa and lies between 9 degrees 22′ S and 17 degrees 3′ S (Kachulu, 2017) with a total land of 120,000 km^2. More than 80% of the population, or 14 million people, is involved in agriculture. Malawi has 2.5 million small landholder farming families. Arable land accounts for 45% (5.4 mha) of the total land area (Ngwira et al., 2014), of which 4.5 million hectares are occupied by smallholders. The average landholding is 1 ha per farming household (FAO, 2015a,b).

The climate in Malawi is relatively dry, sub-tropical, and seasonal. The average temperature in Malawi ranges from 8 degrees Celcius in highlands like in the northern region to 38 degrees Celcius in lowlands along Lake Malawi and the Lower Shire Valley in the southern region (Kachulu, 2017). The rainy season in Malawi mainly occurs during December and April and those months receive 90% of the total rainfall. The annual average rainfall also varies with altitude, ranging from 1,800 mm in highlands to 800 mm in lowlands (FAO, 2015a,b). On the other hand, there are two different dry seasons in Malawi. One cool dry season lasts from mid-April through August while a warm dry season runs from September through November (Vincent et al., 2014). Agriculture in the country is mainly rain-fed and largely dependent on the unimodal rainfall system. The heavy dependence on rain-fed agriculture makes the country highly vulnerable to climate change (FAO, 2015a,b).

The northern region consists of high plateaus and is the least densely populated region in Malawi. Its density is only 63 people per square kilometer, compared to 155 people per square kilometer in the central region. The southern region has a mixture of extremely hot areas, the highest mountain in the country, and fertile highlands. The region has a population density of 184 people per square kilometer. Further, literacy rate is also high in northern region (WHO, 2019). Malawi society is characterized by a patrilineal system in the northern region and by a matrilineal system in the central region and some but not all the districts in the southern region. Each district is further divided into traditional authorities, which are ruled by chiefs. The village is the smallest administrative unit, and each village is under a traditional village headman. A group headman oversees several villages.

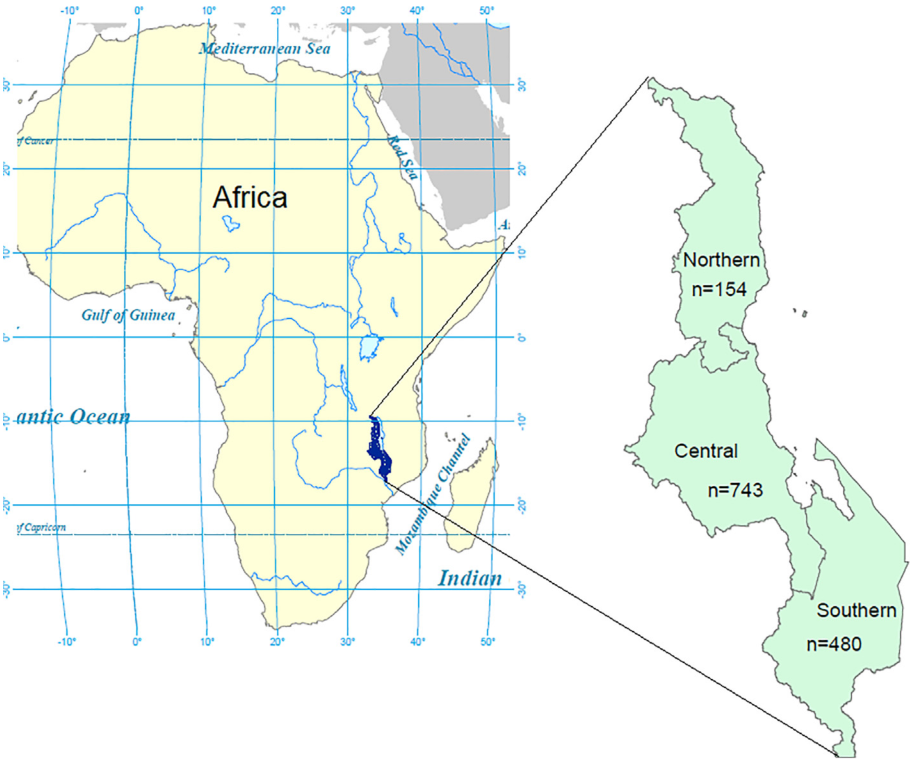

Fig. 1. Study area map.

2.2. Data

The study was the part of the CIMMYT-led project on Sustainable Intensification of Maize and Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA) (Marenya et al., 2016). The study was based on a primary survey of 1,582 households selected through a multi-stage proportional sampling technique. The selection of households was done in three stages. The first stage involved selection of 16 study districts using simple random sampling followed by selection of seven to eight villages from each district using a stratified sampling technique in the second stage. The third stage involved the selection of farm households from selected study districts (Table 1) using random proportionate sampling.

Table 1
Study districts.

