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Climate change extreme events and exposure of local communities to water scarcity: a case study of QwaQwa in South Africa

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ABSTRACT

The exposure of local communities to multiple climate change-related events is on the rise across the globe. Despite extensive disaster research on climate change, exposure and vulnerability, few studies have focused on the exposure of local communities to multiple climate change-related events. For over a decade QwaQwa, in South Africa, has experienced persistent water crises which have been attributed to climate change and socio-economic drivers. However, there is a lack of understanding of the risk drivers to provide a solid basis for disaster risk reduction and resilience-building. This paper; therefore, aims to conduct analyses of hazards and exposure as part of risk analysis of climate change-related events; notably drought, flooding, wildfires, and water scarcity in QwaQwa. Quantitative and qualitative data sources included key informant interviews, household surveys, and field observations. The study employed the indicator method to analyse both the hazard and exposure. Qualitative data were analysed using thematic analysis. On a five-point scale, the findings showed high indices of multiple hazards (3.6) and exposure (3.2). Analysis results were validated at a stakeholders' workshop. The study recommends efficiency in implementing risk-sensitive land use plans, improving early warning systems, and the use of unmanned aerial vehicles to mitigate disaster risks.

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KEYWORDS

Climate change-related events; exposure; hazard; resilience; water scarcity

Highlights

- The high multi-hazard index indicates a high incidence of multiple climate change-related events in QwaQwa
- Water scarcity poses the greatest threat to critical elements in QwaQwa
- Water scarcity was largely attributed to socio-economic factors more than climate change

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1. Introduction

Africa, Europe, the Americas, Oceania, and Asia are all forecasted to witness heightened occurrences and severity of climate-related events, including droughts, floods, storms, wildfires, and extreme temperatures. Asia currently holds the highest count of extreme weather events, tallying 3454 between 1970 and 2019 (WMO, 2021a; WMO, 2021b). Within this timeframe, Africa accounted for 15% of weather, water, and climate-related disasters (WMO, 2021b). Each passing year seems to mark new records of extreme weather events. For instance, in the summer of 2023, there were reports of scorching temperatures in Thailand, Mexico, Hawaii, Vietnam, and Laos, floods in China and Libya, devastating wildfires in Canada, Greece, and Italy, as well as a prolonged three-year drought in the Horn of Africa (Kong, 2023).

Despite Africa's relatively low greenhouse gas emissions, it ranks among the most vulnerable continents to climate change due to its geographic positioning and limited adaptive capacity (Africa Development Bank (ADB), 2022; World Bank, 2021). Climate change is anticipated to notably affect the availability and quality of sustainable surface and groundwater resources, particularly in arid and semi-arid regions, including certain areas in Southern Africa (Kapuka & Hlasny, 2021; UN-Water, 2021). This vulnerability to climate impacts is compounded by non-climatic stressors stemming from socio-economic and political challenges that hinder access to essential services, potentially amplifying disaster risks (Sharma et al., 2018).

South Africa, a southern African country, is considered an upper middle-income country; but is not exempt from negative climate change impacts and increased disaster risks (World Bank, 2021). World Bank (2021) reports that between 1900 and 2017 South Africa suffered more than 100 disasters resulting in 2200 fatalities, 21 million people affected and about USD4.5 billion in damages. Previous studies show recurrent droughts, flooding, wildfires, extreme temperatures, and water scarcity as major climate-related events that affect the country (Melore & Nel, 2020; Mukwada & Mutana, 2023).

QwaQwa, located in South Africa's Free State Province, has grappled with recurring water scarcity for over a decade, primarily linked to climate change-induced factors like droughts, floods, wildfires, and extreme temperatures (Melore & Nel, 2020). The persistent drought, spanning more than five years since 2016, has been particularly impactful (Macupe, 2020; Melore & Nel, 2020). Flash floods, often occurring during heavy rainfall from January to March, lead to property and infrastructure damage, livestock loss, water contamination, and, at times, fatalities (Jones, 2021; Mdakane, 2022; Mdlalane, 2022). Notably, media reports from March 2022 highlighted flash floods that claimed three lives, including two children (Mdlalane, 2022). Wildfires in the region have inflicted significant harm on grazing lands, livestock, and humans, resulting in injuries and fatalities (Sgqolana, 2021; Tlhakudi, 2019). Yet, some analysts also attribute QwaQwa's water scarcity to socio-economic and political factors, such as population growth, rapid urbanisation, inadequate public resource management, and aging infrastructure (Macupe, 2020; Mocwagae, 2020).

