# PARTICIPATORY MAPPING OF KEY DRIVERS OF ECOLOGICAL CHANGE AND ANALYSING EQUITY DIMENSIONS OF ECOSYSTEM SERVICES FLOW IN THE KAT RIVER CATCHMENT

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# DEDICATION

This thesis is dedicated to the people who have supported me throughout my education. Thanks for making me see this adventure through to the end.

# DECLARATION

The work that is presented in this thesis is the original work of the author and has not been submitted to any institution or university other than Rhodes University, Grahamstown, South Africa. The work of other authors reviewed in this research is accurately cited in the thesis.

Signed: Date:

# ABSTRACT

Rivers are important ecosystems which supply ecosystem services critical to social-economic well-being. However, many rivers are degraded due to human activities. Degradation of river systems compromises the quality and quantity of ecosystem services they can supply. Managing important drivers of ecological change requires broad-based stakeholder participation to mobilise collective actions for an effective rehabilitation strategy. This study looked at two crucial research objectives in the Kat River catchment. The first was to undertake a multidimensional, participatory, engaged mapping of ecological changes, as well as current and changing ecosystem services in the Kat River catchment, and the second was to analyse the equity dimensions of ecosystem services flow in the Kat River catchment. Data were collected through semi-structured interviews and participatory GIS mapping exercises.

A purposive sampling method was applied to recruit research participants for interviews and workshops. Between March 13th and May 31st, 2023, thirty-one (31) participants representing four social groups, non-farming individuals, catchment management forum members, commercial and subsistence farmers, participated in interviews. Additionally, twenty-two (22) stakeholders attended 2-day workshops held between 20−21 April 2022, and 30−31 May 2023. Data collected from interviews and workshops were analysed using thematic analysis.

The results of stakeholder perceptions regarding the perceived ecological changes and their key drivers in the Kat River catchment revealed a concerning trend. Participants reported significant changes to the catchment area over time, including increased occurrences of flooding and water pollution and decreased aquatic biodiversity. Furthermore, degradation of ecosystem services, such as water quality, availability of medicinal plants, reeds, and fish populations, was noted. These environmental shifts have been accompanied by a rise in social-economic burdens, including the prevalence of water-borne diseases, cultural burdens (particularly the inability of certain groups to access ancestral grave sites) and declining fish populations.

These findings emphasise the urgent need for intervention strategies to mitigate further degradation of the catchment area and safeguard the well-being of both the human population and the integrity of the ecosystems. Recommended intervention measures include improving wastewater management practices and creating targeted public awareness campaigns. By

addressing these challenges, stakeholders can work towards preserving the integrity of the catchment area, protecting water resources and conserving biodiversity for future generations.

The equity dimensions (distributive and procedural equity) analysis revealed notable disparities in access to the benefits of ecosystem services, as well as in participation of residents in the Kat River Water Users Association. Certain social groups, such as commercial farmers, were observed to receive more benefits from ecosystem services, while other groups, including the elderly and disabled individuals, seem to be negatively impacted by the activities of those who benefit most from ecosystem services in the Kat River catchment. This raises not only an equity issue but also the issue of how costs are externalised by certain groups. Of particular concern was the finding that seventy (70) per cent of the research participants were not aware of the presence of the Kat River Water Users Association, raising concerns about procedural equity in water resource management processes. Additionally, ninety (90) per cent of the participants had the perception that there was unfair water access and allocation across the various social groups, highlighting possible distributive inequities.

The participants expressed a clear interest in learning more about the existence and operation of the Kat River Water Users Association, signalling a need for increased awareness and participation among social groups. Addressing these equity concerns is crucial to ensure that water resource management processes are designed to provide all stakeholders and water-dependent actors with equitable and fair access to decision making.

Moving forward, efforts should be directed towards raising awareness of the Kat River Water Users Association and to promoting inclusive participation among all social groups. This awareness may involve targeted outreach campaigns, community engagement initiatives and policy reforms to foster more equitable water governance practices within the catchment.

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| | |
|---|---|
| CMA | Catchment Management Agency |
| CMF | Catchment Management Forum |
| DWAF | Department of Water Affairs |
| DWS | Department of Water and Sanitation |
| ESKOM | Electricity Supply Commission |
| GIS | Geophysical Information System |
| KRWUA | Kat River Water User Association |
| KRC | Kat River Catchment |
| KRCMF | Kat River Catchment Management Forum |
| NWA | National Water Act |
| NWRS | National Water Resource Strategy |
| PGIS | Participatory Geophysical Information System |
| RSA | Republic South Africa |
| RU-HREC | Rhodes University-Human Research Ethics Committee |
| WUA | Water User Association |
| UNWWD | United Nations World Water Development |

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# CHAPTER 1: GENERAL INTRODUCTION

## 1.1 Introduction

Healthy freshwater ecosystems are critical for social wellbeing. Socioeconomic development is significantly influenced by freshwater ecosystems, which provide a variety of essential goods and services (Allan et al., 2021; National Research Council, 2005). Freshwater ecosystems provide various essential services, including transportation, recreation, the purification of water and human and industrial waste, and the supply of fish and other food for household consumption and income generation (Allan et al., 2021) The management of freshwater ecosystems is increasingly threatened by a growing human population, which in turn intensifies the pressure and stress on these natural resources (Akindele & Alimba, 2021). This study sought to assess drivers of ecological changes, as well as the impact of these ecological changes on the ecosystem services in the Kat River catchment (KRC) area. The study is important in that it traces patterns over a long period of time and reveals multiple phenomena which have caused different forms and processes of ecological change on the freshwater ecosystems of the Kat River catchment.

Human settlements, industries, and agriculture are major sources of water pollution. Pollution of freshwater ecosystems can have adverse effects on their integrity and functionality (Edokpayi et al., 2017). For example, fertilizers, pesticides, and other agricultural run-off can contaminate water sources, leading to a decrease in water quality, which in turn may affect the overall ecological health of the receiving freshwater ecosystems. Industrial and agricultural waste containing nitrogen and phosphorus have been linked to algal blooms in lakes, leading to the production of toxic compounds which can be dangerous to drink or even touch (Drechsel, 2010; Sinclair, 2010). The United Nations World Water Development (UNWWD) report of 2017 highlights the challenges of water scarcity and pollution. It also emphasises the importance of conservation and the need for improved management of freshwater resources. Additionally, it outlines strategies to foster resilience to water-related shocks and stresses. The report states that water scarcity has been compounded by climate change, population growth, urbanization, unsustainable consumption and production patterns, and pollution. It also suggests that water-related infrastructure and institutions need to be improved in order to ensure adequate access to safe and reliable water services, as well as equitable and sustainable use of water resources (Connor, 2017; World Water Assessment Programme (United Nations); UN-Water, 2009).

The sustainable and equitable management of water resources are undermined if important drivers of ecological change on freshwater resources are not identified and addressed across scale, but most importantly at the local scale, for example, through collective community actions. Key drivers of ecological change, such as climate change, which contributes to frequent and intense extreme weather events, can further impact on water resources availability (Bunch et al., 2011; Pollard & Du Toit, 2008). Urbanisation, industrialisation, and rapid human population growth are critical drivers of ecological change in freshwater resources which need urgent interventions across all levels. For example, in India, the demand for water has outpaced its supply due to human population growth, and this has led to a depletion of the country's water table, particularly in the northern states, resulting in water shortages and disputes between states over shared water resources (Chartres & Varma, 2010). This highlights the need for collective actions for equitable and sustainable management of freshwater resources.

Local communities within river catchments are critical stakeholders in the equitable and sustainable management of river resources (Sherwill et al., 2007). For example, worldwide, local communities living on river catchments have contributed to sustainable and equitable management of water resources through i) collective and individual actions for river restoration and protection (Warner, 2006), ii) advocacies that have led to local and national policy shifts (Carr, 2015), iii) communal accountability mechanisms which led to reduction of practices detrimental to river health (Anderson, et al., 2019), iv) participation in citizen science, contributing important data for decision making (Lenton & Muller, 2012), and v) holding government and polluters accountable for actions that are detrimental to the ecological sustenance of the receiving water systems (Percival et al., 2021). These examples suggest that mobilising collective, relational and individual agencies of local communities within river catchments is critical to equitable and sustainable freshwater resources management. An important first step in doing so is understanding the perception of local communities on key pressures and drivers of ecological river changes within their communities. This study used Participatory Geographic Information Systems (PGIS) mapping to explore the perceptions of local communities regarding the drivers of ecological change of the Kat River catchment in the Eastern Cape province of South Africa.

