Agricultural resilience and adaptive capacity during severe drought in the Western Cape, South Africa

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Abstract

Meeting the needs of multiple users and uses of freshwater resources is becoming progressively challenging. The response to the 2015–2018 Western Cape drought in South Africa offers lessons for both commercial crop growers and policymakers to enhance resilience. The drought highlights the complex interactions between water supply for urban and agricultural uses. This study employed a mixed-methods approach by combining the five capitals (natural, physical, financial, human, and social) of the sustainable livelihoods framework with semi-structured interviews to assess the impacts of the hydrologic and socio-economic drought on irrigated apple production. Data used for the study included production statistics, dam and water flow, weather data, and interviews. Results highlight a progressive weakening of the natural and physical capital between 2015 and 2018. Human capital in the form of expert consultants together with social capital of networks proved key to mitigating the impact of drought on apple production. The study also found that growers' adaptive capacity was high as they made use of multiple capitals available to them. This resulted in lower than anticipated impacts on production and in turn stabilized financial capital available to farmers. Lessons from the drought show that building human and social capital can significantly improve the resilience of commercial farms which form part of complex water systems. Urban water-related vulnerabilities and demand are closely interlinked with the vulnerability and adaptive capacity of irrigated agriculture. Thus, policies which facilitate the in-tandem adaptation of these sectors are likely to be most successful in building resilience.

Keywords: Vulnerability; Climate change; Adaptation; Water supply

Introduction

The Anthropocene poses substantial environmental and societal challenges (Crutzen and Stoermer 2000; Folke et al. 2021). Addressing these challenges calls for a deepened understanding of the dynamic relationship between ecosystem services and human societies (Folke et al. 2016). It can be argued that these interactions are most salient in the availability of adequate and clean water resources. Failure in any part of the socio-ecological water system may lead to water insecurity. This can have considerable consequences and could lead to disaster if the ability of the affected community to cope is exceeded (UNISDR, 2009). Meeting the needs of multiple water resource users and uses is becoming increasingly challenging (Mukhamedova and Wegerich 2017). For example, it is estimated that one-third of surface water-dependent cities is already vulnerable to water shortages due to competition with agricultural water users (Garrick et al. 2019). Furthermore, urban water demand is projected to increase by up to 80% by 2050, especially in the Global South (Flörke et al. 2018). This, along with the risks associated with climate change and population growth, will have significant implications for resilience for both urban and agricultural resources (Midgley et al. 2005).

Resilience is defined as "the capacity of systems to cope with hazardous events, trends, or disturbances, in ways that preserve their essential function, identity, and structure, but also maintain the capacity for adaptation, learning, and transformation" (IPCC 2014 p1772). Recent resilience research emphasizes that trade-offs need to be acknowledged (Meerow et al. 2016). This is based on the idea that one person's or group's resilience may lead to another's vulnerability (Alexander 2013). In this regard, Harris et al. (2018) introduce the concept of negotiated resilience, centered on the need to work towards decision-making frameworks that incorporate multi-stakeholder discussions and negotiations. Thus, as part of negotiated resilience, trade-offs and losses can be recognized and negotiated. These negotiations should further be based on clear rationales or priorities, of what is reasonable, equitable or fair, and acknowledge that some perspectives or goals will be prioritized (Harris et al. 2018).

Between 2015 and 2018, the Western Cape (South Africa) experienced a severe hydrologic and socio-economic drought (hereafter referred to as the drought). The multi-year drought negatively affected both agricultural and urban areas (Archer et al. 2019). By the summer of 2018, the impacts of the drought reached their peak, and "Day Zero," the day that the City of Cape Town's taps would run dry, appeared a significant likelihood in the short term (Ziervogel 2019). As a result, Cape Town was projected to become the first global metropole to run out of water (Maxmen 2018). Studies by Otto et al. (2018) and Pascale et al. (2020) indicated that the drought was made more likely to occur due to anthropogenic climate change and that this trend is expected to continue. Most importantly, Cape Town is not unique in this regard, and recently, California, China, India, and many parts of Europe have experienced drought conditions in, and many continue to do so (King 2022).

Assessing the vulnerability and resilience of communities is considered the first step of drought risk management programs (Javadinejad et al. 2020; Nasrnia and Ashktorab 2021). This study aimed to understand the impacts of the drought on irrigated growers in the Western Cape and assess their resilience. This was achieved by making use of the five capitals of the sustainable livelihoods framework (SLF) and focusing on the case study of apple growers in the Western Cape. The sustainable livelihoods framework was developed by the British Department for International Development (DFID) (Scoones 1998). The SLF and five capitals (natural, physical, economic, human, and social) can provide a holistic lens to assess drought impacts. In the framework, stakeholders operate within the context of vulnerability, where they have access to certain capitals (Scoones 1998). The capitals gain weight and value through the prevailing social, institutional, and organizational environment (Serrat 2017). Apple growers were chosen as apples are an economically important crop for the province. Apples are also grown in three distinct regions in the Western Cape which provides a nuanced view of the various strategies and resources available to growers. Studies which capture local level adaptation and lessons in resilience provide important case studies for future climate response.

Case study area: current situation and future climate change impacts

The Western Cape is the largest producer of pome fruit in South Africa and contributes more than 50% to the national pome fruit harvests (Hortgro 2020). Apples are grown on commercial farms in three main regions of the south-Western Cape, namely Ceres, Groenland, and Vyeboom-Villiersdorp (Fig. 1). Total annual rainfall for the area is approximately 600–900 mm, mostly accumulated over the winter June–August (ARC 2020). A more detailed breakdown of the climate of each region is provided in online resource 1.

