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Inventory and drivers of the adoption of flood-based farming systems in South-Eastern Africa: Insights from Malawi*

Arab P. Msume[1] | **Faidess D. Mwale**[1] | **Giulio Castelli**[2]

[1]Faculty of Engineering, Malawi University of Business and Applied Sciences, Chichiri, Malawi

[2]Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, Florence, Italy

Correspondence
Arab P. Msume, Faculty of Engineering, Malawi University of Business and Applied Sciences, Private Bag 303, Chichiri, Blantyre 3, Malawi.
Email: arab.msume@yahoo.com

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Abstract

Rainfed agriculture, which is dominant in sub-Saharan Africa, remains vulnerable to the impacts of climate change. In this framework, flood-based farming systems (FBFS) enable the use of floodwater as an opportunity for crop production. FBFS have received much attention recently; however, there is limited guidance on how they can be promoted effectively in rural areas. To do so and to support the adoption of appropriate systems, it is important to understand the current practice of FBFS. This study focuses on the Balaka District (Malawi) and the types of FBFS in use, the extent of practice, and the factors behind their adoption. A sample size of 398 farmers was considered, using questionnaires, observations, focus group discussions, and key informant interviews to collect primary data. The results showed flood recession agriculture (FRA), depression agriculture, spate irrigation, and inundation canals and dugouts among the FBFS used and that FRA was the dominantly adopted method (54%). Lack of capital investment and level of farmer awareness were the factors most associated with FBFS adoption with $p = .00003$ and $p = .004$, respectively. Capital investment and actions to increase farmers' awareness should therefore be considered to realize the full benefits of FBFS.

KEYWORDS

climate change, flood, flood recession agriculture, water harvesting

Résumé

L'agriculture pluviale, qui domine en Afrique subsaharienne, reste vulnérable aux impacts du changement climatique. Dans ce cadre, les systèmes de culture basés sur les inondations (FBFS) permettent d'utiliser l'eau de crue comme une opportunité pour la production des cultures. Les FBFSs ont récemment fait l'objet d'une grande attention, cependant, il y a peu d'indications sur la manière de les promouvoir efficacement dans les zones rurales. Pour ce faire, il est important de comprendre la pratique actuelle des FBFSs pour soutenir

* Inventaire et moteurs d'adoption des systèmes agricoles basés sur la collecte des eaux de crue en Afrique du Sud-Est: le cas du Malawi

This paper is dedicated to the memory of Arab Pendame Msume, who died suddenly while working on this manuscript during his doctoral studies. His presence, academic activities and scientific contribution will not be forgotten by his colleagues who held him in great esteem.
Giulio Castelli and Faidess Mwale.

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l'adoption de systèmes appropriés. Cette étude, axée sur le District de Balaka (Malawi), a permis de caractériser les FBFSs en mettant l'accent sur les types de FBFSs utilisés, l'ampleur de la pratique et les facteurs à l'origine de l'adoption. Un échantillon de 398 agriculteurs a été analysé à l'aide de questionnaires, d'observations, de discussions de groupes et d'entretiens avec des informateurs clés pour collecter des données primaires. Les résultats ont montré que l'irrigation de décrue (FRA), l'agriculture de dépression (DA), l'irrigation par épandage des eaux de crue (SI) et l'irrigation par détournement des eaux de crue par des canaux de dérivations (ICDO) étaient des FBFSs et que l'agriculture de décrue (FRA) a été majoritairement adopté (54%). Le manque d'investissement en capital et le niveau de sensibilisation des agriculteurs ont été les facteurs les plus élevés associés à l'adoption des FBFSs avec respectivement ($p = 0{,}00003$) et ($p = 0{,}004$). Les investissements en capital et les actions de sensibilisation des agriculteurs devraient donc être considérés comme la pleine réalisation des avantages des FBFS.

MOTS CLÉS

Changement climatique, collecte des eaux de crue, collecte des eaux, agriculture de décrue

1 | INTRODUCTION

Agriculture is vital for the livelihoods and landscapes of sub-Saharan Africa (Kamwamba-Mtethiwa, 2016) as approximately two-thirds of the population rely on agriculture as the main livelihood activity (Li et al., 2021). However, rainfed agriculture remains vulnerable to the impacts of climate change (Mwale, 2014), which adversely affect crop production and productivity (Lal, 2016; Msume, 2017). Most climate change models have projected a decrease in rainfall in Southern Africa (Nyamadzawo et al., 2014), and this implies worsening drought-related food shortages. Climate change has resulted in the increased frequency of crop failure and, consequently, increased food insecurity among smallholder farmers (Demissie et al., 2021).

In most developing countries in Southern Africa, limited capacities to adapt to climate change have led to increased crop failure and severe food shortages. Smallholder farmers are forced to move from drylands to wetlands for food production as an adaptation to climate change (Government of Malawi [GoM], 2017). However, farming in the wetland areas also repeatedly faces flooding due to degradation of the catchment areas, which leads to high silt loads in the rivers (Casale et al., 2008). Practising flood-based farming systems (FBFS), which depend on flood events with varying durations, is a potential opportunity to turn flood water into a resource for crop production. Hence, FBFS have attracted great attention in recent years (Sibide, Williams, & Kolavalli, 2016; Castelli & Bresci, 2017; Castelli et al., 2018).

Depending on the nature of the flood use and inundation, Puertas et al. (2014) classified FBFS in different categories as flood recession agriculture (FRA), depression agriculture (DA), spate irrigation (SI), and inundation canals and dugouts (ICDO). FRA uses the moisture that remains as the seasonal floodwater disappears, while DA, also known as *dambo* (wetland) cultivation, involves the cultivation of crops on depressed valley land that is seasonally or permanently waterlogged (Puertas et al., 2014). In SI, floodwater which originates from episodic rainfall in macro-catchments in the highlands is utilized by diverting it using temporary or semi-permanent structures into the fields to irrigate crops (Hadera, 2001; Chidanti-Malunga, 2009). ICDO are different from other FBFS in the sense that canals flow when water levels in a river reach a certain level (van Steenbergen et al., 2011). They are either dug out or formed by old creeks and offshoots. When the water level rises, these inundation canals fill up and transport the water flow from the adjacent rivers to the fields (Gadad, 2017).

Puertas et al. (2014) pointed out that FBFS come with a number of advantages, such as increased cropped areas of different crops, better groundwater recharge, forest and rangeland support, domestic and livestock water supply, rehabilitation of degraded environments, and balance with ecological functions, in a clear reversal of the destructive nature of floods into multiple blessings. FBFS' potential and benefits have been experienced in a number of African countries including Eritrea, Zimbabwe, and Northern Ghana (Hadera, 2001).