Region	District	Sample
Northern region	Mzimba	157
Central region	Dedza	84
	Dowa	97
	Kasungu	120
	Lilongwe	265
	Mchinji	60
	Ntcheu	90
	Ntchisi	44
	Salima	81
Southern region	Balaka	137
	Blantyre	60
	Chiradzul	49
	Machinga	115
	Mangochi	125
	Mwanza	30
	Thyolo	68
	Total sample size	1582

2.3. Analytical framework

In order to assess the factors affecting the farmers' adaptation decision-making to address climatic shocks, we used a probit model. A latent variable (y^*) representing the expected benefits from adapting to climatic shocks may be written as:

$$y_i^* = \beta_i X_j + \varepsilon_i \tag{1}$$

As we cannot directly observe a latent variable, equation (1) may be written in terms of observable variables and in terms of dependent variable y_i as:

$$y_i = 1 \ if \beta_i X_j + \varepsilon_i > 0$$

and

$$y_i = 0 \ if \beta_i X_j + \varepsilon_i \leq 0$$

where y_i denotes dependent variable and shows that a household will adapt to climatic shocks ($y_\mathrm{i} = 1$) only if the expected net benefits from adaptation are positive (y_i*greater than0). A household will not adapt to climate change ($y_\mathrm{i} = 0$) if his or her expected benefits from adaptation are zero or negative ($y_i^* < 0$). Further, X is a vector of the explanatory or independent variables, βs are observable coefficients to be estimated, and ε is the random errors distributed as a normal distribution with zero mean and unit variance (Abid et al., 2015, 2018).

2.3.1. Dependent variables

The dependent variables used in this model are *ex-ante* and *ex-post* adaptation measures. The *ex-ante* adaptation strategies for climate shocks are defined as measures adopted by farm households in advance in order to cope with anticipated climatic shocks. The *ex-post* adaptation strategies are the measures adopted by farm households after the occurrence of a climatic shock. For the probit model, we used binary variables for both *ex-ante* and *ex-post* adaptation strategies, where the value is assigned "one" if a household adopted a coping measure and zero otherwise.

2.3.2. Explanatory variables

In order to assess the determinants of coping strategies to short-term and long-term climatic shocks, the following explanatory variables were included in the model.

2.3.2.1. Social capital and networks. Under social capital and networks, we categorized the household's capital into physical, social, human, financial, and informational capitals. In physical capital, we considered household assets such as livestock and land ownership. In human capital, we considered age, gender, education, and household size. In social capital, we considered household interaction with the society and market, such as the distance of a household from the main market, extension, credit services and input providers, number of relatives, interaction with influential people, and the number of grain traders in contact with farm households. We also considered the reliance of a household on government subsidies during times of crisis. Under financial capital, access to credit and off-farm income were considered as key variables determining farmers' financial capacity in adapting to climate change. Informational capital includes variables on access to different modes of extension services such as public extension services, television/radio, and interactions with other farmers, and access to climate information.

2.3.2.2. Farm-specific variables. We included dummies for land tenure (1 = owned and zero otherwise), soil fertility (1 = good and zero otherwise), and soil slope (1 = gently sloped and zero otherwise) as farm-specific variables that may affect farmers' decisions to adapt to climate change. For instance, farmers who own land may have flexibility in choosing adaptation measures compared to tenants who have restricted rights to use a piece of land. Similarly, soil fertility may also act as an important factor determining farmers' adaptation strategies. Farmers with good soil may perceive high returns from their land and be likely to adopt a strategy to adapt to climate change risk while farmers may be reluctant to invest in adaptation measures for low-quality land.

3. Results and discussion

3.1. Descriptive statistics

The descriptive statistics are presented in Table 2. The study finds that the majority of the farmers in the study area own land, and only a small number are tenant farmers. Regarding the quality of land, more than 40% of the farmers claimed the quality of their land as very high quality (fertile). More than half of the farmers reported that their land is gently sloped, which implies the easy flow of water during heavy rainfall. Regarding physical assets, most of the households owned livestock, and the mean land ownership in the area was around 1.370 ha, which reflects the prevalence of small-scale farming in the region. The majority of the household heads were male, with an average age of around 45 years old. The average education was around seven years of schooling, and the average household size in the areas was around five members. In regards to social capital and services, farmers reported that it took them on average roughly one and half hours (86 min) to reach the main market by foot. It took them an average of roughly 92 min to walk to extension services and 100 min to walk to input providers.

Membership in different groups promotes the interaction between farmers and is supposed to have a positive impact on their

Table 2
Descriptive statistics (N = 1582).

Variables	Description	Mean	Std. Dev.
Farm characteristics			
Land tenure	Dummy = 1 if own land, 0 otherwise	0.964	0.133
Soil fertility	Dummy = 1 if land is highly fertile, 0 otherwise	0.436	0.188
Soil slope	Dummy = 1 if gently has slope, 0 otherwise	0.572	0.202
Physical capital			
Livestock ownership	Number of livestock units owned (TLU)	0.520	0.880
Land	Owned land (hectares)	1.370	1.310
Human capital			
Sex	Gender of household head, 1 = male, 0 otherwise	0.841	0.141
Age	Age of household head in years	44.700	15.256
Education	Years of education of the household head	6.840	12.548
Household size	Number of family members living together	5.051	0.173
Social networks/ social capital			
Distance to the main market	Walking distance to the main market in minutes	85.634	7.021
Distance to extension	Walking distance to the agricultural extension offices in minutes	91.953	7.321
Distance to input provider	Walking distance to input provider in minutes	100.332	7.942
Membership in farmer groups	Dummy = 1 if a household head or spouse are members of a farmer group, 0 otherwise	0.104	0.210
Membership in WUA	Dummy = 1 if a household head or spouse are members of a WUA, 0 otherwise	0.045	0.020
Number of relatives in the village	Number of relatives the household can rely on in the village	3.425	0.302
Number of influential contacts in the village	Number of influential contacts in the village	2.123	0.214
Number of grain traders	Number of grain traders known to you	4.295	0.343
Reliance on government support	Dummy = 1 if a household does rely on government support in times of need, 0 otherwise	0.618	0.211
Financial capital			
Off-farm income	Dummy = 1 if a household has access to off-farm income, 0 otherwise	0.430	0.210
Access to credit	Dummy = 1 if a household has access to credit, 0 otherwise	0.301	0.011
Informational capital			
Access to public extension	Dummy = 1 if household has access to public extension services, 0 otherwise	0.290	0.100
Access to television/radio extension	Dummy = 1 if the household has access to television/radio extension services, 0 otherwise	0.310	0.422
Access to climate information	Dummy = 1 if household has access to climate information, 0 otherwise	0.390	0.120

