frontiers in Climate

ORIGINAL RESEARCH
published: 20 January 2021
doi: 10.3389/fclim.2020.584245

Farmer Preparedness for Building Resilient Agri-Food Systems: Lessons From the 2015/2016 El Niño Drought in Malawi

David D. Mkwambisi[1], Eleanor K. K. Jew[2] and Andrew J. Dougill[3]*

[1] MUST Institute for Industrial Research and Innovation, Malawi University of Science and Technology, Limbe, Malawi,
[2] Department of Environment and Geography, University of York, York, United Kingdom, [3] Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds, United Kingdom

Across sub-Saharan Africa, climate change is leading to increasingly erratic weather patterns that challenge farming practices, particularly for smallholder farmers. Preparing farmers for these changes and increasing their resilience to extreme weather events is critical for food security in areas where populations are increasing. The El Niño event of 2015/16 led to drought conditions in Malawi which are expected to become more normal in the future. This resulted in widespread crop failure and the need for external food aid. The experiences of Malawian farmers during this time creates an opportunity to identify areas where adaptations in land management practices as part of resilience building initiatives can prepare farmers for future climates. This paper presents results of household surveys and interviews of 201 farmers from a case study in southern Malawi. Half of the farmers surveyed practice Conservation Agriculture (CA), a Climate Smart Agriculture technology that increased resilience to this drought event. The majority of households relied on agriculture for all their livelihood streams, indicating that diversification away from sole dependence on agriculture would increase resilience. Our study shows that poorer, female farmers are less likely to practice CA than wealthier male farmers. Results also illustrate that while farmers had access to seasonal weather forecasts, a key tool to guide land preparation and planting, they remained reluctant to believe them or to amend cropping or land management practices. Agricultural extension services within Malawi can play a vital role in preparing farmers for future extreme weather events and ensuring forecast communication link to predicted agricultural impacts and land management actions for building resilience into agricultural systems. Extension services need to focus on supporting poorer female farmers to adopt CA practices and providing farmers with the tools and knowledge to respond effectively to seasonal and sub-seasonal climate information.

Keywords: climate services, conservation agriculture (CA), sub-Saharan Africa, climate adaptation, disaster preparedness, climate smart agriculture

OPEN ACCESS

Edited by:
Colin Kelley,
Columbia University, United States

Reviewed by:
Bridget Bwalya Umar,
University of Zambia, Zambia
Diriba Korecha Dadi,
University of California Santa Barbara, United States

****Correspondence:***
Eleanor K. K. Jew
eleanor.jew@york.ac.uk

Specialty section:
This article was submitted to Climate Services, a section of the journal Frontiers in Climate

Received: *16 July 2020*
Accepted: *22 December 2020*
Published: *20 January 2021*

Citation:
Mkwambisi DD, Jew EKK and Dougill AJ (2021) Farmer Preparedness for Building Resilient Agri-Food Systems: Lessons From the 2015/2016 El Niño Drought in Malawi. Front. Clim. 2:584245. doi: 10.3389/fclim.2020.584245

INTRODUCTION

Climate change and weather variability are key factors affecting food systems in most parts of sub-Saharan Africa (Kotir, 2011), especially among rural subsistence farming communities (Shisanya and Mafongoya, 2016). This has been seen recently in Malawi, where agriculture is predominantly rain-fed and practiced by 76% of Malawi's population (National Statistics Office, 2017). The agricultural sector contributes 30% to GDP, which fell 3.2% from 2014 to 2016 (Botha et al., 2018), affecting the delivery of other essential sectors such as health and education. Flooding in 2014/15, followed by droughts in 2015/16, led to a 30.2% year-on-year drop in maize production (World Bank, 2019), which is grown on 90% of cultivated land (Mutegi et al., 2015). This was due to the El Niño event of 2015/16, one of the strongest on record (NOAA, 2015; Whitfield et al., 2019). Not only are El Niño events predicted to become more extreme (Wang et al., 2019), but these types of conditions (erratic rainfall, droughts and flooding) are expected to become more normal according to predicted future climate change scenarios (Niang et al., 2014; Mittal et al., 2017; Hart et al., 2018).

The decrease in maize yields in 2016 led to 6.5 million people within Malawi requiring food aid (USAID, 2016). Increasing farmers' preparedness and resilience to extreme weather events is critical to ensuring food security and continued development within the country. Strategies to achieve this include the Farm Input Subsidy Programme (FISP), widespread promotion of Climate Smart Agriculture, Sustainable Intensification and increased use of irrigation. This culminated in the release of the National Climate Change Management Policy and the National Agricultural Policy in 2016 (Chinsinga and Chasukwa, 2018).

Conservation Agriculture (CA) is a Climate Smart Agriculture technology, designed to increase resilience to climate change through three pillars of soil and crop management: reduced tillage, intercropping or crop rotation and permanent soil cover (FAO, 2008). It is generally conceptualized to be an agriculture system encompassing several technologies. CA has been shown to increase resilience to dry spells and heat stress (e.g., Ngwira et al., 2012; Steward et al., 2018, 2019; Boillat et al., 2019) but has limited uptake among farmers, and increasing evidence of disadoption, where farmers return to their previous practices once the intervention in place to promote CA ceases (Pedzisa et al., 2015; Ward et al., 2016; Chinseu et al., 2019; Bouwman et al., 2021). Reasons for this have been discussed widely (see Hermans et al., 2020), with possible reasons varying from constraints at household level such as poor health, labor and capital availability (Jew et al., 2020), a lack of technical support (Chinseu et al., 2019) and practical limitations, such as a lack of equipment (Habanyati et al., 2018) or land (Bouwman et al., 2021). Given the promising yield results shown from previous studies, understanding how promotion of CA can be improved will enhance farmer preparedness and resilience to erratic climate events.

A further consideration is that of the provision of climate and weather information to farmers, and how they access, interpret, and make decisions based on this information. Appropriate and timely information is expected to improve the capacity of farmers to manage the risks associated with climate variability and change (Vaughan et al., 2019). The use of weather information allows farmers to identify crops and plan for the season (Roudier et al., 2014), and use of climate information can enable national policies to be developed to support farmers in decision making over varying timescales (Vincent et al., 2017; Nkiaka et al., 2019).

As the climate alters and conditions become less suitable for agricultural production (particularly that of the main food crop maize) in the medium to long term future (Stevens and Madani, 2016), greater diversity in livelihoods may also improve agricultural system resilience and preparedness. Currently within Malawi only 23% of households in rural areas are engaged in non-farm enterprises (National Statistics Office, 2017). Previous studies have illustrated the dependency on agricultural livelihoods in many households (Chidanti-Malunga, 2011).

Resilience and preparedness to extreme climate events requires a multifaceted approach (Whitfield et al., 2019), and it is important to understand the extent to which farmers in Malawi have the capacity to prepare and adapt to climate change. Using a case study from southern Malawi, we conducted a survey of farmers who practiced CA and of those who did not during the 2015–16 El Niño drought event. In order to understand the extent of their preparedness and resilience to this, and future extreme weather events, we asked the following research questions: (1) Who are CA farmers, and are there opportunities to increase participation in CA farming?; (2) How do farmers (CA and non-CA) access weather information, and how do they utilize this information in guiding their cropping and land management decisions?; (3) To what extent are farmers' livelihoods resilient to extreme weather and are there opportunities for diversification?

METHODOLOGY

Study Area and Context

Malawi has a sub-tropical climate with one crop growing season that runs from December to April (Mutegi et al., 2015). Malawi has one of the highest population densities in Africa, with ∼150 people per square kilometer in the southern regions and over 50% of rural households occupying <1 ha of land (National Statistical Office, 2015; FAOSTAT, 2017). Poverty affects 59.5% of the rural population (National Statistics Office, 2017) and high dependence on low-productivity small scale farming is considered the greatest barrier to reducing rural poverty (UNDP, 2016).

Since 2005, key investments in the agriculture sector have been hybrid seed (especially maize) and mineral fertilizer which have been supported through the Government's Farm Input Subsidy Programme (FISP) (Chirwa and Dorward, 2013a), which in 2020 has been extended through an Affordable Inputs Programme (AIP). The AIP targets 4.2 million smallholder farming households, each accessing two bags of fertilizer weighing 50 kg each at a cost of US$ 5.8 per bag and 5 kg certified maize seed at US$ 2.60 per pack. The budget of AIP is a staggering Malawian Kwacha (MK) 160 billion (∼ US $208 million) of the MK 245 billion (∼US$ 318 million) allocated to the Ministry of Agriculture, representing a 78% increase from the MK 36 billion (∼US$ 47 million) allocation to the final edition of FISP. Unlike FISP, which included legumes in the package, AIP is focusing entirely on maize as Malawi's dominant staple grain (GoM, 2020).

The participation of the private sector has also increased within the seed and fertilizer industry due to market availability (Chirwa and Dorward, 2013b) since the programme is funded by the Government of Malawi.