Despite the increasing likelihood of multiple risks of climate change, current research on DRR and resilience largely draws its information primarily from single hazard risk assessment outputs which could compromise the relevance of ensuing risk reduction priorities (IPCC, 2022). Thus, there is still a scarcity of studies that consider the multiple and

systemic effects of hazards (Gallina et al., 2020; Marzocchi et al., 2012). Current and future challenges in DRR require the adoption of a systemic character of risk; a recent concept referring to an interaction between natural and human-related hazards where natural hazards trigger a domino effect of a succession of societal and technical impacts (Austrian Institute for Disaster Resilience (AIDR), 2021). Therefore, grasping all the dimensions of multiple and systemic risks is pivotal in building or improving resilience and planning DRR strategies.

To fill that gap, this paper identified and examined four main climate-related events in the study area; droughts, floods, wildfires, and water scarcity and determined the exposure of critical elements to these hazards; thus, laying the foundation for comprehensive risk analysis and drafting disaster risk reduction (DRR) strategies for the turbulent QwaQwa community. A multi-hazard risk analysis is; therefore, important because it will explore the dominant risk factors and the findings will inform how the potential disaster risk in QwaQwa may be ameliorated.

2. Study area

QwaQwa, also known as Phuthaditjhaba, is a town and headquarters of both the Thabo Mofutsanyana District Municipality and the Maluti-a-Phofung Local Municipality (MAP) in the eastern Free State Province of South Africa. MAP is enclosed by Kwa-Zulu Natal on the southeast, Lesotho on the southwest, and by, mostly, commercial farms on the northwest and northeast (Koatla, 2012; Municipalities of South Africa, 2022). QwaQwa forms part of the scenic landscape of the Drakensberg and the Maluti mountains in the eastern part of the Free State province of South Africa. The town is densely populated with 56 251 inhabitants, an annual growth rate of about 0.87%, and a population density of 2 288.75 per km² (Stats SA, 2012). It hosts approximately 80% of the local municipality's population of which the majority (98.09%) are blacks (Moloi, 2015; Stats SA, 2012). Fika-Patso Dam on the Namahadi River, with a capacity of 26.3 million cubic metres (Orange-Senqu River Commission (ORASECOM), 2013), provides most of the household water. Poor basic service provision has been cause for numerous protests in QwaQwa (Mohapi, 2022). Basic infrastructure like roads and drainage systems are in poor condition or non-existent (Melore, 2017). Macupe (2020) and Melore and Nel (2020) argue that QwaQwa is regarded to be so poor that 61% of its population depends on government grants (Stats SA, 2012) (Figure 1).

According to previous research, QwaQwa experiences climate change-related events such as droughts, wildfires, extreme temperatures, flooding, and rock falls (Melore & Nel, 2020). These events, especially drought, have been associated with water problems that have affected the area for more than a decade, affecting the wellbeing of the residents (Macupe, 2020; Melore & Nel, 2020). QwaQwa was selected for this study due to its susceptibility to both weather events and associated water challenges that affect livelihoods and the community's well-being (Manyama, 2020; Melore & Nel, 2020).

3. Material and methods

A mixed method approach was used by integrating qualitative and quantitative methods (Creswell & Creswell, 2018; Gallina et al., 2020) through the use of the convergent parallel