Due to the highly seasonal rainfall, water for irrigation is captured during winter and stored for use in summer (Western Cape Government 2018a). The apple regions make use of different resource systems for irrigation. Growers in Ceres use private farm dams, groundwater, run-of-river, and the Koekedouw Dam. The dam supplies farms in the region for irrigation and, to a lesser degree, the town of Ceres for domestic and processing uses (Witzenberg Municipality 2019). Groenland uses the Eikenhof Dam near Grabouw, as well as private farm dams and run-of-river. Vyeboom-Villiersdorp draws water from the Theewaterskloof dam, private farm dams, and boreholes. Here, run-of-river refers to irrigation water which is directly diverted from the river into an irrigation canal without attempting to store the water.

Irrigated agriculture shares dams and catchments with towns and cities in the province, notably Cape Town. With 3.7 million residents, Cape Town is the second largest city in South Africa and largest city in the province (StatsSA 2019). Water is supplied through the Western Cape Water Supply Scheme (WCWSS) with a reliable annual yield of 556 Mm^3 (Ahjum et al. 2015). The WCWSS draws water from two large river catchments, managed as the Breede and the Berg Water Management Areas. These catchments feed the "Big Six" dams: Voëlvlei, Theewaterskloof, Berg River, Wemmershoek, and the Upper and Lower Steenbras Dams (Fig. 1). On average, agricultural allocations receive ~ 35% of available water, while the remainder (~ 65%) is allocated for urban and industrial uses (Rawlins, 2019). The supply of the WCWSS was modeled at a 98% and 95% level of assurance for urban and agricultural users respectively (Le Maitre et al. 2020). The different levels of assurances mean that restrictions are

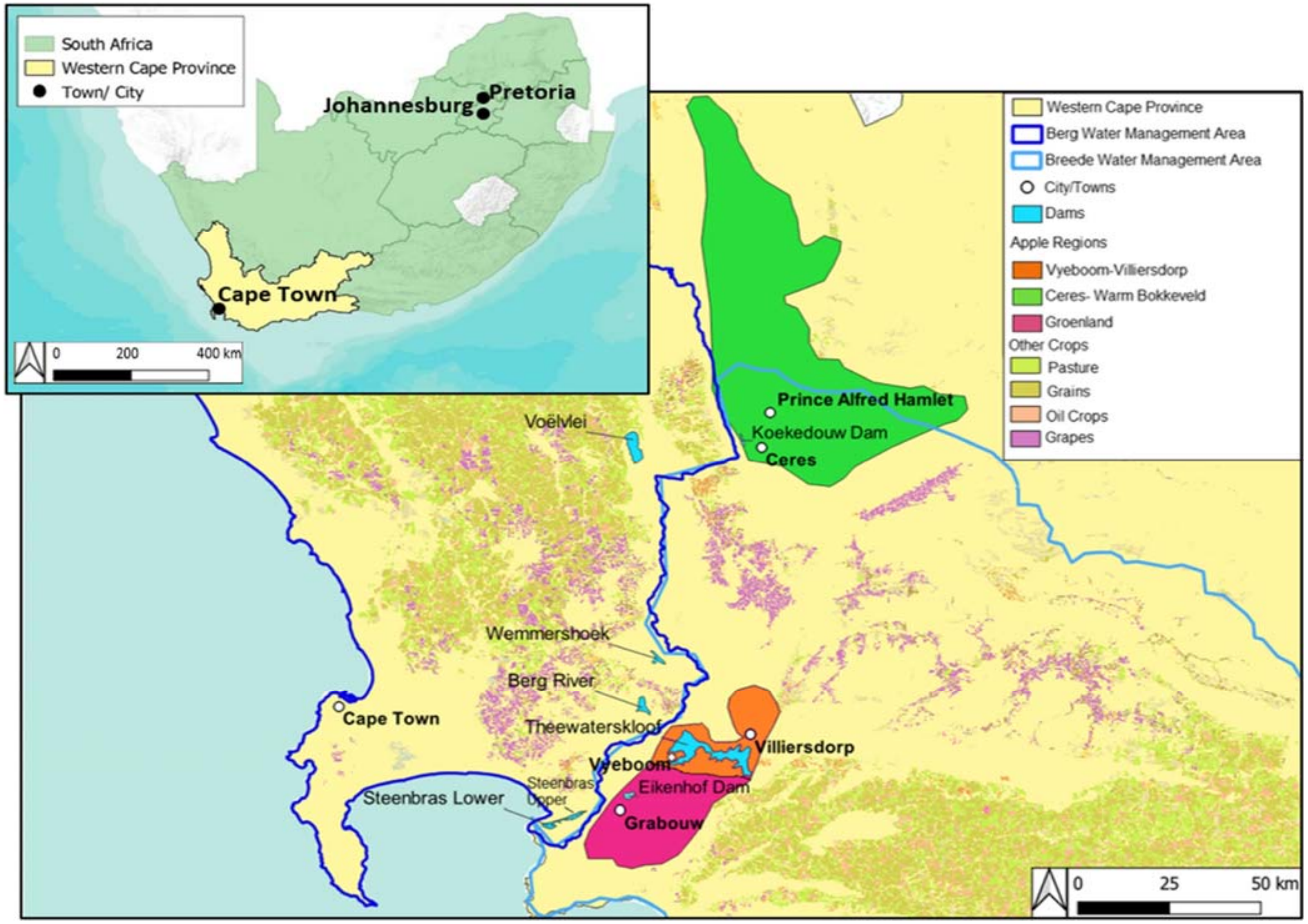

Fig. 1. A map of the Western Cape (yellow) showing the three apple-producing regions: Ceres (green), Groenland (pink), and Vyeboom-Villiersdorp (orange) (Midgley et al. 2021), along with other main crops in the region (Western Cape Department of Agriculture, 2018b), the "Big Six" dams, the Eikenhof and Koekedouw Dams (Western Cape Government, 2018b), as well as the boundaries of the Berg Water Management Area and the Breede Water Management Area (Western Cape Government, 2018b). Insert: Map showing the Western Cape Province (yellow) within South Africa

implemented differentially between users (Ziervogel 2019). Both long-term water allocations as well as short-term restrictions are guided by The National Water Act (1998) (NWA) and the Water Services Act (1997). These Acts aim to balance social benefit, economic efficiency, and environmental sustainability. Basic human needs receive the highest priority for water use and environmental needs follow. Beyond this, water should be allocated to ensure the greatest overall social and economic (Basson 2011). It is important to note that in 2009, it was recommended to the Western Cape Government that a boost in water supply would be needed by 2015 (Muller 2018). However, due to a shift in governance and pressure from environmental groups, the focus of water governance shifted to managing demand rather than increasing supply (Muller 2018).

