Applying participatory mapping approaches to assess local communities' perceptions of climate change and implications on their adaptation strategies: The Case of communal rangeland community, Vulindlela, South Africa

by

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Abstract

This study investigated the role of Participatory Geographic Information System (PGIS) and Participatory Rural Appraisal (PRA) in understanding local perceptions on the causes and impacts of climate change on communal rangeland communities and how local perception shapes communities' responses. First, a systematic literature review was conducted to assess PGIS's contribution to elucidating local rangeland communities' vulnerability and adaptation in Africa. Analysis of 18 papers from ScienceDirect, Web of Science, and Scopus revealed a slow pace in the integration of PGIS in climate change research, thus indicating a knowledge gap. Despite this, PGIS has the potential to empower local communities in co-producing knowledge and creating adaptation solutions. The study then explored the effectiveness of integrating PGIS with PRA techniques in elucidating communal rangeland communities' perceptions of and responses to the effects of climate change on rangeland resources and livelihoods using Vulindlela, South Africa, as a case study. Using focus group discussions, participatory mapping, key informant interviews, transect walks, and household questionnaires, the study uncovered diverse perceptions of climate change's drivers and impacts on livelihoods. It found that local perceptions are influenced by factors such as experience, age, education, and dependency on rangeland resources, which shape community responses to climatic risks. The PGIS mapping exercise highlighted areas most susceptible to events like floods and droughts. Overall, the study demonstrated PGIS as a valuable tool for capturing spatial insights and facilitating local participation. The integration with PRA and PGIS techniques provided a comprehensive understanding of climate change impacts and responses, offering both non-spatial and spatial perspectives. Participatory mapping has the potential to enhance the co-design and formulation of inclusive adaptation plans

PREFACE

The research contained in this dissertation was undertaken in the School of Agricultural, Earth and Environmental Sciences of the completed by the candidate of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg. The research was supervised by Professor Onisimo Mutanga and Dr Matilda Azong-Cho.

I, Nomaswazi Zamanhlabathi Nhlabathi, declare that the contents of this work have not been submitted in any form to another university. This thesis represents my own work except where the work of other authors has been cited and acknowledged.

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DECLARATION 1: PLAGIARISM

I, Nomaswazi Zamanhlabathi Nhlabathi, declare that:

(i) the research reported in this dissertation, except where otherwise indicated or acknowledged, is my original work;

(ii) this dissertation has not been submitted in full or in part for any degree or examination to any other university;

(iii) this dissertation does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons;

(iv) this dissertation does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

a) their words have been re-written but the general information attributed to them has been referenced;

b) where their exact words have been used, their writing has been placed inside quotation marks, and referenced;

(v) where I have used material for which publications followed, I have indicated in detail my role in the work;

(vi) this dissertation is primarily a collection of material, prepared by myself, published as journal articles or presented as a poster and oral presentations at conferences. In some cases, additional material has been included;

(vii) this dissertation does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the dissertation and in the References sections.

DEDICATION

This dissertation is dedicated to my mother and daughter for their endless love, encouragement, and patience. I hope this achievement will be an inspiration for my daughter, to know anything is possible. For my mother to know that all her work in ensuring my education has not been in vain.

To my late Grandmother, for being with me spiritually and getting me through this far.

Lastly, to the Almighty God. It is by the grace of God and his endless blessings upon my life I have come this far.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1: General Introduction

1.1.Introduction

Rangelands in Africa, which offer key and multiple ecosystem services and goods such as grazing lands for livestock and the harvesting of natural resources, have come under serious threats from climate change (Petz et al., 2014; Godde et al., 2020). The Intergovernmental Panel on Climate Change (IPCC) forecasts a further increase in global mean temperatures of 2-6 C; heightened occurrences of floods and droughts and changes in rainfall patterns (Ishumael and Godwell, 2015; Naidoo et al., 2013). These climate change effects constitute a major driver of biodiversity loss and changes in ecosystem services at global scale (Sintayehu, 2018; Weiskopf et al., 2020). Moreover, climate change threatens livestock forage and water supply. This threatens food security and income-generating opportunities. Many countries in Africa and other developing nations, are considered to be most vulnerable to climate change effects (Neely et al., 2009). Climate change vulnerability is described as the extent to which the system is unable to cope with the impacts of climate change, in combination with the system's exposure, sensitivity level and lack of adaptative capacity (Ouled Belgacem and Louhauchi, 2013; Ofoegbu et al, 2017). The vulnerabilities of developing nations are linked to socio-economic and ecological factors inherent in their systems. These include the absence of government policies and support for human development, ineffective agricultural policies, and limited market access. Additionally, there is insufficient infrastructural support and a poor natural resource base characterized by low-quality soil, poor soil fertility, and limited access to irrigation facilities (Ouled Belgacem and Louhauchi, 2013; Briske et al., 2015; Habib et al., 2022). Moreover, their strong reliance on natural resources intensifies their vulnerability. Briske et al. (2015) suggests that poor communities are vulnerable from an environmental and socio-economic perspective.

The deterioration of rangelands as a result of climate change has prompted a need for an effective planning and monitoring of rangelands systems to mitigate the adverse impacts of human activities and to enhance their sustainability (Cho and Mutanga, 2021). The conventional top-bottom-approach to land-use planning and management of rangeland ecosystems is mainly based on 'expert' knowledge that does not take into account the concerns of local resource users (Hodbod et al, 2019). Expert knowledge mainly relied on quantitative data sources that excluded spatial representation of cultural and indigenous knowledge (Canevari-Luzardo et al., 2015). The integration of indigenous knowledge in spatial planning has been largely overshadowed by expert knowledge system (Finca et al., 2023).

Yet there are evidence demonstrating the use of indigenous knowledge to mitigate the effects of climate change. For example, in the Sahelian regions of West Africa—particularly Mali, Niger, and Burkina Faso—smallholder farmers are increasingly adopting traditional water harvesting techniques such as *zai* (planting pits) and half-moon structures to address climate challenges (Partey et al., 2018). These methods constitute climate-smart practices for soil and water conservation, helping communities cope with recurring droughts, erratic rainfall, and soil degradation (Partey et al., 2018). The *zai* technique involves digging pits before the planting season to capture rainwater and concentrated organic matter. This enhances water retention and soil fertility, benefitting crops like sorghum and millet (Zougmoré et al., 2023). Similarly, half-moon structures, which are semi-circular embankments, capture runoff water and direct it to the plant root zone. These structures improve water infiltration, reduce soil erosion, and create favorable microenvironments for crop growth in the face of increasingly unpredictable climatic conditions (Partey et al., 2018; Zougmore et al., 2023). Additionally, the Dogon people of Mali deliberately integrate drought-resistant tree species with crops such as millet and sorghum, a practice that preserves the ecological services provided by trees (Sanogo et al., 2017). These services include enhancing water retention and serving as windbreaks, which protect crops from environmental stressors (Sanogo et al., 2017). In essence, the widespread adoption of these techniques underscores the value of integrating indigenous practices into modern innovation frameworks to build resilience against climate challenges.

Indigenous knowledge pertains to a combination of skills and practices that are developed within a particular culture, and specific geographical society that is being transferred from one generation to the other (Muyambo et al., 2017; Selemani, 2020). Indigenous knowledge has been very instrumental for communities' mode of production, lifestyles, and their social organizations. Although the value of indigenous knowledge is highly recognized in international development conferences, such as the United Nations Conference on Environment and Development (Muyambo et al., 2017), it has been poorly applied in climate change mitigation and adaptation strategies (Nyong et al., 2007). Minimizing the role of indigenous knowledge in climate change adaptation strategies may result in solutions that do not align with local realities, with adverse consequences on communities' resilience to the effects of climate change (Egeru, 2012; Aggrey et al., 2021). Poor and non-literate communities have successfully utilized their indigenous knowledge to identify climatic effects through local indicators and respond rapidly to the effects (Kupika et al., 2019). Pastoral and agro-pastoral communities' responses to climate change depends on how they perceive and understand the causes, risks and impacts on their livelihoods (Alam et al., 2017; Kupika et al., 2019), and their vulnerability has been widely documented (Reid and Huq, 2005; Naidoo et al., 2013; Ishumael and Godwell, 2015; Habib et al., 2022). Hence, applying participatory approaches will enhance comprehension of local rangeland communities' interpretation of climate change and foster the integration of local and expert adaptation knowledge. The development of the Participatory, bottom-up approaches aim to connect local and expert knowledge by engaging local stakeholders in planning land use and managing natural resources (Tripathi and Bhattarya, 2017; Cho and Mutanga, 2021). Involving local communities in the planning and decision-making assists in generating sustainable adaptation solutions that are adaptable to local needs (Aggrey et al., 2021). The use of indigenous knowledge can therefore facilitate the adjustment of local livelihoods in response to the impacts of climate change (Kupika et al., 2019).

Participatory mapping, as one of the participatory techniques, and involving several non-spatial and spatial tools, have been employed in climate change research to assess vulnerability, adaptation, climate change causes and impacts. (Kieslinger et al., 2019). These tools include the use of mental mapping, participatory sketch mapping and digital mapping (Hill et al., 2015; Cho et al., 2023), participatory 3-dimensional modelling, and the use of aerial photography, remote sensed satellite images and Global Positioning Systems (GPS) (Williams et al., 2020). In addition, it involves the use of Participatory Rural Appraisal (PRA) techniques (interviews, focus group discussions, transect walks, social and resource mapping, wealth ranking, historical timeline, hazard mapping, climate hazard ranking and seasonal calendar, among others (Daze, 2014; Pearson et al., 2017; Maharjan et al., 2017; Sontakki et al., 2019). PRA has been commonly used to generate local-based environmental and livelihoods resilience knowledge (Uddin and Anjuman, 2013). PRA techniques ensure an in-depth assessment of local knowledge-based experiences of the rural communities to climatic changes. It results in tangible collection of information that is built upon the voices of the local actors through an interactive process (Derr, 2018). Numerous studies have illustrated the usefulness of the PRA approach in communicating local climate change knowledge. For example, Derr (2018) demonstrated the utilization of various PRA tools on climate change perceptions that resulted in accumulated forms of data such as community maps, season calendars, historical timelines, and focus group discussions. Nevertheless, PRA techniques which are often non-spatial are inadequate in providing spatial insights. Participatory Geographic Information System (PGIS) thus fills in the gap through integrating the spatial dimension of indigenous knowledge system (Finca et al, 2023).

PGIS is a tool which facilitates the incorporation of indigenous knowledge in a Geographic Information System (GIS) platform to facilitate spatial analysis and planning (Malaki et al, 2017; Nyantaki-Frimpong, 2019). The use of PGIS in this study was intended to identify the variability experienced in climate change impacts on the rangeland from diverse perceptions of local rangeland community members. Integrating PGIS into climate change knowledge production processes enables the creation of locally and contextually relevant maps and decision-support tools, facilitating effective communication of diverse local knowledge to relevant authorities and scientists (Bitsura-Meszaros et al., 2019). Vajjhala (2005) asserts that PGIS plays a key role in analysing not just where people live but how they are affected by unpredictable climatic events from a local spatial perspective. Various studies have demonstrated that PGIS is a useful tool to achieve the inclusion of local communities' indigenous knowledge in responding to climate change impacts.

PGIS methodologies are highly effective in fostering cross-perspective engagement, leveraging the unique capabilities of geospatial technologies to capture and visualize knowledge from diverse systems. This approach facilitates the integration of indigenous knowledge with other data forms, enabling a comprehensive analysis of local landscapes and the intricate interactions between human and environmental factors (Young and Gilmore, 2017). Diverse knowledge forms can be represented as multi-dimensional and multi-scaled layers on a map, allowing for direct comparison and interaction within the mapped space (Young and Gilmore, 2017).

By integrating geospatial technology, PGIS not only allows local actors to store and analyze knowledge but also enables the visualization of spatial relationships in ways that surpass the limitations of traditional qualitative methods (Malaki et al., 2017). This mapping approach serves as a critical tool for identifying hazard-prone areas and documenting environmental risks (Peñalba et al., 2021). For instance, residents with intimate knowledge of their village's geographic features can efficiently pinpoint vulnerable areas on the map (Penalba et al., 2021). By actively involving local participants in the mapping process, PGIS empowers them to articulate their needs and priorities, fostering a sense of ownership over both the data and its outcomes (Panek and Netek, 2019). In contrast, traditional non-spatial qualitative method, typically focus on expressing participants' perspectives without necessarily illustrating the spatial variabilities, essential for place specific interventions (Panek and Netek, 2019; Malaki et al., 2017). Moreover, the iterative nature of PGIS enhances its flexibility and adaptability, enabling communities to continuously update and refine their contributions. This dynamic process contrasts with the more fixed structure of traditional qualitative methods (Mfondoum et al., 2019).

Numerous studies demonstrated the use of PGIS for community participation to visualize their local knowledge of climate change. For example, Maharjan et al.'s (2017) study exemplifies the use of PGIS to facilitate local participation in the hazard mapping process, identifying areas that are prone to climatic-induced hazards such as floods, drought, and riverbank erosion. In addition, a study conducted by Ziadat et al., (2012) shows the application of PGIS to facilitate the participation of local farmers in rainwater harvesting suitability analysis to mitigate land degradation, which is a result of climate change effects, on dry rangeland systems. However, the integration of PRA and PGIS techniques in enhancing a holistic understanding of local perceptions of climate change and the variability in the perceptions based on generational differences has not gained visibility in climate change and rangeland research.

Both PRA and PGIS constitute components of participatory mapping and promotes inclusivity and equity in the mapping process. The integration of the PRA and PGIS techniques provide a comprehensive understanding of local perception of climate change from spatial and non-spatial dimensions. The participatory mapping approaches further facilitate the promotion of transdisciplinary research approach through bolstering the integration of local and scientific knowledge systems (Kieslinger et al., 2019; Sandham et al., 2019; Karaya et al., 2021). In the context of rangeland management and monitoring, PRA and PGIS have demonstrated their relevance in enhancing community rangeland planning and management (Malaki et al, 2017; Sandham et al., 2019; Aggrey et al., 2021).

The application of participatory techniques is essential for fostering the co-creation of locally tailored and adaptable solutions to resource management challenges, ensuring resilience and sustainability (Villamor et al., 2014, Mazeka et al., 2019). The growing challenges posed by climate change and related social issues, as outlined earlier in the background of this study, demand more robust and sustainable solutions. Inclusivity is increasingly recognized as a suitable developmental approach, ensuring that the voices of disadvantaged groups are considered in resource management decision-making (Gent, 2017). PRA and PGIS techniques provide opportunities to generate local knowledge and integrate it with expert knowledge, creating comprehensive knowledge systems that inform context-specific practical and policy decisions.

1.2.Problem Statement

Despite evidence of the significant role of participatory mapping in communicating local indigenous ecological knowledge, there is a notable research gap in developing countries, particularly in Africa. Specifically, there is a lack of research systematically illustrating how participatory methods such as PGIS promote the use of indigenous knowledge to explain local rangeland communities' perceptions of climate change vulnerability and adaptation (Canevari-Luzardo et al., 2015; Membele et al., 2022). The field of PGIS in the context of climate change vulnerability and adaptation in Africa remains largely underexplored. Various studies encourage the integration of the local and expert knowledge systems to address the complexities in environmental events and social systems' vulnerability and adaptation (Kieslinger et al., 2019; Cebrian-Piqueras et al., 2020) Local bottom-up knowledge can be generated through participatory approaches such as the PRA techniques and facilitated using PGIS, reflecting both the scientific truth of the local context and the truth known to the people of the area (Krishnamurthy et al., 2011; Sandham et al., 2019; Aggrey et al., 2021).

1.3.Aim and Research Objectives

The proposed study aimed to promote the use of participatory mapping to enhance local involvement in assessing climate change impacts and generating climate-based solutions. This was achieved through the application of PRA and PGIS techniques to explore local rangeland communities' perceptions of the causes and impacts of climate change and their implications for local adaptation strategies. This aim was pursued through the following sub-objectives:

- To examine the role of PGIS in enhancing local knowledge generation of communal rangeland communities' vulnerability and adaptation to climate change within the African context.
- To demonstrate the effectiveness of integrating Participatory mapping techniques in elucidating local perceptions of climate change.
- Assessing the implications of diverse perceptions of climate change on pastoral communities' adaptation responses

1.4.Research Questions

This study seeks to answer the following overarching research question:

How does participatory mapping enhance the generation of local knowledge on communities' perception and responses to climate change?

Sub-research questions:

- How has the integration of the PGIS approach advanced understanding of community vulnerability and adaptation strategies to climate change in Africa?
- How does participatory mapping contribute to the generation of local knowledge about the causes and impacts of climate change on rangeland resources and livelihoods?
- What are the implications of local perceptions for rangeland communities' responses to the effects of climate change on rangeland resources and livelihoods?

1.5.Study Rationale

Vulindlela, like other semiarid regions in Africa and globally, faces significant challenges from climate events such as dry spells, droughts, and floods. For instance, Jurry's (2022) analysis of historical and projected climatic trends highlights declining rainfall patterns and increasing seasonal dry spells across KwaZulu-Natal Province, adversely impacting natural vegetation and the livelihoods of local communities. While scientific modelling provides valuable insights into climate variability and its impacts on natural and human systems, there remains a critical gap in methods to generate relevant local knowledge. Incorporating local perspectives is vital for understanding the effects of climate change on natural resources and livelihoods and for fostering the active participation of local resource users in addressing these challenges. This is particularly important because climate change impacts are place-specific, shaped by geographical, social, economic, and cultural differences (Weckroth and Ala-Mantila, 2022). Addressing the variability in people's exposure and sensitivity to climate impacts requires an integrative approach that combines expert GIS analyses with social data.