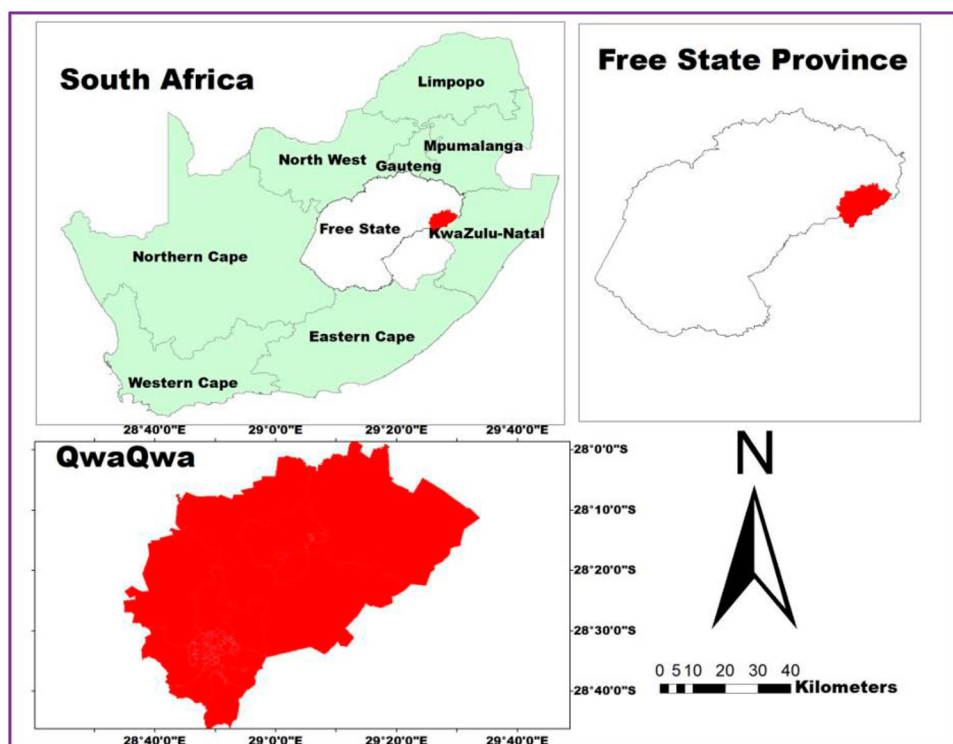


Figure 1. QwaQwa map showing South Africa and the Free State province (Source: Authors).

design. The integration of the two methods of inquiry enhanced the understanding of the research problem and yielded a more detailed and balanced conclusion. The preliminary field trip was undertaken from 13 to 16 December 2021 which provided an opportunity for the researchers to familiarise with the study area and gain an understanding of the area's natural, land use, infrastructural, and socio-economic features. Field notes and photographs were taken to capture and keep a record of the field data (Genkova, 2020).

3.1 Sampling

The study targeted all the thirty wards in QwaQwa; however, a total of thirty-three villages from seventeen wards were selected using the simple random sampling method because it was easy, practical, and gave every ward a chance to be selected (Leedy & Ormord 2021). Through purposive sampling 340 household representatives were deliberately selected to participate in the household survey based on the assumption that they were well-informed about the household and community's activities and challenges in order to provide more comprehensive and representative information (Leedy & Ormord 2021). Selected participants were at least eighteen years old and had resided in QwaQwa for a minimum of five years at the time of data collection. A deliberate attempt was made to include the ward councillors in the sample since they represented their wards for development issues and has a wide understanding of the prevailing challenges.

The selection of key informants followed the South Africa National Disaster Management Centre (NDMC) guidelines on Disaster Risk Management key stakeholders (NDMC, 2017, 2016). Hence, nine key stakeholders were identified and selected using a purposive sampling method. They were selected from organisations and government departments whose functions related to disaster risk management (DRM) with a particular focus on climate change and water resource management; such as disaster and risk management, agriculture, small businesses, environmental affairs, water provision, municipal and traditional authority. All study participants gave their informed consent. Written approval to conduct research was obtained from the municipality mayor, the *Bakoena* royal kingdom, and an ethical clearance certificate from the General/Human Research Ethics Committee (GHREC) of the University of the Free State.

3.2 Data collection

The study used both secondary and primary sources of information to understand and assess climate-related problems facing QwaQwa. Observations, household questionnaires with the 340 household participants, detailed interviews with nine key informants, and consultation with relevant experts complemented literature review to inform the identification of hazard and exposure indicators. Generic factors that characterise drought, floods, wild fires, and water scarcity and those that characterise exposure were selected from primary and secondary data as indicators for the two risk components. Where face-to-face interviews were not possible with the key stakeholders; due to COVID-19 [*an infectious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)*] World Health Organization (WHO) protocols, (WHO, 2023) the interview questionnaires were emailed to the respondents and telephonic follow-ups made. The interview guide was detailed to enable the gathering of enough information for the study. Data collection was conducted from April to August 2022.

3.3 Data analysis

The multi-hazard analysis for this study adopted a more-than-one-hazard approach and followed the NDMC hazard analysis guidelines using an indicator method (NDMC, 2016). Indicators are defined as constructs that quantify and simplify the information that is complex so that its significance is clearer and for more effective communication in risk reduction initiatives (Hammond et al., 1995; Ivčević et al., 2019). The indicator method involved the identification, analysis, and prioritisation of hazard components (NDMC, 2016) in order to understand their level of risk. Indicators were useful in comparing and aggregating different hazards occurring in the same location (Kappes et al., 2012). This method was preferred because it provided a holistic view of the climate change impacts in question by factoring in the characteristics of each hazard (Kappes et al., 2012; Marzocchi et al., 2012). It also addressed limitations in local data availability for QwaQwa by involving the local community and key stakeholders in the generation of data through interviews and surveys (NDMC, 2016). Additionally, it is simple, both to execute and for the end-users to understand and apply, but at the same time it takes '*account of the legislative framework, international best practice, the complexities of data, theory and disaster management administrative environment.*' (NDMC, 2016, p. 11).