productivity and access to different services. However, study findings show that only a few farmers belonged to local farmer organizations (10%) or water user associations (5%). The absence of formal farmer groups or the limited number of groups may contribute to the lack of participation of farmers in such groups or associations. Additionally, respondents reported that they have an average of three relatives in their villages who can help them during an emergency or disaster. Similarly, on average, each household had two influential contacts who can help them to get assistance or relief in case of emergencies or disasters. More than 60% of the respondents reported they rely on the government in case of emergency or risk, and only 40% of the farmers were self-reliant and did not require any support from the government.

Regarding financial capital, less than half of the respondents had access to off-farm income and the rest are dependent on agricultural income. Only 30% of the households had access to credit. Limited access to credit may have a long-lasting impact on the agricultural productivity of farmers as it directly affects their buying power and access to farm inputs. Study findings also show farmers' difficulties in accessing information services, particularly public extension services, television and radio, and climate change information. Only one-third of the farm households have access to extension services and digital media, whereas climate change information was available to about 40% of the farm households.

3.2. Long-term and short-term climatic shocks

Rural farming households in Malawi face multiple market and non-market livelihood shocks and risks. Here we divided these shocks and risks into long-term and short-term. The long-term shocks are evaluated over a ten-year period and include drought, crop pests and diseases, floods, and hailstorms. Short-term risks and shocks include crop and livestock yields, prices, and market fluctuations and are evaluated over a five-year period.

The results show that farm households in Malawi reported drought as the long-term climatic shock that affected the livelihoods of the largest proportion of the sampled household in the past ten years (Table 3). More than two-thirds of the households experienced drought at least once in the past ten years, and about 45% of the households experienced it one to two times in the past ten years. An additional one-fourth of the farmers experienced drought three to five times in the past ten years. These findings are in line with those of Pauw et al. (2010) and ICA, (2014) that reported the frequent occurrence of drought in parts of Malawi. As reported by farmers, the occurrence of drought is very frequent in the Southern region and to some extent in the northern region. In the central region, the frequency and intensity of drought is very low.

Crop pests and diseases ranked second as the long-term climatic shock most experienced by farm households in Malawi. Additionally, about 45% of households experienced Experienced flooding from heavy rains over the past ten years. About 35% of the

Table 3
Exposure of household livelihoods to climatic risk in the past ten years (N = 1582).

Climatic shocks	Exposure (%)	Exposure frequency (%)			
		None	1–2 times	3–5 times	greater than5 times
Droughts	66	34	43.2	21.3	1.5
Too much rain or floods	41.2	58.8	32.1	8.3	0.8
Crop pest and diseases	48	52	32	11.7	4.3
Hailstorms	33.3	66.7	27	5.7	0.6

farmers experienced one to two flooding or heavy rainfall events in the past ten years. However, only 8.9% of farmers reported three to five episodes of flooding or heavy rainfalls in the past ten years. The farm households located in the southern region and some in northern region were found to be more affected by floods (Davies, 2015). This study also finds that about half of the farm households reported their crops were exposed to crop pests and diseases at least once in the past ten years. About 11.7% of farmers reported three to five occurrences of crop pests and diseases, and 5% reported experiencing them five times in past ten years. Around one-third of the farm households stated that they were exposed to a hailstorm, which usually occurred once or twice in past ten years. Together these results show that farm households in Malawi experience various climatic shocks that could affect their livelihoods in multiple ways.

We also analyzed the farmers' experiences with short-term livelihood shocks arising directly or indirectly from climatic shocks. As shown in Table 4, large increases in food prices, large increases in agriculture input prices, large decreases in agricultural output prices, livestock diseases, or death were the key short-term livelihood shocks experienced by farm households over the last five years in Malawi.

Large increases in food prices are the most important concern reported by farm households. The increases are directly related to ongoing changes in climate and the occurrence of extreme climatic events that negatively affect food productivity in Malawi and other sub-Saharan African countries. Pauw et al. (2011) reported that about 2% of Malawi's GDP is lost due to the combined effects of drought and floods, and most of these damages are related to the agriculture sector. The gap in supply and demand for food products in Malawi has resulted in a rapid increase in food prices. Given the current economic condition of most of the population in Malawi, this increase in food prices will directly affect the ability of poor households to afford food, which is a major component of food security.