Collaborative planning and resource management—integrating local knowledge with expert input—have proven effective in building community resilience and ensuring resource sustainability in the face of climate shocks (Cho et al., 2023). Such a collaborative approach is crucial for strengthening food security and safeguarding natural resources, both of which are increasingly threatened by diverse climatic regimes. Studies in the region have largely overlooked the impacts of climate change on rangeland resources and neighbouring communities from the perspective of those most affected. (Reyes-García et al., 2023) highlights that indigenous and local communities, whose livelihoods are highly sensitive to climate change, remain underrepresented in research and policy discussions.

1.6.Research methodology and limitations of the study

The study adopted a mixed-methods approach, integrating both quantitative and qualitative techniques. Quantitative data collection involved the use of questionnaires featuring both closed and open-ended questions, designed to efficiently capture individual perceptions (Maxwell et al., 2017; Jones et al., 2013). For the qualitative component, GIS-integrated participatory community mapping was employed to document participants' spatial perceptions of climate change, its impacts, and vulnerability factors (Maman et al., 2009; Hodbod et al., 2019). In addition, focus group discussions, transect walks, key informant interviews, and desktop reviews were conducted to gain deeper insights into the subjective experiences of climate change. The study involved 62 participants, comprising both male and female community members who rely on rangeland resources for activities such as livestock ownership and rangeland management. Participants were selected using purposive and snowball sampling methods. The application of mixed-methods approach facilitated data triangulation, providing comprehensive insights into the effects of climate change from the rangeland community's perspective. Quantitative data from household questionnaires were analyzed descriptively using Excel, while qualitative data from focus groups, interviews, and transect walks were analyzed thematically, with coding supported by NVivo software.

Due to time constraints, caused partly by the political barriers, the scope of the study was limited to one research site. The inclusion of the neighbouring area, namely, Nhlazuka community may have enhanced the richness in the data on the research subject. In addition, although purposive sampling was used to select a diverse group of participants to capture the different perceptions of climate change, the researcher could only access a limited number of elderly participants to share a historical perspective of climate change experiences in the study area. It is assumed that having more elderly participation in the research would have provided a broader perspective of climate change experiences in the study area.

1.7.Dissertation outline

The dissertation begins with a general introduction in Chapter 1, which outlines the problem statement, study aim and objectives, and research questions. It also highlights the rationale for the study and concludes by presenting the structure of the dissertation.

Chapter 2 provides a systematic review of the literature on communal rangeland vulnerability and adaptation to climate change in Africa. It examines the role of PGIS in collaborative knowledge production, empowering local actors, and improving decision-making for local adaptation strategies.

Chapter 3 investigates rangeland communities' perceptions of climate change using participatory approaches, with a focus on the Vulindlela rangeland community in KwaZulu-Natal, South Africa. This chapter highlights the contributions of PRA and PGIS mapping techniques in elucidating local perceptions of climate change causes, impacts, and responses.

Chapter 4 concludes the dissertation by synthesizing the study's findings, presenting key insights, and offering concluding remarks and recommendations.

CHAPTER 2: Understanding Africa-based communal rangeland vulnerability and adaptation to climate change using Participatory GIS (PGIS): A systematic literature review

Abstract

Participatory Geographic Information Systems (PGIS), a community-based and geo-spatial information systems approach is perceived as a valuable tool for the enhancement of knowledge on local rangeland communal communities' vulnerability and adaptation to climate change. The increasing climatic conditions heightens the vulnerability of communal rangeland communities, through threatening the sustainability of their primary source of livelihoods. This necessitates an effective and collaborative management planning of the rangelands. This paper constitutes a systematic literature review intended to assess the contributions of PGIS in explaining local communal rangeland communities' vulnerability and adaptation to climate change in the African context. Eighteen papers were retrieved from the ScienceDirect, Web of Science, Scopus databases to assess the progress, emerging knowledge gaps and opportunities. The selected articles were further analysed using bibliometric and content-based analytical methods. The results demonstrated that PGIS has the potential to empower local communities to co-produce knowledge and co-create adaptation solutions even though its integration in rangeland communities and climate change research is at a low pace. Given that rangelands across the globe are diverse in terms of geographical, environmental and cultural factors, there is a likelihood of dynamism in their vulnerability and adaptation capabilities which need to be identified through research. A lack of sufficient knowledge of rangeland communities' vulnerability and adaptation set barriers to evidence-based policy and interventions.

Keywords: Local Ecological Knowledge, Indigenous Knowledge, Participatory Geographic Information Systems, Climate change, Vulnerability and Adaptation, Pastoralists and Agro-Pastoralists.

2.1. Introduction

Rangelands in Africa face imminent threats from the impact of climate change, associated with diminishing and erratic rainfall patterns, soaring temperatures, recurrent droughts, and the occasional occurrence of floods (Petz et al., 2014; Bayrak et al., 2020; Godde et al., 2020; Angerer et al., 2023). These rangelands constitute of arid and semi-arid climates, characterized by low and unpredictable precipitation levels (Menghitsu et al., 2020). Livestock and mixed crop-livestock production systems serve as the primary means of livelihood for the inhabitants of the pastoral communities (Menghitsu et al., 2020). The livestock heavily rely on the rangelands as a fundamental source of feed (Abule et al., 2005; Mapfumo et al., 2021) The heavy dependence on livestock and crop production as the primary source of sustenance renders these communities highly susceptible to the adverse effects of climate change (Berhanu and Beyene, 2015; Perez et al., 2015; Abegunde et al., 2019; Mapfumo et al., 2021). Their vulnerability is exacerbated by the recurrent occurrence of drought, recognized as the most devastating climatic hazard in these arid regions, compounded by their reliance on rainfall and natural resources (Abate, 2016; Abegunde et al., 2019; Mapfumo et al., 2021; Samuels et al., 2022). The intensification and recurrence of drought have resulted in critical shortages of water and pasture, diminishing crop and livestock productivity, and a surge in livestock disease outbreaks and fatalities. Consequently, this has led to heightened food insecurity, malnutrition (Ifejika Speranza et al., 2009; Perez et al., 2015; Abate, 2016; Tilahun et al,, 2017), and a loss of income-generating opportunities (Neely et al., 2009; Mapfumo et al., 2021).

Climate change vulnerability is a multifaceted concept encompassing exposure, sensitivity to perturbations, and the capacity to adapt within a given system (Ouled Belgacem and Louhaichi, 2013; Ofoegbu et al., 2017; Koech et al., 2019). Vulnerability can be viewed through two lenses: biophysical vulnerability, which pertains to the exposure of natural and social systems to climate-induced hazards such as flooding, droughts, cyclones, and their resultant impacts (Singh Jatav, 2020); and social vulnerability, linked to socio-economic conditions that shape a community's susceptibility to climatic hazards, including factors like income and educational attainment (Singh Jatav, 2020; Samuels et al., 2021; Membele et al., 2021). Pastoralism isn't merely a livelihood; it represents a way of life intertwined with socio-cultural norms and values centred around livestock production (Ayantunde et al., 2011). In communal areas, notably pastoralists and agro-pastoralists, social and economic challenges prevail. These encompass high poverty levels, uneven distribution of natural resources, limited employment opportunities, inadequate infrastructure and technology to cope with extreme climatic variations, limited access to institutional and political support for influencing local policies and governance, inadequate healthcare services, among others (Ngcobo, 2018; Nalau et al., 2018). Consequently, these socio-economic stressors exacerbate the vulnerability of pastoral and agro-pastoral communities to climate change. The vulnerability of rural communities, including these groups, to climate change has been widely documented (Reid and Huq, 2005; Naidoo et al., 2013; Ishumael and Godwell, 2015; Habib et al., 2022), necessitating adaptive measures in response to climate impacts (Hoffmann, 2013). The adaptation strategies employed by pastoral and agro-pastoral communities in response to climate change depends on their understanding of the causes, risks, and impacts. Their understanding is often drawn from traditional knowledge systems and collaborative co-knowledge production through participatory approaches. Pastoral communities possess an intricate understanding of their grazing communal lands gained through generations of herding practices (Tilahun et al., 2017). Livestock farmers' keen observation of changes in their environment, cause them to adjust their forage and herding practices according to the availability of resources (Godana, 2016).

2.2. An integrative IK and PGIS approach in understanding pastoral communities' vulnerability and adaptation to climate change in Sub-Saharan Africa

Indigenous knowledge is inherently dynamic and shaped by local communities' interactions with their specific biophysical and social environments, resulting in context-specific interpretations (Ghazali et al., 2021). While indigenous knowledge pertains to specific indigenous groups (Adade Williams et al., 2020), Local Ecological Knowledge (LEK) encompasses insights from local individuals, whether or not they are indigenous, who have accumulated in-depth environmental knowledge through personal and collective experiences generated from prolonged interaction with their local surroundings (Nalau et al., 2018; Adade Williams et al., 2020). As stipulated by Cho et al. (2023) the integration of human perspective in studying natural phenomenon such as climate change is essential in elucidating human experiences of the phenomenon. LEK is grounded in local people's experiences, perceptions, observations, understandings, skills, and practice and interpretation of the socio-ecological systems and their changes (Malaki et al., 2017). Furthermore, the local knowledge system guides pastoral adaptation decision-making (Liao, 2017; Leal-Filho et al., 2021).

Pastoralist communities apply indigenous knowledge to forecast the onset time of rainfall to determine livestock migration patterns as opposed to the contemporary scientific forecasts that quantify rainfall amount (Ifejika Speranza et al., 2009). The timing of rainfall is of great importance to the pastoralists because their livestock migration patterns depend on the availability of grass and water supply in different grazing sites rather than on the average amount of rainfall available (Ifejika Speranza et al., 2009). Pastoralist farmers observe climatic indicators such as the presence of murky clouds as a sign of impending heavy rainfall, observing animal behaviour such as the sudden noise from the frogs in the afternoon which signifies an oncoming drought (Muyambo et al., 2017). These interpretations assist them in making livelihood decisions on livestock migration patterns as well as harvesting and planting seasons (Abate, 2016; Kom et al., 2022). Integrating IK with PGIS will potentially promote spatial knowledge generation, planning and management of rangeland ecosystem services and livelihoods dependent on these services.

PGIS is a multidisciplinary approach that involves integrating local knowledge captured through interviews and focus groups, into GIS environment to facilitate spatial analysis and validation of this knowledge (Canevari-Luzardo et al., 2015; Nyantaki-Frimpong, 2019). This tool can be leveraged to augment the integration of indigenous knowledge in climate risk management and the transformation of pastoral systems to adapt to climate change impacts (Cho et al., 2023). The conventional geographical mapping tools may not be able to document local knowledge because of the advanced technical expertise required to perform the analysis (Malaki et al., 2017; Mfondoum et al., 2019). PGIS then overcomes this gap by integrating the conventional top-down 'expert' or scientific knowledge with bottom-up participatory knowledge derived from the experiences, observations, and perceptions of local individuals or communities (Nyantaki-Frimpong, 2019; Buba et al., 2021).

The significance of PGIS in enhancing local knowledge of pastoral communities regarding climate risk management lies within the participation process itself, bringing marginalized groups into discussions and thereby enhancing the empowerment and legitimacy of communities and their knowledge. It also fosters the co-production of knowledge essential for building sustainable pastoral livelihoods in the midst of climatic risks (Sullivan-Willey et al., 2019). Often, this technique aids in identifying conflicts, determining access and ownership of resources, documenting local adaptive measures, and complements scientific methods (Pearson et al., 2017; Sullivan-Willey et al., 2019; Hodbod et al., 2019; Nébié et al., 2021). Moreover, PGIS contributes to the generation of spatial knowledge essential for place-based adaptation interventions. While PGIS has garnered considerable attention as a tool for empowering local communities in participatory spatial planning and natural resource management (Piccolella, 2013; Albgali and Iwama, 2022; Cho et al., 2022), ethical concerns related to access and control of GIS technologies and the representation of local knowledge have often raised broader questions (Chambers, 2006). Such concerns are associated with empowerment of local actors and ownership of the PGIS process and outputs.

Indigenous knowledge is inherently spatial due to its close ties with geographical localities and its intrinsic interaction with the environment. In this context, PGIS prove to be particularly valuable in documenting local spatial knowledge (Membele et al., 2021). Numerous scholars have illustrated the use of PGIS in enhancing local knowledge and capturing dialogues concerning climate change. For instance, Sulieman and Ahmed (2013) combined remote sensing data with local knowledge to monitor changes in pastoral resources in eastern Sudan, attributing shifts to factors including climate change variability. Participatory mapping was employed to engage local participation in mapping regions affected by climate change and susceptible to climate-induced risks like flooding and drought, in support of disaster risk reduction efforts (Kienberger, 2014; Maharjan et al., 2017). Many of these approaches effectively incorporated the voices, interests, and perceptions of local communities into discussions on vulnerability, traditional agricultural practices, and environmental knowledge. Vargas et al. (2022) employed participatory mapping with agro-pastoralists in the Central Andes of Chile to delineate their spatial perceptions of both the natural and human components of their territory. This exercise revealed areas of conflict with wildlife and identified drought as the primary threat to their livestock production. Consequently, PGIS facilitated the mapping and prioritization of areas for mitigating climate-induced risks and conflicts with wildlife.

Despite evidence demonstrating the application of PGIS in communicating local and indigenous knowledge, a significant research gap persists in developing countries, including Africa. Studies conducted in Asia, Europe, the United States of America, Africa, and Latin America underscore the importance of local spatial knowledge in understanding the global dimensions of climate change, particularly in coastal and agrarian communities (Nethengwe, 2007); (Mahanama et al., 2013); (De Souza and Clarke, 2018), (Obiero et al., 2022) (Zeballos-Velarde, 2021), (Bullen and Miles, 2024). While research on pastoral vulnerability and adaptation to climate change exists, it often fails to explicitly capture the spatial variability in communities' experiences (Choden et al., 2020). PGIS offers a critical spatial dimension, illustrating how climate change impacts can vary geographically due to specific environmental and socio-economic factors, thus supporting the need for context-specific interventions. Focusing this study on Africa was crucial given the limited availability of local spatial knowledge regarding rangeland communities' exposure and responses to climate change effects (Canevari-Luzardo et al., 2015; Membele et al., 2022). This regional focus aims to contribute to the development of sustainable livelihoods that are resilient to the effects of climate change.

The study then seeks to address the following research question: How has PGIS integration in rangeland communities' climate change vulnerability and adaptation research contributed to the empowerment of local communities to participate in mapping of adaptation solutions in Africa? This research question is translated into the following objectives: To evaluate how PGIS has been utilized in facilitating an understanding of pastoral communities' vulnerability and adaptation to climate change; to determine PGIS contribution in the co-development of spatially related vulnerability and adaptation knowledge and in the empowerment of local resources actors to participate in identifying adaptation solutions.

2.3. Methods

2.3.1. Literature Search strategy

This review research is based on the analysis of articles retrieved from three databases: ScienceDirect, Scopus, Web of Science. These three databases were selected based Systematic literature review allows a rigorous assessment of the state of knowledge on a particular topic, structured to search for existing evidence (Menghistu et al., 2019). The study follows the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement (Page et al., 2021) for a detailed selection and analysis of research articles.

Literature Search

To retrieve publications in relation to the research questions, certain keywords were needed for the literature search. The search terms were combined and separated differently for each search database: ScienceDirect, Scopus and Web of Science, using the Boolean operator: "Participatory GIS" OR "Participatory GIS Methods" OR "Participatory Mapping" AND "Climate change" AND "Vulnerability" OR "Adaptation" AND "Pastoral Communities" OR "Rangeland Communities" (Table 2.1). This was done to allow an exhaustive result from each database. This yielded a total of 2522 records downloaded as RIS Files, exported on Endnote to filter and eliminate duplications, title and abstract screening. The search for papers published on local rangeland communities' vulnerability and adaptation to climate change was done for the last 20 years with the earliest publication found in year 2000. The search was restricted to the African context.

Screening

The study carried out the first exclusion process of removing (n=20) articles that were duplicated. Once duplicates were removed, the remaining articles (n=2502) were examined based on their bibliographical information in terms of title and abstract for articles integrating Participatory GIS and Indigenous Knowledge Systems in the context of climate change research for pastoral and agro-pastoral communities, removing (n=2431) articles. Articles that were not in English were removed. The full-text screening was carried out to examine articles (n= 71) that might not have been cleared in the title and abstract screening, with (n=11) articles eligible for review. Additional (n=7) articles were identified and manually searched through the list of references of the included articles and retrieved on google scholar web search engine. A total of 18 articles were then reviewed.

