Journal of
Water & Climate Change

Journal of Water and Climate Change Vol 15 No 8, 3431 doi: 10.2166/wcc.2024.385

Building resilience to multiple climate-change-related risks in QwaQwa using the community capitals approach

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ABSTRACT

QwaQwa, in South Africa, experiences high exposure to multiple climate-change impacts. The area is particularly vulnerable to the effects of climate change. As such, this paper aims to assess community resilience, estimate the risk of multiple-climate change impacts in QwaQwa, and propose strategies to reduce risk and build resilience. Data were collected using a household survey and key informant interviews with a sample of 349 participants. An indicator method, based on the Community Capitals Framework, was used to measure resilience and estimate risk. The composite resilience indicators were weighted using principal component analysis. The Cronbach's alpha (α) test indicated a very good internal consistency in the scaled items. The results indicated that medium resilience to climate-change impacts in QwaQwa was mostly driven by access to all six capitals measured in this study: natural, human, social, financial, political, and infrastructural capitals. The multi-hazard risk estimate resulted in a very high index of 4.1. These results were validated at a stakeholder workshop. Strategies that use nature-based solutions, training and education for people of all ages, sectors and professions, and increased community and local government cooperation were deemed essential for boosting resilience and reducing disaster risks in the area.

Key words: climate change, community capitals framework, community resilience, disaster risk reduction, multi-hazard risk, South Africa

HIGHLIGHTS

- Community resilience of QwaQwa to climate-change-related events was analysed and estimated using indicators.
- The community capitals were used as a proxy to assess vulnerability.
- The estimated multi-hazard risk index for climate-change-related events was very high.
- The findings confirmed previous research on the influence of non-climatic factors in increasing climate-related disaster risk.

1. INTRODUCTION

Global attention given to climate-change-related risks has been growing due to the increase in prevalence and lack of adequate preparedness, mitigation, and adaptation strategies in both the developed and developing world (Mukasa *et al.* 2020; Yadava & Sinha 2020). In pursuit of a relevant strategic response, the idea of '*resilience*' has gained significant attention in disaster research (Berkes & Ross 2016; Dapilah *et al.* 2020). Manyena (2009:15) views resilience '*as the intrinsic capacity of a system, community or society predisposed to a shock or stress, to "bounce forward" and survive by changing its non-essential elements and rebuild itself*'. '*Bouncing forward*' captures the idea of a community that moves forward and is in control of the new disaster experience (Manyena 2009; Manyena *et al.* 2011). This paper adopts this definition because of its proactive undertone to disaster risk reduction (DRR) and its emphasis on the inherent community resources that enable it to improve its condition after hazard impacts.

Contrary to the popular inclination towards vulnerability assessment in the risk matrix, which has been popular in disaster research such as Wu (2021), Yadava & Sinha (2020) and Cutter *et al.* (2003), we used community capitals for resilience in multi-hazard risk assessment as a proxy to assessing community vulnerability and this forms this study's special contribution to the risk analysis methodology. While both the Sustainable Livelihood Framework (SLF) and the Community Capitals Framework (CCF) similarly focus on understanding and analysing various facets of community development, they differ in the aspects they each emphasise on. Whereas the SLF places its emphasis on enhancing people's livelihoods and includes the idea of capitals, the CCF expands that idea of capitals from five to seven and offers a more complete approach to the analysis of community resilience in the local context (DFID 2001; Flora & Flora 2008; Gutierrez-Montes *et al.* 2009). It goes beyond identifying vulnerabilities by analysing the available capitals. The CCF, by Flora & Flora (2008), posits that every community possesses strengths which are termed 'capitals' or 'assets' or 'resources'. Flora & Flora (2008) postulate seven different interactive capitals which are natural, human, social, financial, infrastructural/built, political and cultural capitals. These capitals can be nurtured to generate more capitals or depleted when they are not invested in, therefore resulting in either the strengthening or weakening of the community in relation to shocks (Emery & Flora 2006; Flora & Flora 2008; Mattos 2015).

CCF was selected because it is a pragmatic community-based disaster resilience framework for local stakeholders, practitioners and researchers that focuses on effective resource mobilisation all through the disaster cycle (Gill & Ritchie 2014). Existing literature shows a growing application of the CCF, such as Daniel *et al*. (2022), Himes-Cornell *et al.* (2018), Belle *et al*. (2017) and Stofferahn (2012), who used CCF to study the influence of capitals on how communities deal with disasters.

This study goes beyond just analysing community capitals, to use capitals in risk analysis of multiple climate-change-related hazards in QwaQwa, and details are provided in Section 3.2. QwaQwa was selected for this study due to its susceptibility to weather events such as recurrent droughts, flooding, wildfires and associated water challenges that affect the livelihoods and the community's well-being (Manyama 2020; Melore & Nel 2020). The area experiences a myriad of other weather events such as strong winds, heavy rainfall, lightning, thunder, snow, and hail (Manyama 2020; Melore & Nel 2020; TMDM 2021). However, this study focused on droughts, flooding, wildfires and water scarcity due to their severe impact on the study area. These weather events were selected because they were ranked in the high to extremely high ratings in the TMDM (Thabo Mofutsanyana District Municipality) risk calculation (TMDM 2021). For example, repeated droughts that last for five years have been recorded and have significantly threatened water availability (Macupe 2020; Melore & Nel 2020). The period between January and March usually experiences flash floods due to heavy rainfalls and results in significant damage to infrastructure, property, and livestock as well as loss of life (Jones 2021; Mdakane 2022). For instance, flash floods that occurred in January 2022 were reported to have claimed three lives Mdakane (2022). The combination of these climatic and non-climatic socio-economic issues that are experienced in QwaQwa are replicated in other areas and countries across the globe, and together, they significantly affect the community's livelihoods and well-being (Pohl *et al*. 2017; UN-Water 2021; Li *et al*. 2022). There is lack of research that has been done in QwaQwa on risk analysis of multiple climate-change-related events.

This particular undertaking is the first in QwaQwa and is especially relevant in connection to South Africa's commitment to building community resilience against climate-change-related events, as emphasised in the South African Disaster Management Act and White Paper on Climate Change (RSA 2011; Republic of South Africa (RSA) 2015).

2. STUDY AREA

QwaQwa (Figure 1) is a former 'homeland'; that is, it is one of the ten territories *'established by the Apartheid Government, [were areas] to which the majority of the Blacks population was moved to prevent them from living in the urban areas of South Africa'* (South Africa History Online (SAHO) 2019:1). These territories suffered marginalisation and were characterised by poor economy, poor farming land and poor environmental conditions such as over-grazing and soil erosion (SAHO 2019; Mocwagae 2020).

According to Climate Data (2023), the area experiences a temperate, mild climate that is typically warm. There is a noticeable decrease in precipitation during the winter months as opposed to the summer. The average temperature is 13.4 °C (56.1 °F). This location receives about 1,020 mm (40.2 in) of precipitation annually. Phuthaditjhaba enjoys an average of 9 h of sunshine per day; September is the month with the most hours of sunshine and boasts of 278.91 h of sunshine on average. Table 1 shows the weather for Phuthaditjhaba by month.

According to Table 1, precipitation varies by 172 mm/7 in. between the wettest and driest months. The average temperature varies by 11.1 °C/20.0 °F over the course of the year. January (73.48%) has the highest relative humidity of any month.