Participatory Geographic Information Systems mapping is a multidisciplinary approach that integrates expert and locally situated knowledge, allowing for a robust discussion at spatially relevant scales in the matters of catchment management (Álvarez Larrain & McCall, 2019; McCall, 2008). It can be described as the stakeholder's visual representation of values, assessment, and experience of the Kat River catchment, reflecting both present and historical changes.

Participatory GIS mapping is efficient and valuable in assessing and identifying ecological changes and ecosystems services, due to its involvement of multi-stakeholder local and technical insights (Kinchin, 2000). Its strength rests on the fact that local actors actively participate in the mapping exercise and can thus serves as an important tool for understanding community perceptions, and for mobilising collective actions for equitable and sustainable water resources management (Giuffrida et al., 2019). In this study, PGIS was used to co-identify 1) the perception of research participants on the drivers and pressures of ecological change in the Kat River catchment (KRC) area; 2) ecosystem services and the benefit derived by society and 3) perceived socio-economic concerns/burdens arising from the ecological changes. Although PGIS has been criticized as only being a tool for understanding perception, its robustness in linking stakeholders to catchment processes through an engaged participatory process provide impetus for its use in studies like this one. In addition, its application allows for understanding the equity implications of ecosystem services flow within the Kat River catchment. Its application also allows for a comprehensive understanding of the various ecosystem services offered by the Kat River. Additionally, PGIS can be used to identify the stakeholders who benefit from the ecosystem services and to assess their level of satisfaction, as well as to inform decision-making to better manage the KRC area and its ecosystem services. The intersection between equity and ecosystem services flow has not been extensively studied (Vallet et al., 2019). For example, understanding the equity-ecosystem service flow intersection is critical and contributes to the efficient and equitable distribution of ecosystem service flows among the societal groups in the catchment. By so doing i) it can contribute to more sustainable and equitable management of water resources (Hoekstra, 2014), ii) it will reduce the risk of ecological degradation and climate change, as well as ensure that all citizens have access to the benefits of ecosystem services (Yalew et al., 2021), iii) it can help to ensure that the interests of all stakeholders are taken into consideration and that the benefits of ecosystem services are shared equitably, and iv) all stakeholders can be better informed and empowered to make decisions which benefit both people and ecosystems (Rossi, 2011). Essentially, studying the equity-ecosystem service flow intersection helps to shed light on and contribute to knowledge by revealing i) the trajectory of ecosystem services flow in the catchment, ii) which social group(s) benefit the most and which benefit the least, iii) which social groups are most affected by the diverse ecological change and which are not/least affected, iv) informed and actively participating stakeholders in the governance of the Kat River catchment water resources, and v) those participating less in the water resource management.

For many years the Kat River catchment has supported a thriving irrigated agricultural economy, drawing water from local river bodies including rivers and streams. Citrus farming in the catchment has enjoyed so much success that the Kat River catchment area has become one of the major hubs of agro-economy in South Africa. For this reason, the Kat River catchment is an important contributor to the economy of the Eastern Cape province through earning foreign currency and creating jobs (Magni, 1999; Motteux, 2000). In order to gain a nuanced understanding of this social-ecological complexity, an in-depth study is required. This study focuses on the key drivers of ecological changes, impacts of perceived ecological changes on the flow of ecosystem services, and analyses equity dimensions of ecosystem services flow in the catchment. The analysis focuses on how different social groups within the catchment share the risks and benefits that arise from governance of the resources, and how they participate in the governance of these resources. The in-depth study includes a participatory geographic information system GIS mapping method in which local stakeholders narrate their experiences and key observations of the ecological changes.

## 1.2 Rationale and significance of the study

Freshwater ecosystem services are critical for socio-economic development. The quality, quantity and reliability of supply of these services can be impacted by drivers and pressure of ecological change such as climate change, alien invasive species, water pollution and other anthropogenic activities. The effects of these pressures and drivers on ecosystem services flow on different societal groupings raises distributive and procedural equity questions. For instance, which societal groups benefit from ecosystem services, and which do not? Which groups contribute the most to the drivers and pressures causing changes, and which bear the brunt of the resulting externalities affecting the flow of ecosystem services? Additionally, which societal groups have access to governance and decision-making processes that influence the quality, quantity, and reliability of supply of ecosystem services at the catchment scale?

These questions thus necessitate the need to study the intersection between equity and ecosystem services flow. The Kat River catchment area is an ideal case study because not much attention has been paid to its equity-ecosystem services intersection/nexus. This study thus fills this important knowledge gap by advancing our understanding of the intersections between equity and ecosystem services flow in a complex social-ecological system.

## 1.3 Research Aim and Objectives

The overarching aim of this study is to map key drivers of ecological change and to analyse distributive and procedural equity dimensions of ecosystem services flow in the Kat River catchment area.

The two specific objectives of the study are:
1. To map key drivers of ecological change and ecosystem services flow and associated benefits and risks in the Kat River catchment.
2. To analyse the distributive and procedural equity dimensions of ecosystem services flow in the Kat River catchment.

## 1.4 Thesis structure

Chapter 1: This is the general background chapter. A general introduction and background to the study is provided here. The chapter ends with the rationale, aim, objectives and the thesis structure.

Chapter 2: This is the literature review chapter. An extensive review of the literature is provided here, focusing on the different approaches to mapping ecosystem services, and the equity dimensions of ecosystem services flow and water resources management in South Africa.

Chapter 3: This is the methods chapter. The research design of the study is explained here, elaborating on the methods of data collection, sampling strategy, research participants and data analysis.

Chapter 4: This is a results chapter, focusing on participatory mapping of key drivers of ecological change, ecosystem services flow and social-economic burdens/concerns.

Chapter 5: This is a results chapter, focusing on the equity dimension of ecosystem services flow in the Kat River catchment area.

Chapter 6: The final summary for the preceded chapters. The main findings of the study are summarised here. The chapter ends with a conclusion, recommendations, and study limitations.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Key drivers of riverine systems ecological change

Ecological changes are global phenomenal that may lead to systemic shift in ecosystems such as freshwater ecosystems (Jaiswal et al., 2021). Ecological changes are caused by diverse ecological drivers such as climate change, over-exploitation of resources, human-induced pollution, habitat destruction and human population growth (Prakash & Verma, 2022). Ecological changes are shifts/alterations that alter or transform freshwater ecosystems at various scales over time (Mahlaba, 2022). This implies that persistent ecological changes may eventually lead to loss of biodiversity and a decrease in the overall health of freshwater ecosystems. The focus of this study was to understand the spatial and temporal elements of ecological changes in freshwater ecosystems. As the human population continues to grow, the demand for resources increases (Dai et al., 2012). This identifies human activities such as overexploitation of water resources and human-induced pollution as some of the primary key drivers of ecological change in freshwater ecosystems. These drivers put a strain on ecosystems, leading to the destruction of habitats, the overuse of resources, and the introduction of pollutants into the environment (Krausmann et al., 2013). For example, large-scale commercial agriculture activities have caused an alteration in water biodiversity due to the release of toxic agricultural waste in the water body (MacDougall et al., 2013). These changes impact on the food web, and the overall health and resilience of an ecosystem (MacDougall et al., 2013). As a result, (i) ecosystems are less able to withstand changes in the environment and are more likely to experience disruption or collapse. Such disruptions can put food security and human health at risk, as well as reduce the economic benefits of ecosystems (Dai et al., 2012); (ii) The reduction of biodiversity can lead to a decrease in the number of natural resources available for human use (Wato et al., 2020), and (iii) it negatively influences both humans and animals, as degraded freshwater ecosystems affect the availability of water resources (Lyytimäki, 2015).

The impacts of these key drivers of ecological change on ecosystem service flow is vital to the sustainable management of water resources in a society (Grizzetti et al., 2016). Therefore, this puts the water resources and the services they provide in a critical state and impacts both the ecology and human beneficiaries (Rossi, 2011). For example, (i) changes in the availability of water resources can lead to a decline in crop yields, a decrease in biodiversity, and an increase in water-related diseases (Dodds et al., 2013), (ii) changes in the quality of water can lead to a decrease in the availability of water for drinking and irrigation, as well as an increase in water pollution, (iii) changes in climate can lead to increased evaporation, which can reduce the quantity of water available for human use, (iv) water pollution from human activities can reduce the availability of clean water, further exacerbating water scarcity, and (v) climate change has resulted in higher water temperatures, which can lead to a decrease in water quality, a decrease in water availability, and an increase in water demand (Scrimgeour & Wicklum, 1996). These changes in water resources can affect the availability of ecosystem services such as water provision, regulation, and food production. In addition, it can have a direct impact on economic growth and the social well-being of local populations (Nyam et al., 2020). Therefore, it is essential to understand and manage the key drivers of ecological change to ensure sustainable water resources. These key drivers of ecological change can be categorized into two groups, namely, direct drivers and indirect drivers (Millennium Ecosystem Assessment, 2005).