Furthermore, the Western Cape is vulnerable to the impacts of climate change (Western Cape Government 2018a). Climate change projections show some degree of reduced rainfall and increased temperature in the range of 1.5 to 3 °C for the mid-century (2040–2060) (Western Cape Government 2018a). The projected reduction in rainfall will lead to lower runoff, stream flows, and lower storage in irrigation dams at the end of the rainy season. This would lead to more frequent water restrictions (as seen during the 2015–2018 drought), putting apple orchards under stress and reducing yields and fruit quality (Midgley et al. 2021). Thus, irrigation water demand to maintain current production levels is expected to increase by approximately 10% by 2050 (Schulze et al. 2011).

Methodology

We employed a mixed-method approach to understand drought resilience and adaptive capacity for the case study region. We applied the five capitals approach of the SLF within a complex adaptive systems perspective (online resource 2). We contend that SLF can be used as a measure of adaptive capacity (here we use the definition by Brooks et al. (2005), where the adaptive capacity inherent in a system represents the set of resources available for adaptation, as well as the ability or capacity of that system to use these resources effectively in the pursuit of adaptation), as it can provide insight into how systems or communities draw on their available capitals (or capacities) during shocks. Our methodology made use of interviews, and analysis of production and environmental variables (explained in detail in the following sections).

It is noted that due to the perennial nature of apple crops, it is difficult to isolate the impacts of drought as climate impacts of previous seasons may only affect production in subsequent seasons (Fernandez et al. 2020). It is also acknowledged that factoring in the costs of changing irrigation infrastructure and the longer term costs of damages to trees incurred through reduced irrigation and the removal of orchards, the full impact of the drought may not be captured entirely through the indicators studied.

Sustainable livelihoods framework (SLF)

Table 1 defines the five capitals according to Yazdanpanah et al. (2013) and presents the chosen indicators and data used for the assessment of each capital.

Table 1. The five capitals of the sustainable livelihoods framework (SLF), their definitions, and corresponding indicators and data used for the case study

Capital	Definition	Indicators	Data utilized
Natural	Natural capital refers to the renewable and non-renewable resources made available by the bio-physical system which can be used for production, such as water and soil.	Rainfall Streamflow deficit index (SDI)	1988–2018 rainfall data for stations at Ceres, Villiersdorp, Vyeboom, and Elgin (Groenland) (Agricultural Research Council, 2020) 1988–2018 streamflow data (Department of Water and Sanitation, 2019). SDI was calculated using DrinC Software (Nalbantis and Tsakiris, 2009)
Physical	Physical capital refers to the built environment or infrastructure. Physical capital can also be expanded to include technological innovations or measures that improve physical capital's efficiency.	Total on-farm dam storage capacity Irrigation allocations from Eikenhof, Koekedouw, and Theewaterskloof Dams Dam levels in the Western Cape Water Supply Scheme Borehole distribution	List of Registered Dams (DWS, 2018) Cape Town Dam report (City of Cape Town, 2018) Borehole distribution (Department of Water and Sanitation, 2021)
Financial	Financial capital refers to the funds and monetary resources available to individuals, communities, or sectors.	Class 1 pack out (apple quality approved for export) Distribution to markets and the total value of production	Class 1 pack out (approved for export) data (Hortgro, 2020) Distribution to markets and total value of production (Department of Agriculture Forestry and Fisheries, 2018)
Human	Human capital is the knowledge, skills, capabilities, and well-being (health, age) of individuals in a community.	Use of experts in the agri-science field, such as soil, pests, or irrigation (among others) consultants, knowledge.	Information was obtained from expert interviews and published literature (cited where applicable).
Social	Social capital is defined as the networks or features of social organization, such as norms, values, and trust which facilitate cooperation.	Social connections at the farm level, i.e., the level of connectedness individual growers have with other sectors or communities.	Information was obtained from expert interviews and published literature (cited where applicable).

These indicators were chosen due to their availability and are based on similar indicators which were used by Swanepoel and Raaijmakers (2019) in their study on wheat farmers in the Western Cape. As multiple datasets from various sources were used for the analysis, there were some incongruencies with resolution, which we address individually throughout the text where necessary. Next, we provide some details of each capital and data used to access it. Due to the mixed method approach employed, we distinguish them according to the approach used for the related capitals.

Natural, physical, and financial capitals

For natural capital, the long-term average (LTA) for the 30-year period 1988–2018 as well as rainfall totals for each drought year between 2015 and 2018 was calculated. Since apples are irrigated, production is vulnerable to hydrological drought, which may not be evident when considering rainfall alone (meteorological drought). The streamflow drought index (SDI) was used to understand hydrological drought conditions. DrinC software developed by Nalbantis and Tsakiris (2009) was used to calculate 6-month SDI. DrinC uses a water balance equation (the Hargreaves equation was selected) along with streamflow data, rainfall, and temperature data to calculate SDI. The results are given as an index value running from − 4 (extreme drought) to 4 (extremely wet) (Nalbantis and Tsakiris 2009). Streamflow for Ceres was measured by DWS flow meters at Golfbaan, Witbrug, and the Koekedouw Dam. For Groenland, streamflow data was obtained at Elfo and Groenland. Flow data for Vyeboom-Villiersdorp was obtained for the Vyeboom Irrigation pipeline from the Theewaterskloof Dam. It should be noted that data was missing for this pipeline between 2007 and 2009 and 2015–2016; this was due to operational and maintenance obligations (DWS, *personal communication*).