Research took place in southern Malawi, within the districts of Machinga and Balaka during August and September 2016 (**Figure 1**). These districts were selected according to the criteria of having experienced some, but not complete, crop loss in the 2015/16 season with CA practiced by some farmers for at least 3 years. Populations within Balaka and Machinga have been rated as highly vulnerable to climate-related risk and shocks within Malawi (Government of Malawi, 2018). Within each District we followed government extension structures which comprise of District Agriculture Development Offices (DADO). The DADO is divided into Extension Planning Areas (EPAs). These are geographically demarcated areas composed of several villages. EPAs are managed by an Agricultural Extension Development Officer (AEDO). Each EPA is then divided into Sections that have a smaller number of villages and act as a unit for local level field demonstration. In this study, an Extension Planning Area (EPA) was selected where both CA and non-CA was practiced, and within each EPA two Sections were selected where farmers had access to agricultural extension advice through the presence of an Agricultural Extension Development Officer (AEDO). Lead farmers who demonstrate CA practices to their fellow farmers are also present in all Sections. These selection criteria enabled comparisons between CA and non-CA farmers. Four Sections were selected in total.

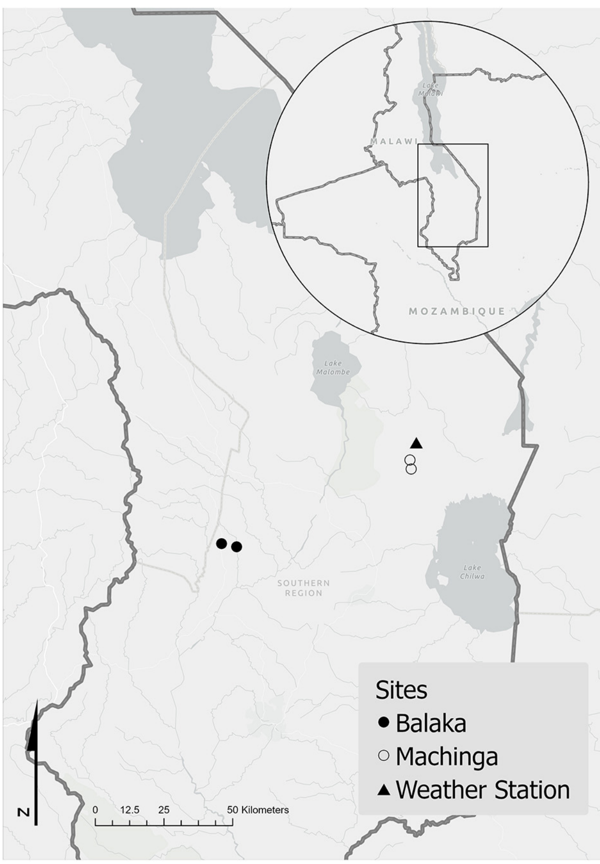

FIGURE 1 | Study sites within Malawi.

Prior to the start of the research, interviews were conducted with agricultural extension officers to gain an understanding of the study sites. Within the two sections studied in Machinga, CA was promoted by Total Land Care (a local NGO) from 2013 to 2017, and had been adopted by approximately 1.5% of the 2,600 households within the Sections. Maize is the dominant crop grown, with limited livestock keeping. Fishing in nearby Lake Chilwa is an important source of income for many households. In Balaka, CA was introduced in 2007 by the Food and Agriculture Organization of the United Nations (FAO) as part of a 5-year programme. Since then, CA has been promoted by other organizations including World Food Programme, ActionAid, and World Vision, this has led to a higher adoption rates of 5.5% of the 2,967 households within the two sections. There are few other income generating activities within the area other than agriculture and other resource-based livelihoods such as selling of charcoal, firewood and brick molding.

Methods

Household surveys consisting of open and closed questions (see survey in **Supplementary Material A**) were conducted within each Section. The survey gathered details of agricultural practices, yields and access to information and support during the 2015–16 farming season. Surveys were completed by farmers who did not practice any CA methods (non-CA) and farmers who self-identified as practicing CA in at least one of their plots of land. This was verified by checking their descriptions of their farming practices. CA was considered to be practice of at least one of the three pillars of CA including intercropping or crop rotation, minimum or zero tillage and permanent organic soil cover, such as mulching or use of a cover crop. Sampling for CA farmers was exhaustive, initially using those registered in Section records, on village lists and then through identification by lead farmers. Non-CA farmer sampling was conducted through random selection of names from village household lists. The household survey was initially written in English and then translated into Chichewa by five research assistants, who checked for different local words to ensure understanding. This was conducted through an iterative process over intensive piloting for 1 week prior to the research period.

This resulted in a total of 201 complete questionnaires, 104 from CA farmers, and 97 non-CA farmers (**Table 1**).

Descriptive and inferential statistics were performed on quantitative data referring to demographics and crop yields in R 3.3.2 (The R Foundation for Statistical Computing, 2016). Qualitative data referring to weather information and subsequent practices was coded in NVivo 10 (QSR International, 2012).

RESULTS

Who Are CA Farmers?

The average age of respondents (both CA and non-CA) was 43.5 ± 15.3 (mean ± SD, $n = 200$). The average age of CA farmers was

47.4 ± 13.8 ($n = 103$), and the average age of non-CA farmers was 39.3±15.8 ($n = 97$). This is a significant difference in the ages of farmers between the two types of farming systems (MW, $p < 0.0005$), illustrated in **Figure 2**. There are also differences in gender between the two groups. Of the 201 respondents there were 116 women, and 85 men. More women ($n = 68$, 58.6%) cultivated non-CA than men ($n = 29$, 34.15%), and more men ($n = 56$, 65.9%) practiced CA compared to women ($n = 48$, 41.4%). This relationship between gender and agriculture system is significant (χ^2 (1, $n = 201$) = 10.83, $p < 0.005$). Results show that differences between gender and wealth are also significant, with women more likely to be poorer (Fisher's exact test, $p < 0.05$, **Supplementary Figure 1**).

There was some evidence of an association between wealth and the type of cultivation (Fisher's exact test, $p = 0.058$) (**Figure 3**). When assessing the association between gender and wealth within the farming types there was a significant association between wealth and gender for CA farmers (Fisher's exact test, $p < 0.05$), with male farmers wealthier than female farmers (**Figure 3**).

TABLE 1 | Distribution of non-CA and CA farmers participating in the household survey.

District	Section	Non-CA	CA	CA LF	Non-CA LF	Total
Balaka	1	24	20	8	0	52
	2	23	17	3	1	44
Machinga	1	25	21	5	0	51
	2	24	22	8	0	54
Total		96	80	24	1	201

LF = Lead farmer.

Seasonal Weather Forecast Information

The seasonal forecast is provided by the Government of Malawi's Department of Climate Change and Meteorological Services (DCCMS) and for 2015/2016 the prediction was communicated as normal to above normal rainfall for the whole country (GoM, 2015), despite the regional prediction of drought as associated with the strong El Niño Southern Oscillation conditions (Blamey et al., 2018). Below average rainfall amounts were expected from October to December 2015, while average rainfall amounts were predicted to occur from January to March 2016 with January 2016 expected to be the wettest month. Finally, prolonged dry spells were expected between February and March 2016 (GoM, 2015).

Agriculture, weather, and weather information in the study area was communicated by the Farm Radio Trust, an NGO supporting extension and advisory services through radio and mobile phone. In addition, the DCCMS disseminated the weather information through newspapers, radio and TV communications.

Accessing Weather Information

Results from the household surveys show that the majority of farmers (166, 82.6%) got their information about the weather from the radio. Other sources of information included extension services and other phone services (**Table 2**). Extension service information was accessed by 22.1% of CA farmers compared to 11.3% of non-CA farmers. Few farmers (3.5%) obtained no information about the weather at all.

Response to Weather Information

When farmers were asked whether they were aware that the rainfall for the 2015/16 season would be erratic, 77.6% said that they had not known. Of the 82.6% of farmers who received their weather information from the radio, 76.5% (127) did not know that rainfall would be erratic. Qualitative data indicated that

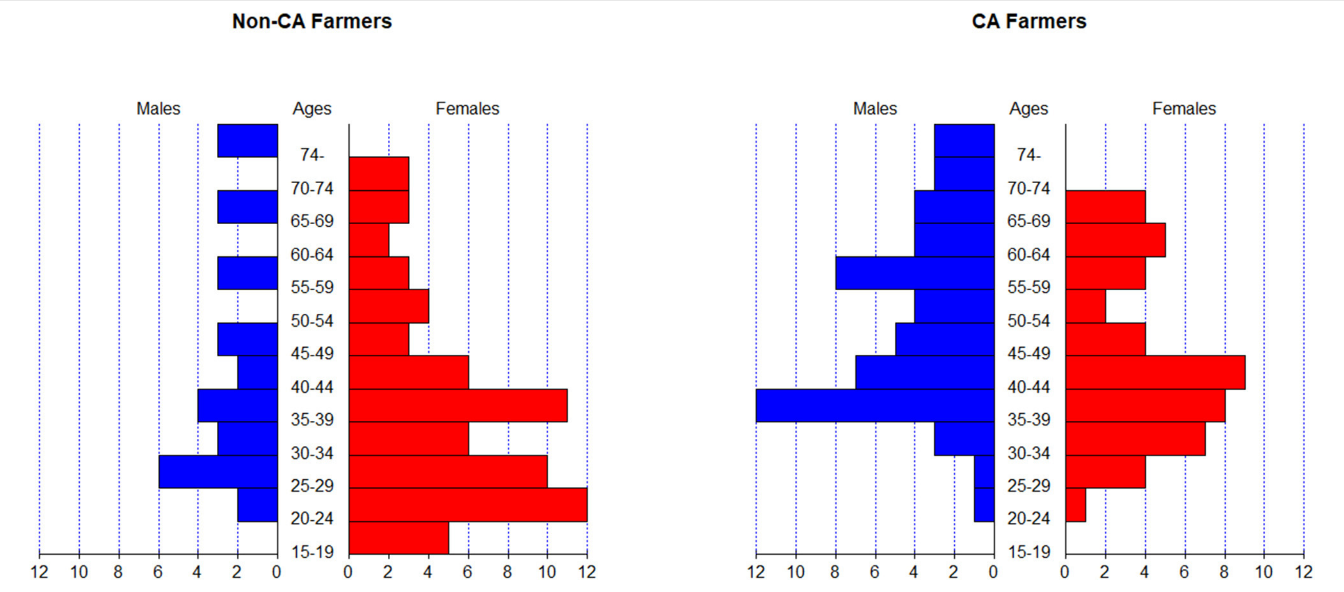

FIGURE 2 | Distribution of ages by respondents for CA and non-CA farmers (Household survey, $n = 201$).