In spite of such a background, the implementation of FBFS is unsatisfactory as it enjoys little attention from many governments, donors, academic institutions, and engineering organizations (Puertas et al., 2014). The blind spot is closely related to a lack of understanding and appreciation of how these systems work and, consequently, their potential for agricultural development (Mehari, Schultz, & Depeweg, 2005; Castelli & Bresci, 2017; Castelli et al., 2018). These gaps in knowledge about FBFS prevent the further development of these systems, which would support increased food security, reduce poverty, and improve livelihoods.

Previous studies show that although FBFS are one of the mitigation strategies used by smallholder farmers in most developing countries including the Southern African region in light of the changing climate patterns not much has been documented on their use. For instance, Nyamadzawo et al. (2014) stress that increased reliance on wetlands in smallholder areas in Zimbabwe necessitates exploration of the current extent of some FBFS such as DA, the benefits and hazards associated with the technology, and sustainable wetland utilization options. Similar observations were also made in Zambia by Kuntashula et al. (2006), who reported that the frequent droughts that have characterized Southern Africa and the poor performance of rainfed crops in upland fields in the last few years have resulted in mounting pressure on dambos, hence the need for further alternatives for the sustainable management of wetlands. Although Zambia is promoting the use of rainwater harvesting technologies (RWHT) with the aim of improving the productivity of its smallholder agricultural systems in light of climate change, the extent of the adoption of these technologies is unclear from the literature. Hence, the call for further research and documentation (Kaczan, Arslan, & Lipper, 2013).

There is clearly little documentation on FBFS in Southern African countries, especially on its current status, challenges, and factors contributing towards sustainable wetland management. The low interest in FBFS from governments, donors, academics, engineering organizations, and policy makers signals the need to carry out detailed studies to document such systems (Puertas et al., 2014). Therefore, this study was conducted to contribute to the knowledge on appropriate FBFS technologies in the context of developing countries, especially in Southern Africa.

In Malawi (Southern Africa), the practice of FBFS has expanded since the 1990s (Flood-Based Livelihood Network [FBLN], 2018). However, like in other Southern African countries, this is not well documented, and there have been very few studies on FBFS as a potential strategy for smallholder farmers to adapt to climate change despite the farmers' strong preference for these technologies (Chidanti-Malunga, 2009). FBLN (2018) and Nthara (2015) have documented the FBFS practised in Malawi. Their studies give an overview of the range of FBFS that are prevalent in different parts of Malawi and agree that farmers have adopted a number of these systems, though with little technical and financial support. Their studies also established that FBFS present a unique opportunity for smallholder farmers in floodplains, as the unreliability of rainfed agriculture forces these farmers to turn to areas that are normally flooded to utilize either receding floods or residual moisture, and that the country still registers some potential areas for FBFS that are not fully utilized. However, this documentation provides no justification for the FBFS landscape and thus offers no guidance on which specific FBFS to promulgate.

Therefore, for the promulgation of appropriate systems it is important to understand the FBFS that are easy for smallholder farmers to adopt as they significantly contribute to the productivity of these farming systems. The area of Balaka (Malawi) is one such example that is used here to characterize FBFS, with a focus on the type of FBFS in use, the extent of practice, and the factors behind their adoption.

2 | MATERIALS AND METHODS

2.1 | Study area

The area of the present study is the Balaka District, located in the eastern region of Malawi in Southern African. Balaka has six extension planning areas (EPA), namely Bazale, Ulongwe, Mpilisi, Phalula, Rivirivi, and Utale, as shown in Figure 1, with 83 sections and 137,503 farming households (GoM, 2020a). The study was conducted in three purposively sampled EPA namely Utale, Ulongwe, and Mpilisi in the Mkaya, Kalembo, and Amidu traditional authorities, respectively, with a total population of 78,211 farming households and 14 sections.

According to Kabambe et al. (2018), Utale, Mpilisi, and Ulongwe are the EPA in Balaka most prone to floods and dry spells; hence the purposive choice of the areas for the study. The study areas are characterized by an annual rainfall of about 768 mm and an annual average temperature of 29°C (Figure 2). The rains are usually concentrated from the month of November to March as illustrated in Figure 2.

For the 30 years from 1989 to 2019, the study areas experienced different rainfall variations, with the 1997/1998 season receiving the highest amount of rainfall

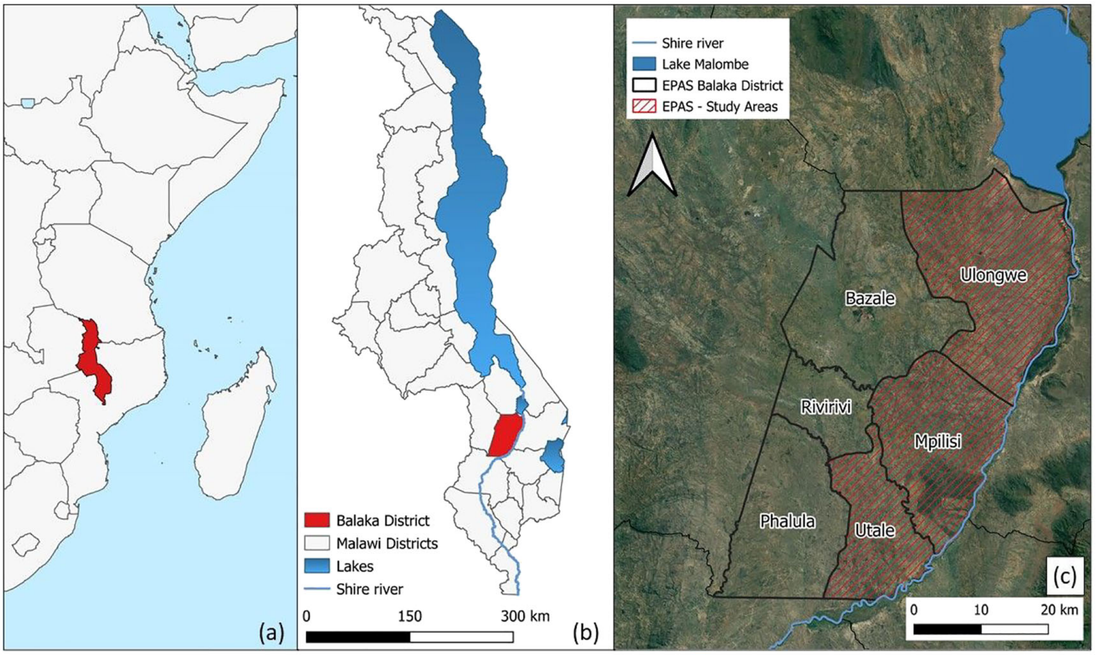

FIGURE 1 (a) Position of Malawi, (b) position of Balaka District, and (c) study areas and Shire River. EPA, extension planning area