For physical capital, a list of registered on-farm dams were obtained from the DWS. They were grouped according to the closest town (indicated in brackets), as designated by the DWS, for each region, Groenland (Grabouw), Vyeboom-Villiersdorp (Villiersdorp), and Ceres (Ceres and Prince Alfred Hamlet). Irrigation allocations from the literature were used (GWUA n.d.) along with borehole distribution data supplied by the Department of Water and Sanitation. It should be noted that many boreholes were sunk during the drought (J. Kriel, Agricultural Research Council, *personal communication*), many of which were unregistered.

Concerning financial capital, we note that there are only national data for the total value of apple production and distribution to markets and the performance of individual areas cannot be extracted. This was addressed by using supplemental data from the annual reports from South Africa's official Perishable Products Export Control Board (PPECB) published between 2012 and 2019 (PPECB 2012–2019) and reports from the Bureau for Food and Agricultural Policy (BFAP) published between 2015 and 2019 (BFAP 2015–2019). The Western Cape contributes 80% to apple production in South Africa, and the areas surveyed in this study account for a large portion of the Western Cape's contribution (Sikuka 2018). Therefore, it can be assumed that the case study areas are a strong driver of the trends observed in the aggregated financial indicators.

Human and social capitals

For the assessment of human and social capitals, qualitative rather than quantitative approaches can be seen to be more appropriate (the latter are usually only able to assess capitals rather than flows and dynamics). Semi-structured, in-depth interviews (n = 10) were conducted with key stakeholders in the apple and water sectors in the study region from February 2020 to October 2020. Approval from the Stellenbosch University Ethics Committee (REC-2020-8267) was granted before the interviews were conducted. Participants were informed about the process and data protection and signed consent forms before participating. The interview questions covered topics of drought response, impacts, and risks as well as access to information and expertise. Stakeholders included growers, provincial government officials, members of water user associations, technical experts/consultants, and industry leaders. The interviewees were selected due to their experience and knowledge in the field. The interviews took place on the farms and some were conducted online via videocall (due to COVID-19 restrictions). Interviews lasted from 30 to 90 min. All interviews were voice-recorded and transcribed verbatim.

Results

Natural and physical capitals

Rainfall (*natural capital*) for the three production regions shows large spatial and temporal variation (online resource 3). Vyeboom-Villiersdorp experienced the most persistent low rainfall totals, with all four years (2015–2018) recording lower rainfall than the LTA. Ceres experienced lower than average rainfall from 2016 to 2017, with 2017 recording less than 50% of the LTA. Groenland experienced variable rainfall over the drought, with 2016 and 2018 recording more rainfall than the LTA and 2015 and 2017 recording lower than average rainfall.

From an apple farmer perspective, natural capital is complemented by physical capital, such as irrigation from boreholes, dams, and runoff from rivers. Due to the low rainfall, the water managed by the WCWSS experienced severe decreases in water levels which dropped to 20% by early 2018 (Fig. 2). The Koekedouw Dam supplying Ceres also dropped to 20% by February 2018 (Witzenberg Municipality 2019). It can be assumed that on-farm dams showed similar decreases in storage as the WCWSS dams because these dams are dependent on rainfall from the same catchments. Our measurement of hydrological drought conditions showed that in the 30-year study period, the 6-month streamflow drought index was lowest during the 2015–2018 drought for three of the six flow meters analyzed (see online resource 4). Ceres and Vyeboom-Villiersdorp experienced longer and more severe hydrological drought conditions compared to the Groenland region.

Ceres has the greatest on-farm dam capacity, followed by Groenland (online resource 5). Growers in Ceres also receive approximately 10 million m^3 of irrigation water per annum from the Koekedouw Dam (Ogundeji 2013). Groenland growers receive approximately 33 million m^3 per annum of irrigation water from the Eikenhof Dam (GWUA n.d.). Vyeboom-Villiersdorp has roughly one-third and one-quarter of the on-farm storage capacity of Groenland and Ceres, respectively. However, Vyeboom-Villiersdorp does have access to water from the Theewaterskloof Dam, of which they are allocated approximately 13.2 million m^3 per annum (DWS, 2018). Once the on-farm dam storage is supplemented with irrigation water supplied by the municipal dams, Ceres becomes the region with the lowest access to stored water (Groenland has the highest). In terms of groundwater, Groenland has the highest number of boreholes of the three regions (online resource 6), providing growers with higher resilience under climate change. Vyeboom-Villiersdorp has more access to natural capital than Ceres as they receive more rainfall and have access to more water for irrigation. However, the Vyeboom-Villiersdorp growers rely considerably on water allocations from the