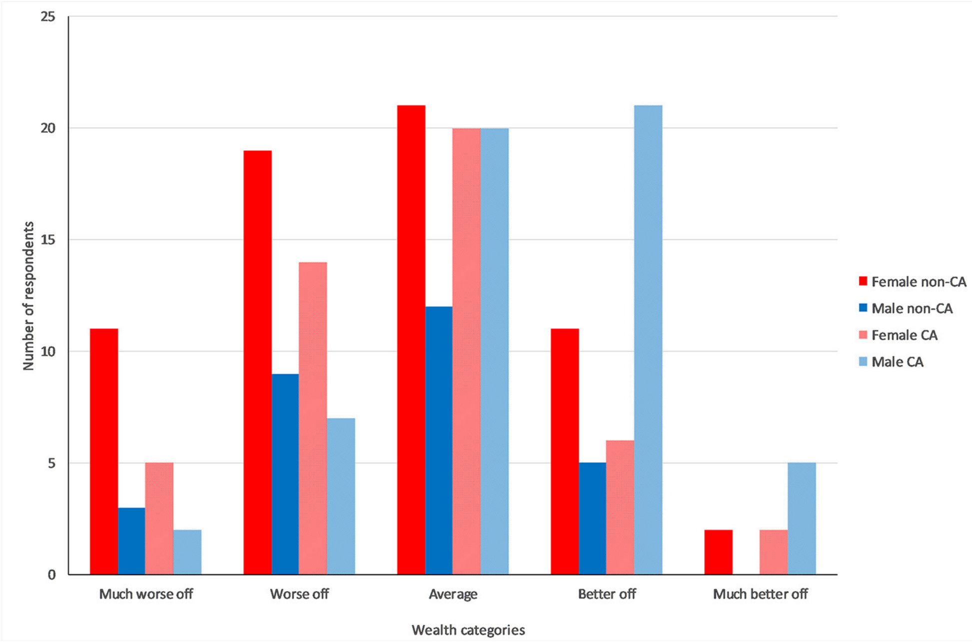

FIGURE 3 | Wealth and gender by farming type (Household survey, *n* = 201).

TABLE 2 | Sources of weather information [multiple answers accepted (Household survey *n* = 201)].

Method	CA farmers (*n* = 104)	Non-CA famers (*n* = 97)	Male (*n* = 85)	Female (*n* = 116)	Total (*n* = 201)
Radio	85 (81.7%)	81 (83.5%)	77 (90.6%)	89 (76.7%)	166 (82.6%)
Extension services	23 (22.1%)	11 (11.3%)	17 (20%)	17 (14.7%)	34 (16.9%)
SMS/phone services	5 (2.9%)	1 (1%)	5 (5.9%)	1 (0.9%)	6 (3%)
From friends	6 (3.8%)	10 (10.3%)	2 (2.4%)	2 (1.7%)	16 (8%)
Personal observations	3 (2.9%)	1 (1%)	3 (3.5%)	13 (11.2%)	4 (2%)
Newspaper	2 (2.1%)	0	1 (1.2%)	1 (0.7%)	2 (1%)
None	4 (3.8%)	3 (3.1%)	1 (1.2%)	6 (5.2%)	7 (3.5%)

within this group there was a mistrust of radio weather forecasts, with 10 respondents saying that the weather forecast on the radio had been for good or higher rainfall, 11 saying that the weather experts are not accurate and 5 saying that they do not believe the radio. One respondent said "*I did not know... The weather experts through the radio lied to us... I won't trust them again*" (female CA farmer, Machinga, household survey 2016).

Of the 34 (22.9%) who both listened to the radio weather forecasts and knew that the rainfall would be erratic, qualitative data indicated that four respondents based their knowledge on their own observations of change in wind, and the remaining respondents had heard it on the radio, however three of these said that they had not believed the forecast. Two respondents said that initially the forecasts had said that the rainfall would be good, but that the forecast changed just before the rains were due to start.

There was no evidence of differences between crop yields of farmers who had been aware that the weather would be erratic in 2015/16 compared to those who were not aware (**Table 3**).

There was some discrepancy between gender and engagement with weather forecasting. Of the 116 female farmers, 99 (85.3%) did not know that the rainfall would be erratic, compared to 67.1% of men (57 of 85). With regards to radio access, 89 women (76.7%) got their weather forecast from the radio, and 76 of these women (85.4%) did not know that the rainfall would be erratic. In comparison, 77 male farmers (90.6%) got their weather forecast from the radio, and 51 (66.2%) did not know that the rainfall would be erratic.

Future Weather Predictions for 2016/17

Respondents were asked what they thought the weather would be like for the coming growing season (November 2016–April 2017). Half (100) of respondents stated that they did not know what the rains would be like. Qualitatively, 10 respondents said that the weather had become unpredictable, and others said that it was "God's plan" or that they were "resigned to fate." Of the remaining half of respondents, 95% said that

TABLE 3 | Crop yields for farmers who were aware of erratic rainfall and those who were not.

Crop	Yield knowledge of weather	Yield - no knowledge	Mann Whitney *U* Test
Hybrid maize	658.2 ± 578.7 (*n* = 45)	602.2 ± 651.4 (*n* = 169)	*p* = 0.1531
Failed harvest	9 (16.7%)	25 (12.9%)	
Local maize	357.6 ± 251.1 (*n* = 19)	301.2 ± 246.6 (*n* = 54)	*p* = 0.2478
Failed harvest	4 (17.4%)	12 (18.2%)	
Groundnuts	489.5 ± 524.9 (*n* = 27)	314 ± 314 (*n* = 66)	*p* = 0.3014
Failed harvest	5 (15.6%)	18 (21.4%)	
Pigeonpeas	186.9 ± 215.7 (*n* = 29)	127.2 ±160.7 (*n* = 87)	*p* = 0.1669
Failed harvest	15 (34.1%)	43 (33.1%)	
Cowpeas	196 ± 157.5 (*n* = 12)	149.9 ± 195.2 (*n* = 47)	*p* = 0.1176
Failed harvest	9 (42.9%)	36 (43.4%)	
Cassava	169.9 ± 21.8 (*n* = 2)	227.1 ± 198.9 (*n* = 12)	*p* = 1
Failed harvest	3 (60%)	4 (25%)	

Household survey 2016 [n = 200, Weather awareness =NA (n = 9)].

they thought the rains would be "good" or "early." Reasons for this were largely based on indigenous local knowledge (environmental observations), with respondents citing current weather conditions such as "hot and windy" or "northerly winds." Other reasons included the use of indigenous local knowledge, including that the mango trees had flowered well, there were many ants and termites, or that it smelt like rain. Other responses were largely based on fate, with respondents believing that there would be good rains because it would be compensation for last season's poor rains, that God would be merciful, or that good rains followed bad ones.

Preparation for 2016/17

Respondents were asked if they would take any action to protect their crops from extreme weather such as drought or flooding in the 2016/17 season. CA farmers seemed to be happy with the impact that their methods had on reducing the impact of dry spells in the previous season, with 75 farmers (72%) saying that they would continue with CA methods. Hybrid maize yields for CA farmers were double those of non-CA farmers (Jew et al., 2020). These methods included mulching and using planting basins. There was some emphasis on the management of box ridges to enable moisture to be retained or released through adding drains. Other methods included growing a wider variety of crops with some drought tolerant varieties and planting early. The remaining CA respondents ($n = 26$, 25%) did not know what they would do. Reasons for this included it being hard to prepare because they did not know what the rains would be like, and that they did not know what to do to help them to protect the crops.

The responses of non-CA farmers were similar. Evidence from neighbors farming CA encouraged some farmers to begin CA practice, with 43.3% of farmers indicating that they would like to either undertake full CA in the following season or to adapt practices applied through CA, such as box ridges or mulching. Other methods included using drought tolerant crops, planting a diverse range of crops, practicing irrigation and using mineral fertilizer. Five farmers said that they would seek extension officers' advice on what to do. Again, 29 farmers (30%) did not know what they could do to protect their crops from extreme weather conditions, with some farmers explaining that it is difficult to plan when they do not know what the weather will do, and others saying that they would have to accept what happens, with one respondent suggesting that he would look for alternative income sources to continue to support his livelihood.

