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Exploring the Adaptive Capacity of Sugarcane Contract Farming Schemes in the Face of Extreme Events

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Adaptive capacity determines the extent to which exposure to natural hazards and extreme events translates into impacts. This study traces the effectiveness of adaptive capacity of two different sugarcane contract farming schemes (so-called outgrower schemes)—Phata and Kasinthula—in Chikwawa district in southern Malawi which, due to their proximity, are similarly exposed to extreme events, but have shown different impacts in terms of sugarcane production. We develop a framework to explore and compare the adaptive capacity at scheme management level, and relate the findings to the historical changes in yield, the occurrence of extreme events in the district and the lived experiences of the scheme management over the last ten years (2010–2019) using qualitative data from interviews with scheme managers. The total level and components of adaptive capacity differ in several aspects. Phata had much better prerequisites to mitigate the impacts of the extreme events (i.e., maintain production), particularly related to the Asset base, Knowledge and information, Innovation, and Forward-looking decision-making. Kasinthula on the other hand, was impacted by compound events whilst having low financial capacity, weak governance and reduced human capacity. Kasinthula had limited capacity to recover from the severe 2015 floods, the adaptive capacity thus drawn upon and were not restored when next event occurred (drought). This novel, comparative approach to assessing adaptive capacity, linking to past events, has been shown useful in order to determine the components that are missing and need to be built in order to reduce risk from extreme events and climate change. These findings are important to ensure future adaptation of sugarcane outgrowers, and relevant also to other contract farming arrangements or similar kinds of agricultural organizations.

Keywords: Malawi, adaptation, floods, droughts, cyclones, outgrowers

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INTRODUCTION

Extreme events cause significant economic losses and numerous deaths in Sub-Saharan Africa annually (World Bank, 2016). The extent and frequency of these events are expected to increase in the future. Droughts have caused most weather and climate related deaths, while floods and storms have caused most economic losses [World Meteorological Organization (WMO), 2014]. Malawi

is one of the most vulnerable countries to climate change and increasingly affected by extreme events, with major floods (in 2015) and a drought (in 2016) in recent years. The total costs of damages and losses of these two events were estimated at USD 335 million, and USD 366 million respectively (Government of Malawi, 2015b, 2016). The majority of the population is dependent on smallholder agriculture, which becomes increasingly challenging with climate variability, change and extreme events.

Rain fed agriculture is particularly vulnerable to climate change and variability, and irrigation, including small-scale, rainwater harvesting or large-scale interventions, has been promoted as an adaptation strategy in Malawi (Government of Malawi, 2015a). Sugarcane production in Malawi is among the most important export earnings in the country, and an important source of employment in the sugar producing areas (Chinsinga, 2017), requires irrigation due to a single rainy season, and increasingly also due to more frequent and prolonged dry spells. Through contract farming agreements, so called outgrower schemes, smallholder farmers comprise part of the sugar industry. The outgrower schemes are built up as block farm arrangements with joint irrigation systems, which thus facilitate large-scale production of sugarcane on smallholder community land. The success of these outgrower schemes varies (Herrman and Grote, 2015; Dubb et al., 2017; Adams et al., 2019), and there is limited knowledge about how these outgrower schemes are affected by extreme events, as well as how well they adapt to climatic challenges (Zhao and Li, 2015). Assessing the adaptive capacity of such organizations would thus provide a useful measure of how the schemes are prepared and can recover from events such as droughts, floods and cyclones.

LITERATURE REVIEW

Adaptive capacity is "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, take advantage of opportunities, or to cope with the consequences" (IPCC, 2007, p. 869). It is a stock of latent assets that can be drawn upon to enable adaptation. Thus, adaptive capacity is a critical component of risk, and determines the extent to which exposure and vulnerability to extreme events translates into negative effects (IPCC, 2007, p. 869). Factors that contribute to the adaptive capacity of a system involve social, political, economic, technological and institutional aspects that depend on scale and context (Vincent, 2007). For almost two decades, there has been a rapid growth in research on adaptive capacity (Mortreux and Barnett, 2017).

Multiple approaches and frameworks have been developed in order to assess, quantify and anticipate adaptive capacities of various systems at a range of scales. These include national to local and household level assessment (Vincent, 2007; Jones et al., 2017; Matewos, 2020), and most relevant for this study—various kinds of institutions, such as resource governance regimes (Pahl-Wostl, 2009), community-based natural resource management (Armitage, 2005), or private sector business entities and networks (Parsons et al., 2018; Canevari-Luzardo et al., 2020). The literature that covers the adaptive capacity of institutions is rapidly evolving and the various dimensions of an institution's governance and management that contribute to its adaptive capacity are well-covered (Gupta et al., 2010; Engle, 2011). Jones et al. (2017) identify five characteristics of local adaptive capacity that are applicable to the scale of organization in focus in this study: Asset base, Institutions and entitlements, Knowledge and information, Innovation, and Forward-looking decision-making. These characteristics are outlined below.

Adaptive capacity was earlier commonly attributed predominantly to the presence of the five capitals, or assets, i.e., natural, physical, financial, social, and human capacity (Vincent, 2007; Jones et al., 2017; Mortreux and Barnett, 2017). Availability of a diverse range (abundant and redundant) of assets are critical for an organization to be able to respond to emerging circumstances (Ospina and Heeks, 2010). However, as the theory and conceptualization of adaptive capacity has advanced, it has been recognized that the focus on capitals, or assets, alone is not sufficient to understand the complete and multifaceted dimensions that either support or inhibit the capacities (Mortreux and Barnett, 2017). In order for the various capacities to be used, or activated, other factors have to be considered, e.g., those that enable mobilization of capabilities (Jones et al., 2017; Mortreux et al., 2020). These include psycho-social factors linked to behavior, such as risk attitudes (e.g., Jain et al., 2015), personal experiences (e.g., Hertwig et al., 2004; Olsson et al., 2004, and Parsons et al., 2018) and trust (e.g., Pelling and High, 2005).

Interconnectivity, i.e., being part of networks and have connections with a wide variety of institutions, is likely to positively affect the adaptive capacity of an institution at any scale, such as national to household (Adger, 2003; Vincent, 2007), and context, such as resource management and governance (Armitage, 2005; Pahl-Wostl, 2009), or private sector (Parsons et al., 2018; Canevari-Luzardo et al., 2020). The ability of an institution to manage social relations (e.g., those who form part of the network) at multiple scales is seen as a factor that is likely to support adaptive capacity (Jones et al., 2017). Where there may be power imbalances and dynamics within these social relations, and fair governance that considers equity social differentiation of entitlement to assets, is likely to promote adaptive capacity (Gupta et al., 2010; Cohen et al., 2016; Jones et al., 2017).