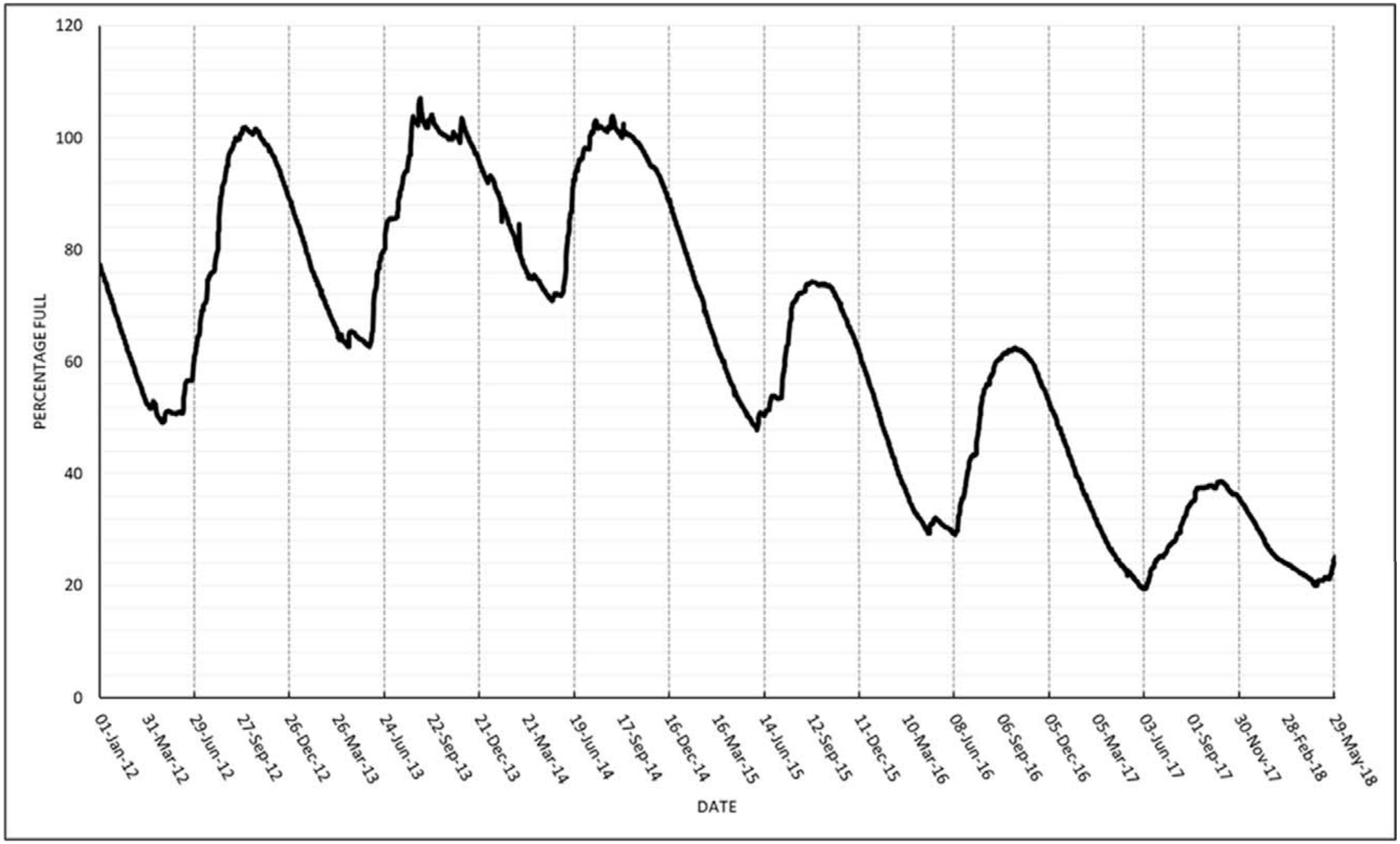

Fig. 2. Percentage of storage capacity available in the "Big Six" dams of the Western Cape Water Supply Scheme, from 2012 to 2018 (City of Cape Town, 2018)

Theewaterskloof Dam and are thus vulnerable to water restrictions and competition with urban water users.

Water supply for irrigation from dams jointly used by agriculture and urban users can be subject to restrictions during times of drought. In 2016, restrictions were imposed on both urban and agricultural users. However, agricultural water restrictions were put in place later than urban restrictions in the first half of the drought period. For Cape Town urban water demand, water restrictions increased progressively from 20% in January 2016, to 30% (November 2016), 40% (June 2017), and 50% by February 2018. In May 2016, a 20% restriction on agricultural withdrawals was placed, increasing to 30%, 50%, and 60% in March, October, and December 2017 respectively (Ziervogel 2019). Water allocations for agriculture in some regions, including from the Theewaterskloof Dam, were completely cut in February 2018 (Ziervogel 2019).

Financial capital

For financial capital, the impact on production in terms of physical quantity (tons) produced was not as significant as was previously expected (online resource 7). The Vyeboom-Villiersdorp region showed steady volumes of export-quality apples throughout the drought years. For Ceres, production of exportable apples increased from 2015 to 2017 but slightly decline in 2018. Only the Groenland region experienced a sharp decline in 2018, likely due to the compounded impacts of multiple preceding dry years (PPECB 2018). The value of production showed an increase between 2014 and 2016, with a noticeable decrease in 2017 and recovery to 2016 levels in 2018. Drought and heatwaves, particularly in the Ceres region, affected fruit quality and export volumes for the 2015–2018 period (PPECB 2015–2019). According to PPECB (2017), there was a decrease in export volumes in 2016/2017 due to lower demand from international markets, heatwaves, and drought. In the 2017/2018 production year, there was a noticeable increase in demand in the international markets compared to the previous year, which may explain the recovery observed in 2018 (PPECB, 2018). The low pack out for Groenland in 2018 is likely due to damage by hail and heat (Fresh Fruit Portal 2018).

However, apple sales distribution data showed a noticeable decrease in 2018 (online resource 7), which is likely due to the compounded impacts of the previous drought years (PPECB 2018). The increase in processing tons over the drought period is an indication of the effects of the drought on fruit quality (aside from 2018). Apples selected for processing are of lower quality than those destined for export and local markets (Midgley 2016). Sunburn damage due to higher temperatures and smaller fruit caused by drought were cited as quality issues between 2015 and 2018 (PPECB 2018). Shifting fruit meant for the export market to the local or processing market due to quality can be highly disruptive because it puts prices under pressure and considerably decreases profitability (Midgley 2016). It should be noted that the noticeable drop in pack out, and to a minor degree production value in 2014, is likely due to severe hail as well as unsatisfactory market access (BFAP 2015, PPECB 2015).