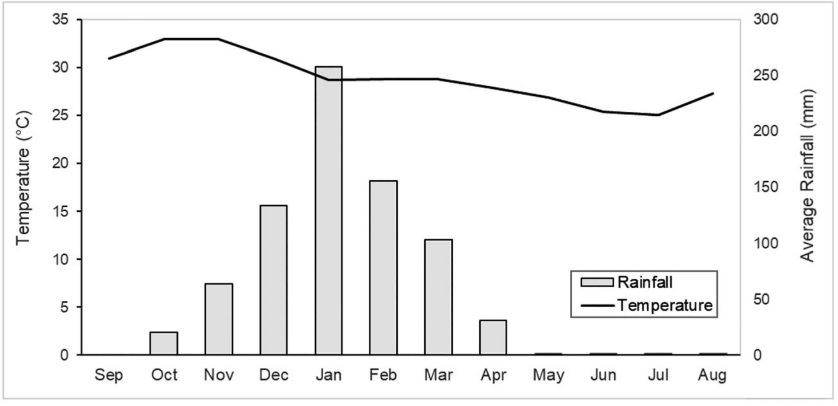

FIGURE 2 Monthly distribution of rainfall and temperature for the study areas (1990–2019). *Source*: Government of Malawi, 2020b based on the hydrological year)

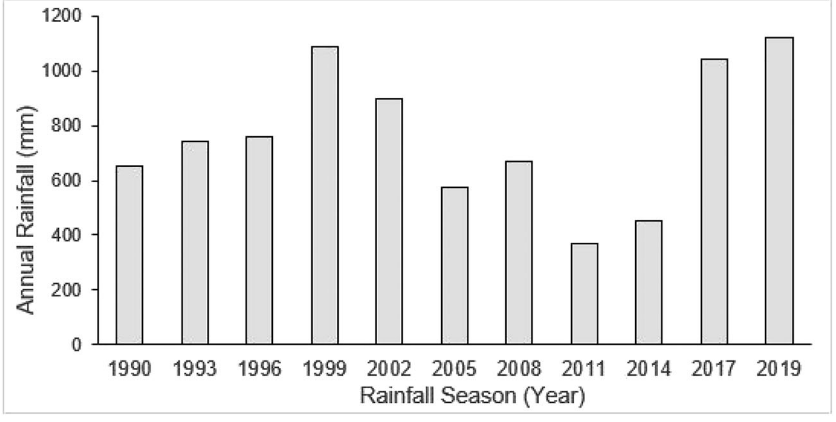

FIGURE 3 Average annual rainfall data for the study areas from 1990 to 2019. *Source:* Government of Malawi, 2020b

and the 2011/2012 season receiving the lowest amount of rainfall as illustrated in Figure 3.

The perennial prolonged dry spells negatively impact maize yield across the southern region of Malawi, including the Kalembo area in Balaka (Project Concern International [PCI], 2018). Back-to-back drought and flood events in two growing seasons in 2015 and 2016 led to extensive crop failure and damage and a substantial increase in maize prices, leaving farmers in the Ulongwe and Mpilisi EPA and their families desperate (PCI, 2016). This trend as depicted in Figure 3 threatens the sustainability of the agricultural sector and other rainfall-dependent sectors. Therefore, there is an urgent need to intensify adaptation and mitigation measures such as conservation agriculture (CA), catchment management, and crop and livestock production practices (GoM, 2017).

Since most agricultural systems in Balaka are rainfed, agriculture activities are carried out from October to April, with several challenges including floods, dry spells, and droughts that severely undermine productivity (GoM, 2017). The increase in cases of crop failure has forced some farmers to use FBFS by taking advantage of the regular occurrence of floods after the rainy season. Using FBFS, they grow different crops such as maize, sweet potatoes, tomatoes, beans, pumpkins, cowpeas, green leafy vegetables, onions, and watermelons. Most of these crops are cultivated individually, and the management of the field and water depends on the farmers (GoM, 2017). However, government and non-governmental organizations (NGO) encourage farmers to form farming groups or associations. These groups can, but do not have to, be registered and have an elected committee to run their affairs. This makes it easy to access loans for inputs from microfinance lending institutions.

Farmers in the study areas rarely sell their produce to government-regulated markets. Instead, they sell their produce to local traders who sell it to major trading centres such as Ulongwe, Mwima, Mangochi Turn Off, Chiendausiku, and Utale (GoM, 2017). Farmer benefits are largely linked to labour, input costs, and market availability. For example, the farmers who produce sweet potatoes and cowpeas under FBFS have minimal input costs and readily available markets from local traders. As a result, the FBFS benefit these farmers. Those that produce maize using these systems require considerable amounts of input and labour to operate the pumps. In the end, these farmers draw few benefits.

2.2 | Data collection

The study was based on a household survey, key informant interviews (KII), focus group discussion (FGD), as well as field observations conducted in the study areas as used by Msume (2017) and Gilbert (2013) in their studies. To determine the respondent sample size, a simplified formula was employed for the proportions as indicated by Mora & Kloet (2010) in Equation 1. The formula was adopted assuming a 95% confidence level and 0.05 precision and was applied to a population of 78,211 smallholder farmers in the study areas. The resulting sample size was

$$n = \frac{N}{[1 + N(e^2)]}, \tag{1}$$

where

- n is the sample size;
- N is the population size, equal to 78,211; and
- e is the level of precision (sampling error), equal to 5%.

Therefore, after the calculations, the data collection for the household survey was based on a sample size of 398 respondents from the study areas. From the sampled population, 50% were adopters and 50% non-adopters of FBFS in the study areas. This study defined an adopter as a farmer who has adopted one of the FBFS promoted in the study areas. The household survey was conducted in the study areas in order to collect both qualitative and quantitative data using a questionnaire.

KII were also conducted on a sample size of 22 respondents, who were purposively selected because of their experience in the agriculture extension service and were hence expected to give a substantial contribution to the study. KII were conducted with community, government, and NGO experts, using their particular knowledge and understanding to provide insights on the nature of the problems and give recommendations for solutions (Ali, David, & Ching, 2014). An interview guide was used as a tool for data collection.

Field observations were carried out to appreciate the FBFS practices in the study areas. In the same way as Mwenda & Fadda (2014), FGD were also used in the study to identify farmers' perceptions on climate change, their experience-based farming knowledge, and practices for adaptation to climate change. Two FGD were conducted in each EPA, targeting both adopters and non-adopters of FBFS who did not participate in the questionnaire interviews. A voice recorder was used to record the proceedings of the sessions, in addition to notebooks which were used to take notes during the discussions. Secondary data from previous studies, government publications, and reports were also reviewed.