Other Routes to Resilience

Resilience - Crop Diversity

Households grow a range of crops for both subsistence and for sale (**Table 4**). All households grew either a hybrid maize (modified seeds for drought tolerance or early maturing) or local maize seed (grown from seeds local varieties of crops mostly kept from the previous harvest). The results show that most of the farmers grew hybrid maize followed by pigeonpeas. The majority of households grew at least three different crops (**Figure 4**).

Table 5 illustrates that both CA farmers and non-CA farmers experienced similar perceived decreases in yields from their expected to harvested yields. The exception is cowpeas, where CA farmers perceived a lower decrease in yield than non-CA farmers.

Resilience - Livestock

Respondents were asked to list the type and number of animals that they kept (**Table 6**). The most commonly kept animals are goats and chickens, which are kept for subsistence and also for sale. Almost twice as many households engaged in CA kept chickens than those who did not practice CA (70.2 vs. 40.2%). Of those households who did keep chickens, CA farmers kept more on average than non-CA farmers (9.3 ± 8.3 (mean ± SD) chickens compared to 5.6 ± 4.2 chickens); this was a statistically significant difference (MW, $p < 0.01$). More CA farmers also kept goats than non-CA farmers (51 vs. 32%), but the difference between the average number of goats kept (4.8 ± 4.4 vs. 3.2 ± 2.2) was not significant (MW, $P = 0.09$). Doves, ducks, turkeys, guineafowl, pigs, rabbits and sheep were also kept for their meat, both for subsistence and sale by a limited number of households. Very few households kept cattle, and of those that did they kept them to sell, with only one household listing transport as a reason for keeping cattle. When converted into Tropical Livestock Units (TLU) non-CA households had an average total of 1.776 TLU, and CA households 2.473 TLU (**Table 6**).

Keeping livestock as assets or diversifying into livestock keeping as another income stream does come with risks from a range of sources. Disease resulting in loss was reported by 60.7% of households who kept chickens. The main disease named was Newcastle Disease. Respondents reported limited losses from wild animals, including the loss of four goats from two separate households to hyenas, and one reported loss of guineafowl. This predation was not assessed if it was linked to drought. There were 38 reports of loss of chickens, reasons for this included predation by wild birds (e.g., hawks and eagles, cited by 19 respondents) and feral dogs (12 respondents).

Climate hazards were reported as a threat to livestock by a limited number of respondents, with singular reports of loss of doves, goats and pigs due to lack of food caused by drought.

TABLE 4 | Crops grown by both CA and non-CA farmers by household.

Crop	CA households	Non-CA households	Crop	CA households	Non-CA households
Hybrid maize	102 (99%)	78 (80.4%)	Pumpkins	6 (5.8%)	1 (1%)
Pigeonpeas	78 (75.7%)	59 (60.8%)	Velvet bean	6 (5.8%)	0
Groundnuts	59 (57.3%)	55 (56.7%)	Beans	3 (2.9%)	2 (2.1%)
Cowpeas	51 (49.5%)	42 (43.3%)	Vegetables	3 (2.9%)	2 (2.1%)
Local maize	37 (35.9%)	43 (44.3%)	Sorghum	0	4 (4.1%)
Millet	34 (33%)	33 (34%)	Tomatoes	1 (1%)	3 (3.1%)
*Cotton	27 (26.2%)	19 (19.6%)	Sugarcane	2 (1.9%)	0
Cassava	13 (12.6%)	11 (11.3%)	Banana	0	1 (1%)
Sweet potato	6 (5.8%)	4 (4.1%)	Hyacinth beans	1 (1%)	0
Soybean	7 (6.8%)	2 (2.1%)	Mustard	0	1 (1%)
Rice	6 (5.8%)	2 (2.1%)	Sesame	0	1 (1%)
*Tobacco	6 (5.8%)	2 (2.1%)			

*All crops are grown for both household consumption and for sale, apart from those marked with *, which are cash crops only (Household survey 2016, $n = 200$, CA $n = 103$, non-CA $n = 97$).*

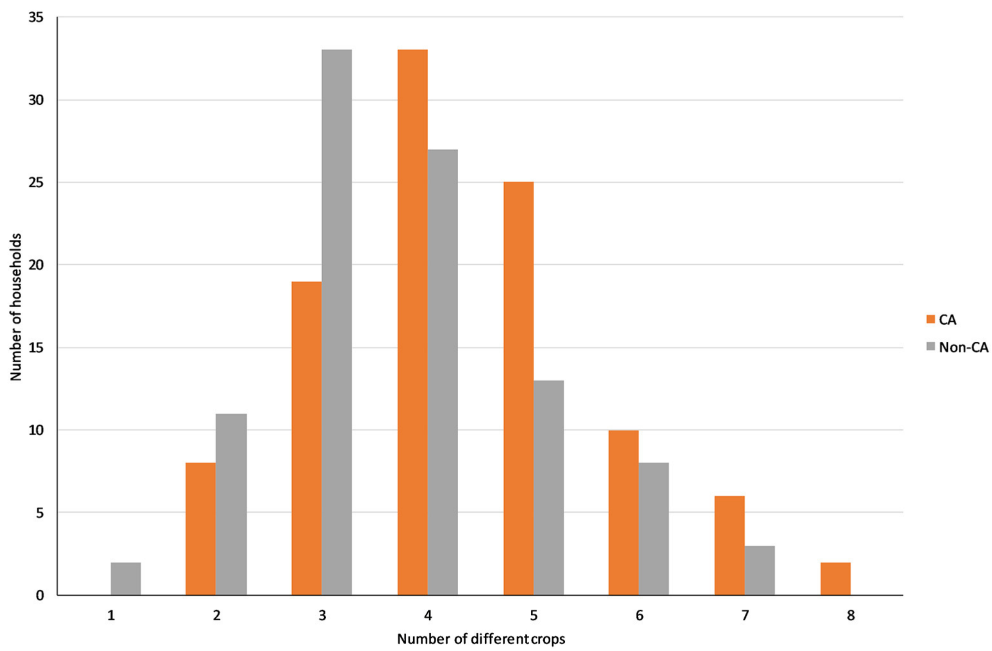

FIGURE 4 | Number of different crops grown per household (Household survey, $n = 200$).

There were 10 reports of loss of chickens due to temperature fluctuations and lack of food.

Off-Farm Livelihoods

The majority of respondents classified farming as their main livelihood activity (**Table 7**). However, most respondents had more than one livelihood activity: 54.2% respondents with two livelihood activities, 22.9% with three, 2.5% with four, and 20.4% having no further livelihood activity.

Examples of businesses include selling produce such as tomatoes, mandazi (a dough bun), and fish. A full list of livelihood activities is in **Supplementary Table 2**. In total 408 livelihood activities were undertaken, of which 245 (60%) involved farming. A further 48 were listed as labor or piecework, which is likely to be farm based.

DISCUSSION

Smallholder farmer preparedness for extreme weather events in Malawi involves long term changes to farming practices and livelihoods, which need to be facilitated through policies and extension programmes that better support farmers' needs. This study identified three areas where improvements are needed to increase preparedness for smallholder farmers: gender equality

TABLE 5 | Crop yields under CA and non-CA in 2015/16 and the yields that are normally expected.

Crop	Number of plots	Total crop fail (%)	Average 2015/16 yield (kg ha^{-1})	SD (kg ha^{-1})	Expected yield (kg ha^{-1})	SD (kg ha^{-1})	Percentage decrease of yield
CA							
Hybrid maize	107	9 (8.4%)	899.6	741.5	2882.7	2154	68.8%
Local maize	5	1 (20 %)	211.5	174.4	1899.1	956	88.9%
Cassava	2	1 (50%)	247.1	-	1853.3	-	86.7%
Pigeonpeas	46	8 (17.4%)	147.3	159.6	588.7	517.1	75.0%
Cowpeas	27	9 (33.3%)	173.7	222.7	325.2	401.3	46.6%
Groundnuts	14	3 (21.4%)	237.2	201.4	1241.8	959.2	80.9%
Non-CA							
Hybrid maize	149	25 (17.3%)	392.2	395.0	1876.1	1415.1	79.1%
Local maize	85	15 (17.4%)	324.5	247.4	1866.9	1183.5	82.6%
Cassava	20	6 (30%)	324.9	428.1	1084.5	527.1	70.0%
Pigeonpeas	130	51 (39.2%)	145.4	187.4	599.0	745.3	75.7%
Cowpeas	78	37 (47.4%)	160.9	175.3	612.1	777.7	73.7%
Groundnuts	104	20 (19.2%)	382.5	409.4	1503.7	1490	74.6%

Average yield calculated using harvested crops (Household survey 2016, n = 200). For statistical comparison between CA and non-CA yields for 2015/16 see ***Supplementary Table 1***.

TABLE 6 | Livestock kept by households (Household survey, *n* = 201).