3.3.1 Multi-hazard analysis

Recurrent climate-related hazards that were considered for this study included droughts, floods, wildfires, and water scarcity. To address the challenge of different hazard characteristics which often complicate multi-hazard analysis (Kappes et al., 2012; UN-ISDR, 2004), this study standardised the commonly shared indicators recommended by NDMC (2016) as shown in Table 1.

The next step was rating the hazards on a five-point Likert scale. The higher the score, the greater the threat of the hazard to human and ecological systems. Another important step in constructing indicators was weighting to show the importance of each indicator or composite indicators. While there are several methods of weighting like equal weighting, expert judgement and statistically determined weighting, there is no standard method (Papathoma-Köhle et al., 2019; Talukder et al., 2017). This study used equal weighting because of its simplicity and also the fact that it values each indicator equally. Using Excel, the average hazard score of each indicator was summed and a hazard index was obtained by dividing the total score by the number of indicators. After the individual hazard indices were obtained, the multi-hazard index was calculated using a formula that was adapted from Jordaan (2012) as shown in Equation (1).

$$MH = \sum_{i=1}^4 w_i^h mh_i^{(h)} \quad (1)$$

$$MH f(w_1^h mh_1^h, w_2^h mh_2^h, w_3^h mh_3^h, w_4^h mh_4^h)$$

Where: mh_1^h = drought hazard

mh_2^h = flood hazard

mh_3^h = wildfire hazard

mh_4^h = water scarcity hazard

And,

w_1^h = equal weighting factor for all variables

Table 1. Multiple hazard indicators.

Hazards				
Indicator	Description	Hypothesised relationship	References	Data source
Probability of occurrence	Likelihood that it will occur	The greater the probability the greater the threat	NDMC, 2016; OECD, 2012	KII
Area covered	The area affected by the hazard	The bigger the area covered the greater the threat	NDMC, 2016; Kappes et al., 2012; OECD, 2012	KII
Frequency	The regularity of the hazard event	The greater the frequency the greater the threat	NDMC, 2016; Kappes et al., 2012; OECD, 2012	KII
Intensity	The severity of the impact of the hazard	The higher the intensity the greater the threat	NDMC, 2016; Kappes et al., 2012; OECD, 2012	KII
Predictability	Certainty in predicting the occurrence of the hazard	The more accurate the predictability the less the threat	NDMC, 2016	KII

Key* – KII – Key Informant Interview.

3.3.2 Exposure analysis of selected critical elements in QwaQwa

The next step after multi-hazard analysis was exposure analysis of critical assets to the four climate-related hazards; namely drought, floods, wildfires, and water scarcity. In disaster and climate risk management, exposure analysis is defined as the identification of elements that are open to damage, injury, or death from climate change-related events (Organisation for Economic Cooperation and Development (OECD), 2012; United Nations Development Programme (UNDP), 2010). The analysis included the identification of critical elements open to harm from weather events and water scarcity. To capture and measure the exposure to the four hazards; drought, water scarcity, flooding, and wildfires, the following indicators representing elements at risk (Table 2) were selected based on literature, observation, and consultation with experts.

The next step after the selection of indicators was exposure prioritisation and scoring. The critical elements at risk were scored using the indicators on a five-point Likert scale. The higher the score, the greater the exposure to the threat of climate impacts. The scores of each indicator were added for each critical element analysed and an average score for each indicator was calculated using Excel. The exposure indicators were sorted, or ranked, from the highest to the lowest, using exposure analysis numerical values. Then the scores of all four exposure component indicators were added for each hazard analysed. After summing up, the total score was divided by the number of indicators to obtain the exposure index for each hazard. Calculating the overall exposure index(EI) is the final step of exposure analysis. The EI was calculated using Equation (2) adapted from Jordaan (2012).

Exp = \sum_{i=1}^4 w_i^{exp} Exp_i^{(exp)} \tag{2}

Exp f(w_1^{exp} Exp_1^{exp}, w_2^{exp} Exp_2^{exp}, w_3^{exp} Exp_3^{exp}, w_4^{exp} Exp_4^{exp})

Where: Exp_1^{exp} = Exposed population
 Exp_2^{exp} = Exposed structures
 Exp_3^{exp} = Exposed land use
 Exp_4^{exp} = Exposed water source
And,
 w_1^{exp} = equal weighting factor for all variables

Table 2. Exposure Indicators and their description.