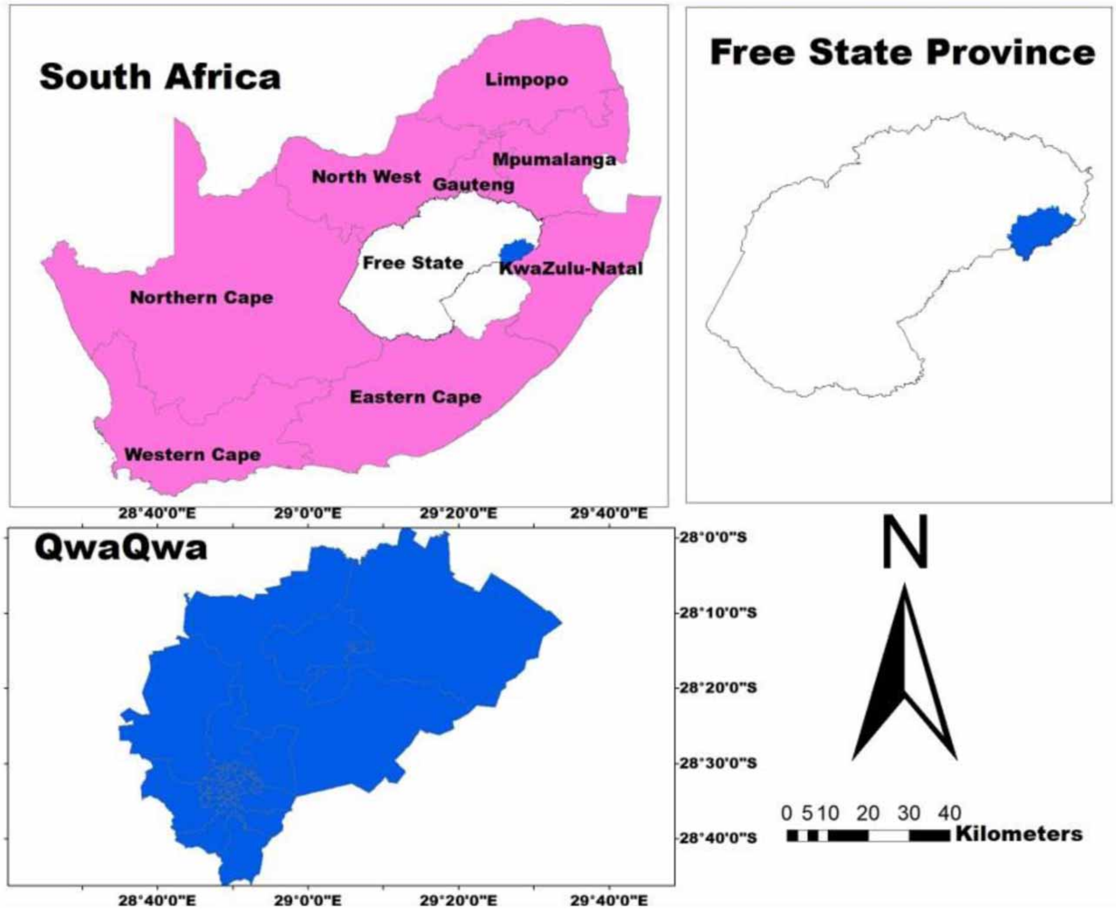

Figure 1 | Map of QwaQwa showing South Africa and Free State Province (*source*: Authors).

September (43.63%) is the month with the lowest relative humidity. Table 1 shows that January (183 mm) was the wettest month, while July (12 mm) was the driest month. (Climate Data 2023). Mukwada & Mutana (2023) argue that the climate of Phuthaditjhaba has been changing. The changing climate has been affecting the Drakensberg mountains and increasing the frequency and severity of weather events like droughts (Mukwada 2022). Repeated droughts have been linked to high temperatures; the most notable example of this was the drought that occurred in 2015–16. Since 2014, there have been three significant droughts in total. There have only been four years since 2002 when the region has seen rainfall that is above average (Macupe 2020; Melore & Nel 2020; Mukwada & Mutana 2023). Mukwada & Mutana (2023) further state that the catchment's streamflow has been reduced due to the ongoing increase in the maximum temperature and recurrent drought, which has led to a decrease in Phuthaditjhaba's water supply. Household water is mostly provided by Fika-Patso Dam which is on the Namahadi River and has a capacity to hold 29.5 million cubic metres of water (Department of Water & Sanitation (DWS) 2023).

QwaQwa is made up of both urban and rural areas; it is a very densely populated area with 25% of the Free State province (56,251 people) (Department of Water Affairs 2011; Stats SA 2012). QwaQwa falls under the Maluti-a-Phofung Local Municipality (MAP) in Thabo Mofutsanyana District Municipality in the eastern Free State Province of South Africa. Phuthaditjhaba is QwaQwa's urban centre and the administrative centre of MAP (Nishimwe-Niyimbanira 2016). The majority of MAP's population (98.09%) are Blacks and the remaining 1.9% is made up of Whites, Indians, Asians and Coloured (Mixed Race) (Stats SA 2012; Moloi 2015). It is noteworthy that epidemiologic data have shown that black populations are more vulnerable to climate change impacts than other population groups (Akerlof *et al.* 2015; Otto *et al.* 2017; Madrigano *et al.* 2018). This vulnerability is not primarily because of race, but mostly due to a lack of access to the essential resources that empower them to cope with or withstand climate-change-related impacts (Madrigano *et al.* 2018).

Table 1 | Weather averages by month for Phuthaditjhaba

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature °C (°F)	17.8 °C (64.1) °F	17.6 °C (63.7) °F	16.3 °C (61.3) °F	13.3 °C (55.9) °F	10 °C (50.1) °F	7 °C (44.6) °F	6.7 °C (44.1) °F	9.7 °C (49.4) °F	13.3 °C (56) °F	15.2 °C (59.4) °F	16.4 °C (61.4) °F	17.6 °C (63.6) °F
Min. Temperature °C (°F)	13 °C (55.4) °F	12.9 °C (55.2) °F	11.1 °C (52) °F	7.8 °C (46.1) °F	3.8 °C (38.8) °F	0.6 °C (33) °F	−0.1 °C (31.9) °F	2.4 °C (36.4) °F	5.9 °C (42.7) °F	8.6 °C (47.5) °F	10.2 °C (50.4) °F	12.2 °C (53.9) °F
Max. Temperature °C (°F)	23.3 °C (73.9) °F	23 °C (73.4) °F	21.9 °C (71.5) °F	19.3 °C (66.7) °F	17.1 °C (62.8) °F	14.5 °C (58.2) °F	14.6 °C (58.3) °F	17.5 °C (63.6) °F	21 °C (69.8) °F	22.3 °C (72.1) °F	22.9 °C (73.1) °F	23.5 °C (74.3) °F
Precipitation/rainfall mm (in)	184 (7)	141 (5)	107 (4)	55 (2)	26 (1)	14 (0)	12 (0)	31 (1)	33 (1)	109 (4)	135 (5)	173 (6)
Humidity (%)	73%	73%	71%	67%	59%	56%	51%	46%	44%	55%	62%	68%
Rainy days (d)	14	12	10	6	3	1	2	3	3	9	10	14
Avg. sun hours (hours)	8.5	8.5	8.3	8.1	8.5	8.4	8.7	9.0	9.3	8.9	9.1	9.0

Key: Data for 1999–2019 for sun days and 1991–2021 for the rest. *Source*: Climate Data (2023).

QwaQwa is considered one of the poorest areas in the province (Nishimwe-Niyimbanira 2016). The residents have complained about general socio-economic issues such as poor service delivery; especially water, a high unemployment rate mostly among the youth and mismanagement of public resources. Access to sewerage, piped water within the dwellings, drainage and flushing toilets is still limited to a few households (Stats SA 2012). Consequently, the residents have taken their frustrations to the streets in protest against these issues, particularly poor service delivery (Palmer *et al*. 2017; Mamokhere 2019; Moche 2021). Among the challenges that QwaQwa experiences, the most important and urgent one is water scarcity (Macupe 2020; Melore & Nel 2020; Mtengwane 2020; Muyambo *et al*. 2023; Setena 2023). These water challenges are usually ascribed to climate-change-related events like recurring droughts and floods that regularly occur in the area (Melore & Nel 2020).

There is a paucity of studies on DRR and resilience strategies that have been implemented in QwaQwa. However, a joint initiative between South Africa and Lesotho has been operational since the early 2000s to carry out ecosystem management in the Maluti-Drakensberg (Zunckel 2010), because the region provides water to Lesotho as well. In addition, DWS has carried out several intervention projects to mitigate the impacts of climate change in QwaQwa, especially water scarcity, such as financial support, joining the three dams, installing treatment works at Fika-Patso Dam, borehole drilling, providing water tanks, increased pipeline diameter from 160 to 400 mm and repair of water infrastructure (DWS 2020; Parliamentary Monitoring Group (PMG) 2020; Nyaka 2022). However, some of the projects were not completed and the water challenges have persisted at the time of writing (Setena 2023).

3. MATERIALS AND METHODS

3.1. Data collection tools

This study integrated the qualitative and quantitative methods of inquiry (Gallina *et al*. 2016; Creswell & Creswell 2018). The two approaches converged at both data collection and data analysis stages to gain a more comprehensive understanding of the research problem. Literature, field observations, household surveys, key informant interviews and input from relevant experts complemented each other in identifying the resilience indicators. All 30 wards in QwaQwa were targeted for data collection; however, 17 wards and 33 villages were finally sampled. The study used purposive sampling to select the key stakeholders for the key informant interviews following the South Africa National Disaster Management Centre (NDMC) guidelines on Disaster Risk Management key stakeholders (NDMC 2017). These were selected according to their association with climate-change-related impacts and water management. Some of them were from the water-provisioning sector, disaster and risk management, agriculture, small businesses, non-governmental organisations, and local and traditional authorities. The study also used random sampling to select household survey participants.

Relevant letters of approval to conduct research were obtained from the traditional and municipal authorities as well as the Ethics Committee of the University of the Free State. Informed consent was obtained from all participants. Detailed interviews were conducted with key informants (KI) while a questionnaire was used for the household survey and both combined closed-ended and open-ended questions for quantitative and qualitative data sets (see the Supplementary Material). Both data types were crucial to complement each other in understanding local community resilience to climate change-related impacts in QwaQwa. Study findings were validated by key stakeholders at a workshop that was conducted in QwaQwa.

3.2. Analytical framework

In light of the growing focus on strengthening resilience (UN-ISDR 2015; Kais & Islam 2016), we selected CCF as a proxy for assessing community vulnerability because of its advancement of the use of available resources to empower communities to enhance their livelihoods (Flora & Flora 2008; Mattos 2015). The concept has been used in disaster research, particularly in measuring community resilience (Himes-Cornell *et al*. 2018; Daniel *et al*. 2022) and is applicable to QwaQwa and other similar marginalised regions. This study; therefore, adopts a modified risk equation which is expressed as an outcome of the interaction among hazard, exposure and community capitals as follows:

$$Risk = \frac{Hazard \times Exposure}{Capitals}$$

A multi-hazard index (MHI) from the analysis of four hazards; drought, flooding, wildfires and water scarcity (see Supplementary material, Appendix A) and an exposure index (EI) from the analysis of critical elements; population, and structures (see Supplementary material, Appendix B), were combined with the resilience.