2.3 | Data analysis

To characterize the FBFS promoted in the study areas and their adoption levels, a descriptive analysis was used whereby quantitative data from smallholder farmers were summarized, coded, and entered in the Statistical Package for Social Science (SPSS) version 20. This was done by modelling the relationship between two variables by fitting a linear equation to the observed data. One variable was considered to be an explanatory variable and the other a dependent variable. The socio-economic, institutional, and physical factors that are associated with the adoption of FBFS were determined using the linear regression model as specified in Equation 2:

$$Y = \alpha + \sum_{i=1}^{11} (\beta_i X_i + \varepsilon_i), \quad (2)$$

where

- Y is the binary outcome, where 1 means a farmer has adopted FBFS and 2 a farmer has not adopted FBFS;
- α is constant;
- β_i is the coefficient of the independent variable X_i;
- X_1 is the education level (1 = Primary School Leaving Certificate Examination [PSLCE], 2 = Junior Certificate of Education [JCE], 3 = Malawi School Certificate of Education [MSCE], Diploma = 4, Degree = 5, Masters = 6, Other = 7);
- X_2 is the farm size per household measured in acres (1 = less than one acre, 2 = 1–4 acres, 3 = 5–9 acres, 4 = more than 9 acres);
- X_3 is a measure of the capital investment (1 = K0,000–25,000; 2 = K26,000–K50,000; 3 = K51,000–75,000; 4 = K76,000–100,000; 5 = above K100,000).
- X_4 represents the land ownership (nominal level), which is 1 if a farmer owns the land or 2 if a farmer does not own the land;
- X_5 is a measure of the agreement to the fact that the inadequacy of agriculture extension workers was a factor associated with the adoption of FBFS (strongly agree = 1; agree = 2; uncertain = 3; disagree = 4; strongly disagree = 5);
- X_6 is a measure of the agreement to the fact that lack of capacity of extension workers was a factor associated with the adoption of FBFS (strongly agree = 1; agree = 2; uncertain = 3; disagree = 4; strongly disagree = 5);
- X_7 is a measure of the agreement to the fact that extension methodology of FBFS was a factor associated with the adoption of FBFS (strongly agree = 1; agree = 2; uncertain = 3; disagree = 4; strongly disagree = 5);
- X_8 is a measure of the agreement to the fact that low awareness level was a factor associated with the adoption of FBFS (strongly agree = 1; agree = 2; uncertain = 3; disagree = 4; strongly disagree = 5);
- X_9 is a measure of the agreement to the fact that lack of credit facility was a factor associated with adoption of FBFS (strongly agree = 1; agree = 2; uncertain = 3; disagree = 4; strongly disagree = 5);
- X_{10} is a measure of the agreement to the fact that lack of external support was a factor associated with the adoption of FBFS (strongly agree = 1; agree = 2; uncertain = 3; disagree = 4; strongly disagree = 5); and
- ε_i is the random error term.

The qualitative data collected from the FGD and observations were analysed using topics, ideas, and patterns of meaning that came up repeatedly.

3 | RESULTS

3.1 | Adopted FBFS

Figure 4 shows the results of FBFS adopted in the study areas. The most widely adopted FBFS as indicated by farmers and key informants in the study areas was FRA (54%). The least adopted were SI and DA, both at 11%, while ICDO accounted for only 24% (Figure 4).

It is important to note that apart from FBFS, there were also many other in situ RWHT adopted in the study areas. These are CA, compost manure production and application, box ridges, planting pits, contour ridging, contour bunds, and swales. However, these all fall in the dominant category of in situ RWHT. In situ RWHT are different from FBFS in the sense that the former depend on normal rainfall and aim to conserve the rainfall where it falls in the cropped area or pasture, while the latter are specific to flood water and depend on the occurrence of floods.

Direct observations in the study areas revealed that FRA (Figure 5a) is adopted by farmers along the Shire, Mkasi, and Ling'ang'a Rivers in the Ulongwe and Utale EPA by taking advantage of the flooding of the rivers during the rainy season. Farmers make use of the moisture that remains after flooding to grow sweet potatoes, cowpeas, vegetables, and maize crops under FRA. To maximize moisture use under FRA, farmers commence the growing season as soon as the rainy season ends. Some farmers use inundation canals (Figure 5b) to channel water from rivers to their fields, and treadle pumps are used to get water from the canals to irrigate their crops. SI practice (Figure 5c) was also observed among a few groups of farmers who were irrigating their crops using diverted water from streams and road runoff. On the other hand, the study found that some farmers dug shallow wells (Figure 5d) close to the rivers where the water table is very high and used lifting devices such as a bucket with ropes or treadle pumps to draw water from them.

From the KII with extension workers, it was learnt that these FBFS are promoted through different projects implemented by both government organizations and NGO such as Wellness and Agriculture for Life Advancement (WALA), Malawi Drought Recovery and Resilience Project (MDRRP), Project Concern International (PCI), Self Help Africa, Feed the Future, Find Your Feet, and Concern Worldwide. From the interviews with extension workers, the study found that most of the promoters used farmer leaders to illustrate technologies using demonstration plots and conducted field days. Government extension workers were used by the NGO to provide hands-on training to farmers. However, the study established from the extension workers that all these promotions were done using a demand-driven approach, which requires a farmer to ask for the extension services.

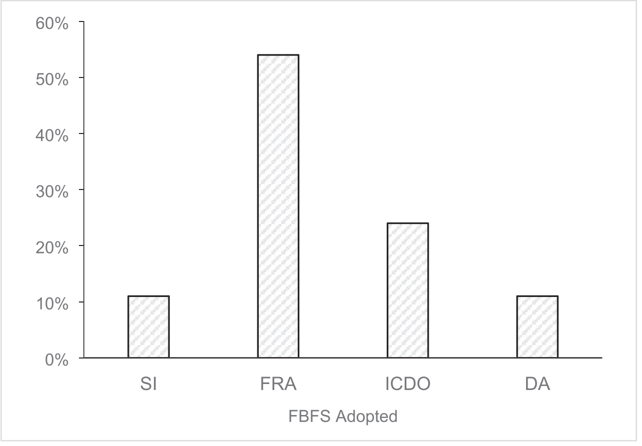

FIGURE 4 Flood-based farming systems adopted in Balaka (n = 199). DA, depression agriculture; FRA, flood recession agriculture; ICDO, inundation canals and dugouts; SI, spate irrigation

3.2 | Importance of using FBFS for the farmers

Figure 6 shows the importance of FBFS mentioned by the farmers during the household survey and FGD. The majority of FBFS adopters (34%) in the study areas indicated that the FBFS increased crop production in their fields. The long history and experience of farmers in using FBFS (such as FRA) was the least important factor (4%) in using FBFS. Increased income, affordability, and simplicity of use accounted for 31%, 22%, and 9%, respectively, concerning the importance of using FBFS in the study areas.