A large increase in agricultural input prices is among the most important risks reported by farm households because it directly affects their ability to access and adopt improved varieties and tools like seed and fertilizer. This has a direct impact on the productivity of food crops and eventually affects local food security and poverty dynamics. A large decrease in agricultural output prices is another important concern among farm households and is generally caused by imperfect market conditions and poor marketing governance. Crop damage by livestock and wildlife was also reported as a major threat to local livelihoods and is indirectly related to the impact of climate change on grazing lands. For instance, it has been reported that warmer weather in sub-Saharan Africa is drying up the grazing areas (Adhikari et al., 2015). Those changes affect farm animals that are dependent on grazing lands for food. Eventually, the animals end up damaging food crops in nearby villages.

Climate change brings social and health risks. Farm households also reported family sickness due to climate-related shocks as another pertinent risk that they face. Sickness due to climate shocks is predominantly prevalent in the areas where people experienced more floods and droughts. Furthermore, farmers reported increasing events of livestock diseases and deaths, which are mainly associated with extreme weather events and long-term climatic shocks such as drought and floods (Elahi et al., 2017). Another important emerging risk associated with climate change is the theft of agricultural produce and assets. Twenty percent of the farm households reported that thier harvest or agricultural assets—particularly machinery and farm implements—have been stolen. This could be linked to the increasing cost of agricultural technologies and an increase in food prices, pushing some people to steal instead

Table 4
Household's exposure to livelihoods shock over the past five years (N = 1582).

Livelihood shocks	Exposure (%)	Exposure frequency (%)			
		None	1–2 times	3–5 times	greater than5 times
Large increase in food prices	42.5	57.5	21.5	11.7	9.3
Large increase in agricultural input prices	40.2	59.8	25.1	8.9	6.2
Large decrease in agricultural output prices	36.7	63.3	22.1	10.6	4
Livestock diseases or death	28.6	71.4	16	8.9	3.7
Family sickness	23.3	76.7	14.2	7.1	2
Crop damage by livestock & wildlife	19.3	80.7	10.3	6.1	2.9
Theft of assets or crops	18.5	81.5	12.6	5.1	0.8
Reduced/ complete loss of household business income	8	92	4.8	1.1	2.1
Death of household member	7.6	92.4	5.2	2.2	0.2
Reduced/lost employment income	3.1	96.9	1.9	1	0.2

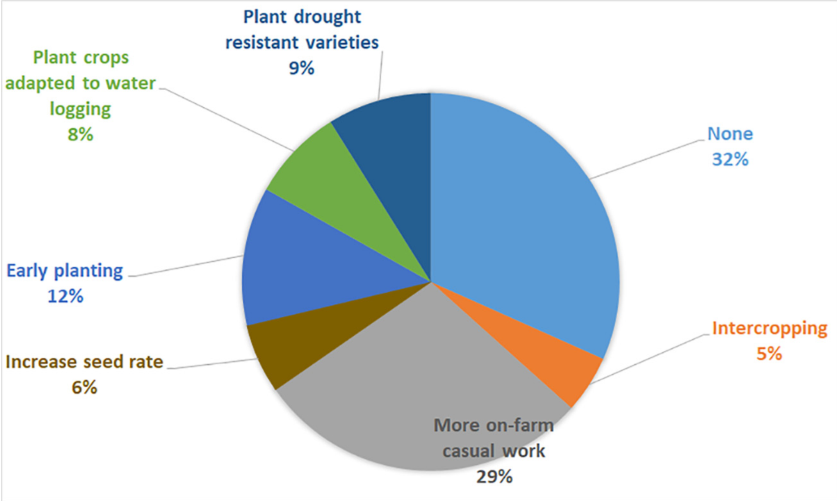

Fig. 2. *Ex-ante* climate risk management strategies (N* = 1520). *The sample size here has been reduced from 1,582 to 1,520, as some of the respondents did not answer this particular question.

of grow their own food or buy a new implement. Reduction or complete loss of household business income is another short-term climatic shock identified by some farm households. The reduction of agriculture-related business is also related to the above-mentioned risks, such as a large increase in agricultural input prices and a large decrease in agricultural output prices.

3.3. Risk management (ex-ante) and coping strategies (ex-post) to climatic shocks

Afterward, we asked farmers about the adoption of risk management strategies before the occurrence of climatic shocks (*ex-ante* adaptation) as well as coping strategies after the occurrence of climatic shock (*ex-post* adaptation). As shown in Fig. 2, farmers adopted a number of measures before the occurrence of climatic shocks. However, more than one-third of the farmers did not adopt any measures in advance to cope with climatic risks. This might be due to the limited information about the occurrence of specific types of climatic shock. As reported by many farmers, limited financial capacity is another factor that restricts farmers from adopting adaptation measures in advance. Farmers reported doing more on-farm casual (manual) works as an important *ex-ante* coping strategy. On-farm casual work, growing drought-tolerant crops, crops adapted to waterlogging, sowing crops early, and intercropping were the key *ex-ante* adaptation measures adopted by farm households in the study areas. Farmers reported doing more on-farm casual work in order to protect and prepare their crops from climatic risks. For instance, they often spent time planting trees and shrubs across their fields or making channels to clear their fields from anticipated heavy rains. Further, farmers who anticipate drought based on their previous experiences go for drought-tolerant crops. Many farmers who used drought-tolerant varieties reported these varieties had a positive impact on their crop harvest. These findings are in line with the findings by Fisher et al. (2015), who reported that farmers who were exposed to climatic risks were more inclined to adopt drought-tolerant varieties. Another strategy to cope with anticipated climatic risks was planting crops early, which was adopted by a number of farmers. Experienced farmers or those who have access to weather forecasting information often adjust crop sowing according to the occurrence of extreme events. Pangapanga et al. (2012) also reported similar findings.