Human and social capitals

On-farm water management was crucial during the drought. Developing farm water budgets emerged as one of the most important tools growers implemented. These budgets were designed by expert consultants and were regularly reviewed as the water allocations changed. Other water-saving techniques implemented on the farm included short-radius irrigation; the use of drip irrigation, water source diversification (i.e., boreholes), the use of nets, summer pruning, applying mulch or soil cover, and reducing fruit on trees (WCDoA 2017). An important strategy taken by growers was to prioritize irrigation to high-value orchards of specific cultivars and younger orchards (PPECB 2018). Other orchard strategies included the replacement of orchards earlier than planned schedules and extending the full bearing age (WCDoA 2017).

> We started with the water budget.., [we asked] where is our biggest income varieties? [because] we want to irrigate them 100%. So these are mainly our export stuff so we tried to keep those varieties and our main export markets filled … and then for the other stuff … we just took off the crop completely and we just kept the trees alive – farmer_001

> One of our main focus points and driving points at this stage is to actually measure on a per orchard base [how much water] we are giving. So doing the irrigation in a more precise way, using every drop. – farmer_002

Another observation made during the interviews was the importance of social capital to growers, such as relationships, networks, and trust. Although this was not always explicitly stated, it was often inferred in the interviews. For example, growers share experiences and advice in WhatsApp groups.

> We have relationships, long, long term relationships that we build over time, and you won't get that everywhere, and it's built through time. – farmer_002

Here, it is important to note that most apple growers can be categorized as co-op growers where they operate under a larger company that decides on production strategies and instructs the growers on which strategies to employ (Fujisawa et al. 2015). These arrangements improve both the human and social capital available to growers through increased access to information and expert knowledge (Maltou and Bahta 2019). It also allows growers to be a part of established connections within the industry and strengthens the collective voice of growers. However, institution led drought strategies are determined by the growers' needs, the established sales networks, and the process of priority setting within the institutions (Fujisawa et al. 2015). This means that the farmer's priorities are considered in tandem with other priorities and thus may not always be aligned to the benefits at the farm level or for individual farms. There is also a risk that growers' willingness to adapt to climate change may be constrained by the co-op.

> The boss [is] that one guy in charge of this big…operation that can lead the strategy of a certain company in a direction. So if the big boss on the top don't understand climate change. It's not going to happen. It doesn't matter how many clever people you have… advising… if he don't believe it, it's not gonna happen. – farmer_003

Another aspect of social capital is governance and the networks and trust relationships between and within government spheres (local, provincial, and national) and stakeholders, civil society, non-governmental, and non-profit organizations. According to Ziervogel (2019), several issues within governance decreased the effectiveness of the drought response, although some of these were improved over time. Issues included poor coordination and relationships between spheres of government, limited engagement between researchers, communities, and government, and poor coordination and collaboration between political representatives, technical water specialists, and strategic managers (Ziervogel 2019).

Preparedness is an essential component of effective drought governance and mitigation. A range of narratives about how prepared the sector was for the drought and ensuing water restrictions emerged from the interviews. Some respondents said that the drought response was reactive, while others said they were prepared and, with water budgets, could maintain profitable production. However, a common fear was uncertainty over further restrictions and the amount of water that other users withdrew from the system.

> You can see…the management of all this water, and the drought was all reactive; there was little proactive. -government official_001

> No, there was the first cut in water quotas, it was really a scramble, and then to take quick decisions; you had market access, you had all this stuff in a crop that still needs to mature. And now suddenly, you need to decide which crops I'm going to let go.- farmer_002

> We have monthly quotas that then when that happened [the drought] we just get our water [quota], and everybody takes their water, cause they were afraid they won't get anything. – farmer_001

> it was really bad when they decided they are not releasing water they are rather allocating it to urban and the livelihoods of humans before agriculture. Those farmers, they had very bad seasons because they don't have anything else to do. We actually just knew by February you [will] have no water, or when you get a chance to pump, you take it. – irrigation consultant_002

In terms of urban-agricultural water trade-offs, it appeared that there was no major conflict during the drought, at least for apple production. The government communicated restrictions to growers, who were then able to budget accordingly. Irrigation from the Theewaterskloof Dam was also restricted but only after many growers had completed their irrigation scheduling. Nevertheless, the potential for competition for water resources between urban and agricultural users was cited as a concern for agriculture under future droughts.

> [They] are already having some issues with the government there who say well you guys you have the dams and everything but sorry for you it's not your water, you have to let the water out of your dam because 100 km from here there is a town who needs the water and you are in the same catchment area, so that's gonna be a issue. Co-operative employee_001

In February 2018, the Groenland Water Users Association (GWUA) released 10 million liters of water from the Eikenhof Dam to Cape Town via the Upper Steenbras Dam. This was an uncompensated donation, and it helped push back "Day Zero" by an estimated 3 weeks (Steenkamp, 2018). It should be noted that, while it was a generous offer by the GWUA, the growers were close to completing their irrigation schedules for the season at the time. Groenland also had normal rainfall in 2016 and 2018 and it was done with the faith that the following season's rainfall would be sufficient (Steenkamp 2018).

Discussion

Managing a complex water system in times of drought

Prolonged droughts such as the 2015–2018 drought pose a serious challenge to balancing the needs of multiple users. The drought challenged policy and decision-makers to implement measures that balanced the needs of both agriculture and urban sectors. The NWA guided these responses, with its core aim of providing water for human consumption (Basson 2011). A primary focus of the drought response from a policy perspective was to lower water demand, in particular urban demand (Ziervogel 2019). However, as the drought progressed, it became clear that water supply was highly limited and thus, water for domestic use needed to be secured. This led to heavy restrictions on agricultural water supply (Ziervogel 2019). Urban demand will always be prioritized over agricultural activities as per legislation (Basson 2011). This trade-off limits the options available to growers to respond to drought. Nonetheless, the results of this study did not show the substantial impacts on production in tons that were expected. These results may capture the success of the drought mitigation measures taken by growers and thus can inform climate change response. Furthermore, the ability of apple growers to draw on various forms of capital to respond to the drought indicates high adaptive capacity, which is a promising feature in view of resilience to climate change.