Animal	Number of households (*n* = 104)	Total number of animals	Average number of animals per household	Average TLU per household	Number of households (*n* = 97)	Total number of animals	Average number of animals per household	Average TLU per household
Cat	8 (7.7%)	13	1.6		5 (5.2%)	6	1.2	
Cattle	2 (1.9%)	2	2.0	1.4	2 (2.1%)	4	2.0	1.4
Chickens	73 (70.2%)	640	9.3	0.093	39 (40.2%)	209	5.6	0.056
Dog	7 (6.7%)	9	1.3		1 (1%)	1	1.0	
Doves	12 (11.5%)	68	6.8		5 (5.2%)	44	11.0	
Duck	11 (10.6%)	32	2.9		3 (3.1%)	6	2.0	
Goats	53 (51%)	252	4.8	0.48	31 (32%)	100	3.2	0.32
Guineafowl	2 (1.9%)	11	5.5					
Pigs	4 (3.8%)	15	3.8					
Rabbits	2 (1.9%)	6	3.0					
Sheep	2 (1.9%)	10	5.0	0.5				
Turkey					1 (1%)	2	2.0	
None	16 (15.4%)				43 (44.3%)			

TLU = Tropical livestock unit.

in promotion of CA: trust in, and capacity to utilize seasonal weather forecast information; and diversification in livelihood streams that are independent from farming.

Gender Biases in CA

Evidence from this study illustrates that it is wealthier, male farmers who are more likely to practice CA, which is promoted through NGOs, extension services and in government policy. This gender gap in relation to the adoption of CA is well-documented across sub-Saharan Africa (Wekesah et al., 2019). Reasons for this are varied, including the role of women within the household, where they retain responsibility for caring duties and household tasks (Farnworth et al., 2016) in addition to their farming activities, resulting in limited time to invest in learning new agricultural techniques. Male farmers are more likely to be connected to village political systems, and have time to attend training meetings. Integrated and inclusive planning of household tasks in line with agriculture interventions within a season is lacking, thereby weakening the resilience of food systems. While reduced tillage may decrease initial labor demands in comparison with ridge making, labor demands are increased for tasks such as weeding (Andersson and D'Souza, 2014), and this increased labor disproportionally falls on women (Montt and Luu, 2020). Women often have limited access to capital, basic tools and transport (Murray et al., 2016) constraining their ability to participate.

This gender bias in agricultural training is known, with policy interventions aiming to increase female participation in

TABLE 7 | Respondent's main occupation (Household survey, $n = 201$).

Farming type	Farmer	Laborer	Business	Teacher	Grand Total
CA	97 (93%)	3 (2.9%)	3 (2.9%)	1 (0.9%)	104
Non-CA	80 (82.5%)	10 (10.3%)	7 (7.2%)		97
Total	**177 (88.1%)**	**13 (6.5%)**	**10 (5%)**	**1 (0.5%)**	**201**

agricultural training, yet there is little evidence to suggest that this has been implemented across sub-Saharan Africa (Quisumbing and Pandolfelli, 2010). A study by Mudege et al. (2017) in Malawi found that barriers to women accessing training and information often stem from negative stereotypical perceptions of women held by husbands and extension workers, which are exacerbated by institutional biases within extension systems that reinforce these gender norms. Preparedness for resilience food systems will require specific interventions targeting women farmers including provision of tailored seasonal extension services.

Given that women's participation within CA can increase their income and household food security (Wekesah et al., 2019) this bias against the involvement of female farmers in new technologies such as CA should be addressed as a priority and would also help to address problems of CA disadoption (Chinseu et al., 2019). Targeting interventions at female farmers, and particularly those who are poorer, would address the current imbalance, thereby increasing their future capacity to invest in further agricultural interventions. Interventions should not increase their workload and there is need to promote labor saving technologies. There is need to have a pre-season household assessment by extension service providers to understand critical factors that will affect attainment of resilience food systems during the agricultural season. This will include understanding assets, sources and quality of labor, income, and alternative food sources that are available to increase preparedness as a buffer against poor yields.

It is also important that interventions take a holistic approach to promoting agricultural technologies alongside investment in health and education services locally. There is evidence not only that factors at household level such as poor health constrain women's ability to participate (Jew et al., 2020), but that successful farming strategies can put women at risk of being dispossessed of land by men (Wekesah et al., 2019). The complexity of gender relations illustrates that changes are needed at policy level and require nuanced development, in addition to greater attention to a research agenda focussing on gender within CA to guide these developments (Farnworth et al., 2016; Murray et al., 2016; Wekesah et al., 2019). Easy and quick "wins" include using female extension officers to increase female participation, which has been successful agricultural innovation across the border in Mozambique (Kondylis et al., 2016). In this case, trainings should be gender sensitive and targeted in its duration, distance to training and language of instruction to encourage women's participation, especially younger women with small children.

In addition, introduction of new technologies among poor smallholder farmers should not advocate for free inputs as they are also disincentives to adoption of such technologies when such support is withdrawn at the end of the project, as poorer farmers lack the capacity to take personal or household risks to invest in inputs. Wealthier farmers are able to take greater risks and invest in new methods, as should they fail they have additional income sources through which to support their households. Additional income sources include diversified crops or livestock, as illustrated in this case study, where CA farmers grow more different types of crops and have higher numbers of livestock than non-CA farmers. New technologies and provision of agricultural inputs and extension advice should be introduced after a detailed analysis of a household including tasks that are taken by women before, during and after the crop growing season. Agricultural extension and advisory services should be designed to support sustainability of new technologies and project-based intervention needs to complement government efforts that seem to be sustainable in nature. As such, testing and validation of technologies should be showcased through community demonstration blocks rather than on household farm sites as this has an implication of special capital and support to new interventions.

Access, Trust, and Response to Weather Predictions

Most farmers in this study had some access to weather information, with the majority of them getting this from the radio. Radio broadcast agricultural extension advice predates 2007 (Chapota et al., 2014), providing a familiar outlet for farmers to receive agricultural advice. Despite this widely accepted and accessed source of information, only 21.4% of respondents were aware that the weather would be erratic, despite the majority of farmers receiving weather reports—only 3.5% of respondents said that they did not get weather information. Instead, farmers rely more on indigenous and local knowledge, personal experience and traditional cropping calendars than on climate information for their decision making (Coulibaly et al., 2015). Understanding why farmers access weather information but do not comprehend its significance is critical. This appears to be due in part to a lack of trust in the information provided, but also to poor communication of weather forecasting, which needs to be delivered by a farmer-friendly method that ensures farmers can understand the messages. Should this communications barrier remain, it will be problematic in the future as the climate changes and the traditional signs become less reliable and as computer-based forecasting becomes more skilful and reliable.

In addition to farmer-friendly forecasting, associated preparedness actions should be included in radio messages. This will allow farmers to put in place interventions that will allow them to address anticipated gaps in rainfall in advance. Limited or lack of access to farmer friendly weather forecasts has several implications to preparedness for building resilient agri-food systems. For example, without it farmers will not be able to make investment decisions on the appropriate type of crops or livestock. They will have no information as to when the rains will start or end, thereby affecting their decision on planting dates. Preparedness programming should include providing relevant information using pathways that will be accessible by resource-constrained farmers. Allowing pre-season farmer learning centers to discuss the weather forecast and understand implications associated with such information will add value to preparedness for resilient agri-food systems.

Despite a push to increase the amount of information communicated via mobile phones (Steinfield et al., 2015), only 3% of farmers accessed weather information through mobile phone services. For example in 2016, mobile phone subscriptions were ∼41.72 per 100 inhabitants, which has stagnated in recent years—estimations for 2018 were 39.01 subscriptions per 100 people, meaning that ∼51.7% households had access to a mobile phone (ITU, 2020). Even though number of mobile subscribers is increasing, agriculture change agents have not embraced their use to support farmer preparedness for resilient food systems.

The results have shown that some farmers showed fatalist attitudes toward rainfall variability. This has several implications on preparedness. Firstly, farmers tend to continue ignoring the notion that farming is business and as such it requires proper planning and forecasting. Failing to understand the main inputs of any business will result in producing services or products that will result in losses. Secondly, by not trusting forecasted weather including rainfall variability shows that farmers invest in decisions that are always affected by weather related risks, including prolonged dry spells. Thirdly, credibility of weather forecast is of paramount importance as previous weather information has been contrary to actual season weather. This has led to most farmers failing to trust the information, and therefore improving local and regional forecasting is of paramount importance.

Access to information is associated with more extension officers working with NGOs because of the available logistical support, including field allowances, which are not readily available in the traditional extension system supported by the government. Having a strong government-led extension service framework that will support and coordinate delivery of advisory services will allow inclusion of tasks that can strengthen farmer preparedness in case of any seasonal risks. Even though there are interventions supporting site specific weather information generation with the involvement of users such as smallholder farmers (Dorward et al., 2015) these are mostly project-based interventions that fail to consider agricultural extension providers. For farmers to start trusting weather information, there is need to engage more players, including religious and traditional leaders, teachers, local volunteers and community radio stations which are often pivotal in addressing local needs (Simelton et al., 2013). Designing targeted capacity building programmes on generation and application of weather information and the relation of this information to the agricultural calendar will be an important step in building greater resilience of African food systems.