To capture and measure community resilience, indicators were selected based on six capitals, namely natural, human, social, financial, built infrastructure and political, instead of the seven capitals (including cultural) proposed by Flora & Flora (2008). We used six capitals in our analysis by incorporating the cultural into the social capital because of the occasional similarity and overlap of the two concepts (Claridge 2022) and '*their complexity and overlap add vagueness to possible operational measures*' Zugravu-Soilita *et al.* (2021). Cultural capital is also one of the most difficult capitals to measure (Gill & Ritchie 2014). The selection of indicators was informed by literature, CCF, consultation with experts, observation, survey and stakeholder interviews. The study used a different number of indicators for each capital because the goal was not to have an equal number of indicators for each capital but rather to capture a comprehensive set of indicators influencing the vulnerability/resilience of the community to climate-induced hazards. This was done in consultation with experts and stakeholders from the communities. They identified these indicators under each capital.

4. RESULT AND DISCUSSION

4.1. Socio-demographic characteristics of respondents

The socio-demographic characteristics are summarised in Table 2.

Table 2 | Demographic characteristics of household survey participants

Characteristics	Sub-characteristics	Frequency (*n* = 340)	Percentage (%)
Gender	Female	176	51.8%
	Male	164	48.2%
Age group (years)	18–25	106	31.2%
	26–34	87	25.6%
	35–44	54	15.9%
	45–54	41	12.1%
	55–64	30	8.8%
	65 +	22	6.5%
Educational level	No formal education	40	11.8%
	Primary school level	24	7.1%
	High school level	138	40.6%
	College level	59	17.4%
	University level	65	19.1%
	Postgrad level	14	7.1%
Marital status	Single	212	62.4%
	Married	62	18.2%
	Widowed	28	8.2%
	Separated	12	3.5%
	Divorced	4	1.2%
	Living together	22	6.5%
Source of income	Unemployed	133	39.1%
	Social grant	82	24.1%
	Formally employed	57	16.8%
	Self-employed	37	10.9%
	Diverse incomes	3	0.9%
	Employer	13	3.8%
	Others	15	4.4%
Household income range (rands, annual)	No response	3	1.22%
	Under R10,800	250	74.80%
	R10,801–R100,000	64	17.07%
	R101,000–R200,000	15	4.07%
	R201,000–R400,000	8	2.85%
	Above R400,000	0	0

Socio-demographic characteristics are important and should be considered in the conceptualisation of strategies aimed at helping the community become more resilient to multiple climate-change-related weather events in QwaQwa. The results presented in Table 2 indicate that the study sample was heterogeneous or diverse in character, although some characteristics, like marital status, employment status, and household income, tended to converge to one or two categories. There was a clustering of results for variables like source of income and household income which gave the overall impression of general low socio-economic status within the community, and hence limited resilience. The socio-demographic analysis confirms the socio-economic issues which were highlighted in the section on the study area where 98% of the community was reported black, there were high unemployment levels and QwaQwa was regarded as very poor. All these issues are precursors to indicate low resilience to disaster risks. However, community resilience strategies can, *inter alia*, target the abundant educated youthful human capital exhibited by the studied sample which mirrored the population demographic (Stats SA 2012). This could have a positive impact on both sources of income and household income, subsequently contributing towards improved resilience.

4.2. Resilience analysis using community capitals

4.2.1. Reliability testing

Prior to measuring household resilience to climate-change-related impacts, Cronbach's alpha (α), a reliability test that measures internal consistency or the relationship between scale items (Tapia *et al*. 2017), was conducted to examine whether the overall set of composite indicators measured the theoretical notion of resilience. The test was run on the scale items of the five-point scale that was used to obtain data on community capital resources. Results, as shown in Table 3, indicate that there was very good internal consistency in the scale items that assessed community resilience with an average alpha value for all six composite indicators of 0.71, suggesting a high degree of interrelatedness. However, the social resources indicators were the least internally consistent ($\alpha = 0.41$). As in similar previous social-science studies on resilience or vulnerability development such as Tapia *et al*. (2017) and Cutter *et al*. (2014), we did not obtain a high alpha value on all components considering the abstract nature of social resources and the perception of participants.

4.2.2. Measuring resilience to climate-change-related impacts in QwaQwa

The community capitals were also scored using a five-point Likert scale. The higher the score, the greater the resilience to the threat of climate-related risk; and the lower the score, the lower the resilience. Capital indicator scores were computed by averaging scores for each indicator using Excel, as shown in Table 4.

The capitals were rated from 'very low' to 'very high' as shown in the note under Table 4. Overall, all the capitals were rated in the moderate category except for the financial capital which scored a low index of 2. The participants' expressed views and opinions embedded in the discussion are necessary (Parkin & Kimergård 2022) to give meaning to the capital scores and for the researchers to get better insights into the participants' rating of the various capitals.

4.2.2.1. Natural capital. Field observation showed vegetation cover and wetlands to be generally in good condition, during the time of the study, as QwaQwa had recently received some rain.

The 2.6 score (see Table 4) indicated moderate resilience of the natural resources in QwaQwa where lack of deforestation and vegetation cover successively scored the highest under this capital. However, the participants expressed concern that the increasing rate of cutting trees for firewood, especially for warmth and cooking during the winter season due to intermittent

Table 3 | Cronbach's alpha reliability test results

Cronbach's alpha (α) test results	
Scale	α
Natural resources	0.76
Human resources	0.78
Social resources	0.41
Financial resources	0.72
Infrastructural resources	0.80
Political resources	0.77

Table 4 | Average scores for the selected capital indicators

Capitals				
Capital	**Indicator**	**Indicator score**	**Average capital score**	**Ranking**
Natural resources	Vegetation cover	2.89	**2.6**	**Medium**
	Deforestation	2.93		
	Soil erosion	2.71		
	Wetlands	2.62		
	Water resources for population	2.37		
	Water resources and climate impacts	2.39		
	Ecosystem management	2.39		
	Livestock access to water	2.51		
Human resources	Elderly ability to cope	2.14	**2.39**	**Medium**
	People living with disabilities (PLWD) ability to cope	2.01		
	Population's health	2.40		
	Skilled workforce to maintain water infrastructure	2.07		
	Skilled workforce to cope with climate impacts	2.05		
	Access to warning information	3.00		
	Response to warning information	3.04		
Social resources	Involvement in social networks	3.02	**2.60**	**Medium**
	Unity in responding to climate impacts and water crisis	2.93		
	Female-headed households' resilience	2.56		
	Women and children safety searching for water	2.03		
Financial resources	Savings to cope with crisis	1.87	**2.0**	**Low**
	Emergency funds for crisis	1.72		
	Participation in financial groups like '*stokvels*'	2.11		
	Remittances from relatives	2.29		
Infrastructural resources	Cultivated land under irrigation	2.47	**2.38**	**Medium**
	Functional water taps	3.17		
	Water sources protected from pollution	2.60		
	Strength of water infrastructure against climate impacts	2.47		
	Functional boreholes	2.37		
	Access to functional sewage system	2.40		
	Roads in good condition	1.89		
	Drainage system ability to cope with flood water	2.13		
	Land use and zoning regulations enforcement	2.30		
	Access to regular electricity supply	1.87		
	Access to good communication networks	2.50		
Political resources	Corruption not responsible for water crisis	1.93	**2.02**	**Medium**
	Local authority management of public resources	1.92		
	Youth representation in public decision-making	2.00		
	Gender consideration in public decision-making	2.26		
	Community engagement in DRR initiatives	2.05		
	Political unity in climate and water issues	1.95		

Note: very low resilience: 0–1; low resilience: 1.1–2; medium: 2.1–3; high resilience: 3.1–4; very high resilience: 4.1–5.

electricity supply, results in serious deforestation. In this regard, TMDM (2021) reports that almost 5,000 households in MAP were mostly using firewood for heating in 2016. Already, soil erosion and degraded land could be seen in some areas (see Figure 2). Melore & Nel (2020) also observed overgrazing and removal of soil for brick moulding in the study area. In addition to these, climate-change-related drought veld fires, strong winds and flash floods have also significantly contributed to soil and land degradation (Melore & Nel 2020; TMDM 2021). This suggests that the combination of anthropogenic factors and climate-change-related events has resulted in environmental degradation. While water resources are a part of the natural capital, well-managed natural resources contribute to maintaining good water quality and quantity.

Furthermore, water resources capacity to withstand climate change impacts and its adequacy for the population were also moderate as shown in Table 4. However, the available water in the rivers and streams such as Melatshera wetlands and

Figure 2 | Signs of land degradation in QwaQwa (*source*: Authors).