Exposure component	Indicator	Description	Hypothesised relationship	References
Population	Population in a high-risk area	Proportion of population living in high-risk areas	The greater the population living in high-risk area the greater the exposure	Birkmann et al., 2013
Structures	Shelter in a high-risk area	Proportion of shelter in hazard prone areas	The more shelter in flood prone areas the greater the exposure	Birkmann et al., 2013
Land	Farming land in hazard prone area	Proportion of farming land in hazard prone areas	The greater the farming land in hazard prone areas the greater the exposure to flooding	Birkmann et al., 2013
Water sources	Surface water sources in high-risk environments	Proportion of surface water sources in high-risk environment	The greater the surrounding danger the greater the exposure	Jordaan, 2012

3.3.3 Qualitative data analysis

For the qualitative responses from both the key informant interviews and household survey open-ended questions, the study employed a thematic analysis in accordance with Braun and Clarke (2019), Clarke and Braun (2013) Braun and Clarke (2006). To become acquainted with the data, the interview transcripts and survey scripts were thus read multiple times and some general themes and codes were identified such as 'climate change', 'drought', and 'corruption'. Then, codes and themes are relevant to our research question. These codes and themes emerged from the collected data. Following that, we revisited the themes and codes to verify they represented the collected data. Thereafter, the themes were finalised before reporting the findings. It is noteworthy that findings from the analyses were confirmed and validated during a stakeholder workshop which was attended by 23 stakeholders in QwaQwa on the 24th of November 2022.

4. Results

4.1 Multi-hazard scoring, rating, and prioritisation

Table 3 shows the hazard indicators that were rated on a five-point Likert scale. The higher the score, the greater the threat of the hazard to human and ecological systems, and the lower the score, the lesser the threat.

The results in Table 3 show high ratings for three climate change-related events; drought (3.7), floods (3.5), and wildfires (3). The most dominant climate-change-related events; according to this analysis result, was water scarcity (4.1). Each indicator had the highest score for water scarcity. It's interesting; though, that although water scarcity has the highest probability and frequency, it was rated the most unpredictable event in QwaQwa (see Table 3). The results also show that the overall computed multi-hazard index (MHI) for the four hazards was high (3.6). This is the overall index for the multiple climate change-related events; after combining all the four hazards in the analysis.

4.2 Exposure scoring, rating, and prioritisation

Prioritisation and scoring of critical elements were done on a five-point Likert scale as explained in 3.3.2. Table 4 shows that landuse (3.6) was rated the most exposed to climate change impacts. In that regard, crop land and grazing and grazing land were

Table 3. Multiple hazard scoring and rating.

Hazard	Probability	Area covered	Frequency	Intensity	Unpredictability	Total score	Hazard index	Hazard rating
Drought	4.1	3.9	3.9	4	2.4	18.3	3.7	High
Floods	3.9	2.9	4.4	3.7	2.4	17.3	3.5	High
Wildfires	3.3	2.3	4.2	3.2	1.9	14.9	3	High
Water scarcity	4.2	4.1	4.6	4.1	3.4	20.4	4.1	Very High
Total hazard score =							14.3	
Multi-hazard index: Total score ÷ no. of hazards $14.3 \div 4 = 3.6$								High

Key: Very low: 0–0.9 Low: 1–1.9 Medium: 2–2.9 High: 3–3.9 Very high: 4–5.

the most exposed elements to climate change events (both scored 3.78). Of particular interest as well as the exposure of populations (3.4) to climate change impacts, which was rated second to landuse. Among the different population groups within this composite indicator were people living with disabilities (PLWD) and the elderly who scored 3.55 and 3.5, respectively. Notably, the most threatening event, according to results in Table 5, was water scarcity.

The exposure ratings for the population, structures, and land uses are all 'high' but 'moderate' for water sources as they can only be exposed to the other three hazards as shown in Table 5. The table mainly shows the overall computed exposure index of critical elements to drought, floods, wildfires, and water scarcity, 3.2. This was the overall exposure index for all critical elements to climate-related events under consideration in QwaQwa and it falls under the 'high' category.

Table 4. Calculation of scores for individual exposure indicators.