Knowledge and information are well recognized factors that contribute to the ability to adapt to climatic challenges and thus promote adaptive capacity (Olsson et al., 2004; Pahl-Wostl, 2009; Jones et al., 2017). Sufficient skills within the institution prevent maladaptive practices, i.e., decisions that are made for short-term gains as opposed to ensuring long-term stability and sustainability (Jones et al., 2017). Learning from past experience and mobilizing such knowledge and skills to preparedness has been highlighted as important in building and maintaining adaptive capacity (Olsson et al., 2004, Armitage, 2005; Parsons et al., 2018). Learning from past experience is particularly important when the climate hazards are not only slow changes such as gradual shifts in temperature and rainfall patterns, but also sudden and abrupt changes such as extreme events. Much of the research on adaptive capacity has focused on gradual climate

change and less attention has been given adaptive capacity in the context of climate extremes (Thonicke et al., 2020). During an extreme event, adaptive capacity is drawn upon and this depletes the asset base, or stock, for a time until it has been restored. In hazard-exposed areas where extreme events are severe, and occur at an increasing frequency (such as Malawi; Botha et al., 2018), it may be that stock of adaptive capacity is unable to replenish after one event before the next one occurs. This eroding capacity in light of existing exposure would lead to increase risk of negative impacts; and this is compounded when combined to increasing frequency of hazard exposure. Assessing riskalso requires consideration of the nature of hazard exposure, which comes from the availability, use and dissemination of weather and climate information, including early warnings.

Climate and weather are not the only elements of uncertainty that influence the management and governance of an institution. Population growth, socio-economic trends, global and local market fluctuations, resource access, politics, and legislations are factors that directly or indirectly affect outcomes of any decision. An organization that face such complex challenges, require a management structure to foster innovation and take advantage of opportunities (Cohen et al., 2016; Jones et al., 2017). Rigidity in management practices, rules and aversion toward experimentation may thus hamper adaptive capacity. Forward-looking decision-making approaches with appropriate timeframes in management, and consideration of a range of uncertainties, projections and predictive modeling are highlighted as contributors to an institution's adaptive capacity (Armitage, 2005; Vermeulen et al., 2013).

In this paper, we take an innovative approach to adaptive capacity, unpacking its multiple components and historically assessing the extent to which it was successful in enabling adaptation to climate change in the face of exposure to extreme events. This approach—assessing the extent to which adaptive capacity existed through retrospectively analyzing how it mediated impacts of extreme event exposure has rarely been applied (Duncan et al., 2017), and contrasts with the more typical approaches which determine adaptive capacity as a latent capacity that will be activated in the case of current or future exposure [e.g., Vincent (2007) and Mortreux and Barnett (2017)]. We do this by assessing adaptive capacity in two closely-located outgrower schemes in the Chikwawa district in southern Malawi which have been exposed to the same extreme events. However, the Kasinthula Sugarcane Outgrower scheme and the Phata Sugar Cooperative have had largely different outcomes of their management and governance, in terms of sugarcane production (as an indicator of the success of adaptive capacity in enabling adaptation in the face of exposure to extreme events). The two schemes' disparate outcomes thus provide a unique opportunity to identify the nature of adaptive capacity that is important in order to reduce negative impacts of exposure to such extreme events and ensure future adaptation.

Since adaptive capacity is a latent stock, or potential that will be drawn upon in the future, usually the only way to assess its effectiveness in enabling adaptation is through modeling studies or by waiting for future exposure to occur (Engle, 2011). Here, we develop a framework to assess and compare the potential adaptive capacity of two sugarcane outgrower schemes looking into the past and use sugarcane production as a proxy for positive outcomes of adaptive capacity in the context of lessened impacts of extreme events. Through in-depth interviews with outgrower scheme managers we obtain information about the schemes' current features and characteristics of adaptive capacity and the lived experience of extreme events according to the scheme management. The comparative adaptive capacity assessment is then presented qualitatively and we relate the findings to their success in enabling adaptation, defined by the sugarcane yield in the light of the occurrence of extreme events in the Chikwawa district of the last 10 years (2010–2019). This approach contributes to providing better knowledge about the causes of poor adaptive capacity and the contributors when stocks were high. This is particularly so when using two contrasting examples of schemes that have been similarly exposed to, but differently affected by, extreme events.

METHODS

Developing a Framework to Assess Adaptive Capacity of Sugarcane Outgrower Schemes

An organization, such as a sugarcane outgrower scheme in focus in this paper, can be seen as a kind of institution, being formed by patterns of rules and decision making (Gupta et al., 2010). An outgrower scheme is a large-scale agricultural entity that is run as a business, managed by experts with technical skills in agriculture and entrepreneurship, but with the aim to benefit smallholder farmers that constitute the members of the scheme. Given the scale-specificity of adaptive capacity, assessing it at the level of the outgrower schemes requires modification of existing frameworks accordingly. Informed by the theoretical drivers of adaptive capacity discussed in the previous section we developed a framework that considers features and characteristics of the scale and kind of organization in focus that are likely to support adaptive capacity (**Table 1**). We adapted the Local Adaptive Capacity (LAC) framework by Jones et al. (2017) by adjusting the framework to local organization level, rather than household and community. Similar to the adaptive capacity wheel developed by Gupta et al. (2010) we further included sub-categories to be assessed. Other frameworks for assessing various scales, contexts and aspects of adaptive capacity were used to adapt the LAC framework to be relevant for the context of sugarcane outgrower schemes (i.e., Vincent, 2007; Gupta et al., 2010; Canevari-Luzardo et al., 2020, **Table 1**). The framework includes the main characteristics of an institution as follows: Asset base, Institutions and entitlements, Knowledge and information, Innovation, and Forward-looking decision-making (Jones et al., 2017; see **Table 1** for descriptions of the characteristics and sub-characteristics).

Case Study Context

Chikwawa is amongst the districts in Malawi most exposed to climate related shocks (Coulibaly et al., 2015; Mwale et al.,

TABLE 1 | Our adaptive capacity framework, adapted from Jones et al. (2017) to correspond to the context and scale of the management level of sugarcane outgrower schemes.

Characteristic[a]	Summary[a]	Sub-characteristic (adapted to an outgrower scheme context)
Asset base	The availability of a diverse range of key assets that allow the organization to respond to evolving circumstances	Wide range of assets[a]: Asset diversity that can substitute each other.
		Financial: Stability[b], absence of loans, absence of dependency on donors.
		The crop(s): Diversity. Vulnerability to climate extremes and pests
		Human: Managers, staff, farmers (beneficiaries) (availability of expertise, knowledge, and human labor)[c]
Institutions and entitlements	The existence of an appropriate and evolving institutional environment that allows for access and entitlement to key assets and capitals	Institutional interconnectivity[b], business partnerships and networks[d] Equity and fairness[a] (Fair governance[c])
Knowledge and information	The ability the organization have to generate, receive, assess, and disseminate knowledge and information in support of appropriate adaptation options	Institutional memory[c], learning from past experience[c], knowledge about adaptation options[a]
		Knowledge and use of climate information and early warnings[a]
		Communication of risk with the farmers and how is capacity building and training with farmers carried out[a]. Alternative livelihood strategies for the farmers.
		Maladaptive practices (i.e., actions or processes that may deliver short-term gains but ultimately increase vulnerability in the longer term)[a]
Innovation	The presence of an enabling environment to foster innovation, experimentation, and learning in order to take advantage of new opportunities	Rigidity/Flexibility in management practices (e.g., Irrigation infrastructure)[a] Rigidity/Flexibility in decision making around innovation[a,c]
Forward-looking decision-making	The ability to anticipate, incorporate and respond to changes with regard to governance, structure and future planning	Time-frame of management[a] Consideration of future uncertainties and projections[c]

Various elements are also inspired by Vincent (2007), Gupta et al. (2010), and Canevari-Luzardo et al. (2020).
[a] *Jones et al. (2017).*
[b] *Vincent (2007).*
[c] *Gupta et al. (2010).*
[d] *Canevari-Luzardo et al. (2020).*