Mpokojwane River were polluted with various kinds of waste including diapers. Participants confirmed our observations; for example, Participant 7 (P7) stated that '*there is a lot of pollution, such as used pampers [diapers] at Melatshera wetlands.*' Moreover, solid waste was observed in several places, along the roads, drainage outlets and informal waste-dumping sites (see Figure 3).

Participants acknowledged that there had been experiences of dry periods as indicated by some participants; for example, P125 stated that '*changing climate [is] making dry areas drier and precipitation [is] becoming more variable and extreme.*' In the same vein P167 pointed out that '*climate change, floods, increase in water consumption exist.*' Some KI also highlighted the prevalence of climate-change factors in QwaQwa; for example, KI6 said that '*I think drought is the main cause of water crisis and this is in turn caused by climate change. It has become hotter and dryer over the years*'. However, some participants also indicated that QwaQwa had adequate water in the dams and rivers to meet demand, yet they were still experiencing water shortages; for example, P231 indicated that '*the water is abundant but it's not getting to the people.*'

Figure 3 | Picture showing waste dumping in an undesignated area (*source*: Authors).

One stakeholder summarised his conclusion about the QwaQwa water scarcity in one short statement by stating that *'Mankind is contributing to QwaQwa water crisis'*. Thus, study participants highlighted that climate-change-related events were noticeable in QwaQwa and contributed to QwaQwa's water issues; however, anthropogenic factors were also at play.

4.2.2.2. Human capital. The human capital also scored moderate resilience (2.39) with PLWD and skilled workforce scoring the least, respectively (see Table 4). The collected data provided insight into how the majority of the participants perceived that the water problems in QwaQwa were partly due to a lack of skilled and efficient workforce in both the municipality and Maluti-a-Phofung Water (MAP Water) to manage and maintain water infrastructure. Some young participants expressed frustration that the majority of the workforce were older people who, according to them, needed to retire and allow the young people a chance to use newly acquired skills to develop the area. For example, P144 stated that *'they are hiring people with no knowledge to work with pipes (fix and buy them) who get hired through connections.'* Similarly, P25 indicated that '*municipality workers only come to see and leave. It takes them about 3 months to attend to water leaks. They should hire young people with skills.'* Such sentiments were consistent with the demography of the study participants who were found to comprise mostly well-educated but unemployed young people.

4.2.2.3. Social capital. Resilient communities are also characterised by the existence of strong social resources, such as trust and social networks, which assemble collective action and arrange the delivery and restoration of services in times of disaster. Thus, they cope better with climate-change impacts (Sutton 2010; Stofferahn 2012). The importance of social capital in South African communities facing climate-related impacts has been assessed in previous studies such as Bahta *et al.* (2016) and Muyambo *et al.* (2017). Results from this study generally show a medium index for social capital (2.6). Interestingly, involvement in social networks, such as family and neighbourhood groups, that come together to plan and carry out disaster mitigation activities, had a high score of 3.02. Thus, the study participants indicated that they usually assist each other in times of crisis. For example, KII6 stated that *'they are very united in a sense that when such disasters happen it takes a certain group of people to unite and fight for those who cannot fight for themselves.'* Participants shared experiences where neighbourhood groups came together to purchase and install water pipes for their communities. A group of residents in a quarter called Bolata covered a huge gulley that had become a life-hazard to both people and livestock. Also, some of the elderly people and people living with disabilities (PLWD) received help from young people who would supply them with water during water shortages and help them relocate to safer locations during flooding. Nonetheless, the assistance was not enough for most people to cope with water and climate-impact issues, especially drought and flooding, because people were also struggling trying to take care of their needs, with limited resources. For example, P19 stated that '*I am single. I cannot fix my roof when its leaking. I need a man's help to help block water when its flooding.'* Also, P25 indicated that '*when we had floods none helped. Another household sold a house after floods.'*

Furthermore, participants had a generally low perception of safety, particularly for women and children during disasters (Table 4). In that regard KII2 stated that '*It is not safe at all, this exposes women and children to rape, crime and in some instances, drowning.'* Additionally, KII6 indicated that '*It's not safe at all. We are living in a very violent country (GBV) so to have women and children fetch water for themselves at long distances sometimes is not safe.'* Despite the rich social fabric of extended family, clan and tribe that Africa is generally known to have (Hilal 2022), this form of community capital faces challenges in urban settings as each household focuses on its needs with little or no resources to spare for the neighbours. It is crucial, therefore, for government and non-governmental organisations to step in and fill this social gap.

4.2.2.4. Financial capital. Access to financial resources contributes significantly to resilience in most households and communities in disaster-prone areas. Mayunga (2007) argues that financial capital is a fundamental determinant of resilience because it increases the capability to withstand, absorb and recover from disaster impacts, while poor access to financial resources indicates low financial resilience. The various factors that characterise financial capital and help individuals and communities to meet up with their livelihoods were rated the lowest in this study, with a financial capital index of 2. The participants indicated that their savings and their emergency funds were low, indicating that in case of a climate-related crisis, most participants would have no financial means to cope or withstand it.

These results are consistent with the latest national census results as well as with previous studies that indicated that QwaQwa is a poor semi-urban area of the Free State province with a 61% dependency ratio (Stats SA 2012; Melore & Nel 2020). There is congruency between the socio-economic results, presented in Table 2, on the source of income and household income and the low score from financial capital analysis results. However, participation in financial groups, like '*stokvels*' (informal financial groups) (2.11), and remittances from relatives (2.29), were rated slightly higher, attesting to the generally strong social fabric in African society. Nonetheless, some participants indicated that their relatives were not helpful in times of crisis.

4.2.2.5. Infrastructural capital. The relevance of the infrastructural capital addressing climate-change impacts on water resources and its mitigation cannot be overstated. Built infrastructure, such as dams, boreholes, water treatment facilities, roads, drainages and communication systems are crucial for the efficient functioning of the community as well as to enable the community to cope with climate shocks (Mayunga 2007). The research participants' overall views on infrastructural capital as a factor in building QwaQwa's resilience to climate-change impacts was also moderate, with a score of 2.38 (see Table 4). Access to regular electricity (1.87) and road quality (1.89) were the least-rated indicators, respectively, which is supported by both existing literature and persistent public demonstrations on poor infrastructure from the communities in QwaQwa (Melore & Nel 2020). Water infrastructure scored 2.47 (see Table 4) indicating a moderate resilience against climate-change-related impacts. We observed leaking water taps and broken pipes leading to water flowing along the streets as shown in Figure 4.

Consistent with previous findings (Felter & Robinson 2021; The Organisation for Economic Co-operation & Development (OECD) 2021), changes in climate, rapid population growth and inadequate and aging infrastructure were cited as factors that put pressure on the quality and quantity of water delivery in QwaQwa. For example, P333 stated that '*old water pipes are the main factors that affect water crisis*'. On the same note, P196 pointed out that '*water cleaning infrastructure is in a bad state, water pollution decreases the amount of healthy usable water.*' This fact was shared by both KI and household survey participants in this study. The analysis also showed that the existing infrastructure was not managed effectively, leading to instances where water taps were occasionally left running and leaking from defective taps and broken pipes was unattended, as illustrated in Figure 4. The community also suffered notable inadequate electricity supplies as pointed out by some participants such as P277 who said '*Government has failed to provide electricity*'. To this end, some students suffered disrupted studies due to electricity cuts that sometimes lasted for days or weeks.

4.2.2.6. Political capital. The political capital incorporates effective political leadership and access to power and resources (Emery & Flora 2006). The study results indicate a low index for the political capital, which scored a 2 out of a possible 5 (see Table 4). Table 4 shows that corruption in local authority (1.93), poor management of public resources (1.92) and political fiddling were some of the major issues that contributed to the low generation of political capital and, therefore, low

Figure 4 | Water from broken pipe flowing in the street in QwaQwa (*Source*: Authors).

resilience. For example, P112 indicated that '*corruption and mismanagement of resources*' were the major factors in dealing with QwaQwa's issues. Moreover, P208 stated that *'poor political management and misusing of funds has led to the infrastructure being inadequate to manage water delivery'*. Furthermore, KII3 stated that '*there is too much interference from political principals, that supersedes the needs of community'*. Such challenges erode the perceived political gains after the change in political dispensation and embracing of constitutional democracy in South Africa.

The issue of corruption was the most prevalent issue mentioned by the study participants as the driver of limited coping-capacity for drought, flood and water problems. It was mentioned 127 times by the household survey participants. It was also one of the main issues that came up from both the key informant interviews and stakeholder workshops. These results corroborate the previous scholarly work as well as media reports (Mananga 2012; Schreiner 2013; Shaidi 2013; Macupe 2020; Mocwagae 2020; Radebe 2020) that governance issues and internal politics, such as nepotism, corruption, institutional incapacity and financial mismanagement, in some South African local authorities compromise community access to essential resources such as disaster relief and water.