Future Farming Planning

A further barrier to acting upon weather information was a lack of knowledge about how to respond to the forecast and make appropriate agricultural changes in advance of the agricultural season. This led to farmers making reactive responses to the erratic rainfall—maize seeds were replanted up to three times by some farmers, which drained their limited capital and had repercussions on their ability to purchase food after these crops had failed. Constraints such as a lack of capital significantly impact farmers' capacity to make either proactive or reactive responses to changing weather patterns. Furthermore, there is no deliberate effort at EPA level to analyse the forecast so that local farmers can understand the implications and then take decisions to create resilient food systems. This is evident in the lack of a significant difference in yields between farmers who were aware of the erratic weather and those who were not (**Table 3**), whereas there were significant differences between the hybrid maize yields of CA farmers and non-CA farmers (Boillat et al., 2019; **Table 5** and **Supplementary Table 1**, for more details see Jew et al., 2020). As illustrated in **Table 5**, farmers perceived a significant decrease in yields from what they would have expected across all crops. However, there are large standard deviations for expected yields per hectare for all crops. This illustrates that farmers have differing expectations from yields. This could be due to differences in fertilizer, pesticide and herbicide application, the type of soil and the amount of effort put into cultivating the crop. While this illustrates that collecting field data of crop yields would be preferable to farmer reporting of yields, it also demonstrates that farmers have high expectations of crops yields, and are likely to be disappointed even when their crop has performed well. For example, hybrid maize yields cultivated under CA were 2.3 times better than hybrid maize crop yields cultivated non-CA conditions, yet CA farmers were still disappointed with their yields, as they were 68.8% lower than they expected. CA farmers expected their yields to be 1.5 times better than those expected by farmers cultivating hybrid maize through non-CA methods, and this was surpassed, however not with the high yields expected (**Table 5**). A lack of evidence of increased yields is thought to be a reason for disadoption of CA (Chinseu et al., 2019), and this illustrates the importance of not "overselling" the benefits of CA to potential adopters, particularly as shown here, CA cultivation of hybrid maize does outperform non-CA cultivation during erratic rainfall conditions. The influence of the different components of CA cultivation on maize performance on this dataset is examined in detail in Boillat et al. (2019).

There was evidence that farmers wanted to continue, or to start, CA farming in the following year. These responses highlight the continued need for effective and available extension advice. The Malawi agricultural extension services are constrained by both a lack of funding and staff capacity (Brown et al., 2018; Jew et al., 2020) illustrating that there is both a need to invest in these services but also that there is a role for NGO support, as long as the messages are consistent (Brown et al., 2017). This weakness can also directly be linked to farmer preparedness as the majority of farmers do not have access to extension workers.

Responses surrounding knowledge about weather information for the coming growing season have shown that there is a need to provide detailed analysis of predicted weather. This will call for DCCMs to invest more in equipment and human resources to support provision of credible weather information. Provision of this information should also be associated with information that will strengthen farmer preparedness for resilient food systems. Understanding both short- and long-term future weather can also allow policy makers to design tailor made agricultural support systems including review of Affordable Input Programme (AIP) and revised extension messages through the agricultural year.

Diversification

Diversification within livelihoods as well as in cropping is critical in addressing food systems resilience (Pelletier et al., 2016). Within this study most farmers grow more than three crops in a cropping season, with CA farmers more likely to grow more (**Figure 4**). The decision to grow more crops was not linked to a deliberate preparedness framework, but taken as a normal risk aversion strategy. Maize remains the staple crop for Malawian subsistence farmers, however, by the end of the twenty-first century it is likely that large losses in productivity will occur across southern Africa regardless of the management strategies put in place (Rurinda et al., 2015). While agricultural technologies such as CA can provide some resilience in the short to medium term it is clear that farmers will need to plant more resilient crops in future. Decision processes will be improved if proper preparedness interventions are included in national programmes, including crop and livestock research programmes, designing of academic programmes and reviewing the agriculture extension and advisory services. This agricultural transformation will require advancement of new technologies that will not only utilize available water, but address other challenges such as shortage of land, pests, and diseases and new feeding habits by the youthful population.

Encouraging farmers to diversify to different crops and promotion of well-planned livestock management initiatives are therefore also desirable and should be included in the preparedness programming. Suitable crops such as sweet potato (Motsa et al., 2015), sorghum (Hadebe et al., 2017), and cassava (Brown et al., 2016) have been suggested, along with legumes such as pigeonpea for their ability to improve soil quality through nitrogen fixing (Waldman et al., 2017), and are therefore suitable for intercropping. However, due to limited programming, such opportunities are not given the required attention, especially during preseason planning.

Beyond encouraging farmers to grow a more diversified range of crops there are also political, social and economic issues to be considered (Tendall et al., 2015). Farmers cultivating more crops does not immediately translate into greater dietary diversity (Rajendran et al., 2017). Instead, greater access to markets and increased purchasing power which enables households to purchase diverse foodstuffs is important (Koppmair et al., 2017). Therefore, ensuring that there are viable markets for crops beyond maize remains a critical contribution to resilience. During agricultural planning both at national, district and section level, there is need for a holistic assessment to address such gaps before the cropping season. The assessment should also look at available markets for both on-farm and off-farm interventions, crop-livestock integration and social protection interventions.

Given the importance of markets and income to increase food security and to lift households out of poverty (Wiggins and Keats, 2013), livelihood overexposure to one sector increases vulnerability. Deliberate promoting of other off-farm activities, especially during the preseason, can be a better practice to support resilience of agri-food systems as farmers will have more income to support agriculture activities. Although most famers had an additional livelihood, most of these were associated with agriculture, particularly through labor on other farms. This means that extreme weather events that affect agriculture will also have negative impacts on the second income stream. Roughly half of households kept goats and chickens, with limited other livestock kept. Goat husbandry has been shown to contribute significantly to household incomes (Kaumbata et al., 2020) and there is opportunity to promote crop-livestock systems. However, this should be done with care, given that livestock and CA can compete for maize residue for feed and mulching, leading to opportunity costs despite potential benefits from the use of manure (Giller et al., 2009; Valbuena et al., 2012). A holistic preparedness assessment before the cropping season will allow to understand available opportunities to support food systems. Livestock systems are also vulnerable to climatic changes and extreme weather events, suggesting that livelihood diversification away from all types of farming would lead to greater resilience. However, opportunities for this in rural Malawi are scarce, demonstrating opportunities for policy interventions to stimulate markets for off-farm income (Berre et al., 2017), with roles for NGOs and external donors.

CONCLUSION

Results from this case study demonstrate that hybrid maize cultivated under CA performed better than under traditional tillage during the El Niño event of 2015/16, which resulted in prolonged dry periods. Despite higher numbers of women being engaged in subsistence farming, it was wealthier, male farmers who were more likely to participate in CA. Participation in CA can help to increase food security and preparedness for extreme weather events, and this bias against the involvement of female farmers in CA should be addressed as a priority.

This study illustrated that the use of climate information to support resilience building in agri-food systems has been largely neglected by extension services and NGOs. Despite increased efforts by government and development partners to release daily and seasonal forecast weather services, many farmers do not trust this information. This has resulted in the continued use of agricultural techniques that do not provide resilience to the forecast weather conditions. Our findings suggest that supporting resilient food systems will require deliberate effort by extension and advisory service providers to invest in building the capacity of farmers to practice interventions based on forecast information. This should include assistance with planning and making decisions on the type of investments needed to achieve resilient agri-food systems. This calls for a holistic approach to preparedness—accessible accurate weather forecasts, coupled with advice on how to respond to seasonal weather forecasts, building capacity for farmers to act on the advice—particularly around access to inputs. There is need for long term adjustments to livelihood activities and cropping decisions that increase diversity both at crop and livelihood level.

An integrated and intensive programme that takes agriculture as a business will require proper planning, utilization of available information and support of crop-livestock systems among all groups, but with a particular focus on women due to their lack of participation in agricultural technologies. This will also require joint implementation of programmes between NGOs and government extension workers to support the improved communication of action-based weather and climate information as a key element in a package of measure aimed at building more resilient food systems.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors upon request, without undue reservation.

ETHICS STATEMENT

The studies the involving human participants were reviewed and approved by Faculty of Environment Research Ethics Committee, University of Leeds. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

DM: wrote the manuscript, provided expert assistance in-country EJ: wrote the manuscript, collected, and analyzed the data. AD: edited the manuscript, project leader.

FUNDING

Funding was provided by the UK's Natural Environment Research Council's (NERC) and Department for International Development's (DfID) El Niño 2016 Programme [grant reference NE/P004091/1].

ACKNOWLEDGMENTS

We would like to thank our research assistants in Malawi for their hard work and dedication throughout the fieldwork period of this research. We greatly appreciate the kindness and co-operation provided by the residents and extension staff within our study sites. We would like to thank three reviewers for their helpful comments which enabled us to improve the manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2020.584245/full#supplementary-material

Supplementary Figure 1 | Wealth comparison between men and women (Household survey 2016, $n = 201$). Y axis- number of people. Statistically women are more likely to be poorer than men [Fisher's exact test ($p > 0.005$)].

Supplementary Table 1 | Yield comparison between crops cultivated under CA and non-CA in 2015/16 (Household survey, 2016).

Supplementary Table 2 | Alternative incomes (Household survey, 2016).

Supplementary Material A | The Household Survey.