Drivers of ecological change can be described as factors that directly or indirectly cause changes in the environment (Table 2.1). These drivers can be natural or man-made, and can include factors such as climate change, land use change and pollution. Human activities can often be the main cause of ecological change, leading to serious environmental degradation (Ruskule et al., 2018).

**Table 2.1** Classification of ecological drivers of changes in the environment (Millennium Ecosystem Assessment, 2005; Ruskule et al., 2018)

| **Direct Key Drivers** | **Change Impact** |
|---|---|
| Over exploitation and pollution | Ecosystem structure, function, and processes. |
| Invasive alien species | Ecosystem habitats change in the community. |
| Climate change on Habitats | Short, medium, and long-term ecosystem and ecological condition changes. |
| **Indirect Key Drivers** | |

| | |
|---|---|
| High human population. | Increases ecosystem service demand and supply. |
| Technological advancement | Scientific and technological discoveries for agricultural farming processes. |
| Culture and religion | Society cultural belief and values. |

### 2.1.1 Direct drivers of ecological change

Direct drivers are factors which influence ecosystem processes and structures explicitly (Nelson, 2005). For example, climate change, pollution, over exploitation of land or resources, and invasive species are all examples of direct drivers of of change of ecosystem processes. The impacts of these direct drivers on the processes and structures of the ecosystem can (i) affect the overall health of the ecosystem and the services it provides to humans and (ii) cause long-term changes in the structure and function of ecosystems, and these effects can be felt by other species and organisms (Mahlaba, 2022; Shi et al., 2021). These direct drivers can also have indirect impacts on other species and organisms, such as through changes in the availability of resources. For example, studies have shown overfishing to be the most influential key drivers of ecological change in some rivers in Europe leading to an estimated 90% stock decline in the river ecosystems (Sumaila & Tai, 2020). Mamun et al. (2022) assert that human population dynamics and activities are important drivers broadly influencing water quality, fish communities and ecological health across the world. In 2022 the population of South Africa increased by 0.87%, and it is estimated to reach 65.86 million by 2027. Essentially, the growing population (indirect driver) is leading to the overexploitation of resources, an increase in unemployment rate, and skyrocketing of food prices (Dorling, 2021; House & Street, 2017). The pressure from human activities, among others, drives ecological change in ecosystems as an increase in food prices not only impacts the production and consumption rate of food, but also the amount of generated waste. Therefore, it is important to monitor and manage direct drivers in order to maintain a healthy ecosystem and protect the ecosystem services they provide to the environment. In addition, it is imperative to explore the drivers of ecological changes, notably water pollution, overexploitation of resources and overpopulation, in order to better understand how they can be controlled.

### 2.1.2 Indirect drivers of ecological change

Indirect drivers influence ecosystem structures and processes through altering or causing one or more direct drivers (Millennium Ecosystem Assessment, 2005). For example, human population growth and an increase in human activities, technological advancements, especially in agriculture, and culture and tradition can all affect one or more direct drivers of ecosystem change. Indirect drivers can have a long-lasting and far-reaching effect on an ecosystem, making it vulnerable to further change (Meyer & Turner, 1992). Indirect drivers can also interact with direct drivers, amplifying their impacts. Indirect drivers can also have impacts on human health, such as air pollution or water contamination (Mamun et al., 2022). Globally, the wellbeing of people and their communities depends significantly on a freshwater ecosystem service. Human activities significantly impact on freshwater ecosystem health, water security, water quality, and the overall sustainable socioeconomic growth (Postel et al., 1996; Arnell, 1999; Dodds et al., 2013). Freshwater ecosystem health and water quality are severely compromised by various human activities. For example, in South Korea, massive industrialization caused severe impact to the ecological integrity of the Nakdong River basin (Kim & An, 2015).

Agriculture in South Africa is thriving and is vital to the economic growth and development of the country`s communities (Houmy et al., 2013). For example, irrigated agriculture is the Kat River catchment`s primary economic activity. Irrigated agriculture has supported citrus plantations with abundant production geared for the export trade, which has contributed to the economy of the area. Over the years, this has made water abstraction by water pumps for irrigation a major driver of ecological change (Burt et al., 2008). In the same area, there is limited access to a reliable source of water for consumption and domestic use, and this has become a concern due to a poor management strategy of the local freshwater resources. Furthermore, the impact of drivers and pressure on biodiversity, hydrological cycles, and water quality has led to pollution and eutrophication, which make the freshwater bodies unfit for domestic consumption (Singh & Singh, 2017).

Located in the Eastern Cape province of South Africa is the Kat River catchment area which has been severely impacted by human settlement and its associated livelihoods activities for a time period that spans centuries (Birkholz, 2009). Human settlement has been influenced largely by the catchment`s geography and fertile soil (Falayi, 2017). The soil is rich for varying agricultural activities such as crop farming, livestock farming and vegetable farming. The role that rivers play in the lives of an individual and the community is important, as water is critical to society for her sustenance and agricultural production (Khapayi & Celliers, 2015). These experiences and interactions shape people's perceptions of the river and its resources, subsequently guiding their behaviours and decisions. Each role the river plays reflects various dimensions of the connections the Kat River community shares with the river. For example, some indigenous people in the Eastern cape of South Africa believes that they connect with their ancestors through the river (Zingraff-Hamed et al., 2021;Gregory, 2006).

Not unexpectedly, the Kat River catchment is faced with various socio-ecological challenges, such as degradation and pollution of freshwater, overgrazing and unfair water allocation. These socio-ecological challenges have had profoundly negative impacts on social, economic, and political sectors in society (Holtzhausen, 2006).

## 2.2 Mapping drivers and pressure of ecological change, and ecosystem services

Different types of methods can be applied to the mapping of the drivers and pressure of ecological changes and ecosystem services within a river catchment. Methods include biophysical methods such as remote sensing and GIS mapping, and participatory mapping (Maes et al., 2013). Mapping ecosystem services and drivers of ecological change using biophysical methods involves assessing and quantifying the physical characteristics of ecosystems which contribute to the provision of the various services they supply (Martínez-Harms & Balvanera, 2012). Physical characteristics such as climate, topography, vegetation, and soil type all play a role in determining the types of services that an ecosystem can provide. Strengths of the biophysical method include (i) it helps to identify areas at risk from human activities and climate change (Canham et al., 2019), (ii) this information can then be used to make decisions about land use, management, and conservation, (iii) it can provide insight into the relationships between ecosystem components, such as their interactions with other ecosystems and the human activities that affect them (Vihervaara et al., 2018). However, there are some limitations associated with this method, namely; (i) there can be a lot of time and expense involved in carrying it out; (ii) it does not take into account the perceptions of human about ecosystems (Mononen et al., 2017); and (iii) it can be complex and requires specialized knowledge and experience and in some cases data interpretation can be complex(Schwartz et al., 2022). The inclusion of local stakeholders' views in the mapping processes is critical, particularly from a policy and management perspective a stakeholder involvement is essential for achieving sustainable management of ecosystems, which is why I chose to use a participatory mapping method in this study.

Participatory mapping is a technique that incorporates stakeholders' engagement in the mapping process with the aid of topographic maps (Brown & Fagerholm, 2015). Participatory mapping methods, such as the participatory geophysical information system (PGIS), allows for collective assessment of the spatial and temporal distribution of ecosystem services and key ecological drivers of change based on local knowledge, preferences, values, or perceptions. PGIS approaches integrate local and expert knowledge in a deliberative manner, providing contextually rich insights into the object being mapped (McCall, 2008). Participatory GIS mapping involves the integration of different stakeholders' knowledge, insight, values, and perspective of ecosystems (Burkhard & Maes, 2017).

This study sought the inclusion of stakeholders' inputs in the mapping of key drivers of ecological change and ecosystem services, to provides integrative measures for both expert and local knowledge of the environment. This makes the technique a democratic approach to policy and decision-making. It is not an overemphasis to assert that the involvement of stakeholder engagement in a free and democratic style, that allows space for diversity of both voice and knowledge, is the strongest value proposition of the PGIS technique, which by contrast other mapping methods such as ecosystem models, GIS and remote sensing do not have (Burkhard & Maes, 2017). This make the PGIS mapping method ideal for this study.