The importance of the political capital in strengthening resilience cannot be exaggerated. It oils the wheels of the community to access all other resources; for example, a lack of effective political leadership may affect the financial assistance that a community can access for disaster response and recovery (Himes-Cornell *et al.* 2018). This capital is important in both developed and developing economies; however, it is especially pivotal in a country like South Africa which has a history of marginalisation and inequality created by apartheid (SAHO 2019; Mocwagae 2020). The citizens, especially the formally marginalised population, expect a political environment that upholds equity in service delivery and redistribution of resources, in order to uplift the living conditions of formerly disadvantaged communities through free basic services (Hemson & Owusu-Ampomah 2005; Mc Lennan & Munslow 2009; Chen *et al.* 2014). Consequently, study participants corroborate previous studies that the expectation for free basic services has been stretched to negligence to conserve water as witnessed by the abundant water loss through leaks and wastage of water (Gouws *et al.* 2010; Ngwane 2011; Maphela & Cloete 2020). The following statements are a snippet of the participants' views on the community's passive and negligent attitude towards water usage. P109 indicated that '*[There is] over usage of water in the community.*' On the same note, P124 stated that *'water is wasted – people leave their taps running and they use sprinkler to wash their cars.'*

4.2.3. Constructing the resilience index

4.2.3.1. Weighting of capitals using the principal component analysis approach. Following resilience analysis, based on CCF, weights were allotted to the capitals to define the significance of each capital in contributing to resilience to climate-change impacts. Weighting of indicators is common in disaster research; however, different methods are used in weighting (Boka 2017; Sharma *et al.* 2018). Weighting can be based on equal weighting (Cutter *et al.* 2003; Beccari 2016) which could be very arbitrary (Piya *et al.* 2012). Some research has based weighting on expert judgement or stakeholders' consultation, which has been generally criticised for subjectivity and lack of concord among participants (Piya *et al.* 2012; Sharma *et al.* 2018). This study, however, preferred to base its weighting of capitals on a statistical method through principal component analysis (PCA) in line with Yu *et al.* (2021), Asmamaw *et al.* (2019), Boka (2017) and Piya *et al.* (2012). This approach is an objective way of creating indices in research that have no pre-determined weights. The assumption behind weighting using PCA is that '*there is a common factor that explains the variance in the resilience indicators. Instinctively, the principal component of a set of variables is the linear index of all the variables that captures the largest amount of information common to all the variables*' (Boka 2017:20).

PCA was conducted on the matrix composed of 33 indicators observed in the 340 household survey questionnaires from QwaQwa. The first part included the results from the Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity which confirmed the suitability of the data for PCA (KMO $= 0.841$; $p < 0.001$). After validating the pertinence of PCA, the coefficients of the primary principal component that would weight each capital were defined. PCA, using varimax with Kaiser normalisation, was carried out to compute the component score coefficient matrix. The capitals or component PCs, and the obtained component score coefficients are shown in Table 5. The component score coefficient matrix shows the weight of the capital components which form the resilience index in QwaQwa. The results show that all the selected community capitals are important in improving resilience to climate-change impacts in QwaQwa; however, human resources got the highest weighting of 0.287, followed by infrastructural resources with 0.282 (Table 5). Interestingly, natural resources scored the least with 0.189. These results are consistent with surveys, interviews and workshop findings that socio-economic issues negatively affect the community's resilience to climate-related events.

Table 5 | Component score coefficient matrix

Capital (component PC)	Component scores
Human resources	0.287
Social resources	0.198
Financial resources	0.245
Political resources	0.228
Infrastructural resources	0.282
Natural resources	0.189

Although some study participants dismissed the impact of climate change, the results also corroborate Muyambo *et al.* (2023) that climate-change-related events in QwaQwa (drought, flooding, wildfires, and water scarcity) are exacerbated by anthropogenic drivers.

Calculation of the resilience index was based on the coefficients of the main component, following Yu *et al.* (2021), Avila-Vera *et al.* (2020) and Liu & Li (2016). The weighted capital scores were obtained by multiplying the capital scores that were obtained from the survey data analysis (see Section 4.1) by the corresponding PCA weights, as shown in Equation (1).

$$Res = \sum_{i=1}^{6} w_i^{\text{cap}}\ res_i^{\text{cap}} \quad (1)$$

$$Res\ f(w_1^{\text{cap}}res_1^{\text{cap}}, w_2^{\text{cap}}res_2^{\text{cap}}, w_3^{\text{cap}}res_3^{\text{cap}}, \ldots res_6^{\text{cap}})$$

where Res is resilience; res_1^{cap}, natural capital; res_2^{cap}, human capital; res_3^{cap}, social capital; res_4^{cap}, financial capital; res_5^{cap}, infrastructural capital; res_6^{cap}, political capital; and w_i^{cap}, different weighting factor for each indicator.

Table 6 shows the calculation of the resilience index, by summing the weighted capital scores.

The results in Table 6 show that the weighted capital scores, just like the capital scores before weighting, are mostly similar. This was possibly influenced by the mostly similar weights that were ascribed to the mostly similar capital scores, as shown in the first and second columns of Table 6. Table 7 shows the categorisation of the resilience index.

Based on the description of the resilience index rating in Table 7, the study findings show that QwaQwa does not have strong enough resilience to bounce back, let alone bounce forward. The general lack of strong community capitals in QwaQwa is congruent with a previous study by Melore & Nel (2020), which found that all capitals were scarce in QwaQwa. Although Africa is considered rich in resources such as natural, human and social resources (Custers & Matthysen 2009; Addae-Korankye 2014), it lags behind most other continents in terms of development and coping capacity, as in the case of QwaQwa. This dilemma could be attributed to poor leadership and management, both of which are linked to human capital (Ndalamba 2019; Mbandlwa *et al.* 2020; Enaifoghe *et al.* (2023)).

Table 6 | Calculation of the resilience index using weighted capitals

Capital component	Capital score (from analysis)	PCA weights for each capital component	Weighted capital scores (weight × capital score)
Human resources	2.60	0.287	0.7462
Social resources	2.39	0.198	0.47322
Financial resources	2.60	0.245	0.637
Political resources	2.00	0.228	0.456
Infrastructural resources	2.38	0.282	0.67116
Natural resources	2.02	0.189	0.38178
Resilience index = sum of weighted capital scores = 2.69378 = 2.7			

Table 7 | Resilience rating guide

Rating	Resilience rating	Remarks
Less than 1	Very low resilience	Collapses in case of disaster
1.1–2	Low resilience	Struggles to recover
2.1–3	Medium resilience	Recovers, but worse than before
3.1–4	High resilience	Bounces back
4.1–5	Very high Resilience	Bounces back better or bounces forward

The resilience index results are congruent with the majority of the participants' perceptions of both stakeholders and household survey participants, who expressed frustration and, sometimes, anger, at the socio-economic and political situation in QwaQwa. These frustrations are usually manifested in general service-delivery protests. These findings were confirmed further by workshop participants who claimed that QwaQwa's water problems and other socio-economic issues were mostly due to lack of proper management of public resources, political meddling, lack of community engagement and disconnect between the traditional leadership and the municipality. The available, although limited, capacity to recover from climate-change impacts, however, could be built on to improve resilience. Having calculated the resilience index, the following section calculated the multi-hazard risk index (MHRI).

4.3. Constructing MHRI

This section shows the computation of the MHRI, an overall composite result obtained from the analysis of risk in this study. It was obtained by combining the MHI (from analysis of multiple hazards, drought, flooding, wild fires and water scarcity), EI (from analysis of exposed elements) and resilience index (from analysis of capitals). The MHI (see Supplementary Material, Appendix A) was 3.6 and the EI (see Supplementary Material, Appendix B) was 3.2. The following equation was used to calculate MHRI, as previously discussed in Section 1:

$$Risk = \frac{Hazard \times Exposure}{Capitals} \tag{2}$$

Thus, MHRI was calculated using the following expanded Equation (2):

$$MHR = \left[\frac{(w_i^{\mathrm{h}} MH_i^{\mathrm{h}}) \times (w_i^{\mathrm{exp}} Exp_i^{\mathrm{exp}})}{(w_i^{\mathrm{cap}} Res_i^{\mathrm{cap}})}\right]$$

where MHR is multi-hazard risk; MH_i^h, multi-hazard; Exp_i^{exp}, exposure; Res_i^{cap}, resilience (capitals); w_1^h, w_1^{exp}, w_1^{cap}, equal weighting factor for all indicators.

Therefore,

$$MHRI = \left[\frac{(3.6) \times (3.2)}{(2.7)}\right] = \frac{11.52}{2.7} = 4.267 = 4.3$$

The multi-hazard risk analysis results for QwaQwa indicate a very high MHRI of 4.3, as shown in the calculation. Previous studies by Mnisi (2020), Nyam *et al.* (2020) and Misra (2014) indicate that climate variability and climate change negatively affect South Africa's renewable water supply. These studies agree with the Global Risk Report (WEF 2019) that the problem is worsened by several non-climate drivers. Notwithstanding, QwaQwa's experience of climate change impacts exacerbated by non-climatic issues confirms these study findings. The insufficiency of all the capitals, together with the pressures of climate-change-related impacts, grossly deplete the communities' resilience capability and, therefore, increase the intensity of disaster risk. This implies an urgent need to improve resilience through various community assets because the little capacity that they have in the community capitals is inadequate to '*bounce back better*' after climate-related shocks. Thus, DRR and resilience strategies are essential at every level of resilience, even the highest, in order to prevent all possible disaster risks and prevent any damage or loss as well as to continue to build resilience against future risks. The projected likelihood, frequency and severity of climate-change-related events suggest that local authorities should be extra-vigilant in strengthening resilience and reducing disaster risk. The findings are consistent with previous study-findings that one of Africa's challenges regarding climate-change impacts is limited capacity (Van der Bank & Karsten 2020; Scholes & Engelbrecht 2021), and consequently greater vulnerability to climate-change impacts.