The adoption of coping strategies to climatic shocks after the occurrence of climatic shocks (*ex-post* adaptation) is provided in Fig. 3. Farmers planted drought-tolerant, disease-tolerant varieties, diversified crops, planted crops early, did more on-farm work,

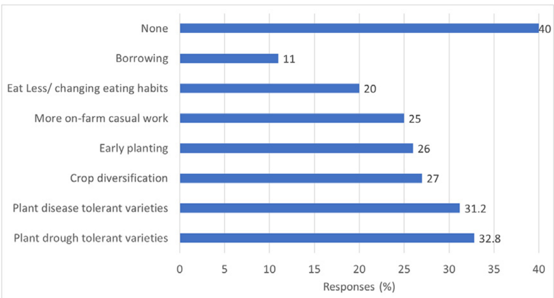

Fig. 3. *Ex-post* coping strategies to climate change (N* = 1518). The sample size here has been reduced from 1,582 to 1,518, as some of the respondents did not answer this particular question.

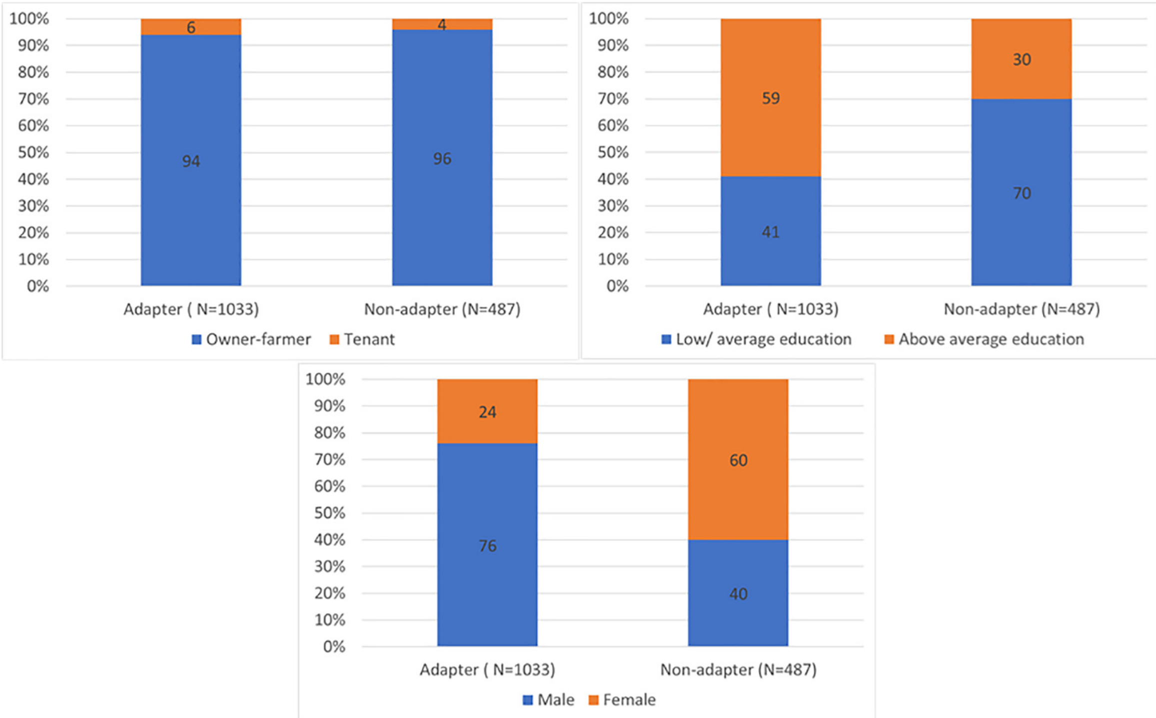

Fig. 4. Adaptation decision with respect to farmers' categories (N* = 1520). *The sample size here has been reduced from 1,582 to 1,520, as some of the respondents did not answer this particular question.

changed their eating habits, and borrowed money as key *ex-post* measures shown in Fig. 4.

Many farmers reported using drought and disease-tolerant varieties after being exposed to drought and crop pests and diseases. Similar findings were observed by Fisher et al. (2015), who reported higher adoption of climate-shock varieties among farmers who were previously exposed to climatic risks. Higher use of drought-tolerant varieties by Malawian farmers may be due to the impact of a long-term Farm Input Subsidy Programme (FISP) introduced in 2005–06 under which farmers were provided with improved varieties, especially drought-resistance varieties (Fisher et al., 2015). Some farmers even use crop diversification as an adaptation strategy to cope with climatic shocks, as some of the crops may survive the adverse effects. Reduction in the impacts of adverse climatic conditions, a slower spread of pests and diseases, and sustained crop production were some of the benefits reported by farm households in the study area. Similar findings were reported by Fadina and Barjolle (2018), who reported that farmers attribute adoption of farm diversification with the sustainability of their food and nutritional security and seek to increase the chances of a minimum production level after harvesting. Smit and Wandel (2006) also reported that diversification leads to better risk management and a steadier income stream. Diversification is also considered as an important strategy or component of farmers' resilience to climatic shocks (Stringer et al., 2009).