2015). Due to the location of the Illovo Sugar Limited estate and mill in the area there are opportunities also for smallholder farmers to partake in the sugar industry by the formation of contract farming agreements. Two outgrower schemes supply the Illovo mill with sugarcane according to supply agreements: The Kasinthula Cane Growers' Association (hereafter Kasinthula) was established in 1997, and Phata Sugarcane Outgrowers Cooperative (hereafter Phata) in 2011. Kasinthula consists of an association of almost 800 farmers and Phata of 1,100. The two schemes' governance models are similar; the land under sugarcane production is administered through a land trust that was formed during the establishment of the scheme in order to lease individual plots of land by the farmers. The agricultural operations are run by management companies, who manage the supply agreements with Illovo. The farmers are members of the scheme, and perform specific agricultural tasks in the fields. Farmers may also be employed by the management company for other agricultural operations that require certain skills. The management companies are the levels of organization in focus in this study, as these are where the decisions regarding financial, agricultural and human resource matters take place, which the farmers in the scheme then follow. Both schemes have their executive managers contracted from AgriCane, an agricultural management consultancy. AgriCane was part of the establishment of Kasinthula, and again, was contracted early 2019 to take over the management and turn the scheme around from a near bankruptcy. AgriCane has managed Phata since the onset.

Extreme Events in Chikwawa

Through history, there have been several extreme events occurring in Malawi, with their frequency and intensity increasing over time (Botha et al., 2018). A large number of these events have affected the Chikwawa district (Government of Malawi, 2015b, 2016, 2019; USAID, 2019; Zuzani et al., 2019) (see **Figure 1**). These events include droughts, storms, cyclones and floods, which have affected the district on a large scale including damages to buildings and infrastructure, injuries, and lost lives (Government of Malawi, 2015b, 2016, 2019; USAID, 2019; Zuzani et al., 2019). The agricultural sector has been mostly affected and this issue continues to be a great concern in the country (Government of Malawi, 2016; World Bank, 2019). The three most severe events during the last decade, in terms of costs of damages and losses, in Malawi and Chikwawa, were floods in January 2015, droughts in the 2015/2016 and 2016/2017 seasons, and tropical cyclones, including floods in January-March 2019.

The rainfall in January 2015 was the highest recorded (Government of Malawi, 2015b), and the Southern Region, received 400% higher rains than usual, compared with the long term mean (Reliefweb, 2020). The floods that resulted from these rains caused vast costs in damages and losses (Government of Malawi, 2015b; Hendriks and Boersma, 2019). The agricultural sector incurred great losses in Chikwawa due to a large amount of crops and livestock being lost or damaged, as well as damages to irrigation systems. The costs of damages on irrigation infrastructure reached 623 million Malawian Kwacha in the Chikwawa District, which was highest in the country.

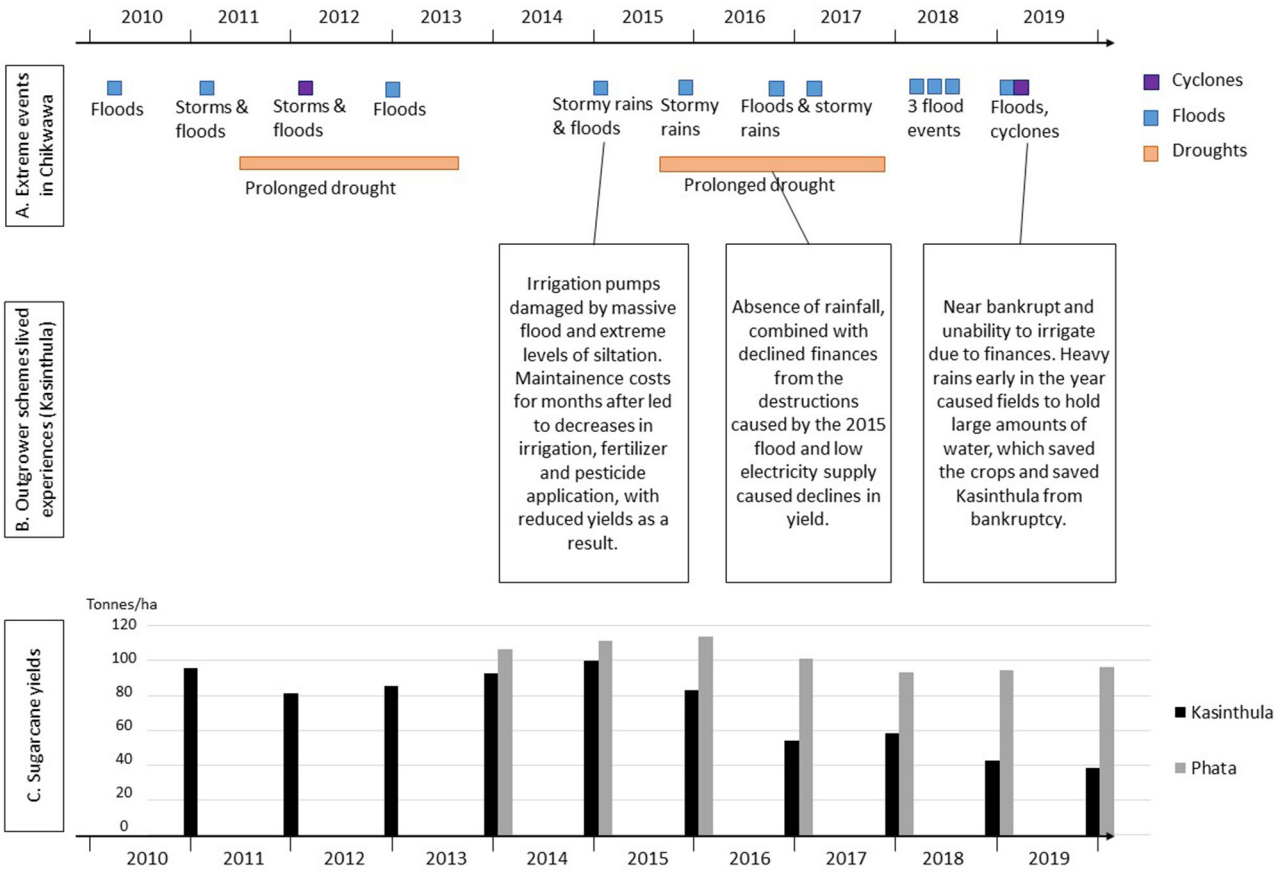

FIGURE 1 | Timeline over **(A)** the occurrence of extreme events (droughts, cyclones, storms, and floods) during 2010–2019 in the Chikwawa District (sources: ReliefWeb, PreventionWeb, EM-DAT, Government of Malawi, 2015b, 2016, 2019), **(B)** The lived experiences of the effects of extreme events by Kasinthula managers (Phata managers stated there were no, or marginal effects) (source: interviews), **(C)** Sugarcane yields, Phata, and Kasinthula schemes (obtained from scheme managers).