5. CONCLUSIONS AND RECOMMENDATIONS

This study used an indicator technique based on the CCF, where six community capitals were used to assess community resilience and create an MHI for different climate-change-related consequences in QwaQwa. The analyses were based on primary data from the household survey, key informant interviews, and observations. To develop a thorough understanding of the resilience and risk to climate-change-related impacts in QwaQwa, descriptive and inferential studies as well as qualitative analyses were explored. PCA was used to weight the composite community capitals. To compute the MHRI, the resultant resilience index was combined with the MHI and EI. The results were validated at a stakeholders' workshop.

Resilience analysis results indicated moderate resilience to climate-change-related impacts in QwaQwa. The moderate resilience index implied that the QwaQwa community could recover from a climate-related event, but they would be worse off than before the event. PCA results showed that the six community capitals did not have a wide gap in their weights, indicating how access to all the community capitals was significant in resilience building. However, human resources had the highest weighting and natural resources had the lowest weighting. This result was consistent with the general perception from both study participants and workshop participants who indicated that QwaQwa's resilience to climate-change-related impacts was negatively affected by socio-economic drivers. Management of public resources, corruption, poor collection of municipal revenue and inadequate and poor infrastructure emerged among the major drivers of reduced resilience in the study.

The study findings confirmed previous studies as well as general media sentiments that QwaQwa's climate-related challenges are worsened by socio-economic and political incapacity to address climate-change impacts. Thus, the very high MHRI indicates that investing in community capitals is fundamental in strengthening community resilience and reducing disaster risk to climate-related events. Notably, this paper has a limitation that future research could take note of. The previous place of residence of participants was not included as an important factor in determining the extent of their response to the proposed adaptation methods to confront climate change in the area under study. Nevertheless, a clear understanding of the major components of disaster risk allows the development of appropriate strategies. DRR strategies, such as training and education across all ages and sectors, increased collaboration between local authorities and the community, engaging the youth in on-the-job-training and entrepreneurship programmes, investing in climate-resilient infrastructure and using nature-based solutions, among others, are crucial to improve resilience to climate-change-related impacts in QwaQwa. To come up with a specific and comprehensive DRR strategy, this paper recommends a subsequent tailored paper that will specifically focus on the DRR strategies for the area.

ACKNOWLEDGEMENTS

Sincere gratitude goes to the Water Research Commission (WRC) of South Africa for their initiation, support and funding of this project, 'Threats of extreme weather events: improving the resilience of QwaQwa to the multiple risks of climate change' Proposal Number 2019/2020-00239/KSA Water Resource Management and Ecosystems. We are also grateful to the University of the Free State, the study participants, the QwaQwa municipality and traditional leadership and the data collection assistants.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Addae-Korankye, A. 2014 Causes of poverty in Africa: a review of literature. *American International Journal of Social Science* **3** (7), 147–153.

Akerlof, K. L., Delamater, P. L., Boules, C. R., Upperman, C. R. & Mitchell, C. S. 2015 Vulnerable populations perceive their health as at risk from climate change. *International Journal of Environmental Research and Public Health* **12**, 15419–15433. https://doi.org/10.3390/ijerph121214994.

Asmamaw, M., Mereta, S. T. & Ambelu, A. 2019 Exploring households' resilience to climate change-induced shocks using Climate Resilience Index in Dinki watershed, central highlands of Ethiopia. *PLoS ONE* **14** (7), e0219393. https://doi.org/10.1371/journal.pone.0219393.

Avila-Vera, M., Rangel-Blanco, L. & Picazzo-Palencia, E. 2020 Application of principal component analysis as a technique to obtain a social vulnerability index for the design of public policies in Mexico. *Open Journal of Social Sciences* **8** (9), 130–145. doi:10.4236/jss.2020.89009.

Bahta, Y. T., Jordaan, A. & Muyambo, F. 2016 Communal farmers' perception of drought in South Africa: policy implication for drought risk reduction. *International Journal of Disaster Risk Reduction* **20**, 39–50.

Beccari, B. 2016 A comparative analysis of disaster risk, vulnerability and resilience composite indicators. *PLoS Currents Disasters* **8**. doi:10.1371/currents.dis.453df025e34b682e9737f95070f9b970.

Belle, J. A., Collins, N. & Jordaan, A. 2017 Building resilience in natural capital to reduce disaster risks and adapt to climate change: a case of wetlands in the eastern Free State; South Africa. *American Journal of Environmental Sciences* **13** (5), 358–377.

Berkes, F. & Ross, H. 2016 Panarchy and community resilience: sustainability science and policy implications. *Environmental Science & Policy* **61**, 185–193.

Boka, G. T. 2017 *Measuring Resilience to Climate Change in Ethiopia*. Working Paper 268, African Development Bank, Abidjan, Côte d'Ivoire.

Chen, L., Dean, J., Frant, J. & Kumar, R. 2014 South Africa: what does 'service delivery' really mean? Council on Foreign Relations. Available from: https://www.cfr.org/blog/south-africa-what-does-service-delivery-really-mean (accessed: 24/04/22).

Claridge, T. 2022 The difference between social and cultural capital. Institute for Social Capital. Available from: https://www.socialcapitalresearch.com/the-difference-between-social-capital-and-cultural-capital/ (accessed: 27/03/23).

Climate Data 2023 Phuthaditjhaba Climate (South Africa). Available from: https://en.climate-data.org/africa/south-africa/free-state/phuthaditjhaba-55825/ (accessed: 03/12/23).

Creswell, J. W. & Creswell, J. D. 2018 *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th edn. SAGE Publications, London, UK.

Custers, R. & Matthysen, K. 2009 *Africa's Natural Resources in a Global Context*. International Peace Information Service, Antwerp, Belgium. Available from: https://www.cncd.be/IMG/pdf/20090812_Natural_Resources.pdf (accessed: 20/11/22).

Cutter, S. L., Boruff, B. J. & Shirley, W. L. 2003 Social vulnerability to environmental hazards. *Social Science Quarterly* **84**, 242–261.

Cutter, S. L., Ash, K. D. & Emrich, C. T. 2014 The geographies of community disaster resilience. *Global Environmental Change* **29**, 65–77.

Daniel, L., Mazumder, R. K., Enderami, S. A., Sutley, E. J. & Lequesne, R. D. 2022 Community capitals framework for linking buildings and organizations for enhancing community resilience through the built environment. *Journal of Infrastructure Systems* **28** (1), 04021053.

Dapilah, F., Nielsen, J. Ø. & Friis, C. 2020 The role of social networks in building adaptive capacity and resilience to climate change: a case study from northern Ghana. *Climate and Development* **12** (1), 42–56.

Department of Water Affairs 2011 *Blue Drop Report. Chapter 4: Free State Province*. Department of Water Affairs, South Africa. Available from: https://www.dws.gov.za/Documents/BD/BDFS.pdf.

DFID (Department for International Development) 2001 *Sustainable Livelihoods Guidance Sheets*. Department for International Development, London, UK. Available from: https://www.livelihoodscentre.org/-/sustainable-livelihoods-guidance-sheets (accessed: 15/09/21).

DWS (Department of Water and Sanitation) 2020 Maluti-A-Phofung Local Municipality Interventions – Free State Province. Department of Water and Sanitation, Pretoria, South Africa. Available from: https://static.pmg.org.za/200310maluti.pdf (accessed: 12/04/21).

DWS (Department of Water and Sanitation) 2023 Water is life, Sanitation Is Dignity. Available from: https://www.dws.gov.za/Hydrology/Weekly/ProvinceWeek.aspx?region=FS (accessed: 17/04/23).

Emery, M. & Flora, C. 2006 Spiraling-up: mapping community transformation with Community Capitals Framework. *Community Development* **37** (1), 19–35. https://doi.org/10.1080/15575330609490152.

Enaifoghe, A., Jili, N. N. & Mthethwa, R. M. 2023 Ethical Leadership decadence of good governance failures in South African public service. In: *Ethics – Scientific Research, Ethical Issues, Artificial Intelligence and Education* (Radenkovic, M., ed.), IntechOpen, Rijeka, Croatia, ch. 14. doi:10.5772/intechopen.1001099.

Felter, C. & Robinson, K. 2021 *Water Stress: A Global Problem That's Getting Worse*. Council on Foreign Relations. Available from: https://www.cfr.org/backgrounder/water-stress-global-problem-thats-getting-worse (accessed: 30/08/21).

Flora, C. B. & Flora, J. L. 2008 *Rural Communities: Legacy and Change*, 3rd edn. Westview Press, Boulder, CO, USA.

Gallina, V., Torresan, S., Critto, A., Sperotto, A., Glade, T. & Marcomini, A. 2016 A review of multi-risk methodologies for natural hazards: consequences and challenges for a climate change impact assessment. *Journal of Environmental Management* **168**, 123–132. https://doi.org/10.1016/j.jenvman.2015.11.011.