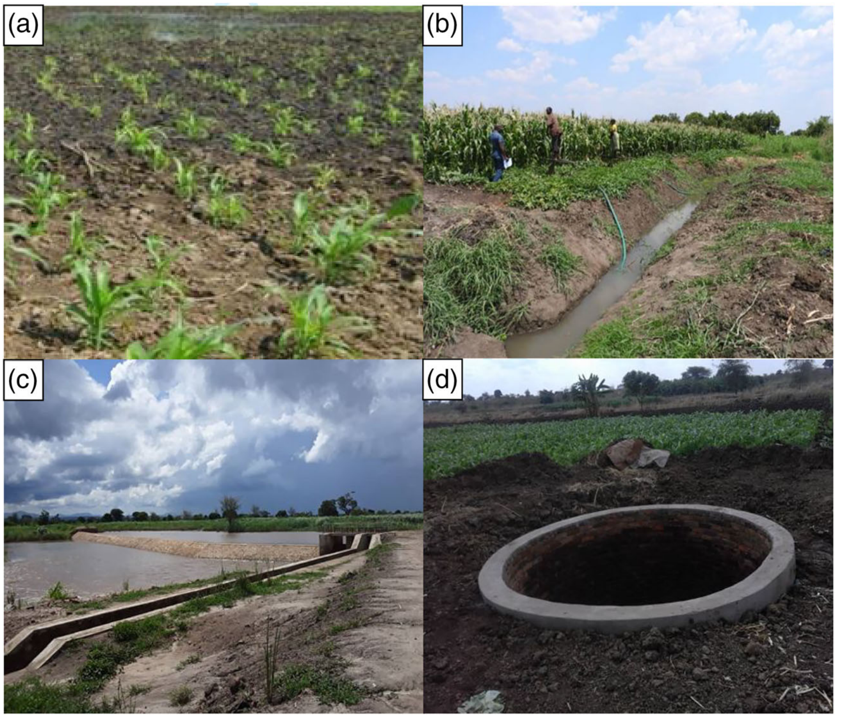

FIGURE 5 Flood-based farming systems adopted in Balaka: (a) flood recession agriculture, (b) inundation canal, (c) spate irrigation, and (d) dugout

3.3 | Factors associated with FBFS adoption in Balaka

Table 1 shows the results of a linear regression analysis. Two main factors were significantly associated with adoption of FBFS during the household survey in Balaka. These were lack of capital investment (p = 0.00003) and level of awareness (p = 0.004). The remaining factors, which included farm size (p = 0.005), credit facility (p = 0.005), land ownership (p = 0.005), inadequacy of extension workers (p = 0.005), capacity of extension workers (p = 0.005), external support (p = 0.005), type of soil (p = 0.005), rainfall intensity (p = 0.005), extension methodology (p = 0.005), and level of education (p = 0.005), were not associated with the observed variable of the extent of practice of FBFS. To that end, lack of capital investment and level of awareness of FBFS seem to be crucial factors associated with the adoption of FBFS.

4 | DISCUSSION

The study found that there were four FBFS adopted by smallholder farmers in the study areas, and these were FRA, SI, ICDO, and DA. From the FGD and the household survey with the adopters, the study revealed that the majority of farmers adopted FBFS because they boost crop production and income (Figure 6) as these systems help in the production of cash crops such as fruit trees, cassava, and others. Some indicated that they adopted

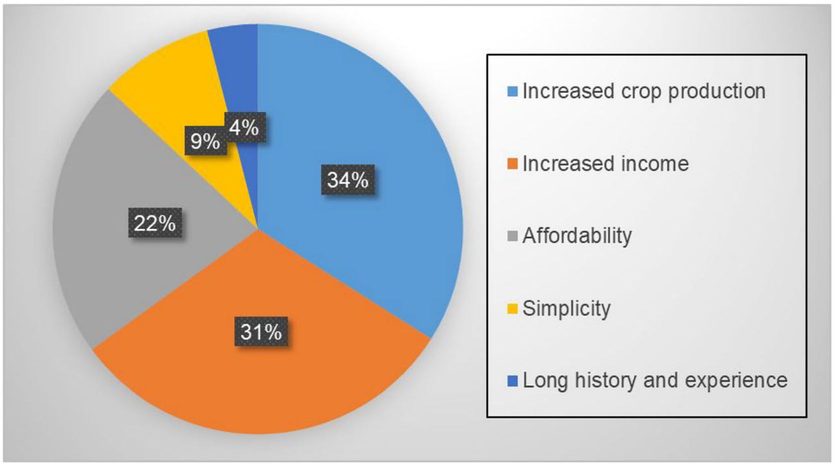

FIGURE 6 Importance of using flood-based farming systems for the farmers (n = 199)

TABLE 1 Socio-economic, institutional, and physical factors associated with adoption of flood-based farming systems in Balaka

Coefficients[a]							
	Unstandardized coefficients		Standardized coefficients			95% CI for B	
Model	B	SE	Beta	t	*p* value	Lower bound	Upper bound
(Constant)	1.748	0.347		5.035	.0000008	1.065	2.43
Education level (X_1)	−0.012	0.019	−0.035	−0.611	.541	−0.05	0.026
Farm size (X_2)	−0.003	0.022	−0.007	−0.123	.902	−0.05	0.041
Capital investment (X_3)	−0.079	0.019	−0.232	−4.27	.00003	−0.12	−0.04
Land ownership (X_4)	−0.01	0.02	−0.029	−0.505	.614	−0.05	0.03
Inadequacy of extension workers (X_5)	0.019	0.055	0.017	0.348	.728	−0.09	0.128
Capacity of extension workers (X_6)	0.143	0.126	0.058	1.14	.255	−0.1	0.39
Extension methodology (X_7)	−0.029	0.145	−0.01	−0.199	.842	−0.32	0.257
Awareness level (X_8)	−0.054	0.018	−154	−2.93	.004	−0.09	−0.02
Credit facility (X_9)	0.126	0.132	0.048	0.954	.341	−0.13	0.385
External support (X_{10})	0.045	0.243	0.009	0.185	.853	−0.43	0.524

them because of their long history and experience in using FBFS (such as FRA). Affordability and simplicity of use also contributed to the adoption of FBFS in the study areas.

Several studies have established that FBFS contribute in several valuable ways as a mitigation measure against climate change. A number of African countries including Eritrea, Zimbabwe, and Northern Ghana attest to the potential and benefits of FBFS (Hadera, 2001). FBFS, such as SI, which involve the deposition of fine sediments suspended in diverted water, contribute to soil fertility (Castelli & Bresci, 2017). In addition, the provision of water for agricultural activities and the contribution to groundwater recharge are among some of the key contributions of SI (Puertas et al., 2014).

The study found that the extent of the adoption of FBFS by the smallholder farmers varied. From the household survey conducted among the adopters, FRA was the most commonly adopted (54%) FBFS by the smallholder farmers in the study areas. As reported in the FGD and the household survey, the system was mostly adopted as it is cheap, simple, can withstand the effects of climate change, and farmers have wide experience of it. This was also echoed by the KII conducted with the extension workers in the study areas. The KII with extension workers reported that since the study area is continuously experiencing downward trends in both amount and days of rainfall, farmers adopt FRA to grow a second crop as an alternative by taking advantage of receding flood water and residual moisture in their fields.