Table 2.1: Eligibility criteria for articles to be included for review

Criteria	Included	Excluded	Reasons for the applied criteria
Publication language	Articles in English Only	Articles not in English	Due to the language limitations of the reader
Publication theme	-Articles on Participatory GIS and Indigenous Knowledge Systems -Articles in the context of Climate Change -Articles in the context of communal rangeland/ Pastoral and Agro-pastoral Communities	-Articles that applied the traditional GIS only -Articles that applied IKS only	To remain within the scope of the systematic review
Article type	Peer-reviewed articles	-Not peer-reviewed articles -Reviews -Indexes	

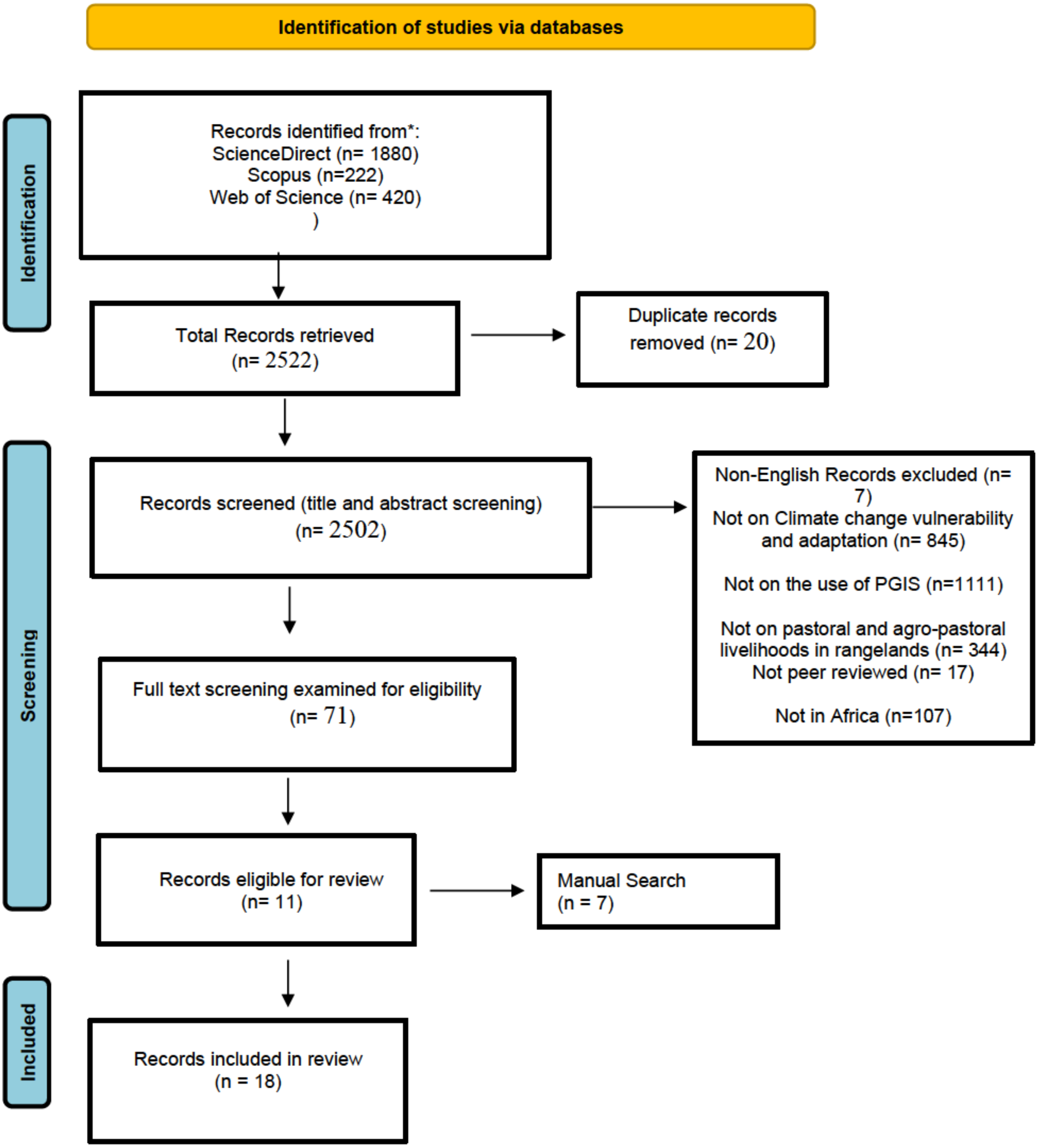

Figure 2.1: The PRISMA Flow diagram of the systematic review process

2.3.2. Data Extraction and Analysis.

This section discusses how the data was captured through a deductive coding process and thematically analysed. The coding process involved the use of predefined themes mainly to restrict the analysis based on the research questions. The selected papers were read and manually assigned different codes using the NVivo software, accessible from the University of

KwaZulu-Natal's software repository. The thematic coding process in NVivo was employed to systematically analyze data on seasonal migration in search of fodder and water under varying climate scenarios, spatial analysis of the most affected areas, and the role of PGIS in co-producing knowledge on local vulnerability and adaptation, as well as facilitating local participation in adaptation decision-making. The process began with importing the literature into NVivo, followed by familiarization with key sections related to migration patterns, climate variability, and participatory approaches. During the open coding phase, relevant text was manually coded to identify references to livestock mobility, climatic stressors, and resource scarcity, using initial codes such as "migration routes," "climate impacts," and "water sources." The axial coding phase then grouped these initial codes into broader themes, such as climate-induced migration and vulnerability hotspots, linking concepts related to PGIS and local knowledge generation. For instance, seasonal migration theme was refined by examining how different regions experience climate impacts, resulting in subthemes related to regional vulnerabilities and factors influencing migration (e.g., drought, water availability, pasture depletion). The role of PGIS was analyzed by coding references to participatory mapping, data sharing, spatial maps, and community involvement. These were consolidated under themes like local adaptation knowledge and participatory decision-making.

Through iterative refinement, overlapping themes were consolidated, and NVivo's query functions were used to analyze the frequency and interconnections between codes. This approach provided a deeper understanding of the spatial distribution of migration patterns, the factors driving these movements, and the critical role of PGIS in empowering local communities for climate adaptation.

Additionally, a trend analysis was conducted to examine the variability of annual research publications and concepts from 2000 to 2023. Using Excel's schematic analytical tools, the analysis depicted the growth pattern and rate of publications focused on climate change impacts on rangeland communities and their responses. The themes emerging from the coding process were then utilized for thematic analysis to illustrate how PGIS contributes to building local rangeland communities' perspectives on the causes, impact and responses to climate change. This comprehensive framework highlighted the dynamic relationship between migration, climate risks, and participatory adaptation planning. The major themes merged from the coding process are categorized as follows: 1. the co-production of spatial knowledge and, 2. the empowerment of local actors in promoting local adaptation to see how PGIS improved local adaptation decision-making.

2.4. Results and Discussion

2.4.1. Growth analysis of the publications on Participatory GIS and rangeland communities' climate change vulnerability and adaptation research

This section illustrates the trend in publications on the application of PGIS to enhance an understanding of the vulnerability and adaptation of rangeland communal communities to the impacts of climate change (Figure 2.2). Overall, the results depict a slow progress in research in this domain. Nevertheless, 2015, 2017 and 2021 experienced highest number of publications. This could be the result of the IPCC reports, particularly the fifth report, that recognized the importance of Indigenous Knowledge in climate change adaptation actions. The fifth assessment report highlights the need to provide participatory and cost-effective strategies, inciting more research and conversations on the topic (Apraku et al., 2021; Mbah et al., 2021). Although, climate change discourse is increasingly encouraging, the integration of indigenous knowledge, the growth has not really gained momentum from a spatial perspective (Chanza and Musakwa, 2022). More research has been conducted on participatory methods integrating local communities in understanding climate change vulnerability and adaptation, yet the spatial dimension has not gained adequate visibility. The low trend of publications demonstrated in the results, indicates much needed research to be conducted on climate change vulnerability and adaptation from a local and spatial perspective.

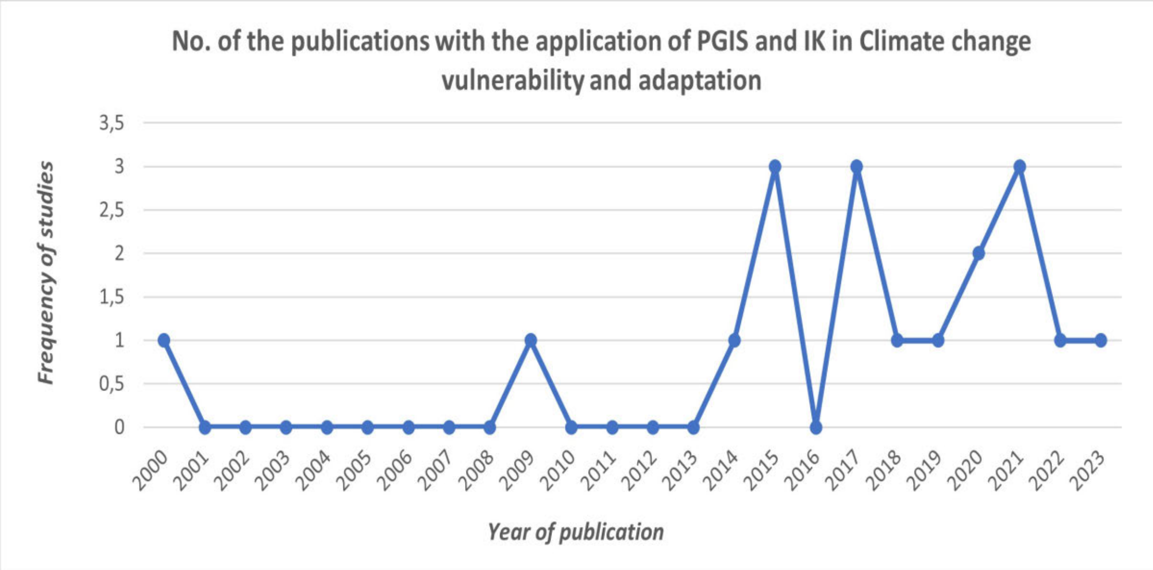

Figure 2.2: Frequency of publications on PGIS contribution towards understanding rangeland communal communities' vulnerability and adaptation to CC

2.4.2. Analysing the contributions of PGIS in enhancing understanding of pastoral communities' vulnerability and adaptation to climate change in Africa

This section delves into an examination of studies conducted in Africa that have employed PGIS to harness local knowledge for a deeper comprehension of pastoral communities' vulnerability and adaptation to climate change. The reviewed studies have been organized thematically and subsequently synthesized. This analysis delves into the key concepts that were thematically extracted to assess the role of PGIS in facilitating local adaptation among rangeland resource users in managing the risks posed by climate change.

2.4.2.1. PGIS contribution towards co-production of Local adaptation Knowledge

The strength of PGIS lies in its ability to facilitate the integration of expert and local knowledge systems, producing robust insights that enhance the sustainable management of natural resources. This section highlights PGIS' contributions to generating a comprehensive understanding of rangeland communities' vulnerability to climate change. The synthesis of two knowledge systems—local perspectives and scientific information—plays a critical role in climate change vulnerability assessments. PGIS methods are instrumental in enabling this collaborative knowledge production, as highlighted in the work of Bitsura-Meszaros et al. (2019), which emphasizes the benefits of co-creating knowledge. Key benefits of PGIS include enhanced communication, fostering co-learning, and enabling well-informed decision-making, followed by disseminating knowledge in ways comprehensible to all stakeholders, as demonstrated in studies by Karaya et al. (2021) and (Nyadzi et al., 2021), Canevari-Luzardo et al. (2015) and (Laituri et al., 2023) also illustrate how the process of knowledge co-production incorporates various data collection and mapping techniques that centre on integrating local knowledge with spatial interpretation. This approach effectively integrates local insights within a GIS framework, facilitating the representation of spatial knowledge and adaptation strategies. For example, (Hill et al., 2015) demonstrate the use of satellite imagery and participant-generated perception maps, georeferenced with QGIS, to create spatial maps that provide valuable insights into the utilization of grazing land and water resources. These maps demonstrated how PGIS can effectively bridge local and scientific knowledge, empowering communities to adapt more sustainably to climate change impacts.

PGIS and other participatory methods play a vital role in understanding and shaping livestock mobility patterns, which are key adaptive strategies employed by pastoralists to manage climatic risks. This finding is consistent with the argument advanced by (Elias, 2015), Hill et al. (2015), (Sixbert and Paul, 2019), (Napogbong et al., 2020) and Karaya et al. (2021) that participatory mapping can effectively enable the mapping of livestock mobility across seasons in search of pasture and water. By incorporating the spatial knowledge of pastoralists with scientific data, PGIS provides a more holistic understanding of how mobility is influenced by environmental factors such as drought, fluctuations in forage availability, and shifting water sources. This comprehensive perspective is instrumental in supporting informed decision-making and sustainable resource management within pastoral systems.

Cho et al. (2023) highlighted the application of various participatory approaches, including the use of a threat assessment matrix tool, focus group discussions, and local spatial mapping techniques such as sketch maps and digital images. These methods facilitated discussions and the mapping of threats to rangeland productivity. By employing these approaches, a platform was created for local actors to visually depict and analyze the spatial distribution of threats while considering the underlying factors contributing to these challenges. Cho et al.'s (2023) study demonstrated that through the use of PGIS pastoral communities could identify and analyse vulnerable areas in their environment and the corresponding factors influencing their vulnerability. In summary, the utilization of participatory methods, as demonstrated in these studies, provide insights into the vulnerabilities and adaptive strategies employed by rangeland resource users in response to climate change.

2.4.2.2. The Role of PGIS in Advancing Good Governance in Rangeland Resource Management

In addition to supporting the co-creation of combined expert and local knowledge, the review found that PGIS also contributes to good governance. This is evident in its role in conflict resolution, promoting gender equity, and empowering local actors.

The effects of climate change manifestation in terms of scarcity in natural resources exacerbates natural resource conflict. PGIS assist in identify the conflict hotspots and the factors perpetuating it. For instance, Smith et al. (2000) conducted a participatory risk mapping study, revealing the various types of risks perceived by locals, with conflict over resources ranking among the most significant. The generation of this spatial knowledge through participatory methods establishes a platform for conflict resolution, benefiting and enhancing local adaptation efforts. Daze's study in 2014 illustrates how the PGIS process has led to efforts aimed at strengthening land use planning and decision-making processes, resulting in the creation of mobility corridors for the free movement of livestock herds. Equitable decision-making power over land uses could mitigate conflicts generated by scarcity of resources. The subsequent paragraph discusses how PGIS promotes gender equality in resource use.

Rangeland resource use in Africa is shaped by distinct gender roles, leading to differing impacts of climate change on women and men. Cultural and social norms significantly influence decision-making power and adaptive capacity in the context of climate change (Daze, 2014). Addressing these gender and cultural dynamics is essential for fostering an inclusive and effective process that represents diverse community perspectives. Studies such as those by Pearson et al. (2017) and Nébié et al. (2021) highlight that men and women often have different perceptions of resource access and threats, with women's voices frequently marginalized in participatory processes. Furthermore, Smith et al. (2000) point out, not all community members actively engage in participatory mapping exercises. This often results in the dominance of more vocal or influential groups, typically men, while the perspectives of subgroups, such as women, remain underrepresented. Recognizing and addressing these disparities is critical for ensuring equitable participation and integrating diverse viewpoints into the sustainable management of rangeland resources. Moreover, women's and men's specific needs account for their interests in different spaces thus explaining the disparities in their vulnerabilities.

PGIS initiatives aim to involve marginalized groups, including women, ethnic minorities, and low-income communities, in the collection, analysis, and interpretation of geographic data related to climate change, resource management, and social services (McCall and Minang, 2005); Cho and Mutanga, 2021). Gender-sensitive methodologies are often employed to address inequities; ensuring women's voices are represented alongside men's by acknowledging their distinct experiences and responses to environmental challenges (Malaki et al., 2017). Efforts to address social inequities include engaging marginalized groups, such as indigenous communities or the economically disadvantaged, through culturally appropriate tools and accessible processes. Community mapping exercises and participatory workshops are often tailored to overcome barriers like illiteracy or limited mobility, ensuring inclusive participation. By prioritizing inclusivity and cultural sensitivity, PGIS processes create more equitable and comprehensive representations of local knowledge.

Furthermore, PGIS has emerged as a pivotal tool for empowering local communities in participatory spatial planning, decision-making, and natural resource management, fostering their adaptation to climate variability (Piccolela, 2013; Nébié et al., 2021; Albagali and Iwama, 2022; Cho et al., 2022). The participatory process enhances the legitimacy of local knowledge and empowers local actors (Sullivan-Wiley et al., 2019). By integrating scientific and local inputs, communities can draw their own conclusions, transcending external solutions (Valdivia et al., 2013), while ensuring marginalized groups' voices are heard (Bitsura-Meszaros et al., 2019). For example, Daze (2014) demonstrates how PGIS fosters dialogue between customary institutions and government bodies, enabling traditional rangeland management practices to inform resource management. This underscores PGIS's role in bridging local and institutional knowledge, improving decision-making, and addressing climate risks. Moreover, through participation in PGIS exercise local resources users develop capacities to assess their vulnerabilities and co-design solutions to stabilise their livelihoods against climatic shocks (Malaki et al., 2017; Nébié et al., 2021).

2.5. Conclusion and Recommendation

This review paper set out to investigate the growth of research on the integration of PGIS approach in rangeland communities' vulnerability assessment and adaptation research. It further examined the contributions of PGIS in empowering local actors to contribute towards' their adaptation to climate change. Overall, the findings reveal a slow growth in PGIS integration in pastoral vulnerability and adaptation to climate change research. However, the findings illustrate significant contributions made by PGIS in facilitating the participation of local communities in knowledge generation on the vulnerability of their resources and adaptation measures undertaken. Representation, access, and ownership of natural resources play a crucial role in determining the level of vulnerability and the community's ability to cope with climatic risks. This is particularly relevant in understanding the vulnerability and adaptive capacity of pastoral communities. Additionally, PGIS assisted the local resources users to articulate their vulnerability to climate change based on lived experiences and to contribute towards the identification of adaptation solutions.

The dearth in the studies conducted in PGIS integration in rangeland communities' vulnerability and adaptation, as already alluded to above, calls for more research in this area. The generation of knowledge in this regard is particularly crucial for policymaking and enforcement of context-specific local adaptive strategies, ensuring that local adaptation aligns with the specific sensitivities and needs of each community. A comprehensive and holistic approach to understanding the challenges and opportunities faced by these communities can also inform the development of more effective and targeted interventions.