While still recovering from this devastating flood event, Malawi experienced a major drought period (Government of Malawi, 2016). Prolonged dry spells during the 2015/2016 season were particularly affecting the southern Malawi, resulting in crop failure and subsequent food shortage (Government of Malawi, 2016). During October to December 2015, Malawi received 32.8 percent less than average rainfall (Government of Malawi, 2016). This worsened from January to March 2016, which is the most critical period for sugarcane production. Chikwawa, along with six other districts, received significantly below average rainfall over the same six months period (Government of Malawi, 2016). Chikwawa was reported to have lost 90% of their crops caused by the drought, while still recovering from the losses caused by the 2015 floods (Government of Malawi, 2016). The drought continued across the following season, 2016/2017 which further exacerbated food insecurity and loss of livelihoods (Government of Malawi, 2017; Mazvimavi et al., 2017).

The beginning of 2019 saw several tropical cyclones affecting southern Africa. Malawi was first severely affected by the continuous and extensive rainfalls caused by the Tropical Cyclone Desmond during end January 2019. Severe flooding occurred in southern Malawi, affecting almost 16,000 people Chikwawa (International Federation of Red Cross Red Crescent Societies [IFRC], 2019). In early March another severe weather system caused heavy rains in Malawi, which intensified into Cyclone Idai (Government of Malawi, 2019). Chikwawa suffered the highest agricultural losses, and lost 11% of the maize harvest, an irrigation infrastructure for the value of 3.74 million USD (Government of Malawi, 2019).

Methods—Data Collection and Analysis

We applied a case-study approach to explore nuances to the contexts under which the adaptive capacity of two sugarcane schemes have played out historically over the past decade, in the face of extreme events (Crowe et al., 2011; Parsons et al., 2018). The information from various sources were collated to provide a nuanced description of the contexts at study, including literature, interview data, field observations and yield data. In order to gain insights into the various characteristics and sub-characteristics of the adaptive capacity framework (Section Developing a Framework to Assess Adaptive Capacity of Sugarcane Outgrower Schemes, **Table 1**), we conducted seven

TABLE 2 | Interview schedule.

Date	Interview method	Interviewee number	Role of Interviewee
June 2017	semi-structured in-depth interview—individual	1	Agricultural manager, Kasinthula
		2	Human resource manager, Kasinthula
		3	Land trust manager, Kasinthula
November 2017	semi-structured in-depth interview—individual	1	Agricultural manager, Kasinthula
		3	Land trust manager, Kasinthula
March 2020	Informal interview—individual	4	General manager, Kasinthula (newly appointed)
March 2020	Semi-structured in-depth—group	5	General manager, Phata
		6	Financial manager, Phata
		7	Safety and health environment officer, Phata
March 2020	semi-structured in-depth interview—individual	1	Agricultural manager, Kasinthula (previously acting general and financial manager)
		8	Manager with responsibility of outgrower relations, Illovo

individual interviews and one group interview with totally seven managers and senior staff members of the two sugarcane outgrower schemes Kasinthula and Phata (June 2017, November 2017 and March 2020, one of whom was interviewed twice; **Table 2**). The interviews further assessed the changes in yield as well as broader effects and lived experiences (at scheme management level) of the extreme events over the last decade. Data on sugarcane yield (tons per hectare) were provided by the managers of Kasinthula (years 2010–2019) and Phata (2013–2019—Phata's first harvest took place in 2013). The scale of institution (relatively small organizations) and scope of information required (management level insights), the number of available respondents from the two schemes were low. However, in order to triangulate and provide additional context, a ninth interview was held with a manager at Illovo who is managing the contact and relationship with the outgrower schemes, in March 2020. Field observations and informal conversations with farmers and other stakeholders were conducted parallel to the interviews during the three field visits, and although not formally captured, information gained confirmed the information provided through the interviews.

The responses from the in-depth interviews were transcribed, hand-coded, and qualitatively analyzed using inductive thematic content analysis (Neuendorf, 2019). Key words from the characteristics and sub-characteristics in the framework (**Table 1**) guided the choice of codes, and was adapted as new themes emerged during the transcription and coding. After familiarization with the responses, the coded information was condensed and sorted according to characteristics and sub-characteristics and summarized to provide an overview of the various aspects of adaptive capacity (see **Table 3**).

In order to assess the occurrence of extreme events at district level over the last 10 years (2010-2019) we reviewed academic and gray literature. Gray literature included local and international reputable sources, including Post Disaster Needs Assessment Reports, a disaster related dataset obtained from the Malawian Department of Disaster Management Affairs (DoDMA) which included reports of disaster events at district or village level, ReliefWeb, PreventionWeb, EM-DAT (International Disaster Database) and the Dartmouth Flood Observatory. Academic literature was searched using Google and Google Scholar with search terms including "extreme events," "extreme weather events," "natural hazards," "weather shocks," "floods," "droughts," and/or "cyclones," and "Malawi" and/or "Chikwawa." The information from the literature review was consolidated into a spreadsheet, where each event was dated and described according to the available information from the various sources. The events that occurred in Chikwawa during 2010-2019 were plotted in a timeline according to time and nature of event (i.e., floods, cyclones or droughts) (see **Figure 1**).

RESULTS

Effects of the Extreme Events on Smallholder Sugarcane Production–Lived Experiences and Yields

A number of extreme events have been documented in Chikwawa over the last ten years (2010–2019) (**Figure 1**). The exposure to these events has arguably been the same for the two schemes, considering they are located only a few kilometers apart (the distance between the fields of the two respective schemes ranges between 1 and 12 km). The intake points for the irrigation pumps in the Shire River are ∼7 km apart between the two schemes. Despite similar exposure, the two schemes have been affected differently. The differences in effects, and the lived experiences, of the extreme events, are noteworthy as they reflect different levels of adaptive capacity. Phata managers, on one hand, reported that the scheme was not affected by the 2016 drought, nor the major floods in 2015 and 2019, other than that the events caused "*minor inconveniences*." The slight decline in yield in 2016 and 2017 for Phata (**Figure 1**) is according to the Phata managers within an acceptable range, and caused by disturbances in the national electricity supply which affects the irrigation. Phata could maintain yields despite the electricity shortage due to investing in a generator. Thus, their adaptive capacity was sufficient to be drawn on and enable adaptation, such that the impacts were minimal.

The managers of Kasinthula, on the other hand, explained how the onset of the extreme flood in 2015 was the beginning of a series of cascading and drastic events that had severe consequences to the scheme—its finances, management and yields (**Figure 1**). Unlike Phata, which was not yet established, the Kasinthula scheme also experienced the floods, storms and drought events that occurred between 2010 and 2013 (see **Figure 1**), but the impacts on yield of these events were negligible, according to the interviewed managers. The 2015 floods caused

TABLE 3 | A summary of the mechanisms and features of two sugarcane outgrower schemes (Phata and Kasinthula) corresponding to various aspects of adaptive capacity, obtained through in-depth interviews with scheme managers.