FRA has at length been considered a sustainable way of increasing food productivity (Laube et al., 2012; Puertas et al., 2014), with positive examples from small- to large-scale farming (Chidanti-Malunga, 2009; Nyamadzawo et al., 2014; Puertas et al., 2014; FBLN, 2018). It is assumed that areas that experience annual flooding in most African countries could yield significant positive results from FRA (Laube et al., 2012). This is not surprising as in other African countries, such as Ghana, FRA plays a strategic role in ensuring food security among the poorest communities because the crop cycle takes place during the dry season when other crop harvests are depleted (Puertas et al., 2014). This is also shared by Comas et al. (2012) as statistics from Mauritania showed that sorghum production using FRA can provide as much as a quarter of the national cereal production in favourable years. FBLN (2018) and Chidanti-Malunga (2009) argued that of all the FBFS, FRA is preferred in Malawi to the use of pumps, citing the system's low capital requirements and running costs as key motivators for adoption.

On the other hand, results from the household survey with non-adopters found that low levels of awareness were significantly associated with the adoption of FBFS at $p = .004$ (Table 1). According to the KII, the low level of awareness in the study areas was due to the lack of allocated resources to conduct awareness campaigns on FBFS. A review of various activity reports implemented by a selection of irrigation stakeholders revealed a gap in resource allocation for the implementation of FBFS awareness as compared to other interventions (GoM, 2017).

According to the KII with the Extension Methodology Officer (EMO), high workloads also contributed to the low level of awareness of FBFS in the study areas. This was partly due to serious staffing shortages, especially at service delivery level, with a considerably high extension worker-to-farmer ratio, standing at 1:2644 in the study area, way in excess of the recommended ratio of 1:800 (GoM, 2020a). Similarly, the intense engagement of extension workers by various agriculture departments and NGO working in their jurisdiction further contributed to their high workload, which consequently contributed to the low level of FBFS awareness. These were singled out as key factors that likely impacted the dissemination of FBFS in the study areas.

Previous studies found concrete links between the availability of extension workers and promulgation of agricultural technologies and services. Msume (2017) pointed out that the availability of an extension worker in the community and the usefulness of the extension messages are significant determinants of technical efficiency. Mloza-Banda & Nanthambwe (2010) also added that poor access to extension information on farming technologies attributed to poor extension services provided by the extension workers in the field. Although extension workers serve as a link for disseminating information between experts and farmers, Kamwamba-Mtethiwa (2016) reported that they are overwhelmed by the amount of assignments allocated to them. In addition, mobility challenges among extension workers hindered FBFS awareness campaigns as their only means of transport in the study areas were push bikes, which could not be used to cover long distances. According to key informants, extension workers sometimes used their own resources for transport, thus hampering their efficiency and effectiveness as they carried out their responsibilities. Chinsinga (2009) equally noted that the extension workers are unable to fully provide extension services in their areas because of serious transport constraints.

Lastly, the low level of awareness of the FBFS in the study could also be attributed to the methodology used in the provision of extension services to farmers. The study found from the KII that they used a demand-driven approach during the promotion of FBFS, which stipulates that farmers should request extension services. Even though the study noted that this approach works well with educated farmers, it requires adequate awareness and sensitization, which is not at sufficient levels as the participants in the KII revealed.

Mloza-Banda & Nanthambwe (2010) also argued in their study that the "demand-driven approach" might not be suitable for the introduction of new RWHT, such as FBFS, for farmers in Malawi. This is because FBFS are more knowledge-intensive than input-intensive, and therefore success depends more on what the farmer does.

On the other hand, during the household survey with non-adopters, the study also found that the lack of capital (resources) was significantly ($p = 0.00003$, Table 1) associated with the adoption of FBFS that required more capital to develop, such as SI, ICDO, and DA. This was particularly the case in areas where FRA cannot be adopted. According to the survey, this is due to the fact that the majority of farmers (62% of the total farmers) in the study areas were resource-poor, in line with the poverty rate in the study areas (GoM, 2017). According to the KII with irrigation experts in the study areas, SI, ICDO, and DA systems require irrigation equipment and other construction materials. For instance, SI involves the construction of a weir (diversion structure), conveyance canal, secondary and tertiary canals, and also blocks or plots in the field, making it expensive for most farmers to afford (Puertas et al., 2014).

Similarly, to the challenges faced with SI, the inability of farmers to construct shallow wells and purchase pumps contributed to the low adoption of ICDO and DA as these technologies require a water-lifting device to pump water from the shallow wells or canals to the fields. From the KII with irrigation experts and the household survey with the farmers, it was found that some of the farmers who adopted the two technologies accessed the pumps and shallow wells through the government and NGO working in the study areas. The government distributed MoneyMaker pumps through the MDRRP in the study area. Some pumps were distributed by the PCI and WALA projects.

Farmers operating these systems (SI, ICDO) in most developing countries often find it difficult to meet running costs (Senay & Verdin, 2004). In agreement, Msume (2017) reported that farmers with high access to external support, such as farm inputs, are more likely to adopt RWHT compared to farmers with no access to external support. Similarly, in Iran 90% of RWHT-adopting farming households benefited from highly subsidized RWHT plastic sheets (Shalamzari et al., 2016). A similar case is documented in Malawi by Chidanti-Malunga (2009), where the majority of adopters of ICDO and DA received pumps from the government and NGO for free.

Although there were some efforts by the Department of Irrigation (DoI) to support farmers with construction materials for the implementation of SI, ICDO, and DA, this was not conducted on a wide scale as the department was poorly funded and understaffed. Observations showed that some catchment areas in the study areas had riverbeds, which are typically spate, but the farmers did not utilize the water that comes from the mountains in the areas due to inadequate resources (construction materials) as indicated during the FGD. Similarly, during the KII with the Land Resource Conservation Officers (LRCO), it was reported that the Rainwater Harvesting Association of Malawi (RHAM) also took the initiative to promote SI in the study areas, though their promotion was confined to a specific small area due to a dearth of funds.

In addition, the implementation of FBFS such as SI, DA, and ICDO requires farmers to form groups since group efforts make it easy to access loans for inputs from microfinance lending institutions. However, according to the KII with irrigation experts in the study areas, the study found that this arrangement was not welcomed by many farmers as they were not ready to share their plots with others in groups. The farmers feared that if they belonged to a group they would lose their rights to their piece of land as the government does not provide money to farmers in return for changing their land tenure to public land (Chidanti-Malunga, 2009; GoM, 2019). This also could be one of the contributing factors to the low adoption of SI, DA, and ICDO in the study areas.