CHAPTER 3: Exploring rangeland communities' perceptions of climate change through participatory approaches: The case of Vulindlela rangeland community, KwaZulu Natal, South Africa

Abstract

African rangeland communities face heightened social and economic vulnerabilities due to climate change, threatening their traditional livelihoods. Understanding these communities' perceptions, responses, and adaptations is crucial for developing effective, context-specific strategies. Pastoralists and agro-pastoralists, heavily reliant on rangeland resources, are particularly affected. While research often explores rural perceptions of climate change, the spatial dimensions have not been adequately examined. A spatial perspective is vital for identifying localized challenges and crafting tailored solutions. This study evaluates the integration of Participatory GIS (PGIS) with Participatory Rural Appraisal (PRA) to examine climate change's impact on rangeland resources and livelihoods in South Africa's Vulindlela community. Using focus groups, key informant interviews, transect walks, and household surveys, the research uncovered diverse perceptions of climate change causes, attributed to natural phenomena, higher powers, or human actions. These views are shaped by factors such as age, experiences, and dependence on rangelands, influencing adaptive responses. PGIS mapping highlighted areas most affected by climate events like floods and droughts, revealing spatially specific impacts on rangeland resources. Participatory mapping proved effective in capturing these nuances, enabling the creation of inclusive adaptation plans aligned with community needs and aspirations. By integrating cultural and ecological values, this approach enhances sustainability awareness and resilience within the socio-ecological system.

Keywords: Indigenous Knowledge, Participatory Geographic Information Systems, Participatory Rural Appraisal, Climate change, Vulnerability and Adaptation, Pastoralists and Agro-Pastoralists.

1. Introduction

Understanding local communities' perceptions of climate change is essential for effective planning and promoting environmental sustainability consciousness to enhance community resilience, especially with escalating global warming beyond 1.5℃ (Malhi et al., 2020); (Princiotta, 2021). Global warming, driven by increasing greenhouse gas emissions like carbon dioxide, is altering current climate patterns (Senda et al., 2020). African rangelands are particularly vulnerable, experiencing declining and erratic rainfall, rising temperatures, and recurrent droughts and floods (Angerer et al. 2016; Kariuki, 2018; Bayrak et al., 2020; Godde et al. 2020). These changes are reshaping grasslands, reducing their nutritional quality and soil organic matter, leading to increased erosion and water loss (Senda et al., 2020; Godde et al., 2020).

Climate change impacts are shaped by social, economic, and cultural factors such as age, education, gender, and income. Local perceptions, influenced by microclimatic events, personal experiences, attitudes, and education levels, also play a significant role in determining how communities experience and respond to these impacts (Ayal and Leal Filho, 2017), Ambrosio-Albala and Delgado-Serrano, 2018). For instance, older generations may interpret climate change based on long-term observations, while younger individuals may have differing perspectives due to limited environmental experiences (Reichel and Fromming, 2014). Higher education can further enhance understanding of climate change and associated hazards, shaping adaptive capacities (Reichel and Frömming, 2014). These perceptions, intersecting with broader socio-economic and cultural contexts, influence the ability to adapt to climate impacts (Bone et al., 2011); (Gemeda et al., 2023).

However, the factors shaping pastoral communities' perceptions and responses to climate change remain poorly understood. Many studies, such as (Bomuhangi et al., 2016), (Bhatta et al., 2020), and (Takakura et al., 2021) rely on qualitative methods—interviews, focus groups, and surveys—to capture experiential knowledge. These approaches prioritize narratives and subjective experiences, often focusing on socio-economic vulnerabilities like livelihood loss and food insecurity. While valuable, these methods frequently overlook the spatial dimensions of climate change impacts, such as how these impacts differ across geographic locations and landscapes.

Incorporating spatial analysis into the discourse on local perceptions can deepen understanding of climate change impacts on rangeland communities. This study seeks to address this gap by evaluating the effectiveness of PGIS and PRA in capturing the diverse and dynamic perceptions and responses of rangeland communities to climate change.

3.2. Utilizing Integrated Participatory GIS and Participatory Rural Appraisal approaches to explore Pastoral Communities' Perceptions of climate change causes and impacts

The use of participatory approaches in climate change research has grown over the years due to criticisms of top-down and techno-scientific thinking for inadequately explaining local climate change perceptions (Kieslinger et al., 2019; Ramaano, 2022). PRA techniques, for example, are valuable tools for generating local knowledge of climate change events within communities (Uddin and Anjuman, 2013). Pastoralists, for instance, employ PRA to identify climate change indicators such as abnormal temperature increases and delayed rainfall onset (Abate, 2016). These indicators not only help pastoralists interpret climate variations but also in anticipating droughts. Some local actors attribute climatic changes to supernatural beliefs, while others link them to human actions (Reichel and Fromming, 2014; Azong and Kelso, 2021). Additionally, pastoralists forecast floods by observing cloud coloration and sudden rainfall (Muyambo et al., 2017). Similarly, Boran pastoralists in Ethiopia use animal behavior and traditional practices like reading animal intestines to predict droughts or floods (Iticha and Husen, 2019; Apraku et al., 2021).

Local indicators for weather forecasting, which were once reliable, are now less accurate due to the increasing complexity of environmental changes (Egeru, 2012). Recognizing the importance of local knowledge in community responses to climate threats has led to a paradigm shift towards capturing these perspectives (Muyambo et al., 2017; Kleslinger et al., 2019). Utilizing local knowledge enhances understanding of local vulnerability and strengthens adaptive capacity (Kupika et al., 2019). Combining PGIS and PRA provides diverse dimensions of local climate change perspectives, with PGIS introducing spatial context and PRA focuses on the social, cultural, and economic aspects of local experiences (Nyantaki-Frimpong, 2017; Buba et al., 2021).

Although both PGIS and PRA are community-driven approaches aimed at empowering local populations in decision-making and knowledge generation, they differ in their methods, tools, and objectives. PGIS is a spatially focused approach that combines GIS technology with participatory methods to map, analyze, and manage geographic information from a local perspective (Young and Gilmore, 2017). It uses tools such as GPS, GIS software, and remote sensing to gather data on land use, resource distribution, and environmental risks (Hill et al., 2015). PGIS empowers communities by enabling them to control how their land and resources are represented and managed, operating across scales from local to regional or national (Buba et al., 2021). By integrating georeferenced data with local knowledge, PGIS facilitates the creation of spatial maps highlighting key locations like water sources or grazing areas, revealing spatial patterns and vulnerabilities (Ziadat et al., 2012). It further supports spatial decision-making by overlaying local data with scientific datasets such as satellite imagery, enabling communities to identify areas most affected by climate change or resource scarcity (Krishnamurthy et al., 2011; Eddy et al., 2017). These maps provide a geospatial representation of local knowledge, helping visualize relationships between environmental and social phenomena. However, the use of PGIS offers some limitations. PGIS requires technical expertise in GIS software and spatial data analysis, which may be limited in rural or remote areas.

PRA, on the other hand, emphasizes qualitative insights into the social, cultural, and economic dimensions of local communities. It employs participatory tools like focus group discussions, seasonal calendars, and ranking exercises to capture local perceptions, practices, and priorities (Daze, 2014; Cho et al., 2022). While PRA may include basic, non-technical maps, it does not incorporate advanced geospatial technologies like PGIS. Instead, its goal is to empower communities by validating their local knowledge and facilitating their active participation in addressing needs and social issues (Vaz et al., 2021); Aggrey et al., 2021). These insights are essential for understanding vulnerabilities and adaptation strategies at a local level but lack the precise spatial detail provided by PGIS.
PGIS excels in capturing spatial data and visualizing geographic patterns but may overlook deeper social and cultural dimensions unless supplemented with qualitative methods. For example, social networks, power dynamics, and cultural values are harder to represent through spatial data alone. Conversely, PRA offers rich qualitative insights but lacks the technical

precision to create detailed spatial representations, potentially limiting its ability to accurately depict geographic distributions of resources or vulnerabilities. Combining PGIS and PRA can address these limitations. PGIS can integrate PRA's qualitative findings to enrich spatial analyses with social and cultural context, while PRA can benefit from PGIS's geospatial accuracy to ground its narratives in precise geographic realities. Together, these approaches provide a more comprehensive understanding of local challenges and solutions, integrating spatial and non-spatial dimensions.

PGIS serves as an integrative tool, enabling geo-referencing of local knowledge and incorporating multiple perspectives to reveal climate sensitivity in the immediate environment (Krishnamurthy et al., 2011; Logie et al., 2023). This mapping technique communicates and generates spatial information on climate change impacts (Krishnamurthy et al., 2011; Burdon et al., 2019; Rawat et al., 2021). Combining participatory mapping and PRA techniques provides a spatial-specific assessment of local climate change perceptions. While PRA and PGIS techniques have been employed independently, combining them can yield a comprehensive assessment of local knowledge depth and spatial dimensions (Cho and Mutanga, 2021). Several studies have effectively employed PGIS to integrate indigenous knowledge, revealing local communities' perceptions and responses to climate change impacts. For instance, Maharjan et al. (2017) mobilised community participation in hazard mapping using PGIS, which led to the identification of climate-induced hazard-prone areas. Similarly, Krishnamurthy et al. (2011) utilized PGIS to identify socio-economic and biophysical variables which contribute to an understanding of hurricane risks and vulnerability. Reichel and Frömming (2014) explored participatory mapping to capture local perceptions of space and natural hazards, creating multimedia and georeferenced maps. Conversely, various PRA tools have been utilized to assess pastoral farmers' perceptions of climate change. For instance, Leweri et al. (2021) conducted participatory discussions and household semi-structured interviews. The participatory discussions and interviews were conducted to document pastoralists' perceptions on rainfall variability and its impacts on livestock production, with a purpose to illustrate the rainfall variability as the main driver of livestock mortalities.

Numerous studies have applied the integration of PGIS and PRA approaches to assess local climate change perceptions. While studies such as Malaki et al. (2017), Buba et al. (2021), Canevari-Luzardo et al. (2015), Rawat et al. (2019), and Burdon et al. (2019) have demonstrated the application of PGIS and PRA techniques in assessing local climate change perceptions, a significant gap remains in capturing the socio-dynamics of pastoral communities, particularly in rangeland contexts. Most studies fail to adequately address how different social groups (e.g., gender, age, and wealth) experience and respond to climate change, which could influence their perceptions and adaptive strategies (Buba et al., 2021; Bullen & Miles, 2024). Considering climate change perceptions from multiple perspectives is crucial for comprehending local vulnerabilities and fostering inclusive adaptive capacity (Shikuku et al., 2017). Capturing the interests, needs, and aspirations of specific groups is essential for informing inclusive intervention measures. Hence, this paper aims to demonstrate the effectiveness of integrating PGIS with PRA techniques in elucidating local perceptions of climate change. The paper further examines how these perceptions may influence pastoral communities' responses to climate change, utilizing the case study of Vulindlela, KwaZulu Natal, South Africa.

3.3. Methods

3.3.1. Study Area

The study was conducted in Vulindlela, a rural area in the upper region of the Msunduzi Municipality, 25km from central Pietermaritzburg (Figure 3.1). Vulindlela was chosen due to the presence of the communal rangeland, the main focus of this study and socio-economic factors typical of South African rural communities (Ngcobo, 2018). Livestock grazing and crop farming are the primary economic activities supporting the community, similar to other communal rangelands in South Africa (Cho et al., 2023). The Msunduzi Municipality lacks data on climate change impacts and suffers from high socioeconomic vulnerability due to unemployment and population growth (Hlahla and Hill, 2018). Moreover, the Vulindlela area is sensitive to flood and droughts due to rainfall and temperature variability which affect livelihoods, food and water security, and human and livestock health (Hlahla and Hill, 2018). The map illustrates Vulindlela's location within the KwaZulu-Natal Province, with the community boundary in orange and the rangeland boundary in red (Figure 1b). Vulindlela is within the KwaZulu-Natal province (Figure 1a).

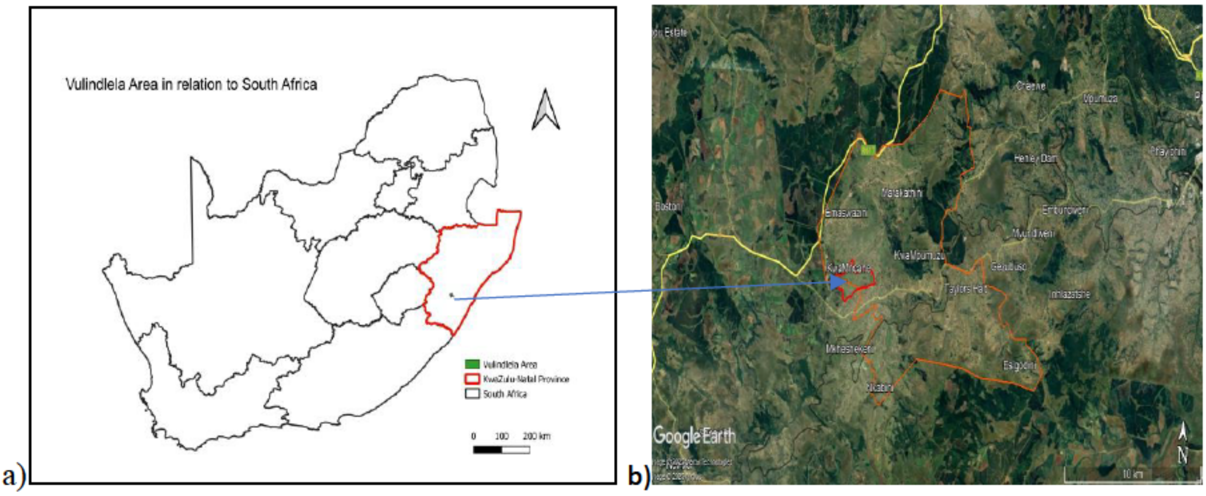

Figure 3.1: Map showing Vulindlela area and the rangeland boundary in Pietermaritzburg, South Africa.

3.3.2. Research Design and Data collection methods

The study adopts a mixed-methodology approach, combining Qualitative and Quantitative methods. Qualitative methods, utilizing participatory tools, captured participants' spatial perceptions of climate change, impacts, and vulnerability factors (Maman et al., 2009; Hodbod et al., 2019). Participants included male and female community members reliant on rangeland resources for various activities, livestock owners, and rangeland management practitioners. Qualitative data, focusing on subjective experiences, were validated through triangulation (Carter et al., 2014). Participant selection for focus groups, transect walks, and questionnaire surveys was facilitated by an official from the uMgungundlovu District Municipality, involved in the uMngeni Resilience Project (URP), which aims to enhance community resilience through sustainable rangeland management (Cho et al., 2023). Local participants' involvement was voluntary and ethically approved (Protocol: HSSREC/0004670/2022). Quantitative data collection involved administering questionnaires to gather individual perceptions efficiently (Jones et al., 2013). Quantitative data collection involved standardized, close or open-ended questions (Maxwell et al., 2017). A purposive and snowball sampling techniques were used to collect data from individuals living near the rangeland. Purposeful sampling was an appropriate technique as it was not the goal of the study to generalize to the larger population of the research area, but rather to obtain insights and understanding of the community's perceptions of climate change. The researcher, therefore, purposefully selected a sample "information rich" (Patton,

2014) in the subject matter. Purposive sampling is when the researcher intentionally selects participants based on a specific theory or idea that guides the research, expecting them to provide useful and detailed information (Curtis et al., 2000) ; (Omona, 2013), (Patton, 2014) (Creswell, 2015). The diversity of the participants was necessary to obtain multiple perspectives on the research questions (Creswell, 2015). Snowball sampling technique was employed to identify and recruit other potential participants with valuable additional information (Heckathorn, 1997); (Atkinson and Flint, 2001), (Handcock and Gile, 2011). Through the snowball sampling technique, some key resource people in the community assisted in referring others with rich knowledge on the climate change effects on the rangeland and livelihoods. Semi-structured questionnaires with open-ended questions were administered by two enumerators over three days to 62 participants. The sample size was restricted to 62 participants because interview got to a saturation point where no new day was obtained from additional participants (Saunders et al., 2018); (Lakens, 2022). Semi-structured questionnaires were administered to diverse groups of female and male crop farmers, livestock owners and herders across different age groups (above 18 years). The questionnaire covered respondents' basic information, perceptions of seasonal changes and extreme weather variability, drivers of climate change, impacts on socio-economic well-being, and local responses.

Data for qualitative analysis, were sourced through key informant interviews, focus group discussions (FGDs), GIS-integrated participatory community mapping, transect walks with GPS, and desktop reviews. FGDs were held on February 14, 2023, with 10 participants selected for their extensive knowledge of the environment (Palinkas et al., 2015; Ames et al., 2019; Buba et al., 2021). Participants, mainly comprising youth (n=8) and elderly males (n=2) from the pastoral community participated in the research. Discussions focused on climate-induced hazards, rangeland conditions, vulnerability factors, and perception's role in vulnerability. Mapping exercises were conducted using Google Maps, with participants sketching their perceptions of weather variability, hazards and vulnerable areas. Spatial analysis was done using QGIS version 3 software, to generate knowledge of the most affected areas and factors contributing to the vulnerability of the areas (Gundumogula, 2020). In addition, the transect walk, guided by knowledgeable community informants, occurred on March 23, 2023, led by two experienced elderly males from the Vulindlela livestock owner association (Maman et al., 2009). Using transect walks to gather spatial data offers several advantages over other spatial tools such as remotely sensed images, especially in the context of participatory and community-based research. In the context of this study, the transect walk was selected to allow for direct observation of the landscape which helped with ground-truthing of the spatial data generated from the participatory mapping exercise. It directly improves the accuracy of the spatial data by incorporating local knowledge and observations of participants who are familiar with the terrain and its changes (Cho et al., 2023). The aim of the transect walk was to explore issues discussed during FGDs and mapping, identifying biophysical and socio-economic parameters influencing rangeland productivity and vulnerability to climate change, along with adaptation mechanisms. GPS recorded geographical coordinates of identified variables. Key Informant interviews were conducted virtually with two rangeland management practitioners and four elders, with one face-to-face interview capturing historical climate change knowledge. The purpose was to gather insights which could not be obtained from the younger generation of participants during the focus group discussions.