Characteristic/sub-characteristic	Summary—Phata	Summary—Kasinthula
Asset base		
Wide range of assets: Asset diversity that can substitute each other.	· Sugarcane only income source for the scheme.	· Sugarcane only income source for the scheme.
Financial: Stability, absence of loans, absence of dependency on donors.	· All loans paid off. · Stable income due to stable production. · Savings in place.	· Large debts. · Reduced income from declining crops. · Dependent on donations and new loans.
The crop(s): Diversity. Vulnerability to climate extremes and pests	· Monoculture	· Monoculture
Human: Managers, staff, farmers (beneficiaries) (availability of expertise, knowledge, and human labor)	· Managers have high expertise and knowledge · Management positions filled. · Access to human labor. · Functioning boards (appointed by members of the scheme) · Capacity building in many topics and skill training high among all farmers (compulsory attendance, courses repeated).	· In-sufficiently skilled managers. · Under-staffed management (many positions vacated and not replaced) · Human labor unmotivated due to staff not being paid during some periods · Boards not appointed (supposed to be appointed by Government). · Low capacity building among farmers, low attendance, and reduced human labor.
Institutions and entitlements		
Institutional interconnectivity, business partnerships and networks	· Connections and agreements with Illovo Sugar, Sugarcane Growers association of Malawi (SUGAM), Fairtrade, NGOs (Concern Universal, Solidaridad, BonSucro), EU, AgriCane, AgDevCo. · Appreciation from Government.	· Connections and agreements with Illovo Sugar, Sugarcane Growers association of Malawi (SUGAM), Fairtrade, Divine Chocolate, NGOs (Concern Universal, Solidaridad, BonSucro), Only last year connections with AgriCane, AgDevCo. · No support from Government.
Equity and fairness (Fair governance)	· Farmers associations represented in boards and decision-making. · Fairtrade committee. · 43% women members (farmers) · 30% women in committees. · Gender based violence committee.	· Farmers association represented in boards and decision-making. · Fairtrade committee. · 32% women members (farmers) · 22% women in committees (on quota).
Knowledge and information		
Institutional memory, learning from past experience, knowledge about adaptation options	· Barely affected by extreme events the past decade. Acknowledges that climate change may come with risk in future. Recalls 1992 drought followed by 1993 droughts. 30,000 ha cane was lost, yield reduced from 110 to 11 tons/ha. · Management and infrastructure set up with climate risk in mind from the onset of the scheme.	· Severely affected by 2015 flood and 2016 drought. Slight damages from 2019 cyclone, but mostly was what kept the cane growing (saved the season's harvest). · Management and infrastructure maintenance changed (drainage systems, dike), agricultural practices changed (soil conservation, new cane varieties).
Knowledge and use of climate information and early warnings	· Monthly government weather bulletins. · Illovo climate data. · Illovo's CanePro data for day to day irrigation scheduling.	· Official channels. · Illovo climate data. · Early warning from Illovo.
Communication of risk with the farmers and how is capacity building and training with farmers carried out. Alternative livelihood strategies for the farmers.	· Farmers trained to improve their livelihood strategies. · Tree planting, food crops, beehives for added benefits. · No climate information dissemination.	· Training has been scattered over the years, and reached only few. Some initiatives only started with the onset of new management. · Tree planting, food crops, beehives being introduced this year. · No climate information dissemination.
Maladaptive practices	Set up to avoid maladaptive practices as follows: · Boards dominated by skilled professionals, with presence from farmer representatives who gives feedback to farmers. · Farmers trained in dividend policy, business understanding, entrepreneurship, sugar production, cane planting, agricultural practices, so decisions with long-term outcomes were supported by farmer representatives.	· Boards had high representation of farmers who lacked business understanding, and understanding of large-scale agricultural production. · Decisions were made with short-term gains, especially related to farmer dividend and management costs. Long-term strategies to assure long-term productivity (maintenance, management stability, capacity building initiatives) were dismissed.
Innovation		
Rigidity/Flexibility in management practices (e.g., Irrigation infrastructure)	· The pump is floating on the surface and is located away from floods and siltation (i.e., not vulnerable to climate extremes), and well managed.	· The irrigation pump was located unprotected from extreme floods and siltation, poorly maintained and easily damaged (Improvements only done recently).

(Continued)

TABLE 3 | Continued

Characteristic/sub-characteristic	Summary—Phata	Summary—Kasinthula
	· Management practices altered with needs and development in the industry.	
Rigidity/Flexibility in decision making around innovation	· Committees and farmer board representatives progressive and flexible. · Management company allows innovations. · Good relationships between farmers and managers.	· Incomplete set of managers and board members hampers progression and flexibility · Short-term decisions hamper innovative decisions (see maladaptive practices in point 3 above). · Conflicts and trust issues between farmers and managers
Forward-looking decision-making		
Time-frame of management	· 5 year strategic plan.	· Previously no strategic systems thinking. 5/10 year plans with the onset of new management and loan terms from development financing company (AgDevCo).
Consideration of future uncertainties and projections.	· AgriCane uses climate projections for crop modeling. · Reliance on Illovo for future pest projections and sugar market. · Fairtrade provides safety in market, but restrictions in pesticide use.	· Before AgriCane there was none.

the entire scheme to be flooded, affecting the cane growth. Furthermore, the main intake point in the Shire River, was due to its location in the river, exposed to large amounts of sand and silt from the floods that damaged the pumps. This, according to one manager at Kasinthula was "*the genesis of the yield drops*". The system silted up every day over a period of several weeks, resulting in unexpected maintenance costs. Reduced finances consequently led to reduced inputs of fertilizer, pesticides and irrigation, which in turn affected the cane growth negatively. The following season, 2015–2016, saw unusually low rainfall, that did not only affect the cane growth but also the national electricity generation (Malawi is dependent solely on hydropower for electricity). The drought in 2016 led to death of sugarcane, and in 2017 the electricity supply was still not sufficient for satisfactory irrigation, which led to further decreases in yield in 2018. Unlike Phata, Kasinthula did not have access to a generator for supplementary electricity. In 2018/2019 the scheme was going toward bankruptcy, and while it was in the process of getting financial relief through a bank loan, the change of management and an investment by an agribusiness investor, the floods and tropical cyclones in January–March 2019 hit the district. Similar to the lived experience by Phata, the Kasinthula did not see destruction to their cane or infrastructure. On the contrary, as expressed by one of the interviewed managers of Kasinthula: "*The cane stayed in water for a while, but this mostly helped. Kasinthula would have died before AgriCane (the new management company) came, if it wasn't for this water staying in the fields*."

Adaptive Capacity of the Kasinthula and Phata Schemes

The adaptive capacity of the respective schemes provides a clear representation of the mechanisms and features that have led to different impacts for the two schemes following exposure to extreme events. **Table 3** presents a summary of the characteristics and sub-characteristics of the adaptive capacity of the two schemes, which is followed by a more detailed narrative of the differences and similarities between the two schemes.

As outlined in the table, the adaptive capacity of the two schemes differs in several regards, and in some display similar outcomes. There are some sub-characteristics where both schemes are displaying low capacity, which is related to the nature of the organization. The schemes have agricultural produce as their single source of income, and this produce is sugarcane alone (i.e., sugarcane as monoculture, highly dependent on irrigation, fertilizer, and pesticide application). Phata has over the years established other characteristics of the Asset base that buffer against the single income and monoculture, such as a stable financial situation where loans are paid off and some savings are in place. Kasinthula has struggled financially over several years, partly because of large debts that were negatively affected by a national finance crisis. Phata furthermore has a less vulnerable irrigation system than Kasinthula. The intake point is located protected from strong currents, and the pump is floating on the surface and therefore prevented from being flooded with water and sand—which was what happened to Kasinthula during the 2015 flood.