Despite a number of reasons presented by farmers for not practising other FBFS such as SI in the study areas, other studies have reported practice of the technology in some parts of the country. FBLN (2018) reported the practice of SI in Karonga, Nkhatabay, and various areas in Lower Shire in Malawi. SI in these areas involves changing the direction of small rivers or streams through the use of simple earthen water control structures. These are often temporary dams constructed across small rivers or streams to redirect the flow into the agricultural fields. The Lower Shire is a geographically flooded area as it receives a lot of runoff from the upper and middle sections of the Shire River and from the Ruo River (Mwale, 2014). The government and some NGO working in this area provided immediate support in response to affected farmers to help restore their livelihoods through the construction of SI structures in Lower Shire (Chawawa, 2018). The situation is also similar in the Karonga and Nkhatabay districts.

This is unlike the study areas, where, regardless of experiencing prolonged dry spells and floods, very few NGO support the farmers with infrastructure developments, and in most cases where support is given, the developments do not involve the construction of big structures, such as diversion structures (weirs) and dams. According to the DoI, the study areas have very few government and NGO irrigation projects working on the promotion of SI. In addition, farmers in the study area also have a long history and experience of FRA, but not of SI. Nevertheless, changing the course of rivers feeding the scheme and damage to the earth diversion and distribution structures of the schemes are major challenges facing the practice of SI in the study area.

A number of studies have also reported the practice of SI in various countries in West Asia, East Africa, and some parts of Latin America (Puertas et al., 2014). However, the implementation of the system continues to face a number of challenges. For example, Fadul et al. (2019) argued that the lack of resources determined farmers' adaptation strategies downstream in a spate-irrigated system in Sudan. On the other hand, as reported by Fadul, de Fraiture, and Masih (2021), SI continues to face a high level of uncertainty owing to its use of such an unpredictable water source as flash floods in ephemeral rivers.

These results suggest that the lack of capital for investment in and operation of the systems are critical factors in the adoption of FBFS. Technologies that require less capital and with low operational costs are more likely to be adopted than those that require more capital. It is for this reason that FRA is widely adopted in the study areas. Therefore, it is important that interventions for the success of FBFS should concentrate on the improvement of the existing practices preferred by the farmers, such as FRA. On the other hand, stakeholders promoting capital-intensive and skill-demanding FBFS such as SI, ICDO, and DA should consider coming up with some strategies that can motivate farmers to practise these technologies.

Equally important is the farmers' awareness of the new technology. Farmers who are more aware of the technology are more likely to practice it than those who are not. Since the majority of non-adopters were not aware of the possibilities of FBFS in the study areas, there is a pressing need to strengthen awareness and improve extension services.

These findings are in line with those of previous studies (Chidanti-Malunga, 2009; Puertas et al., 2014; FBLN, 2018; Traore et al., 2020), which reported FRA as widely adopted in Western, Central, Eastern, and Southern African countries including Malawi as it is associated with low capital and operational costs. These gaps will need to be filled if productive FBFS are to be promoted to improve food security.

5 | CONCLUSIONS

The current study was undertaken to better understand current practices and promulgate appropriate systems of FBFS in the Balaka area (Malawi). It emerged that several FBFS are adopted, which include FRA, ICDO, SI, and DA. The results showed that FRA was more widely (54%) adopted compared to other FBFS. A lack of capital investment and low levels of awareness among farmers seem to be crucial factors associated with the adoption of FBFS and need to be considered for future FBFS development. The study therefore emboldens all stakeholders to promote the technologies that are acceptable to the farmers and seen to benefit them under the local socio-economic conditions, notably FRA. This also calls for the improvement and modernization of FRA technology. The study also encourages all stakeholders promoting capital-intensive and skill-demanding FBFS such as SI, ICDO, and SI to consider coming up with strategies that can motivate farmers to practise these capital-intensive technologies. These strategies should be incorporated in government policies to achieve adoption, sustainability, and prosperity for the livelihoods of farmers in FBFS. Therefore, future studies could consider further exploration of the challenges that farmers face when practising capital-intensive and skill-demanding FBFS as well as the strategies that can be put in place to improve their adoption.

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CONFLICT OF INTEREST

With this submission, the authors confirm no conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome. As corresponding author, I confirm that the manuscript has been read and approved for submission by all the named authors. I declare that this manuscript is original, has not been published before, is not currently being considered for publication elsewhere, and all authors involved have agreed to submit the manuscript to this journal.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available

REFERENCES

Ali, M., David, M.K., & Ching, L.L. (2014) Using the key informants interviews (KIIs) technique: a social sciences study with Malaysian and Pakistani respondents. March 2015.

Casale, M., Drimie, S., Gillespie, S., Kadiyala, S., Msoma, P., Quinlan, T. & Ziervogel, G. (2008) *Experiencing vulnerability in Southern Africa the interaction of multiple stressors*. Washington. USA: International Food Policy Research Institute.

Castelli, G. & Bresci, E. (2017) Participatory rural appraisal for diagnostic analysis of spate irrigation systems in Raya Valley, Ethiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 118(1), 129–139.

Castelli, G., Bresci, E., Castelli, F., Yazew, E. & Mehari, A. (2018) A participatory design approach for modernization of spate irrigation systems. *Agricultural Water Management*, 210, 286–295. https://doi.org/10.1016/j.agwat.2018.08.030

Chawawa, N. (2018) Why do smallholder farmers insist on living in flood prone areas? Understanding self-perceived vulnerability and dynamics of local adaptation in Malawi: A case study of Lower Shire. University of Edinburgh (Master Desertation). Edinburgh. Scotland.

Chidanti-Malunga. (2009) Wetland farming and small-scale informal irrigation in Malawi; The case of Shire Valley. Cranifield University (PhD Thesis), Cranfield, England.

Chinsinga, B. (2009) The political economy of Ministry of Agriculture at the District Level: the case of Rumphi District. Research Paper 015. Future Agricultures. Lilongwe, Malawi.

Comas, J., Connor, D., El, M., Isselmou, M., Mateos, L. & Gómez-macpherson, H. (2012) Why has small-scale irrigation not responded to expectations with traditional subsistence farmers along the Senegal River in Mauritania ? *Agricultural Systems*, 110(2012), 152–161. https://doi.org/10.1016/j.agsy.2012.04.002

Demissie, B., Teklemariam, D., Haile, M., Meaza, H., Nyssen, J., Billi, P., *et al*. (2021) Flood hazard in a semi-closed basin in northern Ethiopia: Impact and resilience. *Geo: Geography and Environment*, 8(2), e00100. https://doi.org/10.1002/geo2.100

Fadul, E., de Fraiture, C. & Masih, I. (2021) Flexibility as a strategy to cope with uncertain water supply in spate irrigation. *Irrigation and Drainage*, 70(5), 1–16. https://doi.org/10.1002/ird.2608

Fadul, E., Masih, I. & De Fraiture, C. (2019) Adaptation strategies to cope with low, high and untimely floods: Lessons from the Gash spate irrigation system, Sudan. *Agricultural Water Management*, 217, 212–225.