3.3.3. Data Processing and Analysis

This section described how the data collected was analysed, to explain local perceptions of climate change and its impacts on communal rangeland communities. Quantitative data from household questionnaires were captured descriptively using Excel to perform the frequency analysis. The questionnaire data were organized into different groups of questions, and the number of respondents in each group was counted. The results were then presented visually using the bar and pie chart excel tools. SPSS and R are great for complex data analysis, like regression, but the research didn't need such advanced techniques. So, Excel was used for frequency analysis because it's easy to use, accessible, and sufficient for this study. Qualitative data from focus group discussions, key informant interviews, and transect walks were thematically analysed using a theoretical approach, as opposed to the inductive approach, in which the thematic analysis is underpinned by the study's theoretical framework (Tuckett, 2005); (Braun and Clarke, 2006). Thematic analysis identifies patterns or themes within the data (Braun and Clarke, 2006; (Kiger and Varpio, 2020). In line with Braun and Clarke's (2006) approach the following steps were applied in this research: (a) familiarisation with the data through reiterative process; (b) generating codes, which involved identifying features in the data that are interesting, relevant or pertinent to the study; (c) categorising similar codes into themes and sub-themes to develop meaning out of the primary data. NVivo software facilitated the coding and categorization of themes, which were identified from the knowledge gaps highlighted in the literature review, into main and sub-themes. These themes covered local perceptions of climatic hazards, responses, vulnerability, and the role of PGIS in understanding climate change awareness and vulnerability; d) the process involved reviewing, defining, and naming the themes to capture their essence and ensure they aligned with the research questions. Finally, appropriate titles were assigned to the themes for the final analysis, ensuring coherence with the overall study objectives. Spatial data from focus group discussions were stored as KML layers and converted to shapefiles using QGIS. XY coordinates from transect walks were translated using Excel and converted to KML layers, depicting features like water resources and livestock routes. Methodological triangulation validated data from multiple techniques, enhancing accuracy. Findings include statistical analysis of questionnaire data and qualitative analysis with narrative quotes. Results are presented in the section that follows. The participatory mapping methods offers some limitations. For instant, power dynamics in participatory mapping which can result in dominant individuals or groups influencing the process, causing biased or incomplete representations of the community's perspectives. Exclusion of marginalized voices, such as women or youth, can occur due to social or cultural barriers, resulting in skewed or incomplete mapping outcomes.

3.4. Results

This section presents findings from the study, aiming to explore how integrating Participatory GIS and Participatory rural appraisal techniques contribute to capturing the Vulindlela communal rangeland community's perceptions of climate change causes, impacts and responses. Results are divided into three subsections addressing research objectives. The first section represents the biographical data of the participants in the research, followed by a description of diverse perceptions of climate change impacts on rangeland communal resources and livelihoods. The third section demonstrates PGIS' role in providing a spatial dimension of climate change perceptions. The final subsection explores how these perceptions influence rangeland actors' responses to climate change.

Table 3.1: The Demographic Characteristics of the Participants

Demographic characteristics	Number	(%)
Gender:		
Male	24	38,7

Female	37	59,6
Age:		
18-30	16	25,8
31-40	13	21,0
41-50	14	22,6
51-60	12	19,4
61-70	7	11,2
Marital Status:		
Married living with husband	9	14,5
Married with absent husband	5	8,5
Divorced	2	3,2
Widowed	3	4,8
Single	43	69,0
Education Level:		
No formal education	12	19,4
Primary education	14	22,6
Secondary education	22	35,4
University	14	22,6
Head of Household:		
Male	31	50
De facto female	10	16,1
De jure female	8	12,9
Single female	7	11,3
Child head	6	9,7
Occupation:		
Unemployed	35	56,5
Employed	17	27,4
Self-employed	3	4,8
Pensioner	1	1,6
Students	6	9,7
Income Level:		
Below R3 500	40	64,5
R3 500- R5 000	13	21,0
R5 500-R10 000	5	8,1
R10 500-R15 000	3	4,8
R30 500-R40 000	1	1,6

3.4.1. Local perceptions of climatic changes and associated hazards affecting local livelihoods

Data from semi-structured interviews revealed that the majority of the Vulindlela communal rangeland community members, spanning diverse age groups, are aware of weather condition changes. However, 8% lack an understanding on the occurrence of climate change, primarily among participants aged 18 to 50, who noted no noticeable weather changes, as depicted in Figure 3.2. Most participants, however, possess a good comprehension of climate change, although they vary in their perceptions of weather changes, causes, and associated impacts on livelihoods, as depicted in Figure 3.2 across different age groups in the questionnaires.

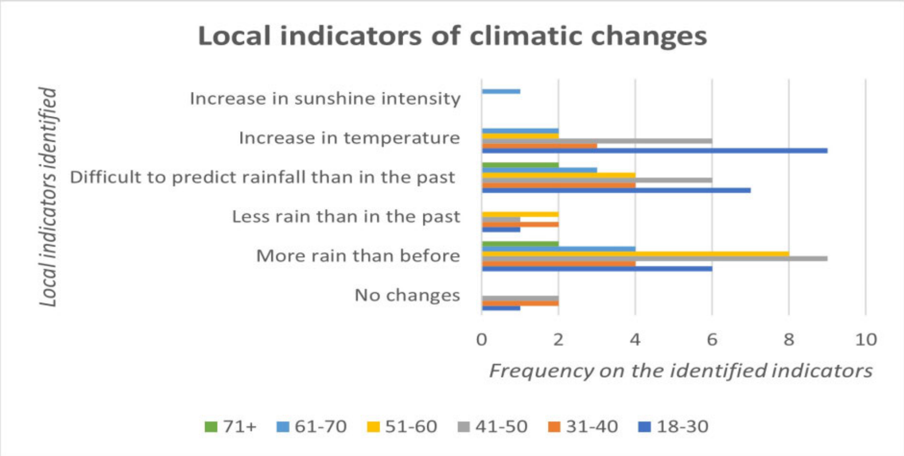

Figure 3.2: Local indicators used in the understanding the perceptions of the weather condition changes from diverse age groups.

Figure 3.2 further shows that all age groups experienced changes in weather conditions, with more rainfall being a commonly observed trend. However, 48% of participants noted a decrease in rainfall compared to the past, spanning ages 18 to 60. Ages 18-30 reported an increase in temperature and the challenge of predicting rainfall nowadays. In contrast, those aged 70 and older associated climate change with increased and unpredictable rainfall. A significant increase in temperature and reduction in rainfall over the past decade, were some of the observations raised during the focus group discussions. For instant, such observation was cited by Mthobisi as quoted below:

"For the past years, temperatures have been increasing drastically with less rainfall" (*Mthobisi, Male, FGD, February 2023).*

Mthobisi's observation was further echoed by Nobuhle, another participant during the focus group discussions, narrated as follows:

"One would expect more rainfall from the number of hot and dry days we've been experiencing, especially in the months of January and February, but less rainfall come" (Nobuhle, Female, aged 26, FGD February 2023)

Moreover, a key informant mentioned climate shifts as early as 1988, citing a dramatic increase in rainfall leading to floods in 2000, quoted as follows:

"I have lived in this area since 1988. Although temperatures were starting to change, the weather conditions were not as drastic as they are currently. We even had heavy rainfall back in the 2000s that were destructive to our houses and the dying of our livestock" (Bab' Mtolo, Key Informant Interview on historical data, February 2023)

Participants' observation of weather changes was associated with their prolonged interaction with the environment. Additionally, participants' ability to predict weather events through their distinct local indicators was investigated and it was found that, in the past, participants could predict rainfall based on specific indicators, as detailed in Table 3.2.

Table 3.2: The Participants' ability to predict rainfall in the past

Category	Indicators of rainfall
Clouds	Lots of clouds in the sky
	The clouds become darker.
	The colour of the sky changes.
	Dark cumulonimbus clouds appear.
	Clouds will change colour and shape instantly.
Birds	Birds called locally 'amahlolamvula' appear.
	Birds fly to hide in the trees.
	Swallows gather before the rain comes.
	Lots of birds not usually seen appear.
	'Izinkonjane', locally associated with rain, appear.
	The air becomes heavy.
Wind/Air	Strong winds before the onset of heavy rain and storms

Participants cited various reasons for their inability to predict rain, including rapid and unpredictable weather changes, rainfall occurring without warning, and precipitation even under clear skies. The study emphasized the community's dependence on natural indicators for forecasting rainfall onset. Focus group discussions yielded specific insights into observed weather conditions and seasonal changes, noting prolonged dry periods and heavy rainfall occurring without the typical darkening of clouds. Additionally, Madlala's observation cited in the quote below, echoed the observations from the focus group discussions:

"The dark and large clouds getting formed in the sky tells us that heavy rainfalls are coming. But now, heavy rainfalls come through even with the absence of the dark clouds, which we find it very unusual. We could also tell of the upcoming heavy rainfalls by birds flying around together, but because birds are now becoming nonexistent, we can no longer use them to tell us of the upcoming rainfall" (*Madlala, Male, aged 49, Transect Walk, February 2023)*

Furthermore, participants provided a description of how the weather patterns have evolved over the years from a historical perspective (Table 3.3).

Table 3.3: Historical Data on climate change

1988	2000	2014	2023
The change in weather conditions were starting to be experienced; Higher temperatures; longer dry periods than rainy seasons; The change in climate was gradual.	Experienced high rainfall and cold weather then; Temperatures were continuing to increase; Floods occurred; Hailstorms	Experienced high rainfall Floods occurred	Experienced high rainfall Floods occurred Intense heat

Focus group participants observed high rainfall leading to floods in January 2023, similar to flood events experienced in January-March 2014, as shown on Table 3.3. They also noted the emergence of annual prolonged dry seasons with intense heat, which are now typical in January and February. Lindokuhle, rangeland practitioner from the Key informant interviews emphasized the severity of drought over floods in Vulindlela, citing a nearly five-year drought period from 2010 to 2015, narrated as follows:

"There has been an occurrence of drought for almost a period of 5 years, which is more severe in Vulindlela as opposed to floods". (Lindokuhle Khanyile, SANBI, Key Informant Interviews, 20 March 2023).

Drought recognition is marked by minimal or no rain during the rainy season (November–February). Younger participants struggled to recall past extreme events, but an elderly key informant provided historical data, as shown in Table 3.3. The elderly participant's ability to recall weather changes underscores age as a determinant of participants' climate experiences. This highlights older generations' better observation of climate changes, aligning with the Sense of Place theory (Ambrosio-Albala and Delgado-Serrano, 2018).

Participants were questioned about their perceptions of the drivers of observed changes in seasonality (Figure 3.3). Younger participants (ages 18-30) mainly attribute climate change variability to human activities and natural temperature increases. Older participants (ages 41-50) cited natural causes, with some mentioning cultural activities. Opinions on seasonal change causes remained mostly unchanged over the years, although some attributed shifts to weather unpredictability, especially in rainfall patterns.

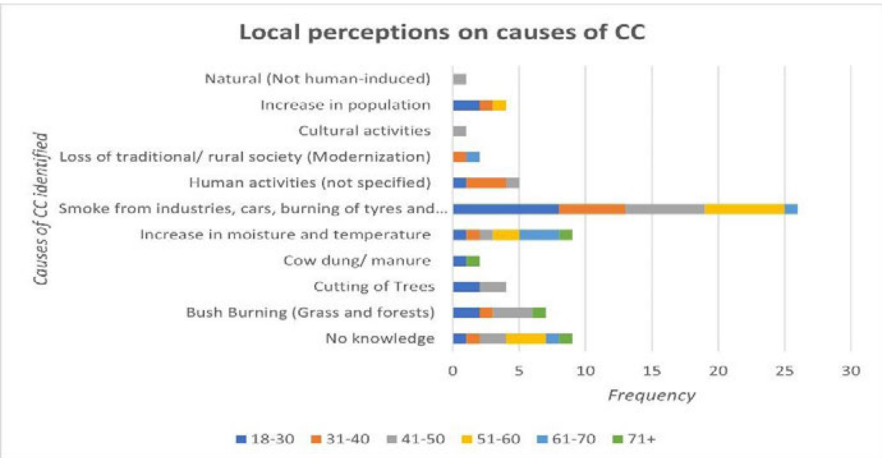

Figure 3.3: The variations in local perceptions of the drivers of climate change

Similarly, findings from questionnaires suggest that climate change and its variability result from various anthropogenic factors. Participants identified multiple drivers of change, including deforestation, grass and forest fires, industrial and vehicular emissions, livestock waste, population growth, and the loss of traditional or cultural practices as areas become more urbanized. Some participants were unable to specify the direct causes of climate change but could associate the drivers with human-induced activities. In contrast, older participants tend to interpret climatic condition changes through supernatural and cultural beliefs, attributing them to a Greater power. In a key informant interview, an elder (referred to as Bab' Mtolo) mentioned that weather changes are perceived as acts of God, not as punishment but as manifestations of divine power.

"God, the Maker is responsible for nature and humankind, so that means He is responsible for the weather changes happening". (Bab' Mtolo, Key Informant Interview on historical data, February 2023)

Participants highlighted adverse impacts on their livelihoods' sources, including livestock, grasslands, water resources, and croplands, due to changes in seasonality, increased temperatures, dry conditions, and flooding. Figure 3.4 shows diverse local perceptions of how climate change affects rangelands and livelihoods, with common effects like water scarcity, declining pasture quality, and livestock loss noted across all age groups. Some older participants recognized exacerbation of poverty by climate change. Key informant interviews with rangeland management professionals supported these findings, emphasizing vegetation loss for livestock due to water scarcity. These align with global literature, indicating similar trends in climate change perceptions in Vulindlela and other developing countries (Kuivanen et al., 2015; Ndlovu et al., 2020).

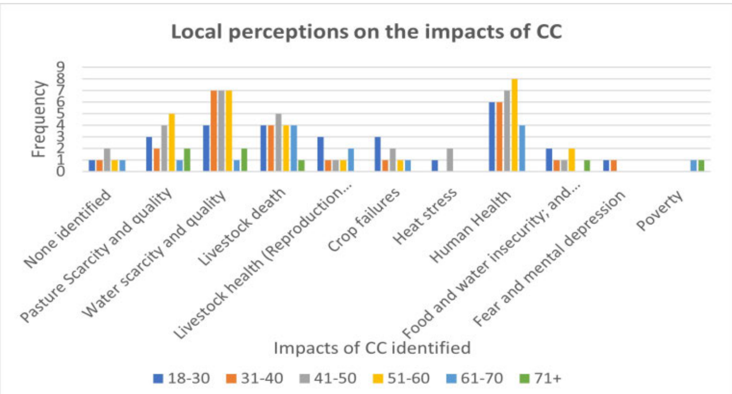

Figure 3.4: Variations in local perceptions on the effects of climate change on both the rangelands and livelihoods

Table 3.4 further elaborates the participants' perceptions of the impacts of climate change on their means of survival.

Table 3.4: The Participants' perceived impacts of climate change on their livelihoods and resources

Means of survival	Impacts of climate change
Livestock	-Loss of livestock as a result; and from heatstroke of cattle drowning in floods; dying from a shortage of water and grass -Reduced animal weight and livestock productivity, which affect the quality and quantity of livestock production -Increased livestock disease and mortality leading to food insecurity and loss of income
Grassland /Rangeland	-Floods result in soil erosion and landslides which remove grass/ vegetation cover -High temperatures and prolonged dry conditions scorch the grass and vegetation, making it unpalatable for the livestock -Unpalatable alien vegetation species invading the rangeland damage the teeth and health of the livestock
Water resources	-High temperatures and dry conditions cause increased water evaporation which dries up the rivers and springs, resulting in serious water scarcity -Heavy rains make water dirty and muddy, therefore unsuitable for drinking by people and livestock
Forest	-Fires break out in dry seasons and destroy the forest and its food resources
Cropland	-Crops burn out in prolonged dry conditions. This leads to food insecurity for the households and loss of income for those who sell vegetables. -The soil dries out making the land unsuitable to cultivate. -A portion of the land is covered in snow in winter making it uncultivatable.

The results in Table 3.4 reveal that the perceived impacts of climate change on participants' livelihoods are interconnected. For instance, the burning of grasslands due to high temperatures and drought adversely affects the quantity and quality of grass available for livestock, resulting in diminished livestock health and weight. This, in turn, has severe consequences for meat and milk production, ultimately leading to food insecurity and income loss for household's dependent on livestock for sustenance and income. As mentioned by Thabani in the focus group discussion, this interconnectedness underscores the complex web of effects stemming from climate change.

"*When there is no rainfall and the temperature is high, grass dries out and cannot grow, and this affects the health of the livestock because they can't have grass as their feed resource. You can see them by the decrease in their weight and the diseases they get" (Thabani, Male, aged 26, FGD February 2023)*

Lindelwa gave further insights on the impacts of climate change as quoted:

"When the temperatures are high, and there is limited availability of water, our jojo tanks are empty because it hardly rains, we suffer from heat stress and constant headaches as well as the changing of seasons causing flu. Our clinics are far from most of us so accessing medical services is difficult". (Lindelwa, Female, aged 23, FGD February 2023)

Another participant elaborated more on the insights given by Lindelwa, particularly on the health of the children associated with the effects of climate change on household needs as quoted below:

"One would think Jojo tanks are effective because we are able to store water when the municipality doesn't supply. But now, they are drying out since we are having longer period of no rainfall and dry temperatures. We use jojo tanks for our crops and in our homes. Now that temperatures are dry and water supply is limited, our crops dry out and then we have no supply of food. Our kids are not getting the food required for their bodies. Even if it rains, the rains are becoming heavy with more hailstorms causing flooding in our rivers, homes and washing away our crops. Hailstorms are not good for our crops and floods burst our sewage pipes with dirty water washing down in our rivers. We struggle in both summer and winter seasons because they come with different conditions and different problems". (Nobuhle, Female, aged 26, FGD February 2023)

Nobuhle's account illustrates participants limited adaptive capacity due to prolonged dry seasons, affecting water availability for domestic and agricultural needs. Water scarcity forces reliance on poor-quality water, impacting community health, especially vulnerable groups like children and the elderly. Climate change also affects mental well-being, notably among younger generations striving for livelihoods, as seen in Table 3.5. Health effects include illnesses from high temperatures, floods, polluted water, and seasonal changes. Table 3.5 offers a detailed summary of climate change impacts on Vulindlela's community members' health.