REFERENCES

Andersson, J. A., and D'Souza, S. (2014). From adoption claims to understanding farmers and contexts: a literature review of Conservation Agriculture (CA) adoption among smallholder farmers in southern Africa. *Agric. Ecosys. Environ.* 187, 116–132. doi: 10.1016/j.agee.2013.08.008

Berre, D., Corbeels, M., Rusinamhodzi, L., Mutenje, M., Thierfelder, C., and Lopez-Ridaura, S. (2017). Thinking beyond agronomic yield gap: smallholder farm efficiency under contrasted livelihood strategies in Malawi. *Field Crops Res.* 214, 113–122. doi: 10.1016/j.fcr.2017.08.026

Blamey, R. C., Kolusu, S. R., Mahlalela, P., Todd, M. C., and Reason, C. J. C. (2018). The role of regional circulation features in regulating El Niño climate impacts over southern Africa: a comparison of the 2015/2016 drought with previous events. *Int. J. Climatol.* 38, 4276–4295. doi: 10.1002/joc.5668

Boillat, S., Jew, E. K., Steward, P. R., Speranza, C. I., Whitfield, S., Mkwambisi, D., et al. (2019). Can smallholder farmers buffer rainfall variability through conservation agriculture? On-farm practices and maize yields in Kenya and Malawi. *Environ. Res. Lett.* 14:115007. doi: 10.1088/1748-9326/ab45ad

Botha, B. N., Nkoka, F. S., and Mwumvaneza, V. (2018). *Hard hit by El Nino: Experiences, Responses and Options for Malawi*. Washington, DC: World Bank. doi: 10.1596/30037

Bouwman, T. I., Andersson, J. A., and Giller, K. E. (2021). Adapting yet not adopting? Conservation agriculture in central Malawi. *Agric. Ecosys. Environ.* 307:107224. doi: 10.1016/j.agee.2020.107224

Brown, A. L., Cavagnaro, T. R., Gleadow, R., and Miller, R. E. (2016). Interactive effects of temperature and drought on cassava growth and toxicity: implications for food security? *Global Change Biol.* 22, 3461–3473. doi: 10.1111/gcb.13380

Brown, B., Nuberg, I., and Llewellyn, R. (2017). Stepwise frameworks for understanding the utilisation of conservation agriculture in Africa. *Agric. Syst.* 153, 11–22. doi: 10.1016/j.agsy.2017.01.012

Brown, B., Nuberg, I., and Llewellyn, R. (2018). Constraints to the utilisation of conservation agriculture in Africa as perceived by agricultural extension service providers. *Land Use Policy* 73, 331–340. doi: 10.1016/j.landusepol.2018.02.009

Chapota, R., Fatch, P., and Mthinda, C. (2014). The role of radio in agricultural extension and advisory services: experiences and lessons from farm radio programming in Malawi. *MEAS Case Study* 8. Available online at: https://farmradio.org/wp-content/uploads/2020/09/MEAS-CS-Malawi-Farm-Radio-Chapota-Fatch-Mthinda-Feb-2014-1.pdf (accessed February, 2020).

Chidanti-Malunga, J. (2011). Adaptive strategies to climate change in Southern Malawi. *Phys. Chem. Earth. A/B/C/* 36, 1043–1046. doi: 10.1016/j.pce.2011.08.012

Chinseu, E., Dougill, A., and Stringer, L. (2019). Why do smallholder farmers dis-adopt conservation agriculture? Insights from Malawi. *Land Degrad. Dev.* 30, 533–543. doi: 10.1002/ldr.3190

Chinsinga, B., and Chasukwa, M. (2018). Narratives, climate change and agricultural policy processes in Malawi. *Afr. Rev.* 10, 140–156. doi: 10.1080/09744053.2018.1485253

Chirwa, E., and Dorward, A. (2013a). *Agricultural Input Subsidies: The Recent Malawi Experience*. Oxford: Oxford University Press. doi: 10.1093/acprof:oso/9780199683529.001.0001

Chirwa, E., and Dorward, A. (2013b). *The Role of the Private Sector in the Farm Input Subsidy Programme in Malawi*. Available online at: https://eprints.soas.ac.uk/16866/

Coulibaly, Y., Kundhlande, G., Tall, A., Kaur, H., and Hansen, J. (2015). *Which climate services do farmers and pastoralists need in Malawi? Baseline Study for the GFCS Adaptation Program in Africa*. CCAFS Working Paper 112. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Dorward, P., Clarkson, G., and Stern, R. (2015). *Participatory Integrated Climate Services for Agriculture (PICSA): Field Manual*. Walker Institute, University of Reading.

FAO (2008). *Investing in Sustainable Agricultural Intensification: The Role of Conservation Agriculture*. Rome, Italy: Food and Agricultural Organisation of the United Nations.

FAOSTAT (2017). *Malawi Country Profile*. Food and Agriculture Organization of the United Nations. Available online at: http://www.fao.org/faostat/en/#country/130 (accessed October 22, 2017).

Farnworth, C. R., Baudron, F., Andersson, J. A., Misiko, M., Badstue, L., and Stirling, C. M. (2016). Gender and conservation agriculture in East and Southern Africa: towards a research agenda. *Int. J. Agric. Sustainability.* 14, 142–165. doi: 10.1080/14735903.2015.1065602

Giller, K. E., Witter, E., Corbeels, M., and Tittonell, P. (2009). Conservation agriculture and smallholder farming in Africa: the heretics' view. *Field Crops Res.* 114, 23–34. doi: 10.1016/j.fcr.2009.06.017

GoM (2015). *Prospects for the 2015/2016 Rainfall Season in Malawi*. Press Release. Government of Malawi, Department of Climate Change and Meteorological Services, Ministry of Natural Resources, Energy and Mining, Blantyre, Malawi.

GoM (2020). *Ministerial Statement on the Affordable Inputs Programme to the National Assembly by the Minister of Agriculture*. Ministry of Agriculture, Lilongwe, Malawi.

Government of Malawi (2018). *Malawi National Resilience Strategy: Breaking the Cycle of Food Insecurity in Malawi*. Lilongwe: Office of the Vice President, Department of Disaster Management Affairs.

Habanyati, E. J., Nyanga, P. H., and Umar, B. B. (2018). Factors contributing to disadoption of conservation agriculture among smallholder farmers in Petauke, Zambia. *Kasetsart J. Soc. Sci.* 41, 91–96. doi: 10.1016/j.kjss.2018.05.011

Hadebe, S. T., Modi, A. T., and Mabhaudhi, T. (2017). Drought tolerance and water use of cereal crops: a focus on sorghum as a food security crop in sub-Saharan Africa. *J. Agron. Crop Sci.* 203, 177–191. doi: 10.1111/jac.12191

Hart, N. C. G., Washington, R., and Stratton, R. A. (2018). Stronger local overturning in convective-permitting regional climate model Improves simulation of the subtropical annual cycle. *Geophys. Res. Lett. 45*, 11,334-11,342. doi: 10.1029/2018GL079563

Hermans, T. D. G., Whitfield, S., Dougill, A. J., and Thierfelder, C. (2020). Why we should rethink 'adoption' in agricultural innovation: empirical insights from Malawi. *Land Degrad. Dev.* 45, 11,334–11,342. doi: 10.1002/ldr.3833

ITU (2020). *Country ICT Data. International Telecommunication Union*. Available online at: https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx (accessed May 1, 2020).

Jew, E. K. K., Whitfield, S., Dougill, A. J., Mkwambisi, D. D., and Steward, P. (2020). Farming systems and conservation agriculture: technology, structures and agency in Malawi. *Land Use Policy* 95:104612. doi: 10.1016/j.landusepol.2020.104612

Kaumbata, W., Banda, L., Mészáros, G., Gondwe, T., Woodward-Greene, M. J., Rosen, B. D., et al. (2020). Tangible and intangible benefits of local goats rearing in smallholder farms in Malawi. *Small Ruminant Res.* 187:106095. doi: 10.1016/j.smallrumres.2020.106095

Kondylis, F., Mueller, V., Sheriff, G., and Zhu, S. (2016). Do female instructors reduce gender bias in diffusion of sustainable land management techniques? *Exp. Evidence From Mozambique. World Dev.* 78, 436–449. doi: 10.1016/j.worlddev.2015.10.036

Koppmair, S., Kassie, M., and Qaim, M. (2017). Farm production, market access and dietary diversity in Malawi. *Public Health Nutr.* 20, 325–335. doi: 10.1017/S1368980016002135

Kotir, J. H. (2011). Climate change and variability in sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security. *Environ. Dev. Sustain.* 13, 587–605. doi: 10.1007/s10668-010-9278-0

Mittal, N., Vincent, K., Conway, D., Archer, E., Pardoe, J., Todd, M., et al. (2017). Future climate projections for Malawi. *Future Climate for Africa Brief*. Available online at: https://futureclimateafrica.org/resource/future-climate-projections-for-malawi/

Montt, G., and Luu, T. (2020). Does conservation agriculture change labour requirements? Evidence of Sustainable Intensification in sub-Saharan Africa. *J. Agric. Econ.* 71, 556–580. doi: 10.1111/1477-9552.12353

Motsa, N. M., Modi, A. T., and Mabhaudhi, T. (2015). Sweet potato (Ipomoea batatas L.) as a drought tolerant and food security crop. *S. Afr. J. S.* 111, 1–8. doi: 10.17159/sajs.2015/20140252

Mudege, N. N., Mdege, N., Abidin, P. E., and Bhatasara, S. (2017). The role of gender norms in access to agricultural training in Chikwawa and Phalombe, Malawi. *Gend. Place Cult.* 24, 1689–1710. doi: 10.1080/0966369X.2017.1383363

Murray, U., Gebremedhin, Z., Brychkova, G., and Spillane, C. (2016). Smallholder farmers and climate smart agriculture: technology and labor-productivity constraints amongst women smallholders in Malawi. *Gend. Technol. Dev.* 20, 117–148. doi: 10.1177/0971852416640639

Mutegi, J., Kabambe, V., Zingore, S., Harawa, R., and Wairegi, L. (2015). *The Fertiliser Reccommendation Issues in Malawi: Gaps, Challenges, Opportunities and Guidelines*. Soil Consortium of Malawi.