Kasinthula's insufficient adaptive capacity at the time of exposure, resulted in declining yields after the 2015 floods. The Kasinthula managers explained a range of factors that had contributed to the low adaptive capacity. One manager stated; "*The governance of the scheme had numerous issues, with several managers and key staff resigning or being dismissed, and not replaced. There was no trust from the shareholders (members).*" Shortage of human capacity, and sufficiently skilled such, according to the Kasinthula managers, led to a sequence of mismanagement that, alongside with the weather conditions resulted in the scheme going toward bankruptcy. Phata on the other hand, has had a continuous manager and staff base with high and appropriate expertise and decisions have been made accordingly.

Another factor that was mentioned with regards to the low adaptive capacity of Kasinthula, was the influence of unskilled board members (farmers) promoting decisions for short-term gains rather than long-term viability and sustainability of the

scheme. At Phata, the governance structure is, according to the managers interviewed, set up to avoid such maladaptive practices. The boards at Phata are dominated by skilled professionals, with presence from farmer representatives who in turn give feedback to farmers. There is an extensive capacity building program in which every farmer is participating. In the program the farmers are trained in aspects that make them better understand the decisions made by the board. These include dividend policy, business understanding, entrepreneurship, sugar production, cane planting, and agricultural practices. This means that, when board positions become vacant, there is a trained cadre of farmers from which replacements can be drawn, ensuring appropriate skills to build and activate adaptive capacity when required. In contrast, Kasinthula has had very few and scattered initiatives to provide capacity building to (only a few of) the farmers, and many lack understanding of the highly technical agricultural system and business model that is required to run a sugarcane scheme of this scale. This means that the flexible, forward looking component of adaptive capacity in Kasinthula is less able to meet its potential due to limited capacity of the individuals filling the board roles. Kasinthula had thus brought forward decisions including reduced capacity building initiatives and fewer management positions in favor of paying out monthly dividends to farmers that were not adjusted according to the returns of the sales of sugarcane. The distinctly different management and governance approaches between the two schemes was confirmed by the manager at Illovo who is managing the contact with the outgrower schemes: *"Kasinthula was born out of a failed rice scheme, and government stepped in (to establish the sugarcane scheme). Kasinthula had issues around governance and who managed the money. Business understanding is missing, and there is an over-representation of (farmers) at board decisions, who are not interested in longer-term decisions. Farmers had high expectations and no capacity building. Phata was a community decision, where (the management company) AgriCane helped with management and it was professionally done from the beginning."*

Due to the recent onset of new management at Kasinthula, it is apparent that the scheme had realized the gaps in adaptive capacity and made alteration to amend these shortcomings. Many of the mechanisms and features that have strengthened the adaptive capacity of Phata over the years, have recently been put in place also at Kasinthula. This means, that the adaptive capacity of Kasinthula will have the prospect to be slowly built up, but due to the severely lacked capacity in many aspects including the Asset base, Knowledge and information, and Innovation, it is likely to take time. The trust in the scheme management among the farmers seems remarkably low, but has the potential to grow with the new management initiatives. The farmers of Kasinthula last received dividend in 2016, which was partly compensated—after pressure by the farmers—through a lump sum that was paid out in 2017 despite the scheme not having gained any profit the last two seasons. The lack of benefit from the scheme caused disappointment and mistrust, and farmers consequently ceased to participate in their work tasks in the scheme and the fields got overgrown by weed. Such issues of mistrust and unrest take time to build up and needs to be a joint effort between the (new) management, the farmer representatives in the boards, and the farmers.

DISCUSSION

Lessons Learnt From Two Contrasting Sugarcane Schemes' Adaptive Capacity

Despite being exposed to the same hazards, the Kasinthula and Phata schemes showed different outcomes in terms of the ability to maintain production in the occurrence of extreme events. This resonates with the findings of Zhao and Li (2015) who state that the degree of impact of climate extremes is not only depending on geographic location (i.e., the nature of exposure) but also on adaptive capacity. The most significant event—the unprecedented floods in 2015—according to Phata managers, did not affect the Phata scheme, while the Kasinthula scheme was severely affected. The framework developed for assessing the adaptive capacity highlighted the distinctly different levels of adaptive capacity of the two schemes. Overall, Phata's adaptive capacity was more comprehensive across all dimensions, and this resulted in production yields of sugarcane being maintained, even when exposed to extreme events. Kasinthula, on the other hand, had severe lack of adaptive capacity, which was shown in reductions in yields, notably so after the 2015 flood and 2016 drought. The comparison of the evidence of how different levels of adaptive capacity affect impacts in the face of exposure to the same extreme events provides important insights useful to other, similar, kinds of organizations such as other outgrower schemes, contract farming arrangements and agricultural cooperatives. Lessons can be drawn simultaneously from the scheme with lower levels of adaptive capacity, and from the scheme that has been more successful in maintaining yields despite being exposed to climate extremes.

As highlighted also by Cohen et al. (2016), the notably higher adaptive capacity of Phata confirms the importance of fulfilling several of the dimensions of adaptive capacity, but also that the various aspects of adaptive are interrelated over time. As seen with Kasinthula, when exposed to an extreme event, aspects of adaptive capacity, the Asset base in particular, were depleted after being drawn upon. This meant that if exposure occurred again with minimum time lag (for example the drought in 2016), the lower adaptive capacity led to a further reduction in yields. This drought did not significantly affect Phata, due to having invested in a generator. Kasinthula not only lacked financial capacity to irrigate but also had low innovative capacity and lacked capacity in Forward-looking decision-making. It can be argued that during high-yielding seasons, prior to the period of declining yields (i.e., when the financial capacity potentially were higher), an investment such as a generator could have been financially feasible. This shows that sufficient skills, and a sufficient level of commitment and flexibility in the leadership is needed for the financial capacity to be translated into, or activate the, adaptive capacity.

Although the primary concern with extreme events is to reduce risk, this study also shows that, depending on the context, extreme events can have positive effects. In the case of Kasinthula,

due to drought, in combination with financial constraints and national shortage of electricity supply, the irrigation of the crops had been insufficient for an extended period of time and the sugarcane stock was close to succumbing toward the end of 2018. The floods that occurred in Chikwawa early 2019 thus provided the water that the fields needed. This has been confirmed to be the case across the agricultural sector in general in large parts of Malawi, Zambia and Zimbabwe, whereby the heavy rainfalls early 2019 provided relief in the dry conditions and helped recover some of the moisture deficits (FAO-GIEWS, 2019). Although not confirmed during the interviews, it is noteworthy that the yields in 2017 increased slightly after two consecutive years of decline. Similar to the 2019 cyclone, this could be attributed to heavy rainfalls in early 2017 that alleviated some of the moisture deficits that were caused by the 2016 drought. Related to the adaptive capacity characteristic knowledge and information, such experiences could be used to increase the scheme's adaptive capacity for future floods. As suggested also by Parsons et al. (2018), social learning from past events enhanced adaptive capacity among tourism operators in Samoa. Better availability of climate information (weather forecasts and early warnings) would not only warn and prepare farmers to reduce climate risk, but could also be used for innovations to be put in place to take advantage of the opportunity that arises with a flood to store floodwater. Elements of adaptive capacity, such as knowledge about these kinds of adaptation options, flexibility in decision making and of course financial assets, would however also have to be present.