Table 3.5: The Effects of climate change impacts on the health of the Vulindlela community

Impacts of climate change	The effects on the community's health
High temperature and hot seasons	Skin cancer, heat stroke, headaches and fainting; brightness of the sun blinds them.
Floods	Trauma from floods and their destruction causes mental illness such as depression. Older people get diagnosed with diabetes and high blood pressure because of stress brought on by the uncertainty of climate change and its effects.
Polluted water a result of heavy rains	Stomach ache, diarrhea
Seasonal changes	Flu, asthma Chronic illness, such as arthritis get worse.

Nevertheless, the field data also shows that the rangeland community members' perception of climate change is also shaped by external sources of information. Figure 3.6 depicts the various sources of climatic weather information of the participants. Among the 62 participants, 58% get climate change and weather forecasts from television, 37% from school, 27.4% from radio, 16% from local NGOs, 14.5% from newspapers, 8% from Community Awareness Campaigns, 3% from churches, and 6.4% have never heard of climate change as depicted in Figure 3.5. Television and radio emerge as primary communication platforms for climate information. Access to information was also found to be associated with levels of education which varies with the ages of participants (Figure 3.6).

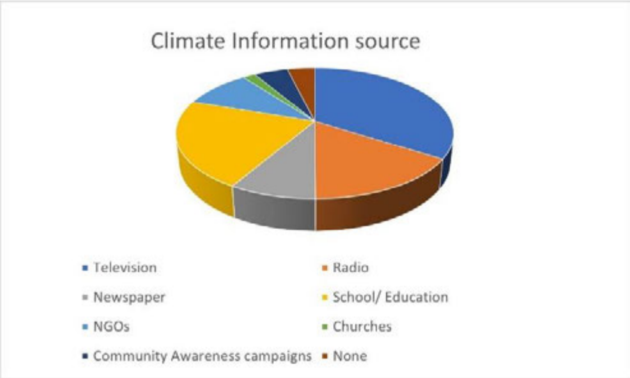

Figure 3.5: Sources where participants derive their climate information from

In addition, Figure 3.6 displays the education levels among participants in the Vulindlela communal community.

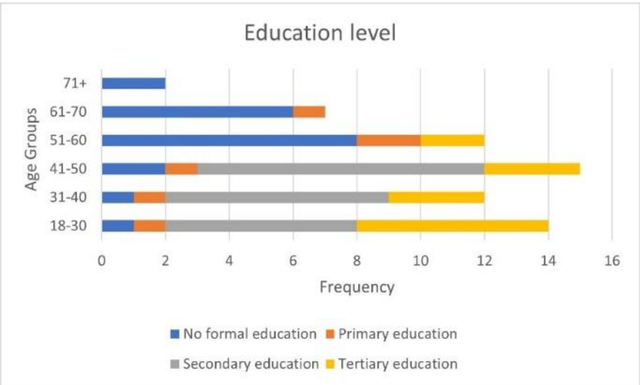

Figure 3.6: Education levels amongst the age groups

Furthermore, the study found education and age important factors that determined rangeland farmers' perception of climate change. For instance, the highest proportion of participants with no formal education, lacked access to external sources of climate change and weather information. On the other hand, majority of participants with tertiary form of education as depicted in Figure 3.6 had access to external weather and climate change information. Secondary education is the highest level attained by 35.4% of the participants in the Vulindlela community. This breakdown is crucial in illustrating the ability of communities to understand and respond to climatic changes. The results demonstrate that participants with formal education can better comprehend climate information and respond to it than the less educated as observed in related studies (Muttarak and Lutz, 2014). The results further indicate that while majority of participants have some form of education, there is a clear distinction between the younger and older populations in terms of how they access and understand climate information.

Secondary and tertiary education level is mostly obtained by the younger generation with some from the older population (41-50 years of age) as depicted in Figure 3.6. This indicate that the younger generation typically relies on formal platforms, while the older generation's understanding of climate change remains rooted in informal and cultural practices. Therefore, the role of education becomes evident in analysing differential understanding and awareness of climate change.

3.4.2. Contributions of PGIS in elucidating local perceptions of climate change and their vulnerability

This section illustrates PGIS' contribution to the understanding of local participants' perceptions of climatic risks that affect both their livelihoods and the sustainability of the rangeland, from a spatial standpoint.

The focus group participants delineated sensitive areas on the rangeland which stimulated discussions around the factors contributing to the vulnerability of the rangeland resources and livelihoods. Furthermore, the occurrence of hazards and the impacts on the rangeland community also formed part of the discussions. Figure 3.7 depicts areas susceptible to the impacts of climate change such as areas affected by drought. The discussions during the PGIS mapping exercise highlighted how a decline in rainfall pattern and dry conditions worsen erosion and vegetation loss. Additionally, climate change impacts such as riverbank expansion, disrupted springs, decreased groundwater levels, and crop failures were noted. Furthermore, PGIS revealed rangeland degradation from invasive plants like Black wattle, leading to pasture loss and reduced grazing lands. The study by Finca et al (2023) reported similar instances of the black wattle perceived by the local rangeland resource users as a contributing factor to rangeland degradation that has been revealed through the participatory mapping approach.

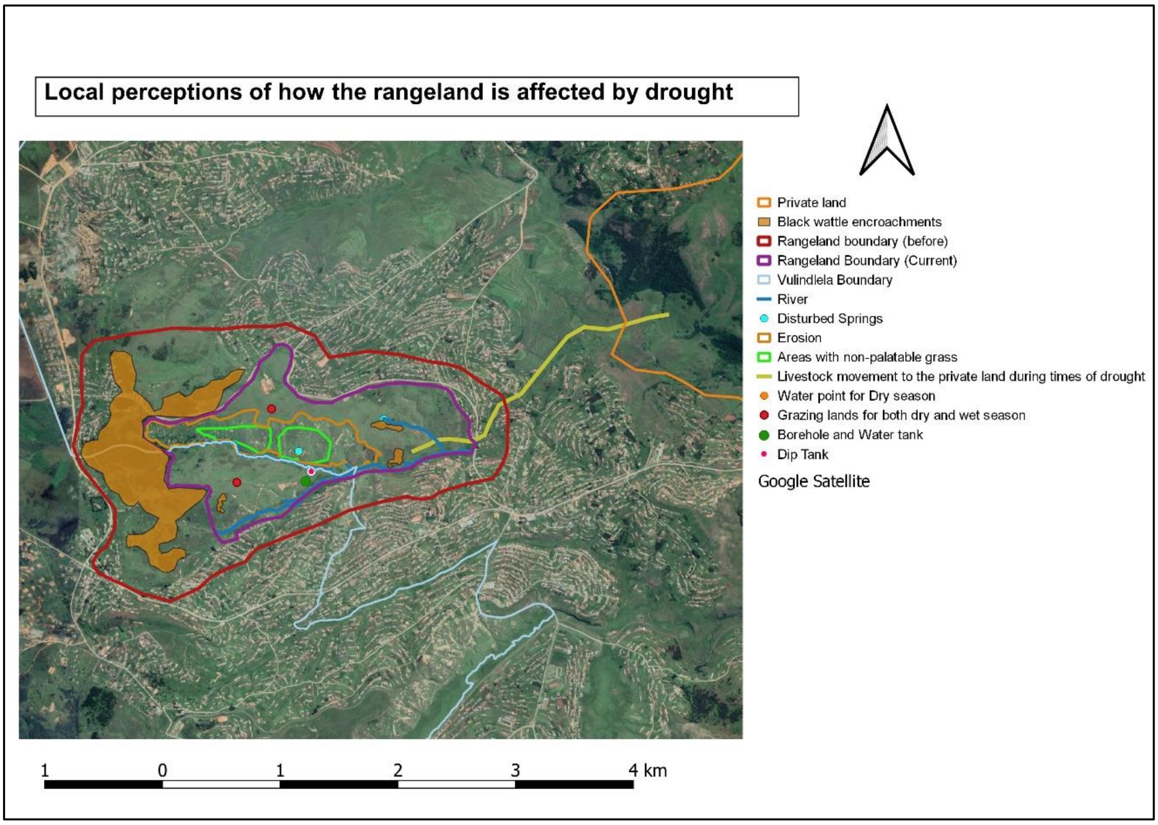

Figure 3.7: Participatory Map depicting areas affected by drought on the rangeland by the local participants on a satellite image. Source: Focus Group Discussion and Transect Walk field results.

Furthermore, during the focus group discussion, Thabani identified a stream where the community access water for both livestock and domestic use during wet and dry seasons (Figure 7). He noted the effects of climatic changes on the stream in the following quote:

"The utilization of the same stream for both seasons (dry and wet) for livestock drinking and household consumption is not entirely because of climate change. It is the closest river to the grazing land, where it is easier for herders to move livestock for drinking". (Thabani, male, aged 26, FGD, February 2023).

Thabani's narration implies that during dry season when the volume of water drops significantly there is competition over water needs for domestic use and livestock consumption. However, Bab'Mtolo, a key informant interviewee provided a counter view to that of Thabani. Bab'Mtolo noted that when there is water scarcity because of drought livestock are moved to private land to access water. His views are captured in the statement quoted below:

"When there is a period of drought and our rivers are dried out, livestock owners move their livestock in search of pasture and water into the privately owned land over the mountains. Springs are usually for the people of Vulindlela to access water and do spiritual activities, but now because of the high temperatures and dry season making our rivers dry out, livestock owners now move their livestock towards our springs." (Bab' Mtolo, Key Informant Interview, February 2023).

Bab' Mtolo further reported the challenges experienced in accessing resources such as the springs, denoted as "disturbed springs" in Figure 3.7, due to prolong dry season. His narration is captured in the following quote:

"With changes in our vegetation, rivers and water availability caused by long dry season and the rich able to buy private lands, we no longer have easy access to grazing lands. Even some livestock owners are now buying hays to feed their livestock. We are no longer able to access the private land because the owner has fenced his land. Our springs are no longer protected because everyone along with livestock want to access water". (Bab' Mtolo, Key Informant Interview, February 2023).

Additionally, an elderly participant provided further insights into the occurrence of floods and high temperatures and the resulting changes on their rangeland during the transect walk, as depicted in Figure 3.8. The participant identified where river expansions occurred resulting from the loss of vegetation associated with dry temperatures that is exposing topsoil to subsequent run-off:

"Years back, riverbanks were smaller, but now they are expanding. Flooding caused by the high rainfalls and the high and dry temperatures result in the loss of vegetation cover. The more vegetation is lost, the more soil can be washed away when there is occurrence of high rainfalls. This causes the riverbanks to expand, and then decrease the grazing land for the livestock". (Bab' Msomi, aged 68, Transect walk, February 2023).

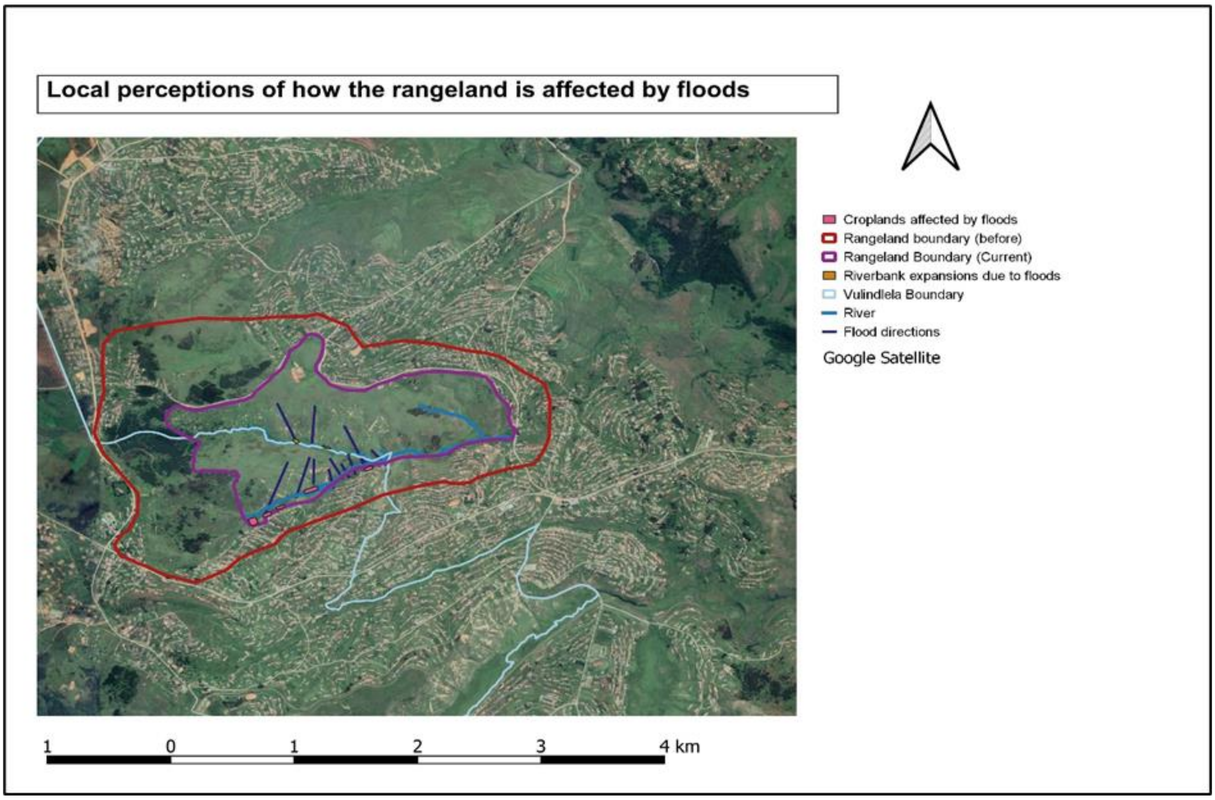

Figure 3.8: Participatory Map depicting areas affected by floods on the rangeland by the local participants on a satellite image. Source: Focus Group Discussion and Transect Walk field results.

One participant during the focus group discussions also identified areas with crop plantations by the community near the rangeland on the digital map, depicted in Figure 3.8 as "croplands affected by floods". She provided insights on the climatic events such as flooding on cropland, in the following quote:

"People plant crops in this area. Those who are settled close to the rangeland, you would see them having bigger cropland as there is more space for them. Heavy rainfalls and hailstorms do destroy crops for everyone, but those who are close to the rangeland get their crops washed away first because that's where flooding comes first before other houses. Since they have more space to crop, they would have more crops to sell or for home consumption, and when floods happen, they lose more crops than anyone else. This means, they spend more money for the seeds which gets damaged by the flood" (Nobuhle, Female, aged 26, FGD February 2023)

Furthermore, participants offered additional insights into measures taken to address the effects of climate change. Using the projected satellite image, participants depicted the locations of these measures (Figure 3.9). Moreover, during the transect walk one participant specifically highlighted some of these measures, including the installation of weirs and eco-logs implemented by the Umngeni Resilience project. Additionally, he mentioned community-initiated measures like the installation of cement structures around springs to protect the connected pipes between the spring and the dip tank. He provided this insight, narrated as follows:

> *"We've come together as a community and built a structure around the spring to protect the pipes that are connecting the spring-water to the dip-tank from cow trampling. The dip-tank needs continuous provision of water to ensure that our cows are washed from diseases. The pipes also assisted us in getting water easily. Having this structure ensures that our spring water is protected, that we can access water in times of drought". (Bab' Msomi, Transect walk, February 2023).*

During the focus group discussions, a participant highlighted how the Umngeni Resilience Project has contributed to educating the Vulindlela community about cost-effective measures to combat soil erosion and improve grassland vegetation. The participant also emphasized how the participatory mapping provided a visual representation of the area contributing to the understanding of the climatic impacts and the urgency to mitigate climate change effects on the rangeland.

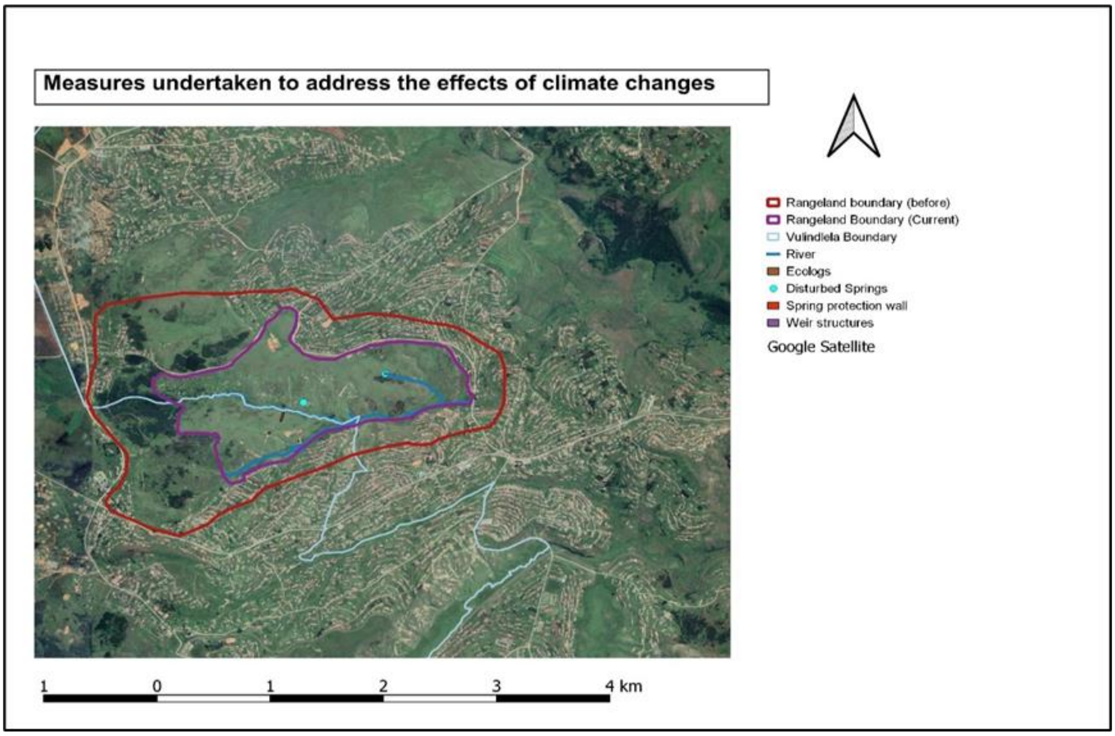

Figure 3.9: Participatory map depicting the identified locations of measures undertaken to address the effects of climatic changes by the local participants on a satellite image. Source: Focus Group Discussion and Transect Walk field results.