Exposure component	Indicator	Drought	Flood	Wildfire	Water scarcity	Total score	Indicator score	Exposure component score
Population/ people	Men	3.7	3.0	3.0	3.8	13.5	3.37	3.4
	Women	3.8	3.0	2.4	4.1	13.3	3.33	
	Children (<15 years)	3.6	3.2	2.4	3.6	12.8	3.2	
	People living with disability	3.9	3.6	2.6	3.9	14	3.5	
	Elderly (>65 years)	3.9	3.2	2.8	4.3	14.2	3.55	
	Female-headed households	3.4	3.0	2.6	4.4	13.4	3.35	
Structures	Informal settlements	3.6	3.6	3.2	4.0	14.4	3.6	3.2
	Commercial buildings	2.9	2.8	1.7	3.7	11.1	2.78	
	School buildings	3.8	3.2	2.3	4.4	13.7	3.43	
	Health facilities	3.7	3.2	1.9	4.6	13.4	3.35	
	Road infrastructure	2.8	3.9	2.7	3.0	12.4	3.1	
	Powerlines	2.9	3.3	3.4	3.0	12.6	3.15	
	Water pipelines	3.1	3.9	2.0	3.9	12.9	3.23	
	Telephone lines	2.1	2.8	3.4	2.6	10.9	2.73	
	Crop land	3.9	3.7	3.2	4.3	15.1	3.78	
	Grazing land	3.8	3.6	3.3	4.4	15.1	3.78	
Land	Nature conservative	3.8	3.7	3.6	3.9	15	3.75	3.6
	Urban green spaces	3.6	3.4	2.7	3.9	13.6	3.4	
	Recreational land	3.4	3.3	2.6	3.7	13	3.25	
	Rivers	3.7	3.1	1.4		8.2	2.73	
	Dams	3.7	3.1	1.4		8.2	2.73	
	Boreholes	2.7	2.2	1.4		6.3	2.1	
Water sources	Wetlands	3.2	2.6	1.9		7.7	2.57	2.6
	Tap water	3.4	3.0	1.6		8	2.67	
Total Score		82.4	77.4	59.5	73.5			
Exposure to specific hazard (Total Score ÷ No. of variables)		3.4	3.2	2.5	3.9			

Key: Very low: 0–0.9 Low: 1–1.9 Medium: 2–2.9 High: 3–3.9 Very high: 4–5.

Table 5. Calculation of exposure scores and rating.

Critical element (CI) (composite indicator)	Hazards				Average exposure per element	Exposure rating
	Drought	Flood	Wildfire	Water scarcity		
Population/people	3.7	3.2	2.6	4	3.4	High
Structures	3.1	3.3	2.6	3.6	3.2	High
Land uses	3.7	3.5	3.1	4	3.6	High
Water sources	3.3	2.8	1.6		2.6	Moderate
Total exposure score					12.8	
Overall average exposure of elements (Total ÷ no. of CI) = 12.8/4					3.2	High

Key: Very low: 0–0.9 Low: 1–1.9 Moderate: 2–2.9 High: 3–3.9 Very high: 4–5.

4.3 Thematic analysis results

Results shown in Table 6 indicate that while some participants viewed climate change as a real problem, some indicated that there was no climate change. However, for those who acknowledged climate change as a real challenge, it had adverse effects on socio-ecological systems, especially water resources. While droughts and floods were mentioned as being responsible for water shortages in QwaQwa, drought was pointed out as the major cause. On the contrary, some participants argued that non-climate factors were responsible for QwaQwa's problems, especially water scarcity; such as corruption, poor resource management, and misuse of water by the residents.

4.4 Observed water leakage

The results also indicated that both the communities and local authorities were reluctant to attend to leakages. Figure 2 shows water leakages that were observed along some streets in QwaQwa.

Table 6. Thematic analysis results.

Participant	Theme	Statement
KI 1	Reality of climate change	<i>'climate change is real, and it is one of our future threats. The municipality is already subjected to a high-risk climate with a low conversion of rainfall to runoff and very high year-to-year variability'</i>
P 16		<i>'no climate change'</i>
KI 2	Effects of climate change in QwaQwa	<i>'It [climate change] has caused reduction in water availability for all the sectors, livelihoods are affected, greatly, decreased dam levels, depletion of ground water sources'</i>
KI 6	Causes of water scarcity in QwaQwa	<i>'[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'</i>
P 125		<i>'changing climate, making dry areas drier and precipitation becoming more variable and extreme'</i>
P 82		<i>'drought [is] the major cause'</i>
P 118	Non-climate causes of water scarcity in QwaQwa	<i>'leadership is corrupt. There is enough water in QwaQwa but we don't have access to it. Dams have water'</i>
P 231		<i>'mismanagement of resources and corruption. The water is abundant but it's not getting to the people.'</i>
P 141		<i>that 'mostly now water is pumped with electricity generation and we lack the equipment and surely there is high population and water become insufficient for everyone'</i>
P293		<i>'waste water and leave taps running'</i>
P213		<i>'households do not pay for water. Water is wasted because many people leave their taps open most of the time'.</i>