Water is a systematic resource and is shared across sectors; thus, it is impossible to consider agriculture in isolation. The benefits of water use also need to be considered at the system scale. While it may seem obvious to prioritize urban water especially considering the economic contribution of Cape Town to the Western Cape economy, agriculture is a major employer and stabilizes the rural economy. Instability in the rural economy may have negative implications for the urban sector (Khan 2001). Thus, it is important to protect agricultural industries to enhance overall social benefit as captured in NWA. It is important to note that while there was an effort to protect agricultural activities by first setting restrictions on urban users, by the end of the drought agriculture received the harshest restrictions (Ziervogel 2019). Heavy restrictions are a risk for growers as apple production requires strict irrigation scheduling. Failure to provide sufficient and timely irrigation may cause substantial crop losses and decrease farm profits. This risk is most salient in regions where growers rely considerably on water allocations from dams or catchments which are shared with urban users. In our case study, Vyeboom-Villiersdorp was particularly vulnerable in this regard as growers rely considerably on irrigation water from the Theewaterskloof. In contrast, while Groenland shares an important catchment with the City of Cape Town, the region was less vulnerable to water restrictions as growers relied more on farm and irrigation dams. This is highlighted in the donation of water for irrigation to the city. Ceres was also subjected to water restrictions; however, the region has a high number of on-farm dams which reduces the vulnerability of these growers to competition for water. Ceres is also less vulnerable to urban reallocations as the Koekedouw Dam is shared with a smaller urban population. Having access to farm and irrigation dams provides some autonomy of the physical capital available to growers and contributes to building resilience to drought. Our results show that it is equally important for policy makers to understand how building resilience in the urban sector can lower resilience or adaptation options available growers. Thus, it is important to develop policies which facilitate in-tandem adaptation of urban-agricultural sectors. This is consistent with studies by De Grandpré et al. (2022) and reinforce the call by Harris et al. (2018) for negotiated resilience.

Using the sustainable livelihoods framework to understand resilience

Natural and physical capitals

Climate change projections indicate that natural capital in the form of rainfall is likely to decrease, which will increase the vulnerability of apple production (Midgley et al. 2021). Natural capital is complemented by physical capital. For South Africa, expanding physical capital is limited as 98% of South Africa's freshwater is already considered fully allocated (Hedden and Cilliers, 2014). Many arid and semi regions across the globe face similar challenges with freshwater security (Sherifew et al. 2014; Flörke et al. 2018). Enhancing physical capital at the farm level will need to focus on developing long term resilience building strategies such as adopting water-saving irrigation systems (drip), more efficient irrigation scheduling, and soil water monitoring systems and on-farm weather stations to guide precision irrigation. Yet, changing irrigation infrastructure may not always be practical or urgent in the face of other challenges the farmer may confront (WCDoA 2018a). Additionally, high upfront costs and delayed returns on such financial investments often deter farmers (WCDoA 2018a). Thus, policy should provide incentives to growers to prioritize longer term resilience strategies, such as insurance discounts or rebates on water-saving technologies.

Financial capital

In general, financial capital available to growers was sufficient to alleviate severe impacts and maintain production during the drought. The interviews showed there was a concerted strategic effort to increase the proportion of fruit marketed for export to maximize farm profits. This included a shift from the local market to exports which can be observed in the crop distribution. The effects were likely aided by the value of the rand and inflation (PPECB 2019). Keeping financial capital stable meant that growers had the means to implement other strategies, such as improved irrigation to increase physical capital. The focus to maintain financial capital was likely taken with the hope that the drought would end. Thus, it can be seen as a short-term response (or survival) strategy rather than long-term resilience building. While these techniques lessened the impacts of the drought, there were findings that indicate climate change may constrain such responses in the future. For example, higher temperatures may lower the quality of fruit harvests (Midgley et al. 2021). Thus, more fruit may be directed for processing which provides lower income for growers and may constrain their financial means to respond to future droughts. This may be of particular concern for growers in warmer regions. This strategy may also not be effective during longer droughts where farm profits are constrained for several consecutive years. Furthermore, it is acknowledged that commercial apple growers can influence farm profits because their products are exportable. These framers also have strong capital bases which aid adaptation (Raaijmakers and Swanepoel 2020). Smallholder farmers and farmers who sell exclusively to local markets do not have access to foreign currency. Thus, it cannot adjust their financial capital as easily as export farmers. Policy should be in-place to secure financial assets for growers and provide timeous relief during and after disasters. But policy should also recognize the unequal vulnerabilities of farm commodities and ensure that policies are supportive and equitable.

Social and human capitals

Apple growers in the Western Cape have strong social capital and networks for information. Social networks were integral in helping growers respond to the drought as well as preparing them for ensuing water restrictions. From the interviews, it was suggested that the government communicated well with growers regarding impending water restrictions. This allowed for planning and contributed to trust-building. An important example of social capital building in the Groenland region, which has positive implications for the other agricultural regions, was donation of water from the GWUA to Cape Town. The drought had raised debates about water use, particularly the value of agricultural water use (Wolski 2018), and such a donation helped improve the public's perception of agricultural water users and contributed to goodwill between urban and agricultural interest groups which can facilitate better cooperation during disasters in the future. Here, an argument can be made for future, compensated reallocation of water from irrigation dams to cities which can help increase farm profits in times of drought (Rawlins, 2019). However, the drought showed that constrained water resources led growers to take drastic measures which are likely to affect crops and profits in subsequent seasons. The actual cost of such losses is difficult to capture and any compensation for water will need to account for such damages if it is to benefit the grower.