The Institutional Adaptive Capacity Framework—Contributions and Limitations

This study has developed and explored an innovative approach to assessing adaptive capacity of institutions, and contributes toward advancements of such assessments primarily in three ways. Firstly, through developing a framework at the management level of an organization or institution not typically explored, namely at the management level of a large-scale agricultural entity involving multiple beneficiaries or shareholders, producing cash crops in a poverty and development context. Such scale of assessment has provided detailed information about multiple aspects of the management and governance of the scheme in the context of extreme events, largely enriched by the lived experiences of the respondents. The relatively small organizations with few staff in management positions however led to a small available group of respondents. Although some level of triangulation of information was provided through the interview with the manager at Illovo, future studies building on this approach could benefit from expanding the scope of responses to also include board members, additional staff members and representatives of institutions or organizations within the direct networks of the schemes.

Secondly, taking a historical approach has enabled obtaining answers to what builds up or erodes adaptive capacity, which in forward-looking adaptive capacity assessment are only potential (Engle, 2011). Assessing the occurrence of extreme events over the last decade and what the effects have been on the sugarcane production—in combination with the lived experiences by the scheme managers, was useful in understanding how high adaptive capacity has better mediated the impacts that result from exposure to extreme events for the one scheme relative to the other with lower adaptive capacity. This study does not only highlight what is necessary for adaptive capacity, but provides nuances of individual choices and actions in both building adaptive capacity and activating it for maximum effect. Building on the framework we have developed in this study we propose future potential studies to further advancing the approach by assessing adaptive capacity using a set of given historical time slices (snapshots in history). This would enable exploring exactly how the adaptive capacity has risen and fallen in response to different drivers, including assessing efforts to increase adaptive capacity and how it was eroded after use following exposure to extreme events.

Thirdly, using productivity of sugarcane as an indicator of the success of adaptive capacity in enabling adaptation was a useful measure, particularly when relating the changes in yield to the lived experiences, occurrence of extreme events and the assessed characteristics and sub-characteristics of adaptive capacity. We do however acknowledge that if looking at other aspects of success, the outcomes of the analysis could have been more nuanced. Even though the sugarcane productivity of Phata was not affected, the effects of extreme events were reported to have been severe and detrimental in the district and caused losses for the people living in the district. Focusing on only sugarcane productivity as an indicator for success, thus disregards the effects these events have had of the scheme members, their households and villages, food crop fields and lives. Such effects inevitably cause decline in the schemes' adaptive capacity within the characteristics human asset, equity and fairness, and knowledge and information. Neither of the schemes provide climate information such as weather forecasts or early warnings to their members. Providing this kind of information—along with knowledge on how to use the information and act to improve adaptation—would have the potential to further build up adaptive capacity within the wider social network of the scheme and strengthen the human capacity (Vaughan et al., 2019). Assessing individual/household level adaptive capacity would thus require a framework with similar theoretical determinants but different, more scale-appropriate indicators.

CONCLUSION

This study aimed to assess the adaptive capacity on sugarcane outgrower schemes in the Chikwawa district in southern Malawi using in-depth interviews with scheme managers to gain a deeper understanding of how the organizations meet the multiple dimensions of adaptive capacity. The extent of the adaptive capacity of the two schemes was described in terms of how it enabled adaptation, shown as sugarcane yield over the last decade, and viewed in the light of exposure to extreme events. This approach provided an opportunity to ground-truth the assessment of adaptive capacity by highlighting the

role of different components and its overall effectiveness in enabling adaptation.

As well as providing indications to what kind of interventions are required to restore the deficient capacities and ensure future adaptation of sugarcane outgrowers, the development of this very specific framework for assessing adaptive capacity of this scale and type of organization is relevant also to other contract farming arrangements or similar kinds of agricultural systems in the developing world that similarly face increasing climate challenges.

This approach also contributes to the literature on adaptive capacity by reiterating the dynamism of adaptive capacity at any one time. Whilst the literature is increasingly recognizing that there are a variety of factors that determine the extent to which latent adaptive capacity is drawn upon, the application of the framework historically, as in this study, illuminates how adaptive capacity at any one time is shaped by what has happened in the past—including the extent to which it has been drawn upon in exposure to events. This temporal perspective on the evolution of adaptive capacity is particularly relevant in the context of climate change, which will likely see a decreased return period between extreme events. As a result, smallholder farming schemes—and other entities at different scales—will have less time to recover and replenish the adaptive capacity that they draw upon when exposed to one event before the next one arrives—leading to compound effects. Use of the framework outlined in this paper provides insights into the status of different components which, in turn, can highlight priorities for rebuilding adaptive capacity to reduce the risk of future exposure.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because of confidentiality. Requests to access the datasets should be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Humanities and Social Sciences Research Ethics Committee, University of KwaZulu-Natal. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RH and KV contributed to the conception and design of the study and developed the theoretical framework. RH planned and performed field work and performed analysis and wrote the first draft of the manuscript. KN contributed to the literature review and wrote parts of the results section. KV contributed to manuscript revision. All authors contributed to final revision, read, and approved the submitted version.

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REFERENCES

Adams, T., Gerber, J. D., and Amacker, M. (2019). Constraints and opportunities in gender relations: Sugarcane outgrower schemes in Malawi. *World Dev*. 122, 282–294. doi: 10.1016/j.worlddev.2019.05.029

Adger, W. N. (2003). Social capital, collective action and adaptation to climate change. *Econ. Geogr*. 79, 387–404. doi: 10.1111/j.1944-8287.2003.tb00220.x

Armitage, D. (2005). Adaptive capacity and community-based natural resource management. *Environ. Manage*. 35, 703–715. doi: 10.1007/s00267-004-0076-z

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

Canevari-Luzardo, L. M., Berkhout, F., and Pelling, M. (2020). A relational view of climate adaptation in the private sector: how do value chain interactions shape business perceptions of climate risk and adaptive behaviours? *Bus. Strategy Environ.* 29, 432–444. doi: 10.1002/bse.2375

Chinsinga, B. (2017). The green belt initiative, politics and sugar production in Malawi. *J. S. Afr. Stud.* 43, 501–515. doi: 10.1080/03057070.2016.1211401

Cohen, P. J., Lawless, S., Dyer, M., Morgan, M., Saeni, E., Teioli, H., et al. (2016). Understanding adaptive capacity and capacity to innovate in social–ecological systems: applying a gender lens. *Ambio* 45(Suppl. 3), S309–S321. doi: 10.1007/s13280-016-0831-4

Coulibaly, J. Y., Mbow, C., Sileshi, G. W., Beedy, T., Kundhlande, G., and Musau, J. (2015). Mapping vulnerability to climate change in Malawi: spatial and social differentiation in the Shire River Basin. *Am. J. Clim. Change* 4, 282–294. doi: 10.4236/ajcc.2015.43023

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., and Sheikh, A. (2011). The case study approach. *BMC Med. Res. Methodol.* 11:100. doi: 10.1186/1471-2288-11-100

Dubb, A., Scoones, I., and Woodhouse, P. (2017). The political economy of sugar in southern Africa – introduction. *J. S. Afr. Stud.* 43, 447–470. doi: 10.1080/03057070.2016.1214020

Duncan, J. M. A., Dash, J. L., and Tompkins, E. L. (2017). Observing adaptive capacity in Indian rice production systems. *AIMS Agric. Food* 2, 165–182. doi: 10.3934/agrfood.2017.2.165

Engle, L. N. (2011). Adaptive capacity and its assessment. *Glob. Environ. Change* 21, 647–656. doi: 10.1016/j.gloenvcha.2011.01.019

FAO-GIEWS (2019). *Southern Africa: Dry Weather Conditions Reduce Agricultural Production Prospects in 2019*. GIEWS Update.