5. Discussion

The results showing an overall high MHI (3.6) for all analysed hazards confirm the prevalence of climate change-related events in QwaQwa as reported in previous studies (Melore & Nel, 2020; Mukwada & Mutana, 2023). The very high rating for water scarcity (4.1) shows why the issue has contributed to several violent protests and has received remarkable media and academic attention in recent years (Melore & Nel, 2020; Mocwagae & Mphambukeli, 2023; Mohapi, 2022). All indicators were rated 'very high' for water scarcity; the probability of having no access to clean and safe water, the area covered, the intensity and the frequency of that event happening were all very high; yet it was also very difficult to predict it. This unpredictability suggests the lack of access to early warning systems or real-time information about imminent events and it affects the people's capacity to prepare for such risks. This finding corroborates Manyama (2020) who found that QwaQwa residents lacked adequate early warning systems to prepare for drought and water scarcity. People can better prepare for imminent climate-related events when they can predict or have access to information (Manyama, 2020).



Figure 2. Water leakage flowing down the streets of Namahadi area in QwaQwa, South Africa (Source: authors).

Drought, flooding, wildfires, and water scarcity are all interrelated and are of critical concern in the area and other regions of South Africa as well as the whole continent of Africa (Mukasa et al., 2020; Mukwada & Mutana, 2023; Schreiner et al., 2018). Drought; however emerged as the second most dominant hazard in this study. Most of the participants confirmed the multi-hazard results that drought was the most common, recurrent, and destructive weather event in both rural and urban QwaQwa. Flooding and wildfires were considered less frequent than drought. Consequently, some of the participants attributed the problem of water quantity and quality to drought impacts. Drought also affected agricultural activities such as crop farming and livestock production.

This finding corroborates previous studies about the high incidence of climate change-related events and attributed water challenges in QwaQwa to recurrent droughts and other climate change impacts (Melore, 2017; Melore & Nel, 2020). However, some household survey participants argued that there was '*no climate change*'. According to the participants, non-climate-related drivers of water scarcity in the area included corruption (closely associated with mismanagement of public resources), population growth, filling job positions with unqualified personnel, non-payment of electricity and water which affects water supply, political battles, inadequate water infrastructure and lack of its maintenance are some of the leading causes of water problems in QwaQwa. Also, the intermittent supply of electricity was affecting water delivery, according to some of the participants. It is noteworthy that the results show corruption as a major driver of water scarcity in QwaQwa which supports Sleet (2019) findings that corruption subverts DRR and resilience-building efforts. This finding also confirms previous research regarding climate change-related impacts on water resources in the area (Mocwagae, 2020; Muyambo et al., 2022).

Interestingly, some of the household survey participants attributed the water scarcity in QwaQwa to household mismanagement of the water resource through overusage of water and negligence in leaving tap water running without being used, non-payment of water services were all honest responses from the participants when asked to indicate the major factors contributing to the water crisis in QwaQwa. These findings corroborate previous findings by Maphela and Cloete (2020), Wilkinson et al. (2018), and Gouws et al. (2010) that the general perception that water is free to low-income households in South Africa subsequently leads to wastage by over usage and leaving water taps running or leaking and non-payment of water where they exceed the free allocated quota by the government. Arguably, although citizens have a constitutional right to free basic services, it is also every citizen's constitutional responsibility to promptly pay for rendered services, wherever necessary (Maphela & Cloete, 2020; Republic of South Africa (RSA), 2000; RSA, 1996).

Gouws et al. (2010) argument that leaking taps could be the greatest challenge to water security in South Africa could also apply to QwaQwa because not only were Nama-hadi streets (see Figure 2) streaming with leaking water but many other areas such as Turfontein, Maboela, Thibella, Letshalemoke, Bolata and Vergeneng; with the exceptions of Tseki where leakages were not observed because the area had 'no water for months'. Wilkinson et al., 2018 argue that such imprudent behaviour in water management should change. The general view revealed in this study is that while climate change impacts; such as drought, floods and wildfires, have an effect on water quantity and quality, there are

also non-climatic drivers of water scarcity in QwaQwa. These findings are supported by previous studies; such as Mocwagae (2020), Melore and Nel (2020), and Manyama (2020).

Furthermore, the high exposure of critical elements to climate change-related events is critical in reducing disaster risks. According to the findings, water scarcity is the most dominant event and it also poses the greatest threat to critical elements than other climate change-related events, and land use and population/people are the most two critical elements to climate change in QwaQwa. This finding is consistent with the 'very high' water scarcity rating from the hazard analysis. It is also consistent with the frustration that has been demonstrated by the residents through service delivery protests (Mocwagae & Mphambukeli, 2023; Mohapi, 2022). Manyama (2020) found that most of the QwaQwa residents were severely affected by both drought and water scarcity. According to Manyama (2020), the impact of these events was exacerbated by poor drought management and inefficient service delivery.