Despite the criticism and limitations, the PGIS mapping method offers, an exclusive stakeholders' involvement method (i) renders the stakeholders well-informed on the ecological changes and ecosystem service flow in the river catchment and (ii) considers their views when developing valuable sustainable insights into management practices in water resources (Fagerholm & Palomo, 2017). Given these strengths, the PGIS mapping method is suitable to achieve the aim of the study, which is to undertake a participatory mapping of drivers and pressures of ecological change, as well as ecosystem services, with a view to analysing their equity implications. The emphasis of this approach lies in its focus on equity. Participatory GIS mapping method has been applied to various studies. For example, it has been applied to map ecosystem services categories such as provisioning and cultural services, and the spatial and temporal distribution of ecosystem services supplies (Burkhard et al., 2012). Other studies have applied stakeholder participation of PGIS in the ecosystem spatial assessment, for example García-Nieto et al., 2015 (2015) used Public Participation GIS mapping method to map ecosystem services and assess the spatial-temporal distribution of a Spanish agroforestry dehesa. The method demonstrated high potential for the identification of key services in agroforestry (García-Nieto et al., 2015). Participatory GIS mapping methods usually achieve better outcomes when mapping ecosystem services at the local scale than geospatial tools approaches alone. Participatory GIS method was used in a study where the authors assessed the drivers of ecological change for a sustainable development in water and agricultural management in South Africa (Nyam et al., 2020) The approach provided a valuable platform for the identification of drivers of change, as well as their characteristics regarding the agricultural development in South Africa (Brown & Fagerholm, 2015).

## 2.3 Ecosystem services

The concept of ecosystem services highlights the importance of natural processes and resources for human health and well-being (Zhang, W. et al., 2007). It emphasizes the need to manage, conserve and protect ecosystems in order to maintain the services that they provide. Ecosystem services have been conceptualized by different authors. Costanza et al. (1997) conceptualized it as benefits human populations derive, directly or indirectly, from ecosystem functions. Daily (1997) conceptualized it is as vital processes that sustain life within natural environments and support the well-being of their inhabitants. Millennium ecosystem assessment, (2005) define ecosystem services as benefits that humans obtain from ecosystems, which are produced by interactions within the ecosystem. Eamus et al. (2005) conceptualized ecosystem services as those goods and services that are provided by or are attributes of ecosystems that benefit humans. This study adopted the definitions of Costanza et al. (1997) and Millennium Ecosystem Assessment, (2005). Ecosystem services are the ecological characteristics, functions, or processes that directly or indirectly contribute to human wellbeing, that is, benefits that people receive from functioning natural ecosystems, such as clean water, clean air and fertile soil. There are four major categories of ecosystem services. (1) Provisioning services, which are material benefits human receive from ecosystems. Examples of provisioning services include water, fibre, and fuel (Spangenberg et al., 2014). (2) Regulatory services, which are functional benefits that humans derive from nature, for example, water purification, air purification, and erosion and flood control (Miah et al., 2021). (3) Supporting services, which are ecosystem-supporting benefits nature provides to humans, such as water and nutrients recycling, soil formation and retention, and (4) Cultural services, which are immaterial benefits/values that humans enjoy from nature, such as aesthetic values, religious and spiritual values, and recreational and ecotourism values (Zhang, W. et al., 2007). Ecosystems supply a range of goods and services that are vital to human livelihoods, health, well-being and survival (Costanza et al., 2014). These services provide benefits to human beings that are necessary to maintain the quality of everyday life, such as food production, climate regulation, air and water filtering and recreation (Millennium Ecosystem Assessment, 2005; Costanza et al., 2014). Table 2.2 outlines the various types of ecosystem services with some examples.

**Table 2.2** Classification of ecosystem services, adopted from the Millennium Ecosystem Assessment (2005)

| **Example of provisioning services** | **Examples of regulating services** | **Examples of supporting services** | **Examples of cultural services** |
|---|---|---|---|
| Food<br>Wood and Fibre<br>Fuel<br>Fresh water<br>Medicine | Erosion and flood control<br>Crop pollination.<br>Water recycling and purification<br>Atmospheric regulation | Soil formation<br>Nutrient cycling<br>Water provision<br>Soil structure and fertility<br>Photosynthesis | Recreational activities<br>Aesthetics and Ecotourism<br>spiritual values<br>Educational<br>Health |

Ecosystem services supplied by river systems can be impacted by ecological changes such as deteriorating water quality, bank erosion, habitat and biodiversity losses (Dodds et al., 2013). This can have a negative impact on river-dependent livelihoods. The impact on livelihoods may not be the same for different societal groupings and individuals, thus raising equity concerns regarding the flow and benefits accruing from ecosystem services in catchments. In the Kat River system for example, large scale commercial agriculture, failing wastewater treatment works and livestock farming are key contributors of ecological change in the catchment. These main contributors' impact on the quality, quantity, and reliability of the supply of important riverine ecosystem services (Döll & Zhang, 2010). There is a need to explore the equity-ecosystem services nexus within the lenses of a social-ecological system. Such an exploration should shed light on the equity dimensions of ecosystem services flow and ecological change in the Kat River catchment, an important research question that has not been addressed in the past.

## 2.4 Equity

Equity is fundamental to creating a just, equitable, and inclusive society. Equity requires recognising and correcting the inequalities that exist in our society (Rawlins, 2019). It involves an ongoing commitment to identifying and rectifying disparities, promoting fairness, and ensuring that everyone can reach their full potential (McDermott et al., 2013). In the South Africa context, the National Water Act stipulates that equity in water resource management is about everyone having access to water and its benefits, as well as ensuring fairness to all in the decision process of allocating water (RSA, 1998). Essentially, equity is required to ensure equitable access to water for all. The country has diverse socio-economic conditions and historical disparities. Achieving equity in water resources is a complex and significant challenge. Equity is not currently adequately conceptualized in water resources management, as the four dimensions of equity, namely, (i) distributive equity, (ii) procedural equity, (iii) recognitional equity and (iv) contextual equity are yet to be sufficiently addressed (Marion Suiseeya, 2016). The third and fourth dimensions of equity are yet to be properly conceptualized, leaving a critical gap in our comprehension of equity (McDermott et al., 2013). It is necessary to address historical injustices, involve communities in decision-making, and consider the diverse needs of the population to achieve equity in water resources in South Africa.

Distributive equity emphasizes and focuses on the fair distribution and allocation of resources, opportunities, benefits, and burdens in society (Schlosberg, 2007). It seeks to address the question of how goods and services should be distributed among individuals or groups, considering factors such as needs, contributions and societal arrangements. Within the context of the ecological changes and ecosystem services flows in the Kat River catchment area, this study seeks to explore concerns and challenges in the various ecological changes and equity implications of ecosystem services flows among people and social groups. The target population are communities within the Kat River catchment area, in particular those groups who have been disadvantaged by differential power relations and inequality, and to determine how to address these barriers to human flourishing (Matin et al., 2018). The equitable flow of ecosystem benefits, particularly for the livelihoods of the disadvantaged and poor, is critical and essential for their well-being.

Consequence-based and rule-based theories (Table 2.3) are often applied in the interpretation of distributive equity. Utilitarianism and welfare economics share a consequentialist perspective and a focus on maximizing overall well-being, with an emphasis on efficiency in the distribution of benefits and costs. Utilitarianism and welfare economics emphasize efficiency in the distribution of benefits and costs (Florio, 2014). This involves optimizing the allocation of resources to maximize overall well-being, while considering the impact on different individuals or groups. Efficiency in terms of the distribution of benefits and costs is important in realising utilities for both welfare economics and utilitarianism.

**Table 2.3** Principles of distributive justice, adapted from McDermott et al., (2013)

| **Theory** | **Principle** |
|---|---|
| Egalitarianism | Equal shares of benefits between groups of people irrespective of their contribution. |
| Merit-based | Distribution of benefits between group of people based on their contribution. |
| Need-based | Distribution according to needs of people. |
| Utilitarianism | Greatest good for greatest number of people. |
| Libertarianism | Equal rights. |

The principle of distributive justice, based on rules, underscores the significance of fairness and equity in distributing goods, services, burdens, risks, and costs among individuals and social groups, irrespective of personal attributes (Carolini & Raman, 2021). These theories focus on the rules applied leading to outcomes, which include egalitarianism, libertarianism, merit-based and needs-based sharing. Libertarianism emphasizes the freedom of equal rights to opportunities for every member in a society (Bartels, 2019; Vos & Boelens, 2018). Egalitarianism and merit-based sharing are two contrasting theories; in an egalitarian society, costs and benefits are distributed equally among individuals, regardless of their starting point (Gudi-Mindermann et al., 2023), while a merit-based system promotes the proportional allocation of benefits based on the relative contribution of the individual to the productive activity from which the benefits are derived (Noh, 2020). In a needs-based system, it is argued that justice ought to recognize and be sensitive to the different needs of people because of inherent disadvantages imposed upon them by societal structures (Bauer et al., 2022). This study draws on the egalitarian theory to analyse equity among the communities within the Kat River Catchment, particularly concerning ecosystem service flows and the impact of water resources activities.