Another important adaptation strategy, doing more on-farm casual work, reflects farmers' past struggles to rearrange and adjust their livelihoods and farming due to climatic shocks. For instance, a flood event or heavy rainfall may negatively affect crop growth. Farmers may need to do more on-farm work to manage farming activities after the disasters, like making channels to clear standing water from the fields or to do mulching in the field to protect plants from heating. Farmers were also found to change their eating habits as an *ex-post* strategy. Farmers described changing eating habits by either reducing the frequency of daily meals from three times to twice a day or reducing the quantity of each meal in order to use saved food for longer period of time. Some of the farmers reported changing the type of food they ate, like switching from perishable commodities to grains such as maize, rice, or wheat that can be stored and consumed for a longer period of time.

Similarly, borrowing money was found to be another strategy adopted by farmers to cope with climate shocks. Most of the time, borrowing is informal and involves relying on relatives in the case of an emergency. The use of informal credit is due to limited access to formal credit institutions at the local level.

3.4. Determinants of adapting to climatic shocks

As the dependent variable is bivariate discrete (one if adopted climate risk adaptation strategy; otherwise zero), we estimated the probit model. The results are presented in Table 5 and are discussed in detail below. In addition to this Table, a correlation matrix presented in Appendix 1 shows the relationship of different independent variables.

Table 5
Parameter estimates of a probit model (odds ratios) for estimating determinants of adapting to climatic shocks.

Variables	Adapting to climatic shocks
Farm characteristics	
Land tenure	0.031 (0.092)
Soil fertility	−0.143** (0.029)
Soil slope	0.396*** (0.082)
Physical capital	
Livestock ownership	−0.026 (0.052)
Land	0.051* (0.008)
Human capital	
Sex	0.168** (0.075)
Age	0.016 (0.064)
Education	0.032** (0.008)
Household size	0.143 (0.105)
Social capital/ social networks	
Distance to the main market	−0.012* (0.006)
Distance to extension services	−0.112* (0.014)
Distance to input provider	0.014 (0.021)
Membership in farmer groups	0.615*** (0.026)
Membership in WUA	0.013 (0.005)
Number of relatives in the village	0.017* (0.021)
Number of influential contacts in the village	0.022 (0.129)
Reliance on government support	−0.315* (0.017)
Financial capital	
Off-farm income	−0.110** (0.016)
Access to credit	0.089** (0.015)
Informational capital	
Access to TV/Radio extension	0.078* (0.017)
Access to climate information	0.240*** (0.001)

3.4.1. Farm characteristics

Farm variables are very important in determining how farmers respond to climate shocks. Among farm variables, soil fertility is negatively associated with the adaptation to climatic shocks, which implies that farmers with fertile lands generally perceive that their soils can absorb climatic shocks and do not adopt any measures. Additionally, the slope of the farmland is positive and significantly related to adaptation to climate shocks. This implies that farmers with gently-sloped land are inclined to adapt to climatic shocks compared to farmers with flat land. This may be because climatic shocks could have more negative impacts on lands with gentle slopes. These findings are consistent with the findings of Barungi et al. (2013).

3.4.2. Physical capital

Regarding physical capital, the amount of land is found to be an important factor influencing farmers' adaptive behavior to climatic shocks. A positive and significant coefficient of a land variable implies that farmers with more land are more likely to adapt to climatic shocks. This is true in the sense that farming activities are sometimes designed to be implemented on a large scale and are not feasible to employ on a small scale. These findings are in line with the findings of Abid et al. (2015), where they found a positive impact of landholding size on adaptation decisions of farmers in Pakistan. Livestock ownership is negative but insignificantly related to adaptation, implying no relationship between owning livestock and climate change adaptation.

3.4.3. Human capital

Regarding human capital, the gender of the household head is positively and significantly related to the adaptation decision. This implies that having a male household head increases the likelihood of adapting to climatic shocks. This could be because male farmers have biased access to most of the resources, and are thus more likely to adapt to climatic shocks. In line with our findings, Ndiritu et al. (2014) also reported low adaptation by female-headed households due to existing biases against women. The positive and significant coefficient of education implies that educated farmers are more likely to adapt to climatic shocks compared to the uneducated or less educated farmers. Consistent with our findings, Czaja et al. (2006) also reported education as an important contributing factor in technology adoption. The other two variables related to human capital, age and household size, have positive but insignificant coefficients.

3.4.4. Social capital

Social capital plays an important role in adapting to climate change and climatic shocks (Adger, 2003). In this study, we found several variables related to social capital positively contribute to adaptation to climate change (Abid et al., 2017). For instance, the negative and significant coefficient of distance to market and extension services imply that improved and close access to markets and extension services increases the probability of adapting to climate shocks. This might be because easy access to market and advisory services make farmers more aware of new technologies, varieties, and information that they need to adapt to various climatic shocks.

Consistent with our findings, Abid et al., (2015) and Elahi et al., (2018) also found a positive impact of improved access to markets and information on the adaptive capacity of farmers.

Membership in farmer groups significantly and positively influences farmers' adaptive behavior. These types of memberships provide farmers a platform where they can interact with other farmers and get different pieces of advice on coping with different kind of climatic shocks and risks. These findings are in line with the findings of other studies (i.e. Ngaruiya, 2016, Pelling and High, 2005). Similarly, the coefficient of the variable number of relatives in the village is positive and significant, implying that more relatives in the village enhance farmers' ability to cooperate and reduce their vulnerability to different climatic shocks. Relatives often help each other during an emergency. Hence farmers with more support from relatives are more resilient compared to the farmers with less interaction or support from relatives. These findings are in line with the findings of Parthasarathy and Chopde (2001). On the other hand, the reliance of farmers on government support negatively influences their adaptive behavior, which implies that farmers who rely more on government at the time of climatic shock are less motivated to adopt adaptation measures as they seek government intervention instead of acting on their own.