Among the exposed populations, people living with disabilities (PLWD) and the elderly were the most exposed to climate change-related events (see Table 4). This finding is consistent with previous studies that reported that PLWD and the elderly are more exposed to adverse climate-related events because they usually are marginalised and lack access to safe essential resources to prepare for or withstand such impacts (Kosanac et al., 2022; Ngcamu, 2023). In addition, exposure of the landuse to climate-related events; especially crop land and grazing land, can have a critical impact on food security, livelihoods, and biodiversity. In this case, agro-based communities especially suffer (Manyama, 2020).

The issue of water is critical not only in QwaQwa but to human and natural systems in general. Therefore, these results are important to the human and ecological well being of QwaQwa area. On the one hand, water sources are mostly threatened by climate change-related events such as drought, floods, and wildfires; on the other hand, water scarcity is a threat to socio-ecological systems, as reported by previous studies such as Chakkaravarthy and Balakrishnan (2019). The exposure of land use and the population/people to climate change impacts could have dire socio-economic consequences on human and ecological systems (Pamla et al., 2021). Such effects could subsequently result in a significant impact on urban communities, food security, livelihoods, and general community well-being cascading to reduced quality of life and poverty (Masipa, 2017; Pamla et al., 2021).

6. Conclusion and recommendations

This paper analysed climate change-related hazards like droughts, floods, wildfires, and water scarcity in QwaQwa, South Africa, using NDMC (2016) risk analysis methods. The process identified risk factors, estimated risk levels, and evaluated risks. Findings revealed that QwaQwa faces high risks due to multiple hazards and exposure to water-related challenges. Considering projected increases in climate events, these high risks raise concerns about QwaQwa's resilience to potential disasters. Insights from key informants and household surveys confirmed the analyses, showing widespread acknowledgment of climate change impacts.

Droughts, floods, water scarcity, and wildfires were all rated as high-risk events in QwaQwa, with wildfires considered the least common. The study found that while many stakeholders and household survey participants recognised climate change

impacts like drought, a significant number attributed water scarcity more to socio-economic causes than climate change. Factors such as population growth, corruption, poor local government management, aging infrastructure, and community behaviour were commonly cited reasons. These socio-economic elements, combined with the impact of climate-related events on water resources in QwaQwa, could heighten the risk of disasters. These findings echo the persistent complaints from QwaQwa residents about water shortages, often expressed through public service delivery protests.

After analysing these results, it's crucial to devise strategies to decrease the community's vulnerability to climate change events in QwaQwa and its surroundings. Approaches like land-use planning, innovative technology application, and early warning systems can mitigate exposure to potential disasters (IPCC, 2022). For instance, areas at high risk include people, structures, and agricultural land require land-use plans that factor in these risks efficiently. Starting planning with data on disaster damages and losses can offer valuable insights, enhancing community protection against potential catastrophes. Amaratunga et al. (2018) highlight the pivotal role of local authorities in adhering to disaster-sensitive building codes and laws. Regular monitoring and evaluation of these plans and regulations will bolster Disaster Risk Reduction (DRR) efforts.

Another suggestion involves leveraging innovative technology, specifically unmanned aerial vehicles (UAVs), which hold significant potential for enhancing Disaster Risk Reduction (DRR) capabilities. Muyambo et al. (2017) advocate for the use of UAVs in disaster risk management across developed and developing regions, citing their efficiency, speed, and cost-effectiveness in safeguarding lives and the environment. These UAVs can gather and swiftly distribute real-time information to aid decision-makers in prevention, preparedness, response, and recovery efforts.

Additionally, it's crucial to disseminate early warning information regarding imminent hazard events to empower vulnerable communities and minimise disaster impacts. Employing diverse communication channels is essential, with cell phone networks being pivotal due to their widespread accessibility. The significance of early warning systems in Disaster Risk Reduction (DRR) is widely acknowledged in disaster research by scholars and practitioners alike (Guzzetti et al., 2020; Pecoraro et al., 2019). However, a notable limitation of this study is the absence of vulnerability analysis, which is vital for a comprehensive understanding of disaster risk in QwaQwa. Hence, we recommend conducting further analysis on vulnerability or resilience and integrating these findings into a comprehensive systemic risk assessment. This holistic approach will inform subsequent planning and decision-making for reducing disaster risks and enhancing resilience against climate change impacts in QwaQwa.

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