Decision-making in water resources management is critical as it affects the allocation and distribution of benefits and costs among social groups (Pollard & Du Toit, 2008). Procedural equity encompasses the manner in which individuals and groups engage, the diversity of participants, and the effectiveness of participation mechanisms. It underscores fairness in decision-making processes, ensuring inclusivity in participation and representation of all affected social groups. (Loft et al., 2017). It addresses issues of power dynamics, access to information, and influential knowledge. Additionally, it takes into account discourses that may lead to unequal participation and influence over decision-making processes in determining the allocation/sharing of benefits, costs, risks, and burdens (Leach et al., 2018). Procedural equity is important because it ensures that all stakeholders have a say in the decision-making process and that their voices are heard. This is especially important in water resources management because water is a scarce resource, and its allocation and distribution can have far-reaching impacts on people and the environment (Candido et al., 2022). For example, in South Africa, in the southwest part of the Kat River catchment area, there are fertile arable plots with access to water. This part was previously occupied by white commercial farmers who established water access mechanisms and infrastructure. This contrasts with the more densely populated area which faces serious challenges with water access. This has led to inequitable water access for social and economic activities (Bartels, 2019). Procedural equity is fundamental to water governance as it addresses inclusivity, participation, and representation (Sohrabi et al., 2022). The challenge is how to get the general public, private sectors, and people at the local and catchment levels involved and not to exclude anyone from decision-making processes that impact how they interact with their environment (Butler & Adamowski, 2015). In South Africa, it seems that catchment management forums (CMFs) are considered to be important tools for stakeholder engagement at the local level. However, it is still unclear whether CMFs are effective at influencing decision-making in the water sector.

Recognitional equity is indeed an essential aspect of creating a fair and inclusive society. It works hand in hand with other forms of justice, such as procedural equity and distributive justice (Rawlins, 2019). Recognitional equity is all about acknowledging and appreciating the identities, cultures, and contributions of diverse social groups. It transcends the mere distribution of resources and has a deeper focus on understanding and respecting the unique identities and experiences of every individual and community (Seetal, 2006). South Africa, which is a democratic developmental state, has been striving to prioritize equity in the domain of water resources re-allocation and decision-making, to combat the inequalities that arose from the apartheid regime (Meissner et al., 2017). However, since the post-apartheid era, the government has been unable to effectively drive and implement water allocation reforms through efficient reallocation (Kidd, 2018), which is the primary water reform pathway. This has had ripple effects on mainly rural populations, by deepening the rural-urban divide and restricting economic opportunities for development. Despite active policies and initiatives, the equity dimension analysis, particularly in the distribution of ecosystem services, has received the least attention, and this has created a fundamental research gap.

### 2.4.1 National Water Act

The National Water Act is an important piece of legislation for South Africa as it aims to ensure sustainable water resource management, promote equitable access to water, and protect the integrity of aquatic ecosystems (RSA, 1998) With water scarcity and increasing demand being major challenges, it is crucial for the government to find ways to balance economic development with environmental conservation. The Act is a step in the right direction towards achieving this goal. The National Water Act of 1998 guides how water resources are managed and distributed in South Africa. It differs from the previous NWA of 1956, which gave landowners the right to ownership and access to water resources, benefiting white farmers at the expense of impoverished societies. Although the NWA of 1998 advocates for fair participation of individuals in the decision-making process, implementation and practice remain a challenge (Movik, 2011). More than 20 years after the promulgation of the law, there is still an equity gap in freshwater resources management. For example, due to dysfunction in information dissemination, few of the local communities in the Kat River catchment benefit from this law. They lack participation and representation in the policy and decision-making, as well as in the management and governance of freshwater resources (Motteux & McMaster, 2002). As per the Act, equity, efficiency and sustainability are the key principles that guide the management of water resources (RSA, 1998). According to the Act, efficiency means using water resources in a way that minimizes waste and promotes social and economic development. Sustainability means providing enough water to meet current and future needs without causing harm to the environment. Equity means ensuring that all people have equal access to water resources regardless of their race, gender, or economic status (McDermott et al., 2013). However, despite enshrining these principles, the law has not been successful in ensuring the equitable sharing of water resources, particularly in the Kat River catchment area, which is experiencing a water crisis. Hence, it is crucial to ensure that all communities have access to relevant information and are involved in the decision-making procedures or proccesses to ensure that the law is implemented fairly and equitably.

To give effect to the provisions of the Act, the National Water Resource Strategy was developed. The Act provided for the establishment of a National Water Resource Strategy (NWRS) that would guide the sustainability of water resources management and governance in the country (Pollard & Du Toit, 2008). This NWRS was developed in consultation with stakeholders, representatives of the water sector and other relevant stakeholders to enable the adequate management of water resources. The national water resource strategy establishes the framework aimed at guaranteeing the protection, utilization, development, conservation, oversight, and regulation of water resources. It also outlines the framework within which water management should occur at the regional or catchment level, within designated water management areas. The implementation of proper and fair water resource policies requires various institutions set up at the catchment and local levels. This should include bodies such as the Catchment Management Agencies (CMAs) at the regional level, the Catchment Management Forum (CMF) at the local and catchment level and the Water User Association (WUA) at a restricted local level. These institutions are essential for ensuring sustainable water resources management. They also provide a platform for stakeholders to come together to discuss water resources issues and develop solutions (Meissner et al., 2017).

Worth mentioning stakeholders and community contributions play a crucial role in the establishment of CMAs, and they are expected to actively participate in the water institutions established within the proposed CMA's water management area (RSA, 1998). These water institutions include CMFs and WUAs. However, it is worth mentioning that only two of the initially planned nineteen CMAs are functional due to implementation challenges. The numbers of proposed CMAs in 2012 were reduced to nine (9) by the Department of Water and Sanitation's Minister. Since there is no CMA in the Kat River catchment area, this study focussed on the Kat River WUA and CMF.

Water user associations play a crucial role in managing water resources at a local level. They are mandated to promote participation, efficiency, sustainability, equity, and diversity among water users within their catchments (Kemerink et al., 2013). The law requires that irrigation boards should be transformed into WUAs to allow the participation of all water users within a catchment. This transformation is aimed at promoting diversity and equity in water resource management. Additionally, WUAs should actively participate in the CMF to ensure that all stakeholders are fairly included and engaged in sustainable water resource management. Catchment management forums provide a platform for the public and stakeholders to participate in managing the water resources within a catchment (Pegram & Mazibuko, 2003).

It is important to assess whether the existing Water User Association is an active participant in the Catchment Management Forum and whether the CMF is an effective institution for participation that can influence water governance and decision-making. Although these bodies serve as channels or networks for water management and governance, evidence from the forums within the Kat River catchment indicates that many stakeholders do not view the CMF as effective. This is because decisions made are not binding, and key government officials responsible for decision-making do not attend CMF meetings regularly. Chapter 5 of the study discusses equity in participation in water resource management in the Kat River Catchment area, which highlights the importance of ensuring that all stakeholders have equal opportunities to participate in decision-making procedures and processes.

### 2.4.2 Kat River Water User Association (KRWUA) and the Kat River Catchment Management Forum

Water User Associations (WUAs) are an important part of South Africa's water governance framework. They help to make sure that water resources are used sustainably and equitably at the local level (Burt et al., 2008). These associations were created to encourage water user's participation, promote efficient water use, and ensure the sustainable management of water in specific areas. Among their many functions and duties, WUAs are responsible for water allocation and protection of water resources, water use planning and supervision over water resources and watercourses, water infrastructure management and regulation of the flow of watercourses, conflict resolution among stakeholders, and investigation and record keeping of water quantity at different levels (RSA, 1998).

In 2001, the water management responsibilities in the Kat River catchment area were transferred from the Irrigation Board to the Water User Association (WUA) which is the Kat River Water User Association (KRWUA). (Motteux & McMaster, 2002). Members of the KRWUAs include commercial farmers, emerging farmers and rural community water users (that is the communities without communal taps) (Burt et al., 2008). The KRWUA oversees the management of water resources. By operating at a local level and comprising local committee members, the association is better positioned to understand more nuanced and subtle local challenges of water access and resource management.