3.4.3. The influence of local perceptions of climate change on rangeland users' responses

Having discussed the local perceptions of climate change causes and impacts on rangeland resources and livelihoods, this section examines the implications of local perceptions on local actors' responses to the effects of climate change. The findings illustrate how perceptions and responses differ across age groups thus giving a generational dimension to climate change.

Participants' responses obtained from the questionnaires, focus group discussions, and key informant interviews show that the communal rangeland community of Vulindlela have different responses and coping strategies to the effects of climatic changes. Table 3.6 presents the coping measures adopted by the local rangeland resource users in response to the effects of climatic variability and changes.

Table 3.6: Summary overview of the different local responses and coping measures towards the effects of climatic changes

Categories of perception	**Descriptions**	**Responses**
Weather prediction challenge	Local resource users are finding it difficult to predict rainfall/ temperature patterns nowadays than in the past.	It becomes difficult for the community to plan their planting and harvesting times that result in crop failures. They respond by replanting new seeds or alternatively purchase food from grocery stores.
Climate change is caused both by anthropogenic activities and natural process	Younger people (18-30) associate changes in seasonality and variability in rainfall and temperature patterns to anthropogenic activities and natural causes such as Deforestation, grass and forest fires, industrial and vehicular emissions, livestock waste, population growth, and the loss of traditional or cultural practices as areas become more urbanized	In response to their view that climate change is associated with anthropogenic causes, they apply the following coping mechanisms: Digging of trenches around houses to allow the flow of water and prevent flood occurrence; replanting of new trees, advocating the reduction of number of cars on the road.
Climate change is associated with failure to comply with cultural norms.	A small number of people in the middle age category (41-50) attribute climate change impacts such as livestock loss and crop failure to retribution due to failure to comply with certain customs and traditional rites and therefore a failure to appease the ancestors, such as slaughtering of goats and cows as a cultural practice.	In order to get rid of the 'bad spirits' associated with the retribution, the middle age group practice what is culturally called 'ukubethela'. In modern terms it is installing lighting poles known as 'abafana'. The latter are believed to protect the house and people inside from the spirits of the dead. They also use salt for the same purpose. The bashing of tins to make sounds that will chase away storms.
Climate change is caused by supernatural forces such as God's manifestation of His supremacy.	The older generation believe that climate change is not natural but occurs as a demonstration of the supremacy of God	Because they perceive climate change as an act of God and therefore beyond human control, they believe there is nothing they can do.

Climate change has huge impacts on livelihoods and rangeland resources	Impacts include: water scarcity; declining pasture quality; and livestock loss and crop failure	Buying of jojo tanks to harvest rainwater; the use of disinfectants, eg jik, to purify dirty water; provision of hay as feeding supplements, and veterinary services for the livestock by external organizations. To supplement their means of livelihood, they rely on government and external organizations support in the form of food relief and seedlings for replanting and social networks (that is help from neighbours and friends).
climate change creates disturbance on the ecosystems	Impacts include: Riverbank expansions; disturbed springs; low groundwater and surface run-off levels; low river flow; and rangeland degradation resulting from encroachment of invasive alien plants, especially Black wattle that leads to palatable pasture loss and the subsequent loss of grazing lands, and lastly crop failures	Use of sandbags and eco-logs on rangeland slopes to prevent soil erosion; they use other water sources such as springs and boreholes; the creation of a buffer zone to prevent the encroachment of invasive alien plants on the stream and the rangeland;

Participants’ responses to climate change in the Vulindlela communal rangeland areas constitutes social, ecological and cultural dimensions. Table 3.6 depicts various coping mechanisms practiced by the rangeland community in Vulindlela. The participants’ responses show that perception determines how people response to climate change and there is a variability with responses across different age groups. The younger generation appear to be inclined to scientific methods of response while the middle and older generation employ cultural belief system as a solution to the adverse effects of climate change. For instance, the belief that climate change is a result of retribution for non-compliance with custom, attracts fetish response. Although, cultural forms of response to climate change might offer some comfort and assurance to those who practice them, there is research evidence that such belief systems discourage farmers from adopting scientific methods of intervention (Azong, 2021). As such more awareness is needed to enlighten farmers on the root causes and impacts of climate change and how they can possibly adjust their livelihoods source to cope with the climatic impacts.

3.5. Discussion

3.5.1. Local rangeland resource users’ perceptions of and response to climate change

This study was framed on the assumption that perception about climate change is influenced by social factors such as age, cultural belief system and education. Moreover, the perceptions of individuals and groups influence their responses to the effects of climate change. The study utilised the PRA and PGIS techniques, to determine how local communal rangeland community members’ perceptions of climate change causes, impacts and responses to climatic effects could influence their responses. Thus, using PRA and PGIS techniques participants explained their experiences of prolonged dry season resulting to drought and areas exposed to climatic risks such as water resources, and grassland.

The results show that the Vulindlela community has a good understanding of climate change, with variability in perception across different age groups. Social variability in perceptions of climate change exists within the community, as noted by Ayal and Filho (2017), Ambrosio-Albala, and Delgado-Serrano (2018). Climate change is perceived differently by individuals, some seeing it as a natural phenomenon, others as an act of a Greater power, while some understood it as caused by anthropogenic activities. These differences highlight how understanding of climate change is influenced by age factor combined with exposure to education both formally and informally. Perez-Ramirez et al. (2019) argue that individuals construct views of climate change based on social experiences and reliance on the environment for livelihood needs, resulting in diverse perspectives. This aligns with Rajala et al.'s (2020) Sense of Place theory, which states that local perceptions of climate change are shaped by communities' lived experiences and interactions with the environment. The results demonstrate that this principle is particularly applicable to local actors in the Vulindlela community, where livestock owners, for instance, share insights on the manifestation of climatic risks due to their close interaction with the rangeland compared to younger participants.

Local indicators used by farmers to predict weather events within the Vulindlela community align with those in other pastoral communities across Africa. Pastoralists use signs like abnormal temperature increases, delayed rainfall, disrupted rainy seasons, and changes in cloud coloration to anticipate rainfall or drought, as noted by Muyambo et al. (2017) and Abate (2016). Similarly, Nyadzi et al. (2021) argues that pastoralists' indicators of climate change occurrence vary by age. The older generation for instance, tends to attribute climatic changes to cultural or supernatural factors, while the younger generation views them from an anthropogenic perspective. This finding concurs with Apraku et al. (2021) observation of how age factor determines people's perception of climate change causes. Despite these differences, Vulindlela's local actors share a common understanding of climate change's impacts on their livelihoods and the rangeland, such as water scarcity and health effects, echoing experiences in other African pastoral communities (Iticha and Husen, 2019; Kupika et al., 2019; Nyadzi et al, 2021; Quandt, 2021).

3.5.2. PGIS contribution in understanding local perceptions of climate change

Logie et al. (2023) highlight PGIS as a collaborative tool for visualizing local perceptions of climate change's impact on specific locations vulnerable to climatic risks. Through Google Earth imagery and GPS technology, participants pinpointed key areas and attributes affected by climate change. Results showed varied perspectives on the causes and impacts of climatic risks ranging from the effects of drought on livestock movement, groundwater access and springs caused by the high and dry temperatures, to the effects of floods on riverbanks and the associated decreasing grazing lands. Lastly, the effects of floods on croplands. Thus, emphasizing the importance of localized knowledge in understanding vulnerability. PGIS was very useful in analysing areas on the rangeland that are most affected by climatic hazards such as flood and drought. Drought was a key risk expressed by the participants which affects water availability for both domestic use and livestock consumption. Although there were varying opinions in participants' narration of livestock access to water during protracted dry season, the bottom-line is the area is hit by high temperature and access to water is a challenge under such a climatic scenario. This finding concurs with the assertion that water scarcity in pastoral communities across Africa affects both livestock and the livelihoods of people who depend on them. Livestock rely on continuous supply of water for drinking, sanitation, and cooling, essentially for their health and productivity. A persistent scarcity of water in pastoral areas exacerbated by climate change has consequences on livestock such as dehydration, reduced milk production, increased susceptibility to diseases and even death. This may result in significant economic losses at both micro and macro levels since livestock contribute significantly to the GDP of pastoral societies. If the issue is not adequately addressed the sustainability of pastoral livelihoods might be severely affected. Research evidence suggests that a multi-faceted approach is required to address the impacts of climate change on water resources in pastoral areas, including improving water infrastructure, promoting sustainable water management practices, strengthening community resilience through diversified livelihood strategies, and enhancing climate adaptation measures (Inman et al., 2020; Stringer et al., 2021). This implies that the resilience of African pastoral communities to the effects of climate require collaboration between governments, non-governmental Organisations (NGOs), and local communities (Inman et al., 2020).

3.5.3. The influence of local perceptions of climate change on local rangeland resources users' responses to the effects of climate change

Climate change impacts are perceived differently, influencing farmers' responses and adaptation measures. This section explores how participants respond to these effects, considering factors that shape their adaptations. The study reveals various adaptation strategies adopted by local rangeland communities, influenced by scientific, local, and cultural factors. Resilience among farmers is linked to access to natural resources, skills, education, markets, and finance (Azong, 2021; Choden et al., 2020). Despite access to natural resource capital like grazing lands and water, households invest heavily in livestock management due to climate change effects. However, reliance on seasonal cash income limits their ability to cover additional costs. Crop failures and market access challenges exacerbate hunger, food insecurity, and poverty cycles for households (Ndlovu et al, 2020).

Farmers' responses to climate change are influenced by generational perspectives. Youth often approach climate change scientifically, employing strategies like trench digging and tree planting, advocating for reduced greenhouse gas emissions. Education shapes their perception and response, as noted by Garai et al. (2022). Conversely, older generations view climate change through traditional lenses, sometimes associating it with cultural practices. Similar instances were reported by Salite (2019) where most participants aged 45 years and older of the studied community linked the occurrences of drought to the non-frequent realization of certain cultural rituals. This belief system can hinder adaptation efforts, as some are reluctant to adopt scientific methods. Limited climatic knowledge among older farmers renders them vulnerable, exacerbated by a lack of access to formal climate information platforms (Salite, 2019). Grassroots climate change awareness is crucial to address this vulnerability (Aggrey et al., 2021). Despite differing views, climate change impacts affect everyone irrespective of social differences, as highlighted by Azong (2021).

This study has demonstrated the hinderance that local perception could pose to the realization of climate actions prescribed by the Conference of Parties' (COP) declarations aimed at mitigating the impacts of climate change. Conversely, misconceptions about climate change could also create a barrier to building a resilient pastoral livelihood system, thus compromising the drive of different initiatives such as the Malabo Declaration and the United Nations Agenda 2030, aimed at eradicating hunger and poverty (Carpentier and Braun, 2020).

3.6. Conclusion

This research aimed to explore how integrating PGIS and PRA techniques contributes to explaining Vulindlela communal rangeland community's perceptions of climate change causes, impacts and responses. This research explored its objective by employing various methods, such as focus group discussions, household surveys, key informant interviews and transect walk with the aid of a GPS. The findings reveal that the livelihoods of the Vulindlela community is threatened by climatic changes and considerably noticed by people regardless of their social group. However, social variability in perceptions exists in the studied community in terms of their comprehension of climate change regarding the occurrence of the climatic events and weather changes. The differences in perceptions are influenced by factors such as age, and educational level.

The findings reveal difficulties faced by local communities to predict weather conditions through local indicators due to climate variability. Implying that local communities are faced with challenges to plan and accomplish their seasonal based activities. The findings further reveal that the perception of farmers in Vulindlela influence their decision on measures to undertake to address the adverse effects of climate change. Local communities' perceptions are further shaped by social differences including age and educational level as observed in the Vulindlela rangeland community.

The study emphasises the importance of understanding local perceptions of climate change when designing mitigation and adaptation programs. PGIS proves valuable in providing spatial insights into the nature of climate change impacts and guiding intervention design. However, combining PRA and PGIS techniques yielded comprehensive information on climate change impacts and responses, integrating both spatial and non-spatial knowledge. It captures social, ecological, and cultural perspectives crucial for shaping decision-making on appropriate adaptation measures. Engaging local actors in mapping climate change effects enhances their participation and commitment to co-designing and implementing solutions.

The research outcomes have practical and policy implications. Practically, efforts are needed to educate pastoral communities, particularly older generations, about climate change and its effects on livelihoods. Policy interventions are essential to enhance pastoral communities' resilience to climate change impacts. Further research is necessary to explore the effectiveness of pastoral communities' adaptation measures and how institutional structures and policy interventions can bolster their resilience.

The integration of PGIS and PRA can be adapted to different rangeland communities by considering local cultures, governance structures, and environmental conditions. This requires tailoring participatory processes to meet the unique needs and capabilities of each region, particularly in areas such as drought-prone zones or those with pastoral communities.

CHAPTER 4: Synthesis, Conclusion and Recommendations

4.1. Introduction

This research primarily focused on applying integrated participatory mapping approaches for understanding local perceptions and vulnerability to climate change in communal rangeland communities. The following specific objectives were addressed in the research: Objective 1 reviewed the contributions of PGIS in explaining local communal rangeland communities' vulnerability and adaptation to climate change in the African context. Objective 2 applied integrated participatory mapping techniques to elucidate local perceptions of climate change and the implications of diverse perceptions on pastoral communities' adaptation responses.

This research presents two main chapters responding to the specific objectives mentioned above. A systematic literature review on the contributions of PGIS in pastoral and climate change research constituted the scope of Paper 1. The review was achieved using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement. Paper 2 presents findings on how participatory mapping techniques could be used to communicate local perceptions of climate change causes and impacts on rangeland resources and livelihoods. In addition, paper 2 addresses the third objective, which is how local perceptions could shape diverse responses to climate change. The findings of the study are drawn by employing various methodologies, including focus group discussions with a participatory mapping exercise, key informant interviews, transect walks, and household questionnaires.

Overall, the research aimed at contributing to climate change discourse through the integration of participatory mapping approaches to depict pastoral communities' understanding of climate change causes and impacts and how their responses can be influenced by their interpretations. In this chapter, a synthesis of the two chapters is provided, highlighting key insights, concluding remarks and recommendations.

4.2. Key insights on communal rangeland communities' perceptions and responses to the impacts of climate change

The study *"Exploring Rangeland Communities' Perceptions of Climate Change through Participatory Approaches"* provides critical insights into the resilience of the Vulindlela communal rangeland community to climate change. It highlights the importance of integrating PGIS and PRA techniques to understand local perceptions and foster co-knowledge creation. The findings emphasize how social factors, such as age and education, influence perceptions of climate change and, consequently, adaptation strategies.

The research illustrates how local actors perceive climate variability and its effects on their livelihoods, noting that traditional indicators guiding farmers' planning around seasonality are becoming unreliable due to an increase in erratic weather patterns. While the participants shared similar observations of climate variability, their interpretations of its causes vary based on social factors. This divergence in perception influences the approaches adopted to address climate challenges. For example, the study demonstrates that younger individuals are more likely to attribute climate change to natural causes, a perspective shaped by education and exposure to media. This group also tends to embrace technology and technical measures to mitigate climate impacts. In contrast, older individuals often interpret climate change through the lens of spiritual or cultural beliefs, favoring divine or spiritual interventions as responses to its effects.

These generational and social disparities underscore the importance of tailoring climate adaptation strategies to accommodate differing worldviews. The study concludes that planning for climate responses must consider these social differences to avoid resistance stemming from incompatible belief systems. Addressing these disparities is essential for fostering inclusive and effective climate resilience initiatives.

The study further highlights the significance of spatial data in understanding location-specific climatic challenges and responses. For example, it identifies sensitive areas affected by climate change, such as water resource in terms of erosion and reduced water volumes caused by recurring droughts. These impacts destabilize local livelihoods by limiting access to essential resources like fodder and water. Using PGIS, participants documented fluctuations in seasonal mobility patterns as they sought water and pasture, noting that this increased pressure on resources, particularly during the dry season. This spatial knowledge contributed in informing decision-making and designing adaptation strategies that not only enhance livelihoods but also promote environmental sustainability.

4.3. Answers to research questions

"How has the integration of the PGIS approach advanced understanding of community vulnerability and adaptation strategies to climate change in Africa?". The review answers the research question by showing how PGIS enhances understanding of community vulnerability and adaptation through integrated knowledge, collaborative mapping, and local empowerment, while also highlighting areas for improvement. It emphasizes the need for more research on PGIS in rangeland communities to inform tailored climate policies and suggests that addressing gaps in gender, local ownership, and social factors will improve resilience and adaptation efforts.

"How does participatory mapping contribute to the generation of local knowledge about the causes and impacts of climate change on rangeland resources and livelihoods?" The outcomes of this research show that participatory mapping, through the integration of PGIS and PRA techniques, significantly contributes to generating local knowledge about the causes and impacts of climate change on rangeland resources and livelihoods. Involving the community in mapping climate change impacts highlights how local perceptions, influenced by factors like age and education, guide decision-making and adaptation strategies.