Flood Based Livelihood Network (FBLN). (2018) Review of flood based livelihood systems experience in Malawi Review of flood based livelihood systems experience in Malawi. Final Report. Lilongwe. Malawi.

Gadad, S. (2017) Introduction to irrigation canals and design. https://doi.org/10.13140/RG.2.2.22799.79524

Gilbert, M. (2013) Factors influencing adoption of conservation agriculture in south uluguru mountains in Morogoro Region, Tanzania. Sokoine University of Agriculture (Master Desertation), Morogoro, Tanzania.

Government of Malawi (GoM). (2017) *Balaka District socio-economic profile 2017–2022*. Lilongwe, Malawi: Ministry of Local Government and Rural Development.

Government of Malawi (GoM). (2019) *Department of Irrigation 2018/2019 progress report*. Lilongwe, Malawi: Ministry of Agriculture.

Government of Malawi (GoM). (2020a) *Balaka District Agriculture Office report, 2020*. Lilongwe, Malawi: Balaka. Ministry of Agriculture.

Government of Malawi (GoM). (2020b) *Rainfall and temperature data for Balaka: 1990–2019*. Malawi: Blantyre.

Hadera, M. T. (2001) Soil and water management in spate irrigation systems in Eritrea. In: Tropical resources management. Wegenigen University (PhD Thesis), Wagenigen, the Netherlands

Kabambe, V.H., Ngwira, A., Aune, J.B., Sitaula, B. & Chilongo, T. (2018) Productivity of pigeon pea and maize rotation system in Balaka District, Southern Malawi. *African Journal of Agricultural Research Full*, 13(43), 2392–2398. https://doi.org/10.5897/AJAR2018.13315

Kaczan, D., Arslan, A., & Lipper, L. (2013) Climate-smart agriculture ? A review of current practice of agroforestry and conservation agriculture in Malawi and Zambia. ESA Working Paper No. 13–07 October 2013. 13. Rome, Italy.

Kamwamba-Mtethiwa, J.T. (2016) Sustainable irrigation development: The adoption of small-scale pumped irrigation in Malawi. Cranfield University (PhD Thesis), Cranfield, England.

Kuntashula, E., Sileshi, G., Mafongoya, P.L. & Banda, J. (2006) Farmer participatory evaluation of the potential for organic vegetable production in the wetlands of Zambia. *Outlook on Agriculture*, 35(4), 299–305. https://doi.org/10.5367/000000006779398290

Lal, R. (2016) Soil carbon management and climate change. *Carbon Management*, 4(4), 439–462. https://doi.org/10.4155/cmt.13.31

Laube, W., Schraven, B. & Awo, M. (2012) Smallholder adaptation to climate change: Dynamics and limits in Northern Ghana. *Climatic Change*, 111, 753–774.

Li, C., Kandel, M., Anghileri, D., Oloo, F., Kambombe, O., Chibarabada, T., *et al*. (2021) Recent changes in cropland area and productivity indicate unsustainable cropland expansion in Malawi Environ. *Environmental Research Letters*, 16(2021), 084052. https://doi.org/10.1088/1748-9326/ac162a

Mehari, A., Schultz, B. & Depeweg, H. (2005) Where indigenous water management practices overcome failures of structures: the Wadi Laba spate irrigation system in Eritrea. *Irrigation and Drainage*, 54(1), 1–14. https://doi.org/10.1002/ird.151

Mloza-Banda, H. & Nanthambwe, S. (2010) *Conservatio agriculture programmes and projects in Malawi: Impacts and lessons national conservation agriculture task force secretariat*. Lilongwe, Malawi: Land Resources Conservation Department.

Mora, R.-J., & Kloet, B. (2010) Digital forensic sampling. In: Digital forensic sampling (Vol. 1). http//en.hoffmannbv.nl

Msume, A.P. (2017) Adoption of rainwater harvesting technologies by smallholder farmers in Malawi: A case study of Zidyana EPA. University of Malawi (Master Desertation), Blantyre, Malawi.

Mwale, F.D. (2014) Contemporary disaster management framework quantification of flood risk in rural Lower Shire Valley. Heriot-Watt University (PhD Thesis), Edinburgh, Scotland.

Mwenda, P., & Fadda, C. (2014) Guiding focus group discussions on varietal diversification and adaptation to climate change in East

Africa Authors. April 2016, 2014–2015. https://doi.org/10.13140/RG.2.1.2367.7840

Nthara, M. T. (2015) *Best Practices scaling up sites (SUPs) on Rainwater Harvesting and conservation agriculture*. Lilongwe: Rainwater Harvesting Association of Malawi.

Nyamadzawo, G., Wuta, M., Nyamangara, J., Nyamugafata, P. & Chirinda, N. (2014) International journal of agricultural sustainability optimizing dambo (seasonal wetland) cultivation for climate change adaptation and sustainable crop production in the smallholder farming areas of Zimbabwe. *International Journal of Agricultural Sustainability*, 0(1), 1–17. https://doi.org/10.1080/14735903.2013.863450

Project Concern International (PCI). (2016) *Resilience of WE groups in Malawi to climate shocks*. Lilongwe, Malawi: PCI.

Project Concern International (PCI). (2018) *Njira project report* (Vol. 92123, Issue 858). Lilongwe, Malawi: PCI.

Puertas, G.-L., Van-Steenbergen, F., Haile, A.M., Kool, M. & Embaye, G.T. (2014) *Flood based farming systems in Africa 5*. Spate Irrigation Network Foundation: Wageningen. the Netherlands.

Senay, G. & Verdin, J. (2004) Developing index. *Applied Engineering in Agriculture*, 20(6), 789–799.

Shalamzari, M.J., Sadoddin, A., Sheikh, V.B. & Sarvestani, A. (2016) Analysis of adaptation determinants of domestic rainwater harvesting systems (DRWHs) in Golestan Province, Iran. *Environmental Resources Research*, 4(1), 27–43.

Sibide, Y., Williams, O.T., & Kolavalli, S. (2016) Flood recession agriculture for food security in Northern Ghana literature review on extent, challenges and opportunities. doi.org/10.13140/RG.2.1.3250.8405

Traore, K., Traore, B., Synnevåg, G. & Aune, J.B. (2020) Intensification of Sorghum production in flood. *Agronomy*, 10(726), 1–15.

van Steenbergen, F., Mehari, A., Alemehayu, T., Almirew, T. & Geleta, Y. (2011) Status and potential of spate irrigation in Ethiopia. May. https://doi.org/10.1007/s11269-011-9780-7

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