The Department of Water Affairs (DWAF), now called the Department of Water and Sanitation (DWS) and the Catchment Management Agency (CMA) are primarily responsible to redress past inequities regarding water resources management. The WUAs have a responsibility to ensure fair participation of stakeholders in the management of water resources to achieve equity, sustainability and efficiency. This includes building capacity and ensuring the involvement of the disadvantaged and poor communities that use water within their area (Pegram & Mazibuko, 2003; Perret, 2002). Appropriate participation in the WUA requires all user groups and relevant stakeholders to be represented (Van der Zaag, 2005; Warner, 2006b). Despite the reality that the KRWUA was formed a long time ago, many local people are not aware of its existence, let alone its responsibilities. This points to the problem of limited dissemination of information in the catchment. This holds the potential to render the association ineffective and collapse the wider agenda of collective water resources management in the catchment (Kemerink et al., 2013; Motteux & McMaster, 2002; Pegram & Mazibuko, 2003).

## 2.5 Conclusion

It is important to understand the drivers and pressures of ecological change on freshwater ecosystems. The impact of these changes can be significant, not only on the health of the ecosystem but also on the species that depend on it. Therefore, it is vital to map drivers of ecological changes and ecosystem services flows to manage water resources effectively, conserve the ecosystem, and promote sustainable development. Distributive equity is a crucial aspect of ecosystem services flows, as we must ensure that the costs and benefits of ecosystem services are allocated fairly among all stakeholders. This can be achieved by developing sustainable water resource management policies which prioritize the needs of vulnerable and marginalized communities. Moreover, procedural equity in water resource management is crucial because it ensures that all social groups are informed and involved in policies and decision-making regarding water governance and management in society. Therefore, it is essential to involve all stakeholders, including the public, in water resource management policies and decisions to promote distributive and procedural equity. This study also sought to analyze the views of the stakeholders on the role and existence of the KRWUA.

# CHAPTER 3: STUDY AREA DESCRIPTION, MATERIALS AND METHODS

## 3.0 Introduction

This chapter provides a description of the study area, along with the general materials and methods employed in this study. The description of the study site encompasses the biophysical properties, geology, and socio-economic activities of the study sites. The chapter discusses sampling techniques, equipment used, analytical framework, homestead count, research questions, research design and the analytical strategies employed.

## 3.1 Study area description

This study was conducted within the Kat River catchment situated in the Amatole District of the Eastern Cape province in South Africa. The catchment is divided into three sub-catchments: Upper, Middle, and Lower sub-catchments. Collectively, the three sub-catchments have a total area of approximately 1,715 $km^2$ (Stats, 2011). At the heart of the catchment lies the Kat River, coursing between Seymour and Fort Beaufort, and originating from Northeast of the Hogsback Mountains and Northwest of the Katberg. The principal tributaries of the Kat River are Balfour, Fairbairn, and Blinkwater streams, while one minor tributary, the Xwentxe stream, flows into the Kat River Dam at Cathcartvale and Seymour.

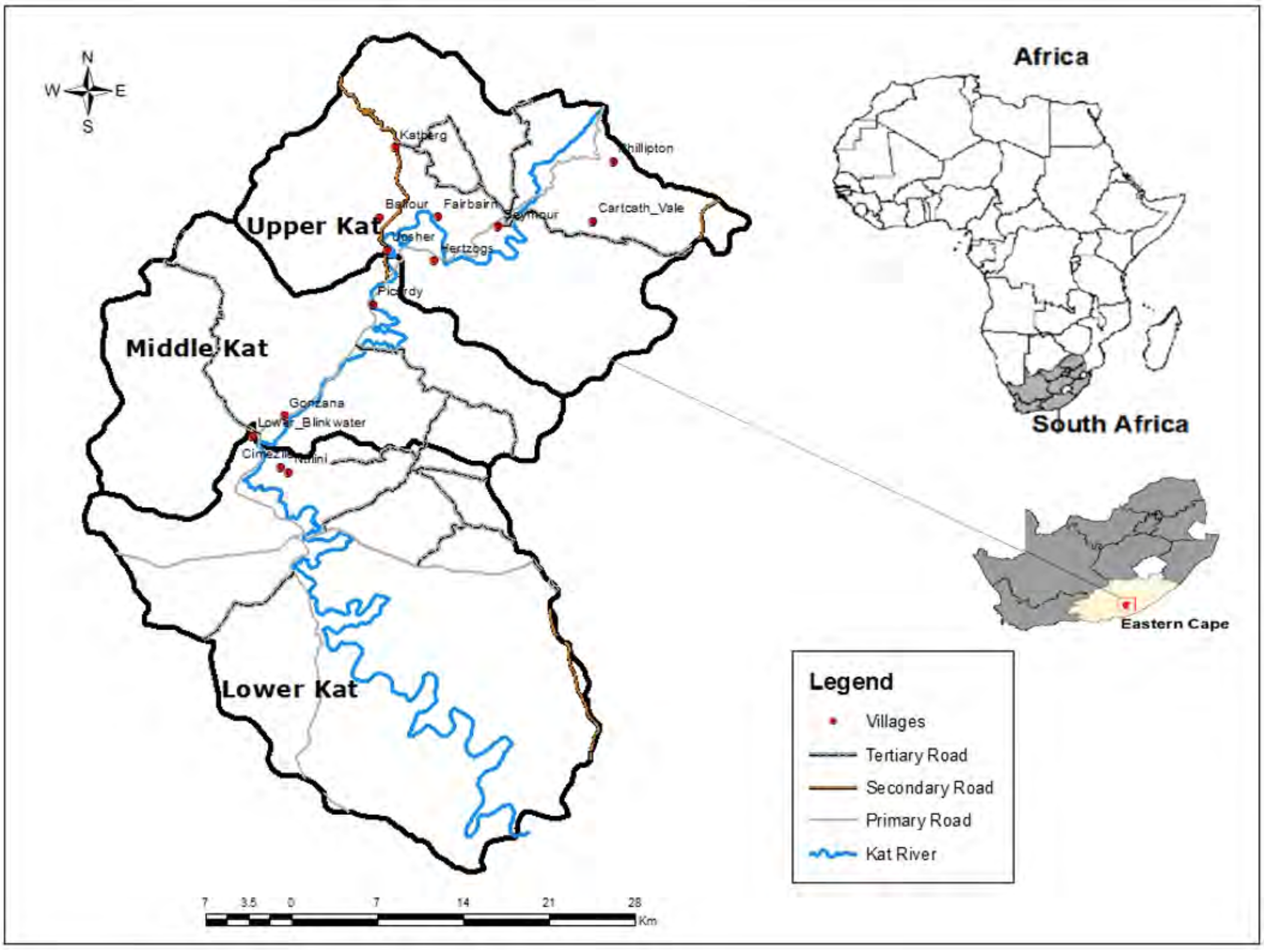


**Figure 3.1** Kat River catchment showing Upper, Middle and Lower Kat and villages in the Catchment.

### 3.1.1 Biophysical characteristics of the study area

#### *Climate and topography*

The climate of the Kat River catchment area is mild and temperate, with temperatures ranging from 20°C to 35°C in summer and from freezing to 20°C in winter (Magni, 1999). The mean annual rainfall of the Upper catchment area is approximately 1000 mm, significantly higher than the lower catchment, which receives 400 mm per annum. Due to high evaporation rates, the catchment is categorized as sub-humid to semi-arid, rendering it unsuitable for rainfed agriculture. Consequently, crop cultivation relies heavily on irrigation, drawing water from the Kat River.

### *3.1.1* ***Topography***

The topography of the Kat River catchment area is by nature a basin, with rolling hills and valleys. It is largely composed of sedimentary rocks and contains several rivers and tributaries that drain into the Kat River (Lerotholi et al., 2004). The catchment area has steep and rugged slopes, creating an ideal flooding environment. The catchment area is surrounded by mountains which help intercept and contain water flow (Maseti, 2005).

### *3.1.2* ***Geology and soils***

The Kat River catchment is rocky. This generally leads to an increased frequency of soil erosion and a high sediment transport rate affecting riparian vegetation. These factors collectively contribute to the deterioration of water quality within the river and the degradation of ecosystems across the catchment (Motteux, 2000). The geological composition of the catchment encompasses sandstone, mudstone, and shale. The soil in the lower Kat River catchment is homogeneous, consisting mostly of sandy loam, which is best for citrus production, and farmers find the soil in the Kat River Catchment good for citrus production (Magni, 1999). Local farmers point out that the soil makes a significant difference for citrus production, both in quantity and quality. (Lerotholi, Sekhonyana, 2005).

### *3.1.3* ***Vegetation***

There are diverse biomes within the Kat River catchment which include forest thickets, grassland, and wetlands. These habitats are home to a variety of flora and fauna including birds, mammals, reptiles, and amphibians (Akamagwuna et al., 2023). The vegetation cover in the catchment area is dense and is mainly dominated by scrubland and grassland. Plants such as shrubs and small trees are common in the catchment area (Rowntree & Du Preez, 2008). These areas are an important source of food and habitat for various species, and they provide important ecosystem services such as carbon sequestration and water purification (Lerotholi et al., 2004).