Gill, D. A. & Ritchie, L. A. 2014 Using the Community Capitals Framework to enhance disaster resilience. Presentation at the Community Capitals Framework Institute, 6 November.

Gouws, C. M., Mbambo, B., Moeketsi, I., Morotolo, M., Motloung, S. & Tempelhoff, J. W. N. 2010 *What About the Votes? Water, Sanitation and Civil Disorientation: the Case of Maluti-a-Phofung Local Municipality (Harrismith)*. Research Group for the Cultural Dynamics of Water (CuDyWat), North-West University (VAAL), Vanderbijlpark, South Africa.

Gutierrez-Montes, I., Emery, M. & Fernandez-Baca, E. 2009 The Sustainable Livelihoods Approach and the Community Capitals Framework: the importance of system-level approaches to community change efforts. *Community Development* **40** (2), 106–113.
Hemson, D. & Owusu-Ampomah, K. 2005 A better life for all? Service delivery and poverty alleviation. In: State of the Nation: 2004–2005 (Daniel, J., Southall, R. & Lutchman, J., eds), Human Sciences Research Council Press, Pretoria, South Africa, pp. 511–537.
Hilal, T. 2022 Social capital: Africa's superpower. Medium (24 September). Available from: https://medium.com/mojablog/social-capital-africas-super-power-70478f294f9e (accessed: 12/12/22).
Himes-Cornell, A., Ormond, C., Hoelting, K., Ban, N. C., Koehn, J. Z., Allison, E. H., Larson, E. C., Monson, D. H., Huntington, H. P. & Okey, T. A. 2018 Factors affecting disaster preparedness, response, and recovery using the community capitals framework. *Coastal Management* **46** (5), 335–358. doi:10.1080/08920753.2018.1498709.
Jones, B. 2021 #FSfloods damaged many homes. *OFM* (28 January) Available from: https://www.ofm.co.za/article/centralsa/301155/-fsfloods-damaged-many-homes (accessed: 22/03/22).
Kais, S. M. & Islam, M. S. 2016 Community capitals as community resilience to climate change: conceptual connections. *International Journal of Environmental Research and Public Health* **13**, 1211. https://doi.org/10.3390/ijerph13121211.
Li, P., Wang, D., Li, W. & Liu, L. 2022 Sustainable water resources development and management in large river basins: an introduction. *Environmental Earth Sciences* **81**, 179. https://doi.org/10.1007/s12665-022-10298-9.
Liu, D. & Li, Y. 2016 Social vulnerability of rural households to flood hazards in western mountainous regions of Henan province, China. *Natural Hazards and Earth System Sciences* **16**, 1123–1134. https://doi.org/10.5194/nhess-16-1123.
Macupe, B. 2020 Impossible choices in QwaQwa: what it takes to get water. *Mail & Guardian* (7 February). Available from: https://mg.co.za/article/2020-02-07-impossible-choices-in-qwaqwa-what-it-takes-to-get-water/ (accessed: 27/08/22).
Madrigano, J., Lane, K., Petrovic, N., Ahmed, M., Blum, M. & Matte, T. 2018 Awareness, risk perception, and protective behaviors for extreme heat and climate change in New York City. *International Journal of Environmental Research and Public Health* **15**, 1433. https://doi.org/10.3390/ijerph15071433.
Mamokhere, J. 2019 An exploration of reasons behind service delivery protests in South Africa: a case of Bolobedu South at the Greater Tzaneen Municipality. In: *The 4th Annual International Conference on Public Administration and Development Alternatives* (In Sebola, M. P. & Molokwane, T., eds.), IPADA, Sovenga, South Africa, pp. 373–379.
Mananga, A. 2012 *Unfulfilled Promises and Their Consequences: A Reflection on Local Government Performance and the Critical Issue of Poor Service Delivery in South Africa*. Policy Brief, Africa Institute of South Africa (AISA), Pretoria, South Africa.
Manyama, M. J. 2020 *Impacts of Hydrological Drought Management on Sustainable Livelihood in QwaQwa, South Africa*. Masters thesis, University of the Free State, Bloemfontein, South Africa.
Manyena, B. S. 2009 *Disaster Resilience in Development and Humanitarian Interventions*. PhD thesis, University of Northumbria, Newcastle upon Tyne, UK.
Manyena, B. S., O'Brien, G., O'-Keefe, P. & Rose, J. 2011 Disaster resilience: a bounce back or bounce forward ability? *Local Environment* **16** (5), 417–424.
Maphela, B. & Cloete, F. 2020 Johannesburg's implementation of the National Water Act, 1998 in Soweto, South Africa. *Development Southern Africa* **37** (4), 535–552. doi:10.1080/0376835X.2019.1647834.
Mattos, D. 2015 Community Capitals Framework as a measure of community development. *Cornhusker Economics* **811**. Available from: https://digitalcommons.unl.edu/agecon_cornhusker/811.
Mbandlwa, Z., Dorasamy, N. & Fagbadebo, O. 2020 Leadership challenges in the South African local government system. *Journal of Critical Reviews* **7** (13), 1642–1653.
Mayunga, J. S. 2007 Understanding and applying the concept of community disaster resilience: a capital-based approach. Draft working paper, in: *The Summer Academy for Social Vulnerability and Resilience Building*, 22–28 July, Munich, Germany.
Mc Lennan, A. & Munslow, B. 2009 *The Politics of Service Delivery*. Wits University Press, Johannesburg, South Africa.
Mdakane, B. 2022 Flash floods claim three lives in Qwaqwa. *Sunday World* (25 January) Available from: https://sundayworld.co.za/news/flash-floods-claim-three-lives-in-qwaqwa/ (accessed: 22/03/22).
Melore, T. W. & Nel, V. 2020 Resilience of informal settlements to climate change in the mountainous areas of Konso, Ethiopia and QwaQwa, South Africa. *Jàmbá: Journal of Disaster Risk Studies* **12** (1), a778. https://doi.org/10.4102/jamba.v12i1.778.
Misra, A. K. 2014 Climate change and challenges of water and food security. *International Journal of Sustainable Built Environment* **3** (1), 153–165. https://doi.org/10.1016/j.ijsbe.2014.04.006.
Mnisi, N. 2020 *Water Scarcity in South Africa: A Result of Physical or Economic Factors?* Helen Suzman Foundation (HSF). Available from: https://hsf.org.za/publications/hsf-briefs/water-scarcity-in-south-africa-a-result-of-physical-or-economic-factors (accessed: 23/03/21).
Moche, T. 2021 TIMELINE: Service delivery protests since the last LGE in 2016. *SABCNews* (2 October). Available from: https://www.sabcnews.com/sabcnews/timeline-service-delivery-protests-since-the-last-lge-in-2016/ (accessed: 25/11/23).
Mocwagae, K. 2020 *Exploring the QwaQwa Water Crisis for Effective Planning in Post-Apartheid South Africa*. PhD thesis, University of the Free State, Bloemfontein, South Africa.
Moloi, T. 2015 History of Qwaqwa. *news24* (14 October). Available from: https://www.news24.com/news24/SouthAfrica/Local/Express-News/History-of-Qwaqwa-20151013 (accessed: 25/02/21).
Mtengwane, G. 2020 QwaQwa water crisis is still at its worst as media spotlight shifts. *City Press* (11 March). Available from: https://www.news24.com/citypress/news/qwaqwa-water-crisis-is-still-at-its-worst-as-media-spotlight-shifts-20200311 (accessed: 27/08/22).