Government of Malawi (2015a). *Irrigation Master Plan*. Department of Irrigation, Republic of Malawi.

Government of Malawi (2015b). *Malawi 2015 Floods Post Disaster Needs Assessment Report* (PDNA).

Government of Malawi (2016). *Malawi Drought 2015-2016 Post Disaster Needs Assessment* (PDNA).

Government of Malawi (2017). *2016/2017 Food Insecurity Response Plan* (FIRP).

Government of Malawi (2019). *Malawi 2019 Floods Post Disaster Needs Assessment* (PDNA).

Gupta, J., Termeer, C., Klostermann, J., Meijerink, S., van den Brink, M., Jong, P., et al. (2010). The adaptive capacity wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. *Environ. Sci. Policy* 13, 459–471. doi: 10.1016/j.envsci.2010.05.006

Hendriks, T., and Boersma, F. (2019). Bringing the state back in to humanitarian crises response: disaster governance and challenging collaborations in the 2015 Malawi flood response. *Int. J. Disaster Risk Red.* 40, 1–7. doi: 10.1016/j.ijdrr.2019.101262

Herrman, R., and Grote, U. (2015). Large-scale agro-industrial investments and rural poverty: evidence from sugarcane in Malawi. *J. Afr. Econ*. 25, 645–676. doi: 10.1093/jae/ejv015

Hertwig, R., Barron, G., Weber, E. U., and Erev, I. (2004). Decisions from experience and the effect of rare events in risky choice. *Psychol. Sci.* 15, 534–539. doi: 10.1111/j.0956-7976.2004.00715.x

International Federation of Red Cross and Red Crescent Societies [IFRC] (2019). *Emergency Plan of Action (EPoA), Malawi Floods.* Available online at: https://reliefweb.int/sites/reliefweb.int/files/resources/MDRMW014do.pdf (accessed December 6, 2020).

IPCC (2007). "Climate change 2007: impacts, adaptation, and vulnerability," in *Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, and K. S. White (Cambridge: Cambridge University Press), 869.

Jain, M., Naeem, S., Orlove, B., Modi, V., and DeFries, R. (2015). Understanding the causes and consequences of differential decision-making in adaptation research: adapting to a delayed monsoon onset in Gujarat, India. *Glob. Environ. Change* 3, 98–109. doi: 10.1016/j.gloenvcha.2014.12.008

Jones, L., Ludi, E., Jeans, H., and Barihaihi, M. (2017). Revisiting the local adaptive capacity framework: learning from the implementation of a research and programming framework in Africa. *Clim. Dev.* 11, 3–13. doi: 10.1080/17565529.2017.1374237

Matewos, T. (2020). The state of local adaptive capacity to climate change in drought-prone districts of rural Sidama, Southern Ethiopia. *Clim. Risk Manage.* 27:100209. doi: 10.1016/j.crm.2019.100209

Mazvimavi, K., Murendo, K., and Chivenge, P. (2017). *The impacts of the El Niño-induced drought on seed security in Southern Africa: implications for humanitarian response and food security*. Technical Report, ICRISAT.

Mortreux, C., and Barnett, J. (2017). Adaptive capacity: exploring the research frontier. *Wiley Interdiscip. Rev. Clim. Change* 8:e467. doi: 10.1002/wcc.467

Mortreux, C., O'Neill, S., and Barnett, J. (2020). Between adaptive capacity and action: new insights into climate change adaptation at the household scale. *Environ. Res. Lett.* 15:074035. doi: 10.1088/1748-9326/ab7834

Mwale, F., Adeloye, A., and Beevers, L. (2015). Quantifying vulnerability of rural communities to flooding in SSA: a contemporary disaster management perspective applied to the Lower Shire Valley, Malawi. *Int. J. Disaster Risk Red.* 12, 172–187. doi: 10.1016/j.ijdrr.2015.01.003

Neuendorf, K. A. (2019). "Content analysis and thematic analysis," in *Advanced Research Methods for Applied Psychology*, ed P. Brough (London: Routledge; CRC Press), 211–223. doi: 10.4324/9781315517971-21

Olsson, P., Folke, C., and Berkes, F. (2004). Adaptive comanagement for building resilience in social–ecological systems. *Environ. Manage.* 34, 75–90. doi: 10.1007/s00267-003-0101-7

Ospina, A., and Heeks, R. (2010). *Linking ICTs and climate change adaptation: a conceptual framework for e-resilience and e-adaptation*. Report, University of Manchester, Manchester, United Kingdom.

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Glob. Environ. Change* 19, 354–365. doi: 10.1016/j.gloenvcha.2009.06.001

Parsons, M., Brown, C., Nalau, J., and Fisher, K. (2018). Assessing adaptive capacity and adaptation: insights from Samoan tourism operators. *Clim. Dev.* 10, 644–663. doi: 10.1080/17565529.2017.1410082

Pelling, M., and High, C. (2005). Understanding adaptation: what can social capital offer assessments of adaptive capacity? *Glob. Environ. Change* 15, 308–319. doi: 10.1016/j.gloenvcha.2005.02.001

Reliefweb (2020). *Southern Africa: Floods - Jan 2015*. Available online at: https://reliefweb.int/disaster/fl-2015-000006-mwi (accessed January 19, 2020).

Thonicke, K., Bahn, M., Lavorel, S., Bardgett, R. D., Erb, K., Giamberini, M., et al. (2020). Advancing the understanding of adaptive capacity of social-ecological systems to absorb climate extremes. *Earth's Future* 8:e2019EF001221. doi: 10.1029/2019EF001221

USAID (2019). *Climate Risks in Food for Peace Geographies*: *Malawi*. Climate Risk Profile.

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

Vermeulen, S. J., Challinor, A. J., Thornton, P. K., Campbell, B. M., Eriyagama, N., Vervoort, J. M., et al. (2013). Addressing uncertainty in adaptation planning for agriculture. *Proc. Natl. Acad. Sci. U.S.A.* 110, 8357–8362. doi: 10.1073/pnas.1219441110

Vincent, K. (2007). Uncertainty in adaptive capacity and the importance of scale. *Glob. Environ. Change* 17, 12–24. doi: 10.1016/j.gloenvcha.2006.11.009

World Bank (2016). *Striving Toward Disaster Resilient Development in Sub-Saharan Africa: Strategic Framework 2016–2020*. Washington DC: World Bank.

World Bank (2019). *Disaster Risk Profile, Malawi*. Washington DC: World Bank.

World Meteorological Organization (WMO) (2014). *Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2012).*

Zhao, D., and Li, Y.-R. (2015). Climate change and sugarcane production: potential impact and mitigation strategies. *Int. J. Agron.* 2015:547386. doi: 10.1155/2015/547386

Zuzani, P., Ngongondo, C., Mwale, F., and Willems, P. (2019). Examining trends of hydro-meteorological extremes in the Shire River Basin in Malawi. *Phys. Chem. Earth* 112, 91–102. doi: 10.1016/j.pce.2019.02.007

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