3.4.5. Financial capital

Regarding financial capital, farmers who have access to off-farm income are less likely to adapt to climatic shocks. This might be due to the fact that farmers with diversified income are less dependent on climate-sensitive agriculture and thus less adaptive. On the other hand, farmers who have access to credit are more likely to take measures to cope with climate shocks. Here, credit seems to be an important factor in enhancing the financial capacity of farmers at the time of disaster. For instance, various farmers used this credit to buy drought-tolerant varieties as well as to buy fertilizer and other inputs for their crops. Access to television and radio and climate information are the other important determinants of adapting to climatic shocks. Often farmers get information from media regarding the different coping measures that could be used at the local level. Similar findings have been reported by various other studies (e.g., Abid et al., 2015; Abid et al., 2016a; Abid et al., 2016b; Ahmed et al., 2015; Deressa et al., 2009; Hassan and Nhemachena, 2008).

3.5. Adaptation across different farmers' categories

In the next step, we explored farmers' adaptation across different farming categories based on their tenancy, education, and gender. The division of adapters and non-adapters with respect to land tenancy does not show any significant association of land tenancy and adaptation. there was a positive association between adaptation and education level. About 59% of the adapters had above-average education compared to non-adapters, the majority of whom have little education. This implies that education has a significant impact on adaptation decisions. Similar positive associations of adaptive behavior with education were reported by Bryan et al. (2013). A higher rate of adaptation for male-headed farm household heads compared to the Female-headed small farms can be observed. About 76% of the adapters were male-headed households, implying that male farmers have more desire to adapt to climatic shocks. This might be because male farmers have more access to information and resources (Ndiritu et al., 2014).

4. Conclusion

This paper used the data collected from 1,582 households through semi-structured interviews and assessed farmers' experiences with different climatic shocks, their risk management and coping strategies before and after the shocks, and the factors affecting the adoption of both *ex-ante* and *ex-post* strategies. The study uses descriptive statistics, correlation graphs, and aprobit model to explore study objectives.

Long-term climatic shocks are challenging farmers in Malawi. According to the findings of the study, drought is found to be the most important long-term climatic shock and concern for the local population in Malawi. The wellbeing of local farming households is largely affected by increasing incidents of drought. Local crops and livestock are also compromised by climate-related water shortages and scarcity in the study districts. The crop pests and diseases linked to other long-term climatic shocks like drought and floods have largely affected the agricultural productivity in the study districts. Farmers sometimes feel hopeless due to the absence of any improved institutional and advisory services. Flooding and heavy rainfalls also affect households through damaging their assets, particularly houses, crops, and animals.

This study showed interesting findings regarding local exposure to short-term livelihood shocks related to climate change. For instance, a majority of the farm households said that a large increase in food prices coupled with a large increase in agricultural input prices has led to an overall increase in the farm households' expenditures. However, the increase in input prices is not reflected in output prices due to imperfect market conditions in the country. Therefore, instead of getting relief from the market, farmers complained that agricultural output prices had been continuously declining over the past five years, and profit margins are at the lowest in past decade. These findings show an important area of intervention by the government to control prices of agricultural commodities so that producers get right price for their produces. An increase in livestock diseases and deaths due to direct climatic shocks also call for immediate action by relevant authorities to allocate required resources at the local level to support farmers. Additionally, health risks caused by climatic shocks are a risk reported by farm households in study districts. Particularly, flooding and heavy rains in parts of the country have led the emergence of new diseases that badly affect local health in the country.

With respect to the adaptive capacity of farming households, we found that a limited number of farmers adopted certain measures in advance of climatic shock(s). Generally, the adoption of such measures was based on previous knowledge and a history of events. The key *ex-ante* measures include more off-farm work, early planting, use of drought-resistant varieties and a higher seed rate. The key reasons for limited adoption of advance measures include limited information about the exact nature and extent of climatic shocks and farmers being unsure about the timing or occurrence of climatic shocks. Financial constraints and limited resources were the other key factors affecting the adoption of measures in advance. On the other hand, farm households adopted a number of measures to cope with climatic shocks. Most farmers preferred drought and disease-resistant varieties, crop diversification, early planting and changing eating habits. The results of probit regression show that farm characteristics, particularly soil fertility and soil slope, significantly influence adaptation decisions, which implies that farmers may be supported in better managing their soils.

Similarly, social networks and social capital are found to be important factors influencing farmers' adaptive decision making. This implies that farmers who interact and network more with other farmers and institutional services are more likely to adapt to changes in climate compared to farmers with less access to those services. Therefore, previously neglected farming communities need to be connected and given given more support and institutional access. Particularly, there is a need to enhance focus on improving access to joint resources that are beneficial at the local level and could be used by locals to cope with climatic shocks. For instance, marketing, extension services, and credit services could be provided on priority basis to neglected communities so that they can efficiently cope with climatic changes and sustain their livelihoods. Similarly, information on climate change is another important determinant. The scope of climate information needs to be enhanced through adding support for climate change adaptation.