In the drought case study, there was a difference in the preparedness narratives among respondents. Some respondents viewed preparedness from a long-term perspective, and they felt that the sector was not prepared for the drought. Other respondents viewed preparedness on a shorter timescale, such as annual or seasonal, and felt they were more prepared for the drought. Nonetheless, the uncertainty over further restrictions and the amount of water that other users might withdraw from the system implies a certain lack of trust in other parties. This may have led growers to extract water even if they did not need it. This highlights the importance of building trust so that water is used as effectively as. While the narratives suggest the government had a good short-term response, the options available to them were constrained by poor long-term planning. It is strongly recommended that long-term resilience policies are developed to avoid reactive short-term decisions.

Social capital was also key to the city's drought response which had positive implications for agriculture. Managing demand has been a key aspect of Cape Town's water management strategy for at least the past decade (Muller, 2018) and was instrumental in avoiding Day Zero and climate policies can learn from Cape Town's example of mobilizing social capital to respond to drought. Through media campaigns, tariff increases, and changes to water infrastructure, urban users managed to reduce their demand from an average of 1200 megaliters per day (MLD) in 2015 to just over 500 MLD in 2018 (DWS, 2018).

Social capital plays a crucial role in mobilizing the different forms of other capitals (Megyesi et al. 2011). Strong collaboration and dialogue are essential to enhancing drought response and adaptation, including between growers and government (notably provincial and local government) and industry (Ziervogel 2019). The tight connections between urban and agricultural water highlighted by the drought shows that there is potential for negotiated trade-offs in terms of water use and drought. Social capital can also help improve preparedness through the distribution of useful and timely information.

The SLF and five capitals provide a holistic lens to assess resilience. Other studies have shown that the SLF can be used successfully to understand resilience to drought to develop drought management policies (Nasrnia and Ashktorab, 2021). Raaijmakers and Swanepoel (2020) made use of the SLF to access wheat farmers adoption of adaptation strategies in the Western Cape. Their study found unequal adoption of adaptation strategies was due inequalities in financial, natural, human, and physical capital notably not social capital. The absence of social capital may suggest its importance across scales and sectors (rainfed vs irrigated or commercial vs subsistence, urban vs agriculture). Roque et al. (2020) warn that not all social capital is positive, and while social capital may facilitate access to resources, it cannot overcome challenges posed by macro-political systems.

Lessons in resilience building

De Grandpré et al. (2022) highlight that while the importance of physical and financial capital is recognized, the role and importance of social capital for agricultural adaptation are not well understood. This study contributes to the growing body of literature highlighting the importance of social and human capital in agriculture. Human and social capital are essential to building relevant skills, local knowledge, social cohesion, financial stability, and farmer self-efficacy. Our case study showed that we cannot continue to rely on traditional capitals such as natural and physical to buffer agriculture against climate shocks. In addition, climate change will lead to significant trade-offs between water users. The recent drought showed that these trade-offs may hinder the types of responses and capitals farmers can use to respond to climate shocks. In the Western Cape and other similar regions such as California where agriculture is practiced on the periphery of urban areas, social capital will be integral to establishing networks and dialogue regarding trade-offs which can aid negotiated resilience. This echoes the recommendations of Muyambo et al. (2017) and Bahta (2021). Building social capital in agricultural systems needs to be tailored to individual communities (Roque et al. 2020).

Another lesson from the drought relates to preparedness. Many of the responses taken by growers were short term, reactive responses. It is common that farmers focus on short-term coping or recovery responses for climate shocks rather than longer term resilience building. This is because farmers often view climate as the backdrop against which more pressing risks play out (Theron et al. 2022). This suggests that outside intervention from government is needed to guide long-term resilience building. This includes providing information on resilience and adaptation strategies as well as incentives for adaptations which improve long-term resilience. Here, human capital can be an important tool, providing farmers and extension services with the necessary information and skills to respond quickly to drought to secure production. These results echo the results by Davis et al. (2021) who call for investment into human capital in agriculture.

Furthermore, while many studies have highlighted the importance of social capital in agricultural adaptation, our study suggests that both social and human capital are vital for resilience building but are often overlooked. The results of this study reinforce the importance of understanding how various capitals contribute to resilience and the need to understand from a systems perspective how climate shocks affect communities.

Conclusion

This study used the SLF to understand the impacts of and responses to the 2015–2018 drought and how these responses may inform climate change adaptation for growers and policymakers. The drought showed that growers in the Western Cape have high adaptive capacity. Their adaptive capacity was strengthened by access to resources (capitals) and knowledge of how to apply them. This highlights the importance of securing access to the various forms of capital as well as knowledge on how to use them to build adaptive capacity of vulnerable communities. Our results also show that production regions have unique environmental and socio-economic vulnerabilities even though they may be spatially close together. This highlights the importance of developing policies which acknowledge and address local vulnerabilities in climate change adaptation planning. Water stress caused by climate change and population growth may further lead to water restrictions (as was the case during the 2015–2018 drought) and water reallocations from agriculture to urban users (Flörke et al. 2018; Garrick et al. 2019). It cannot be denied that urban water-related vulnerabilities and needs will affect the vulnerability and adaptive capacity of irrigated agriculture. Thus, policies which facilitate the in-tandem adaptation of these sectors are likely to be most successful. Most notably our results show that within the limited scope to expand on physical and natural capital in arid and semi-arid regions, human and social capital can be a powerful tool for reducing agricultural vulnerability to the multifarious complexities of drought. Future research should focus on the interplay of these dimensions and how they play out during the next crisis.

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Conflict of interest

The authors declare no competing interests.

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