National Statistical Office (2015). *Statistical Yearbook*. National Statistical Office, Zomba, Malawi: Government of Malawi.

National Statistics Office (2017). *Integrated Household Survey 2016-2017*. National Statistics Office, Government of Malawi.

Ngwira, A. R., Aune, J. B., and Mkwinda, S. (2012). On-farm evaluation of yield and economic benefit of short term maize legume intercropping systems under conservation agriculture in Malawi. *Field Crops Res.* 132, 149–157. doi: 10.1016/j.fcr.2011.12.014

Niang, I., Ruppel, O. C., Abdrabo, M. A., Essel, A., Lennard, C., Padgham, J., et al. (2014). "Africa," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, editors V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. Maccracken, P. R. Mastrandrea, and L. L.White (United Kingdom; New York, NY, Cambridge: Cambridge University Press), 1199–1265.

Nkiaka, E., Taylor, A., Dougill, A. J., Antwi-Agyei, P., Fournier, N., Bosire, E. N., et al. (2019). Identifying user needs for weather and climate services to enhance resilience to climate shocks in sub-Saharan Africa. *Environ. Res. Lett.* 14:123003. doi: 10.1088/1748-9326/ab4dfe

NOAA (2015). *National Weather Service Climate Prediction Center*. NOAA/National Weather Service. Available online at: http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml (accessed January 31, 2017).

Pedzisa, T., Rugube, L., Winter-Nelson, A., Baylis, K., and Mazvimavi, K. (2015). Abandonment of conservation agriculture by smallholder farmers in Zimbabwe. *J. Sustainable Dev.* 8:69. doi: 10.5539/jsd.v8n1p69

Pelletier, B., Hickey, G. M., Bothi, K. L., and Mude, A. (2016). Linking rural livelihood resilience and food security: an international challenge. *Food Secur.* 8, 469–476. doi: 10.1007/s12571-016-0576-8

QSR International (2012). *Nvivo*. Version *10.*

Quisumbing, A. R., and Pandolfelli, L. (2010). Promising approaches to address the needs of poor female farmers: resources, constraints, and interventions. *World Dev.* 38, 581–592. doi: 10.1016/j.worlddev.2009.10.006

Rajendran, S., Afari-Sefa, V., Shee, A., Bocher, T., Bekunda, M., dominick, I., et al. (2017). Does crop diversity contribute to dietary diversity? Evidence from integration of vegetables into maize-based farming systems. *Agric. Food Secur.* 6:50. doi: 10.1186/s40066-017-0127-3

Roudier, P., Muller, B., d'Aquino, P., Roncoli, C., Soumar,é, M. A., Batt,é, L., et al. (2014). The role of climate forecasts in smallholder agriculture: lessons from participatory research in two communities in Senegal. *Clim. Risk Manag.* 2, 42–55. doi: 10.1016/j.crm.2014.02.001

Rurinda, J., van Wijk, M. T., Mapfumo, P., Descheemaeker, K., Supit, I., and Giller, K. E. (2015). Climate change and maize yield in southern Africa: what can farm management do? *Global Change Biol.* 21, 4588–4601. doi: 10.1111/gcb.13061

Shisanya, S., and Mafongoya, P. (2016). Adaptation to climate change and the impacts on household food security among rural farmers in uMzinyathi District of Kwazulu-Natal, South Africa. *Food Secur.* 8, 597–608. doi: 10.1007/s12571-016-0569-7

Simelton, E., Quinn, C. H., Batisani, N., Dougill, A. J., Dyer, J. C., Fraser, E. D. G., et al. (2013). Is rainfall really changing? Farmers' perceptions, meteorological data, and policy implications. *Clim. Dev.* 5, 123–138. doi: 10.1080/17565529.2012.751893

Steinfield, C., Wyche, S., Cai, T., and Chiwasa, H. (2015). "The mobile divide revisited: mobile phone use by smallholder farmers in Malawi," in *Proceedings of the Seventh International Conference on Information and Communication Technologies and Development.* Singapore: Association for Computing Machinery. doi: 10.1145/2737856.2738022

Stevens, T., and Madani, K. (2016). Future climate impacts on maize farming and food security in Malawi. *Sci. Rep.* 6:36241. doi: 10.1038/srep36241

Steward, P. R., Dougill, A. J., Thierfelder, C., Pittelkow, C. M., Stringer, L. C., Kudzala, M., et al. (2018). The adaptive capacity of maize-based conservation agriculture systems to climate stress in tropical and subtropical environments: a meta-regression of yields. *Agric. Ecosys. Environ.* 251, 194–202. doi: 10.1016/j.agee.2017.09.019

Steward, P. R., Thierfelder, C., Dougill, A. J., and Ligowe, I. (2019). Conservation Agriculture enhances resistance of maize to climate stress in a Malawian medium-term trial. *Agric. Ecosys. Environ.* 277, 95–104. doi: 10.1016/j.agee.2018.07.009

Tendall, D. M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q. B., et al. (2015). Food system resilience: Defining the concept. *Glob. Food Sec.* 6, 17–23. doi: 10.1016/j.gfs.2015.08.001

The R Foundation for Statistical Computing (2016). *R version 3.3.2 (2016.10.31) "Sincere Pumpkin Patch*". Platform: x86_64-w64-mingw32/x64 (64-bit).

UNDP (2016). *Human Development Reports*. Available online at: http://hdr.undp.org/en/composite/HDI (accessed October 17, 2017).

USAID (2016). *Malawi El Nino Mitigation Fact Sheet*. Available online at: https://www.usaid.gov/malawi/fact-sheets/malawi-el-ni%C3%B1o-mitigation-fact-sheet (accessed May 2020).

Valbuena, D., Erenstein, O., Homann-Kee Tui, S., Abdoulaye, T., Claessens, L., Duncan, A. J., et al. (2012). Conservation agriculture in mixed crop–livestock systems: scoping crop residue trade-offs in Sub-Saharan Africa and South Asia. *Field Crops Res.* 132, 175–184. doi: 10.1016/j.fcr.2012.02.022

Vaughan, C., Hansen, J., Roudier, P., Watkiss, P., and Carr, E. (2019). Evaluating agricultural weather and climate services in Africa: evidence, methods, and a learning agenda. *Wiley Interdiscip. Rev. Clim. Change.* 10:e586. doi: 10.1002/wcc.586

Vincent, K., Dougill, A. J., Dixon, J. L., Stringer, L. C., and Cull, T. (2017). Identifying climate services needs for national planning: insights from Malawi. *Clim. Policy.* 17, 189–202. doi: 10.1080/14693062.2015.1075374

Waldman, K. B., Ortega, D. L., Richardson, R. B., and Snapp, S. S. (2017). Estimating demand for perennial pigeon pea in Malawi using choice experiments. *Ecol. Econom.* 131, 222–230. doi: 10.1016/j.ecolecon.2016.09.006

Wang, B., Luo, X., Yang, Y.-M., Sun, W., Cane, M. A., Cai, W., et al. (2019). Historical change of El Niño properties sheds light on future changes of extreme El Niño. *PNAS.* 116:22512. doi: 10.1073/pnas.1911130116

Ward, P. S., Bell, A. R., Parkhurst, G. M., Droppelmann, K., and Mapemba, L. (2016). Heterogeneous preferences and the effects of incentives in promoting conservation agriculture in Malawi. *Agric. Ecosys. Environ.* 222, 67–79. doi: 10.1016/j.agee.2016.02.005

Wekesah, F. M., Mutua, E. N., and Izugbara, C. O. (2019). Gender and conservation agriculture in sub-Saharan Africa: a systematic review. *Int. J. Agric. Sustain.* 17, 78–91. doi: 10.1080/14735903.2019.1567245

Whitfield, S., Beauchamp, E., Boyd, D., Burslem, D., Byg, A., Colledge, F., et al. (2019). Exploring temporality in socio-ecological resilience through experiences of the 2015/16 El Niño across the tropics. *Glob. Environ. Change.* 55, 1–14. doi: 10.1016/j.gloenvcha.2019.01.004

Wiggins, S., and Keats, S. (2013). *Leaping and Learning: Linking Smallholders to Markets in Africa*. London: Agriculture for Impact, Imperial College and Overseas Development Institute.

World Bank (2019). *Malawi Overview*. Available online at: https://www.worldbank.org/en/country/malawi/overview (accessed June 07, 2020).

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.