### *3.1.4 Socioeconomic activities and land use*

As the Great Fish River tributary, flowing between Cathcartvale and Fort Beaufort, the Kat River spans about 150 km in length. The river is of vital socio-economic importance for the Nkonkobe Municipality by providing water for agriculture, including crop irrigation and livestock farming. In addition, it serves as a site for spiritual activities and supplies water for domestic needs such as drinking, bathing and laundry. The Nkonkobe Municipality, established within the Amatole District of the Eastern Cape in South Africa, encompasses a diverse range of areas spanning both urban and rural. The municipality boasts a rich cultural and historical legacy. The municipality was disestablished in 2016 and incorporated into the Raymond Mhlaba Local Municipality. Here are examples of settlements in the former municipality, Fort Beaufort, Alice, Hogsback, and Middledrift.

Though the Kat River catchment area is relatively small (1715km² in area) in comparison to other rivers within the region, it is rich in cultural, spiritual, and economic diversity (Mahanty et al., 2006). This diversity creates an environment conducive for knowledge integration, collaboration, and cooperation among stakeholders. The residents of the Upper Kat sub-catchment are primarily smallholder farmers, cultivating crops such as vegetables and cotton. In contrast, the Middle Kat sub-catchment is characterized by emerging and large-scale commercial citrus farmers. The Lower Kat sub-catchment is home to large-scale commercial citrus farmers (Farolfi & Rowntree, 2005).

A multitude of land use practices take place within the catchment, encompassing commercial citrus farming, commercial and subsistence livestock farming, crop farming by smallholders, and commercial forestry within the north-western upper reaches. The Kat River catchment also features four nature reserves, the Mpofu, Fort Fordyce, Sam Knott and Double Drift (Motteux & McMaster, 2002; Naidoo et al., 2008). All these land use practices significantly influence the quality of the river ecosystem services the catchment can provide.

## 3.2 Sampling sites

The study was conducted at three villages located in the Kat River catchment, namely, Cathcartvale, Fairbairn and Picardy. The villages were chosen based on these criteria: (1) the selected villages fall within the same ecoregion, (2) the Kat River system traverses through all the chosen villages, and (3) each village was deemed to be likely affected by human-related activities, including wastewater and agricultural farmlands, due to its geographical positioning. There are less than 100 homesteads in each village. The settlement pattern observed in the Kat River catchment predominantly consists of dispersed homesteads interspersed with arable fields and grazing lands, representing a rural settlement.

A wide range of socio-economic activities take place in the villages. The activities include crop farming, livestock husbandry, handcraft, traditional healing utilizing medicinal plants and retail business. The Kat River system serves as the principal water source for the communities, making it a fundamental resource for the local people. In addition, Picardy village has a community farming project. The farm project is irrigated by a water pump serviced and maintained by the South African Electricity Supply Commission (ESKOM). Figure 3.2 shows the landscape of the Kat River catchment. The photograph was taken during one of the data collections trips and shows the beautiful landscape and residences of Balfour village.

**Figure 3.2** The landscape of the Kat River catchment.

## 3.2 Research Design

This research employed a case study approach. Case study research strives to examine and understand the complexities of reality within its context. Such complexities include objects, events, experiences, and concepts. Its purpose is to unveil a profound understanding of the study subjects (Creswell et al., 2007). This type of research is done in real-life settings and can be used to offer a comprehensive portrayal of a phenomenon. Case study research allows researchers to accumulate detailed information using various data collection methods over a designated period.

This research design has numerous merits, including its capacity to amass intricate details about a particular subject or research query. It also proves valuable for identifying potential problems and/or solutions or for informing policy decisions (Creswell & Creswell, 2017; Yin, 2015). Furthermore, it permits the utilization of multiple data collection techniques such as field observations, interviews, audio-visual material, workshops, and document analysis. This assists in gathering rich contextual information, which subsequently empowers researchers to conduct descriptive statistics of the study subject.

Through the employment of the case study design, I collected data regarding the flow of ecosystem services as well as drivers of ecological change within the Kat River catchment. To accomplish this, I employed semi-structured interviews and conducted Participatory GIS (PGIS) mapping workshops with participants in the catchment. These two data collection methods facilitated in-depth participatory and interactive discussions between me and the research participants. This was complemented by a review of secondary data sources, including peer-reviewed published work and reports (Stake, 2005; Stake, 2013). These methods are described in the sections that follow.

## 3.3 Methods and Materials

### 3.3.1 Conceptual framework

The study employed the ecosystem (dis) services flow model developed by Odume & de Wet (2019) (Figure 1). The framework builds on the original cascade model devised by Haines-Young & Potschin (2010) and Potschin-Young et al. (2018), by making explicit the flow of ecosystem services (e.g., water supply) and disservices (e.g., pandemics) which occur when ecosystem structure and function are subjected to pressures such as pollution, habitat destruction and so on. As shown in Figure 3.3, when pressure is exerted on ecosystems, it may lead to ecosystem (dis) service flows. Usually, ecosystem services flow translates into societal benefit flow, enhancing the well-being of the societal grouping to whom the benefits accrued.

These societal benefits may manifest in physical, economic, and social capitals of the receiving society or societal groupings.

Ecosystem disservices flow is brought about by human pressures, which often translate into a flow of burdens/costs into the receiving societal grouping(s). These may diminish the well-being of those impacted. The negative impact on well-being manifests in the physical, economic and social capitals of the impacted society or societal groupings (Figure 3.3). This framework guides the mapping exercise and the interviews, as it allows an exploration of i) the key pressure and drivers impacting on the Kat River system and its catchment, ii) ecosystem services flow (e.g., water supply), iii) the societal groupings/constituencies which benefit from ecosystem services and those that disproportionally carry the burden of the impact of pressures on ecosystem services, setting the scene for an analysis of the distributive equity dimension, iv) the framework also allows for an analysis of the procedural equity dimension in water management matters, and v) the implications for human well-being (Odume & de Wet 2019).

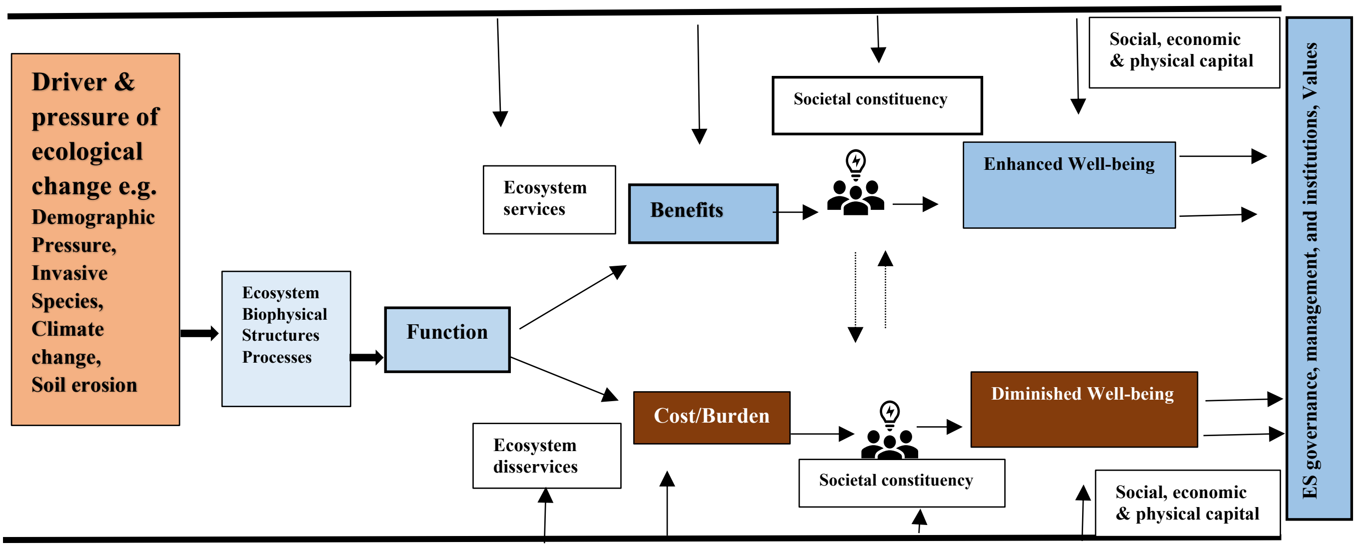


**Figure 3.2** A conceptual framework employed in this study showing that when pressures are exerted in ecosystems, this results in both ecosystem services and disservices, which may translate into benefits or burdens which impact on the same or different societal groupings. These benefits or burdens affect the social, physical, and economic capitals of the recipient societal groupings (Taken from Odume & de Wet, 2019)

### 3.3.2 Sampling Techniques

I used the purposive sampling technique to recruit twenty-two (22) participants for a PGIS mapping workshop and thirty-one (31) for the semi-structured interviews. Participants were intentionally chosen to collaboratively map out the spatial and temporal aspects of observed ecological changes, their corresponding key drivers, ecosystem services and effects of ecological change on ecosystem services within the Kat River catchment. Purposive sampling was also used to recruit participants for in-depth discussions aiming to probe their understanding of the flow of ecosystem services within the catchment. Purposive sampling is a non-probability technique in which participants are selected based on characteristics relevant to the research objectives (Etikan et al., 2016; Tongco, 2007). The purpose of this sampling approach is to intentionally enlist enthusiastic participants capable of providing comprehensive and meaningful insights aligned with the study questions. This was crucial to a beneficial outcome, as the study required input from individuals with profound ecological experience, perceptions, and observations of the ecosystem of the Kat River catchment area.