Mthiyane, S. 2022 Disaster management team assessing damage after heavy rain in Free State. SABCNews (17 January). Available from: https://www.sabcnews.com/sabcnews/disaster-management-team-assessing-damage-after-heavy-rain-in-free-state/ (accessed: 22/03/22).
Mukasa, J., Olaka, L. & Yahya Said, M. 2020 Drought and households' adaptive capacity to water scarcity in Kasali, Uganda. *Journal of Water and Climate Change* **11** (S1), 217–232.
Mukwada, G., 2022 Current crisis and future woes: the case of climate change in the Drakensberg mountains region of Southern Africa and its socio-economic impacts in the region. In: *Mountain Landscapes in Transition: Effects of Land Use and Climate Change* (Schickhoff, U., Singh, R. B. & Mal, S., eds). Springer, Cham, Switzerland, pp. 449–467. https://doi.org/10.1007/978-3-030-70238-0_19.
Mukwada, G. & Mutana, S., 2023 Surviving the limits imposed by a changing climate: the case of urban drought and water supply sustainability in Phuthaditjhaba. In: *Sustainable Futures in Southern Africa's Mountains: Multiple Perspectives on an Emerging City* (In: Membretti, A., Taylor, S. J. & Delves, J. L., eds.), Springer, Cham, Switzerland, pp. 75–89. https://doi.org/10.1007/978-3-031-15773-8_6.
Muyambo, F., Jordaan, A. J. & Bahta, Y. T. 2017 Assessing social vulnerability to drought in South Africa: policy implication for drought risk reduction. *Jàmbá: Journal of Disaster Risk Studies* **9** (1), a326.
Muyambo, F., Belle, J., Nyam, Y. S. & Orimoloye, I. R. 2023 Climate-change-induced weather events and implications for urban water resource management in the Free State Province of South Africa. *Environmental Management* **71**, 40–54.
Ndalamba, K. K. 2019 An exploration into the problematic public policies and the leadership challenge for socio-economic transformation in South Africa. *International Journal of Excellence in Government* **1** (1), 37–47.
NDMC (National Disaster Management Centre) 2017 *Stakeholder Management and Communication*. Department of Cooperative Governance and Traditional Affairs, Pretoria, South Africa.
Ngwane, T. 2011 *Ideology and Agency in Protest Politics: Service Delivery Struggles in Post-Apartheid South Africa*. Master's thesis, University of KwaZulu-Natal, Durban, South Africa.
Nishimwe-Niyimbanira, R. 2016 *A Multidimensional Analysis of Poverty in a Former South African Homeland*. PhD thesis, North-west University, Vanderbijlpark, South Africa.
Nyaka, L. 2022 Map makes strides to quell water crisis. *The Guard* (21 July). https://theguard.co.za/map-makes-strides-to-quell-water-crisis (accessed: 05/12/23).
Nyam, Y. S., Kotir, J. H., Jordaan, A. J., Ogundeji, A. A. & Turton, A. R. 2020 Drivers of change in sustainable water management and agricultural development in South Africa: a participatory approach. *Sustainable Water Resources Management* **6**, 62. https://doi.org/10.1007/s40899-020-00420-9.
OECD (Organisation for Economic Cooperation and Development) 2021 *Water Governance in African Cities.* OECD Studies on Water, OECD Publishing, Paris, France. https://doi.org/10.1787/19effb77-en.
Otto, I. M., Reckien, D., Reyer, C. P. O., Marcus, R., Le Masson, V., Jones, L., Norton, A. & Serdeczny, O. 2017 Social vulnerability to climate change: a review of concepts and evidence. *Regional Environmental Change* **17** (6), 1651–1662. https://doi.org/10.1007/s10113-017-1105-9.
Palmer, I., Parnell, S. & Moodley, N. 2017 *Building a Capable State: Service Delivery in Post-Apartheid South Africa*. Zed Books Ltd, London, UK.
Parkin, S. & Kimergård, A. 2022 A critical analysis of respondent quotes used as titles of qualitative research papers that are published in peer-reviewed journals. *Accountability in Research* **29** (2), 109–132. https://doi.org/10.1080/08989621.2021.1901224.
Piya, L., Maharjan, K. L. & Joshi, N. P. 2012 Vulnerability of rural households to climate change and extremes: analysis of Chepang households in the Mid-Hills of Nepal. In: *International Association of Agricultural Economists (IAAE) Triennial Conference*, 18–24 August, Foz do Iguaçu, Brazil.
PMG (Parliamentary Monitoring Group) 2020 Question NW1571 to the Minister of Human Settlements, Water and Sanitation. Available from: https://pmg.org.za/committee-question/14321/ (accessed: 13/04/21).
Pohl, B., Macron, C. & Monerie, P.-A. 2017 Fewer rainy days and more extreme rainfall by the end of the century in Southern Africa. *Scientific Reports* **7**, 46466.
Radebe, B. 2020 'QwaQwa water crises blamed on infrastructure' SABC News 1 Feb. Available from: https://www.sabcnews.com/sabcnews/qwaqwa-water-crises-blamed-on-poor-infrastructure/ [Accessed: 27/08/22].
RSA (Republic of South Africa) 2011 *White Paper on the National Climate Change Response*. Notice No. 757 of 2011, Government Gazette No. 34695 (19 October), South Africa.
RSA (Republic of South Africa) 2015 *Disaster Management Amendment Act, 2015 (No. 16 of 2015)*. Government Gazette, No. 39520 (15 December), South Africa.
SAHO (South Africa History Online) 2019 The Homelands. Available from: https://www.sahistory.org.za/article/homelands (accessed: 06/12/22).
Scholes, R. & Engelbrecht, F. 2021 *Climate Impacts in Southern Africa during the 21st Century.* Report for the Centre for Environmental Rights, Global Change Institute, University of the Witwatersrand, Johannesburg, South Africa. Available from: https://cer.org.za/wp-content/uploads/2021/09/Climate-impacts-in-South-Africa_Final_September_2021.FINAL_.pdf (accessed: 13/11/22).
Schreiner, B. 2013 Viewpoint – Why has the South African National Water Act been so difficult to implement? *Water Alternatives* **6** (2), 239–245.
Setena, T. 2023 Water levels decrease significantly in Qwaqwa's two major dams. *news24* (4 October). Available from: https://www.news24.com/news24/community-newspaper/express-news/water-levels-decrease-significantly-in-qwaqwas-two-major-dams-20231004 (accessed: 04/12/23).

Shaidi, E. W. 2013 *Investigation into Causes of Service Delivery Protests in Municipalities: A Case Study of Nelson Mandela Bay Municipality*. PhD thesis, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa.

Sharma, J., Murthy, I. K., Esteves, T., Negi, P., Sushma, S., Dasgupta, S., Barua, A., Bala, G. & Ravindranath, N. H. 2018 *Climate Vulnerability and Risk Assessment: Framework, Methods and Guidelines*. Indian Institute of Science, Bengaluru, India. Available from: https://dste.py.gov.in/PCCC/pdf/Reports/DST/DST2.pdf (accessed: 12/07/23).

Stats SA. (Statistics South Africa) 2012 Maluti-a-Phofung Local Municipality Department of Statistics South Africa, Republic of South Africa. Available from: https://www.statssa.gov.za/?page_id=993&id=maluti-a-phofung-municipality.

Stofferahn, C. W. 2012 Community capitals and disaster recovery: Northwood ND recovers from an EF 4 tornado. *Community Development* **43** (5), 581–598. doi:10.1080/15575330.2012.732591.

Sutton, J. 2010 Strengthening community resiliency: new media, social networks and the critical civic infrastructure. In: *20th World Conference on Disaster Management*, 20–23 June, Toronto, ON, Canada. Available from: http://www.jeannettesutton.com/uploads/Strengthening_Community_Resiliency.pdf (accessed: 24/06/22).

Tapia, C., Abajo, B., Feliu, E., Mendizabal, M., Martínez, J. A., Fernández, J. G., Laburu, T. & Lejarazu, A. 2017 Profiling urban vulnerabilities to climate change: an indicator-based vulnerability assessment for European cities. *Ecological Indicators* **78**, 142–155.

TMDM (Thabo Mofutsanyana District Municipality) 2021 *Disaster Risk Assessment 2020/21*. TMDM, South Africa.

UN-ISDR (International Strategy for Disaster Reduction) 2015 *The Sendai Framework for Disaster Risk Reduction 2015-2030*. United Nations International Strategy for Disaster Reduction (UNISDR), Geneva, Switzerland.

UN-Water 2021 *Summary Progress Update 2021: SDG 6 – Water and Sanitation for All*. UN-Water, Geneva, Switzerland. Available from: https://www.unwater.org/publications/summary-progress-update-2021-sdg-6-water-and-sanitation-for-all/ (accessed: 31/08/21).

Van der Bank, M. & Karsten, J. 2020 Climate change and South Africa: a critical analysis of the *Earthlife Africa Johannesburg and Another v Minister of Energy and Others 65662/16 (2017)* case and the drive for concrete climate practices. *Air, Soil and Water Research* **13**. doi:10.1177/1178622119885372.

WEF (World Economic Forum) 2019 *The Global Risks Report 2019*, 14th edn. World Economic Forum, Geneva, Switzerland.

Wu, T. 2021 Quantifying coastal flood vulnerability for climate adaptation policy using principal component analysis. *Ecological Indicators* **129**, 108006.

Yadava, R. N. & Sinha, B. 2020 Vulnerability assessment of forest fringe villages of Madhya Pradesh, India for planning adaptation strategies. *Sustainability* **12**, 1253. doi:10.3390/su12031253.

Yu, J., Castellani, K., Forysinski, K., Gustafson, P., Lu, J., Peterson, E., Tran, M., Yao, A., Zhao, J. & Brauer, M. 2021 Geospatial indicators of exposure, sensitivity, and adaptive capacity to assess neighbourhood variation in vulnerability to climate change-related health hazards. *Environmental Health* **20**, 31. https://doi.org/10.1186/s12940-021-00708-z.

Zugravu-Soilita, N., Kafrouni, R., Bouard, S. & Apithy, L. 2021 Do cultural capital and social capital matter for economic performance? An empirical investigation of tribal agriculture in New Caledonia. *Ecological Economics* **182**, 106933. http://dx.doi.org/10.1016/j.ecolecon.2020.106933.

Zunckel, K., 2010 Maloti-Drakensberg Transfrontier Conservation and Development Programme: a South African perspective. In: *Connectivity Conservation Management: A Global Guide* (Worboys, G. L., Francis, W. L. & Lockwood, M., eds), Earthscan, London, UK, pp. 77–85.

First received 5 July 2023; accepted in revised form 9 May 2024. Available online 24 May 2024