"What are the implications of local perceptions for rangeland communities' responses to the effects of climate change on rangeland resources and livelihoods?" The outcomes of this study further show that social factors, like education and generational differences, shape climate change perceptions and adaptation strategies. It emphasizes the need for adaptation plans that combine scientific and local knowledge, address social disparities, and bridge the gap between traditional and scientific understanding to improve community resilience.

4.4. Conclusion and Recommendations

This research effectively addresses the aim of promoting the use of participatory mapping to enhance local involvement in assessing climate change impacts and generating climate-based solutions. By employing PRA and PGIS techniques, the study explored local rangeland communities' perceptions of climate change causes, impacts, and adaptation strategies. The findings of this research contribute significantly to broader discourses on climate change adaptation in communal rangelands by offering insights into how local knowledge, social factors, and spatial data can inform more inclusive and context-specific adaptation strategies. By highlighting the importance of integrating both traditional and scientific knowledge, the study encourages a more holistic approach to understanding and addressing climate challenges in rangeland communities. The research emphasizes the role of social differences—such as generational divides and educational backgrounds—in shaping perceptions of climate change and, consequently, influencing adaptation decisions. This contribution is valuable to the broader discourse as it underscores the need for climate adaptation policies that are not only scientifically sound but also culturally sensitive and socially inclusive. Tailoring interventions to the varying beliefs and knowledge systems of different community groups ensures that adaptation strategies are more likely to be embraced and successfully implemented.

Furthermore, the study's use of PGIS and participatory mapping tools offers a novel way of incorporating spatial data into adaptation planning. By documenting the localized impacts of climate change, such as water shortages and erosion, the research strengthens the call for data-driven, context-specific interventions. This aligns with global discussions on the importance of local-scale climate information for effective adaptation planning in vulnerable regions, like rangelands, where mobility and resource access are central to livelihoods.

The research outcomes carry important practical and policy implications. From a practical standpoint, there is a need for targeted education initiatives aimed at pastoral communities, especially older generations, to raise awareness about climate change and its impacts on their livelihoods. Education and awareness campaigns should address the diverse belief systems and encourage a shared understanding of climate change and its impacts. Policy interventions are crucial to strengthening the resilience of pastoral communities to the effects of climate change. Policies and interventions should be culturally sensitive and consider spiritual or cultural beliefs, especially for older generations. These strategies could be designed to bridge the gap between traditional and scientific views, ensuring that both younger and older generations are included in adaptation planning. This can ensure greater acceptance and participation in climate adaptation programs, fostering inclusive resilience-building efforts. Additionally, further research is required to assess the effectiveness of adaptation measures implemented by pastoral communities in building a robust pastoral system against climate change challenges that includes from an institutional and policy standpoint.

While the research emphasizes the success of PGIS and PRA techniques understanding local perceptions and vulnerability to climate change in communal rangeland communities, it is important to critically reflect on the potential limitations of these methods. One key limitation is the possibility of biases in participatory mapping, which can arise due to power dynamics within the community. These dynamics may result in certain voices, such as those of marginalized groups or less vocal individuals, being underrepresented in the mapping process. Additionally, disparities in the technical literacy of participants could affect the accuracy and inclusivity of the spatial data collected. Individuals with limited experience or knowledge of geographic information systems (GIS) may struggle to fully engage with the mapping tools, leading to incomplete or skewed data. This could impact the validity of the findings and the ability to generate truly representative climate adaptation solutions. A more nuanced consideration of these potential biases, and strategies to mitigate them, would enhance the reliability and inclusivity of PGIS and PRA methods in future climate change research and intervention planning.

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APPENDICES

***Appendix Figure 1**: List of Articles reviewed*

Author	Year	Title	Location
Butt et al.,	2009	Pastoral Herd Management, Drought Coping Strategies, and Cattle Mobility in Southern Kenya	Kenya
Chagumaira et al.,	2015	Use patterns of natural resources supporting livelihoods of smallholder communities and implications for climate change adaptation in Zimbabwe	Zimbabwe
Cho et al.,	2023	Understanding local actors' perspective of threats to the sustainable management of communal rangeland and the role of Participatory GIS (PGIS): the case of Vulindlela, South Africa	South Africa
Daze	2014	Using Analysis of Climate Change Vulnerability and Adaptive Capacity for Program Decision-Making: Lessons from CARE Ethiopia's Experience	Ethiopia
Elias	2015	Restrictions on Herd Mobility and Its Implications on Pastoral Adaptation to Climate Change: Perspectives from Drylands of Borena in Ethiopia	Ethiopia
Hill et al.,	2015	Participatory Mapping using Digital Earth Tools, Imagery and Open Source GIS in the drylands of Kenya and Tanzania.	Kenya and Tanzania
Ilboudo Nébié et al.,	2021	Participatory Mapping with Herders in a Climate Adaptation Research Project	Burkina Faso
Karaya et al.,	2021	A community-GIS supported dryland use and cover change assessment: The case of the Njemps flats in Kenya	Kenya
Liao	2018	Modeling Herding Decision Making in the Extensive Grazing System in Southern Ethiopia	Ethiopia

Lwasa et al.,	2017	Weather Forecasts for Pastoralism in a Changing Climate: Navigating the Data Space in North Eastern Uganda	Uganda
Malaki et al. 2017	2017	Assessing land use and land cover change using the participatory geographical information system (PGIS) approach in Nguruman Sub-catchment, Kajiado north Sub county, kenya	Kenya
Mdemu	2021	Community's Vulnerability to Drought-Driven Water Scarcity and Food Insecurity in Central and Northern Semi-arid Areas of Tanzania	Tanzania
Msambichaka and Onyango	2019	The dynamics of pastoral mobility routes in relation to food security in semi-arid areas of Simanjiro and Handeni districts in Tanzania	Tanzania
Napogbong et al.,	2020	Fulani herders and indigenous strategies of climate change adaptation in Kpongu community, North-Western Ghana: implications for adaptation planning	Ghana
Pearson et al.,	2017	Participatory mapping of environmental resources: A comparison of a Tanzanian pastoral community over time	Tanzania
Smith, K et al.,	2000	Participatory Risk Mapping for Targeting Research and Assistance: With an Example from East African Pastoralists	Ethiopia and Kenya
Wang et al.,	2022	Sedentarization as an adaptation to socio-environmental changes? Everyday herding practices in pastoralist communities in southern Ethiopia	Ethiopia
West et al.,	2020	Participatory Mapping with High-resolution Satellite Imagery: A Mixed method Assessment of Land Degradation and Rehabilitation in Northern Burkina Faso	Burkina Faso

Appendix Figure 2: Questionnaires

This questionnaire is designed to assess communal rangeland communities' knowledge of climate change impacts, and the environmental and socio-economic factors which expose and increases their sensitivity to adverse climatic events. The questionnaire further teases out the capabilities of these communities to cope with the effects of climate change on their livelihoods. The questionnaires are open to all gender, aged 18 and above, and who interact or depend on the rangeland for their livelihoods. The questionnaire is designed mainly for academic purposes with the hope of developing outputs that will help communities to improve on the management of climatic risks on their livelihoods. The questionnaire is divided into four sections including: Demographic characteristics, awareness of climate change effects on livelihoods, exposure and sensitivity, adaptation strategies and challenges.

Section One: Demographic Characteristics

1.1	**Name of Respondent**								
1.2	**Name of Community**	Vulindlela (1) Nhlazuka (2)							
1.6	**Gender:** Male=1; Female=2; Prefer not to mention=3	(1)			(2)	(3)			
1.7	**Age:** 18-30 = 1; 31-40 = 2; 41 – 50 = 3; 51 – 60 = 4; 61 -70 = 5; 71^{+} = 6; Prefer not to mention = 7	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
1.8	**Occupation:** What do you do for a living?								
1.9	**Marital Status:** Married and living with husband=1; Married with husband absent=2; Divorced=3; Single=4; Widow=5; Widower=6	(1)	(2)	(3)	(4)	(5)	(6)		
1.10	**Level of Education:** Did not go to school=1; Dropped out of school before grade 7=2; Completed complete grade 7=3; Dropped out of school before grade 12=4; completed Grade 12=5; University level+=6	(1)	(2)	(3)	(4)		(6)		
1.11	**Head of household:** Male = 1; Child Head = 2; De-facto female headed Hh (husband temporally absent e.g migrant spouse) = 3; De-jure headed Hh (Husband permanently absent by death or single) = 4; Single female Hh (never married) = 5	(1)	(2)	(3)	(4)	(5)			
1.12	**No. of Household Member(s)**								
1.13	**Income level:** Below R3500 = 1; R3500 – R5000 =2; R5500 – R10000 = 3; R10500 – R15000 = 4; R15500 – R20000 = 5; R20500 – R30000 = 6; R30500 – R40000 = 7; Above R40000 = 8	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Section 2: Participants' awareness of the occurrence, causes, and effects of climate change on their livelihoods: General Questions

1. How long have you lived in this community?
   ……………………………………………………………………
2. For the duration of your stay, have you noticed changes in rainfall and temperature patterns in your area? Yes ☐ No ☐
   - If YES, what has changed? (Tick applicable)

a. More rain than in the past

b. Less rain than in the past

c. Difficult to predict rainfall now than in the past

d. Increase in temperature

e. Others (please specify)

____

3. How were you able to determine when rain will fall in the past?
   ____

____

4. Are you able to know when the rain will arrive nowadays? ☐ Yes ☐ No

If no please explain why you cannot

____

____

5. What did you think were the causes of the changes in rainfall and temperature when you first experienced the changes?
   ____
   - ____ Has your opinion changed over the years regarding the causes of seasonal changes?

Yes No ☐ ☐

- If YES to this question, please explain how. ____

6. ____ _____________ How are the following affected by changes in seasonality?

- Your means of survival e.g livestock, grassland, forest, water etc. ___________________

____
____
____

- your health or that of your family ____

____
____

- your participation in social and cultural activities? ____________________________

7. ____ ___________Have you ever heard about climate change? Yes No

- If yes, how did you hear about climate change

a.) Television

b.) Radio

c.) Newspaper

d.) School/ education e.) NGOs

f.) Churches

g.) Community Awareness campaigns

- what is your understanding of climate change ? __________________

____
____
____

- Please share your local interpretation (belief systems) of climate change if there are any. ____ ____-

8. ____
____
____

8.2.Have you experienced any of the following climatic events? If yes, please indicate how you were affected and the severity of the event

Climatic event	Yes/ No	How long did it last?	How were you affected?	How serious was it?	How did you and your family cope?
Flood		A few days One week 2weeks – one Month Above one month		Very serious Serious Not serious	
Heatwave		A few days One week 2weeks – one Month Above one month		Very serious Serious Not serious	
Drought		A few days One week 2weeks – one Month Above one month		Very serious Serious Not serious	
Spread of pests and diseases		A few days One week 2weeks – one Month Above one month		Very serious Serious Not serious	

Thunderstorm		A few days One week 2weeks – one Month Above one month		Very serious Serious Not serious	
Lighting		A few days One week 2weeks – one Month Above one month		Very serious Serious Not serious	
Fire incidence		A few days One week 2weeks – one Month Above one month		Very serious Serious Not serious	

Section 3: Vulnerability of rangeland communities to Climate change

3.1. Do you have access to the following resources? a.) Television? Yes/ No

b.) Irrigation system? Yes/ No

c.) Groundwater system eg. Borehole? Yes/ No

d.) Electricity? Yes/ No

e.) Natural resources- Land eg. Grazing pastures, forestry wood, crop farming? Yes/ No,

- Water eg. For livestock, household consumption, biodiversity? Yes/ No

3.2. Does your family depend on the rangeland for survival? Yes/ No

If yes, state how? ____

____

3.3. What other means of income do you and your family depend on? ______________________

____

3.4. How have the following infrastructure been affected by the seasonal changes?

a.) Road? _______________

____

____

b.) Bridges? _______________

____

____

c.) Community Centers? _________________

____

____

d.) Schools? _________________

____

____

e.) Community clinic? _________________

____

____

3.5. Are you able to cope with the effects of seasonal (rainfall and temperature) changes? Yes/ No

If no, please explain why you are having challenges to cope with the changes _________________

____

____

3.6. What support do you receive from the government to help you and your family to cope with the effects of climate change? _________________

____

____

3.7. Are you satisfied with the interventions? If Yes or No, please explain why.
____

____

3.8. Do you have any other means of external support (e.g relatives, church, friends etc) to help you cope with seasonal changes? Yes/ No. If yes please state the source and type of support
____

____

Section 4: Adaptive Capacity of the communal communities to Climate Change

4.1. Do you think anything can be done to solve the problems caused by extreme weather conditions? Yes/ No

If yes, what can be done? ____

____

____

4.2. What personal actions do you undertake to deal with extreme weather events?

a. Planting of trees
b. Diversifying livelihoods

c. Nothing

d. Others (please specify) ____

4.3. What actions do the community take to deal with extreme weather events

a. Introduced community adaptation programs (please specify) __________

____

b. Sensitization of community members

c. other measures (please specify) ___________________________________

____

4.4. Who participates in deciding on what actions should be taken at the household and community level and why? _____________________________

____

4.6. Who do you think should have the most responsibility to address climate change? Tick applicable response

a. Individual?
b. National Government?
c. Local Government?

d. Environmental Organisations?

e. Other? Specify

4.7. How has the government supported your community in addressing climate-induced events? (Tick applicable)

a.) Disaster relief support eg. Food parcels, financial support?

b.) Rehabilitation support?

c.) Provision of water?

d.) Other? Specify

4.8. Are you satisfied with the measures in place at the household or community level to enable you to cope with extreme weather events such as flood, drought, storms? If yes or no please explain further ________________________

____

____

4.9. Please indicate the equipment that you use to get information about changing rainfall and temperature:

a.) Radio

b.) Cellphone

c.) Television

d.) Others (please specify)

Section 5: Have you had any training on how to deal with climate change? If yes please respond to the following:

Type of training	Who organized the training	How did it help you?

Appendix Figure 3: Focus Group Discussions interviews

1. **Exposure to climate change**

1.1. Have you observed the changes in rainfall and temperature?,
are you having more rainfall or less rainfall, and how long have you been observing this?
1.2. What do you think is responsible for these changes you have observed?

2. **Sensitivity to climate change**

2.1. How have these changes affected on your resources (Plot it as chart)
2.2. As a result of the changes, are you able to link them to the following ?

	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Severe (5)
Resources available (eg water, grass, forests)					
Access to resources					
The use of resources (Grazing land and water)					
Management of resources					

Exercise: PGIS Mapping

2.3. Sketch Map: to determine those areas that are heavily affected and factors contributing to the sensitivity
2.4. Based on the sketch mapping results: why are those areas more affected than others?

3. **Potential impacts of climate change**

3.1 How has the rainfall and temperature changes affected you and your community regarding the following:

	Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Severely (5)	If severely, please provide

						details
Health: Community Livestock						
Mortality rate: Community Livestock						
Income						
Nutrition						
Children's education						
Loss of Infrastructure						

4. Adaptation to Climate change

4.1. Group exercise:

3.1.1. Draw a map of your livestock movement across seasons- where do you take your livestock during rainy seasons as well as during the dry seasons. How are you coping with those changes? (exercise divided in two parts: Feeding and Water access)

3.1.1.1. Feeding patterns

3.1.1.2. Water Access

3.1.2. The map should include the impacts of these changes on their communities (show areas where communities have been affected.).

3.3. If there are some actions that you wanted to undertake but were unable to do so because of some constraints, please discuss the actions and the constraints faced. (socio-economic constraints) 3.4. Are there any cultural barriers affecting people's response to changes in rainfall and temperature in your communities? If yes to this question, please explain further

3.5. How does your traditional understanding of changes in rainfall and temperatures help you to cope with climate change? Do you think that your traditional understanding of changes in seasonality is sufficient to enable you deal with climate change?

If No, please explain what form of additional assistance you wish to have.

3.6. Discuss how technologies such as mobile phones, radio, and early warning systems have assisted you in dealing with rainfall and temperature changes and climatic events such as drought, flood, thunderstorms etc. Indicate successes and challenges.

3.7. Describe the type of assistance received from the Government and private institutions or other agencies to address the problems associated with climate change and your opinions about the assistance

3.8. Are you satisfied with the assistance received from the government or other institutions to enable your community to cope with the effects of climate change? If yes or no please provide reasons for your response

3.9. How have you benefited from the assistance received so far?

3.10. What additional assistance is needed?

3.11. How are adaptation decisions taken in the household and community levels?

3.12. Access and control of rangeland resources

Resources	Access	control
Water	Men Women Both men and women Traditional authorities	Men Women Both men and women Traditional authorities
Grass	Men Women Both men and women Traditional authorities	Men Women Both men and women Traditional authorities
Forest	Men Women Both men and women Traditional authorities	Men Women Both men and women Traditional authorities
Etc.		

4.13. What can be done to overcome the barriers/ constraints, If there are any?

__Appendix Figure 4__: Key Informant Interviews

1. What are the key climatic-induced hazards that have been identified/ observed and exposed by the communities?
2. How serious was the observed climatic induced hazard?
3. Describe the consequences of climate change on rangeland resources from an expert point of view e.g grassland, water, soil, plantation (forest and crops) etc.
4. What makes the area exposed to climate risks, in terms of:

a. Social factors ie. Level of education, income, institutional support

b. Natural factors i.e rangeland degradation,

5. What expert-driven strategies have been in place for communities to adapt to Climate change and how are the local resources users involved in designing and implementing the strategies?
6. What more needs to be done to overcome such limitations?
7. Are there sufficient resources for the support of local livelihood stability during extreme weather events?

8. What are the challenges hindering the effective implementation of adaptation strategies?