Declaration of Competing Interest

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

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Appendix 1. Correlation matrix of independent variables

	F1	F2	F3	P1	H1	H2	H3	H4	S1	S2	S3	S4	S5	S6	S7	S8	S9	C1	C2	I1	I2	I3
F1	1	-.01	.054*	-.03	-.02	.01	-.04	.02	.01	.00	.02	-.03	.01	.01	.01	.01	-.03	-.02	.03	.00	-.04	-.061*
F2	-.01	1.00	.079**	-.01	-.04	-.03	-.01	-.01	-.03	-.02	.00	.03	-.03	.00	.00	.02	-.02	.02	-.01	-.065*	-.03	-.03
F3	.054*	.079**	1.00	-.05	-.03	.03	.00	.01	-.01	.00	.02	-.01	.01	-.04	-.01	-.01	-.02	.00	.056*	-.05	-.01	.00
P1	-.03	-.01	-.05	1.00	.02	.01	.02	.00	.02	.078**	.072**	.04	-.01	-.01	-.02	.02	.04	.01	-.02	.00	.00	-.01
H1	-.02	-.04	-.03	.02	1.00	.01	.193**	.03	.02	.03	.00	.03	-.05	.02	.03	-.02	.02	.01	.069*	.05	.04	-.02
H2	.01	-.03	.03	.01	.01	1.00	-.339**	.00	.02	.04	.02	.02	.01	.00	.053*	.01	-.01	-.02	.02	.01	.00	.04
H3	-.04	-.01	.00	.02	.193**	-.339**	1.00	.03	.01	.00	.063*	-.05	.00	.01	.00	.00	.02	.04	-.01	.00	.02	-.01
H4	.02	-.01	.01	.00	.03	.00	.03	1.00	.00	-.01	.04	-.02	.00	.00	.01	.03	.00	.02	.03	-.01	-.01	.02
S1	.01	-.03	-.01	.02	.02	.02	.01	.00	1.00	.690**	.497**	.00	.00	.05	.03	.02	.01	.02	.03	-.01	-.01	-.01
S2	.00	-.02	.00	.078**	.03	.04	.00	-.01	.690**	1.00	.460**	-.01	.01	.00	.00	.01	.04	.00	.04	.00	.01	-.01
S3	.02	.00	.02	.072**	.00	.02	.063*	.04	.497**	.460**	1.00	-.02	-.01	-.01	.00	-.01	.00	.00	.03	-.02	-.03	.00
S4	-.03	.03	-.01	.04	.03	.02	-.05	-.02	.00	-.01	-.02	1.00	.00	.02	-.02	.02	-.02	-.01	-.02	-.02	.01	-.060*
S5	.01	-.03	.01	-.01	-.05	.01	.00	.00	.00	.01	-.01	.00	1.00	-.01	-.02	.00	-.03	.02	.02	.05	.01	-.04
S6	.01	.00	-.04	-.01	.02	.00	.01	.00	.05	.00	-.01	.02	-.01	1.00	.087**	.148**	-.02	.01	-.02	-.01	-.01	-.04
S7	.01	.00	-.01	-.02	.03	.053*	.00	.01	.03	.00	.00	-.02	-.02	.087**	1.00	.092**	-.077**	-.04	.05	.00	.04	.00
S8	.01	.02	-.01	.02	-.02	.01	.00	.03	.02	.01	-.01	.02	.00	.148**	.092**	1.00	-.02	-.053*	-.04	-.02	-.02	.01
S9	-.03	-.02	-.02	.04	.02	-.01	.02	.00	.01	.04	.00	-.02	-.03	-.02	-.077**	-.02	1.00	.00	.03	.01	-.04	.00
C1	-.02	.02	.00	.01	.01	-.02	.04	.02	.02	.00	.00	-.01	.02	.01	-.04	-.053*	.00	1.00	-.04	.00	.00	-.01
C2	.03	-.01	.056*	-.02	.069*	.02	-.01	.03	.03	.04	.03	-.02	.02	-.02	.05	-.04	.03	-.04	1.00	.142**	.137**	.097**
I1	.00	-.065*	-.05	.00	.05	.01	.00	-.01	-.01	.00	-.02	-.02	.05	-.01	.00	-.02	.01	.00	.142**	1.00	.563**	-.02
I2	-.04	-.03	-.01	.00	.04	.00	.02	-.01	-.01	.01	-.03	.01	.01	-.01	.04	-.02	-.04	.00	.137**	.563**	1.00	-.03
I3	-.061*	-.03	.00	-.01	-.02	.04	-.01	.02	-.01	-.01	.00	-.060*	-.04	-.04	.00	.01	.00	-.01	.097**	-.02	-.03	1.00

Here, Farm characteristics (F1 = land tenure, F2 = soil fertility, F3 = soil slope); Physical capital (P1 = Land); Human capital (H1 = Sex, H2 = Age, H3 = Education, H4 = HH size); Social capital (S1 = distance to main market, S2 = distance to extension, S3 = distance to input provider, S4 = membership in farmer groups, S5 = membership of WUA, S6 = No of relatives in the village, S7 = No of influential contacts in village, S8 = reliance on government support); Financial capital (C1 = off-farm income, C2 = access to credit), and Informational capital (I1 = access to TV/Radio, I2 = extension, I3 = access to climate information)

Further, ** and * show that correlation is significant at 0.01 and 0.05 level, respectively.

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