The participants that were selected for this study were members of the Kat River Catchment Management Forum (KRCMF) who met two primary criteria: (i) a significant number of years residing and working within the catchment, and (ii) possession of appropriate levels of experience and knowledge about the catchment and (iii) a willingness to actively participate in the study. These criteria are of the utmost importance as they ensure that participants possess a profound understanding of the catchment's history and distinctive attributes. They are therefore well-positioned to offer invaluable insights into the ecology of the catchment.

To initiate contact with the participants, I initiated contact with the catchment's gatekeeper, who serves as the deputy chairperson of the KRCMF. I discussed the concept of the PGIS mapping workshop with him and subsequently extended invitations to the members.

Similarly, aligning with the study's second objective, which aims to analyse the equity dimensions of ecosystem services flow in the Kat River catchment, I employed purposive sampling to carefully select participants who fulfilled the specified theoretical criteria for the research. Consequently, I recruited participants from four distinct social groups in the Kat River catchment for semi-structured interviews: 1. non-farming households, 2. commercial farmers, 3. subsistence farmers, and 4. members of the Kat River Catchment Management Forum committee. These social groups were essential for well-rounded input into the study, given that the Kat River catchment is predominantly a farming community, with other complementary economic activities such as game farming, craft, and retail business. Farming has historically been a pivotal socio-economic activity within the catchment, encompassing various forms such as large-scale citrus farming, livestock husbandry and small-scale vegetable cultivation. Hence, these four groups were chosen due to their significant interaction with the Kat River system for sustenance purposes. The social groups are: 1. commercial farmers are those farmers who practice mechanized farming on a large-scale with the primary aim of selling or exporting their produce. In the Kat River catchment, commercial farmers sell their produce to both local and international markets, 2. Subsistence farmers grow crops primarily for self-consumption, to meet the needs of themselves and their households on small-scale agricultural plots. This type of farming is a livelihood strategy with the potential to eliminate hunger and poverty by ensuring food security at household level. Subsistence farmers either grow food crops or farm livestock or have a mixed-method production of both (Fanadzo & Ncube, 2018; Houmy et al., 2013; Mbatha et al., 2021), 3. Non-farming households are those that do not practice any form of farming, either subsistence or commercial. These households are involved in other activities for livelihood such as making handcrafts (handwoven fabric, pottery, handmade jewellery), providing community services or quarrying (Reardon et al., 1998), 4. The Kat River CMF is a public institution established at the sub-catchment level. Predominantly, its members are individuals who collectively share a common objective and purpose of achieving sustainable water resource management in the catchment (Matiwane, 2012). The Kat River Catchment Management Forum (KRCMF) was established in the year 2000, bringing together community representatives from the broader Kat River catchment area. Many KRCMF members boast over two decades of residence and work within the Kat River catchment, thus possessing a wealth of knowledge about the area.

### 3.3.3 Data Collection

Data were collected using a mixed method approach. This method involves the application of both qualitative and quantitative techniques (Creswell & Creswell, 2017; Palinkas et al., 2015; van Jaarsveld et al., 2005). The use of a mixed methods approach was necessary as the study aims required a diverse range of data, including narrative, visual and numerical. A diverse range of data like this could not be captured by either qualitative or quantitative method alone. Use of both PGIS mapping and a semi-structured interviews method enabled the data to be collected in the designated villages in the area. Firstly, I used a Participatory GIS (PGIS) mapping approach to address the first objective. For the second objective, I conducted semi-structured interviews. The equipment used during the data collection process was pen, notebook, interview question guide document, note board, digital audio recorder, digital photo camera and a projector. The data collection strategies are briefly described in the following sections.

### 3.3.4 Participatory GIS mapping

Two Participatory GIS mapping workshops were conducted. The first workshop was done from 20-21 April 2022 while the second workshop was done from 30–31 May 2023, both at the Mpofu training centre, Kat River catchment. In the workshop, I used Geographic Information and Spatial (GIS) tools such as a topographic map, to gather and analyse information. The topographic map proved invaluable in assisting participants to recognise and analyse the physical attributes of ecological change, as well as the flow of ecosystem services. The PGIS mapping workshop facilitated and enhanced stakeholder engagement by integrating the insights and perspectives of local and expert community members. It created a platform for the convergence of local and expert knowledge, ensuring that the members of the KRCMF played a meaningful role in shaping and identifying mapping activities and outcomes. A total of twenty-two (22) adults participated in the workshops. Figure 3.4 shows participants in action during the participatory mapping, identifying, and examining ecosystem services, ecological changes, and their impacts on ecosystem services in the Kat River catchment area. The mapping exercise and the various dimensions mapped out are discussed in Chapter 4.

**Figure 3.3** Participants during the PGIS mapping exercise in the workshop. Participants gave their permission for the photo to be published.

Prior to initiating the mapping exercise, I introduced the aims of the workshop, which were to explore past and present ecological changes, as well as the ecosystem services supplied by the Kat River catchment. Participants actively contributed their insights and experiences, fostering a collaborative learning environment among themselves and with the researchers.

### 3.3.5 Semi-structured Interviews

The second objective which is to analyse the distributive and procedural equity dimensions of ecosystem services flow in the catchment through the Kat River Water User Association (KRWUA), was addressed through the use of semi-structured interviews. Using an interview question guide (Appendix 2a), interviews were conducted with individuals representing commercial farmers, subsistence farmers and non-farming households from Cathcartvale, Fairbairn and Picardy villages within the catchment.

Figures 3.5 A and A show some photographs taken during the semi-structured interviews. Interviews were one-on-one with the participants and my research field assistants, who provided support in the translation from isiXhosa to English.

A B

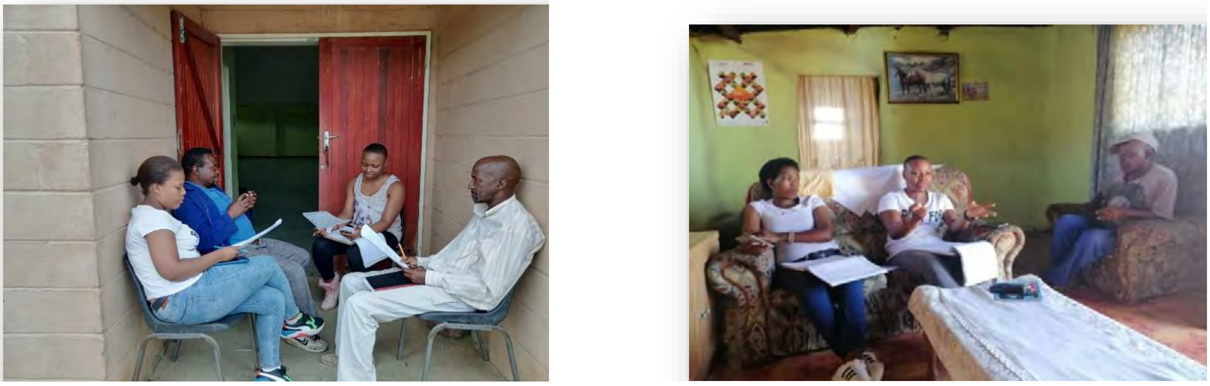

**Figure 3.4** A & B Research participants from the in-person in-depth interviews.

The interview questions covered four sections: 1) ecosystem services flow and distributive equity, 2) drivers and pressure of change, 3) procedural equity and 4) demographic information. The ecosystem services section investigated the benefits the community receives from the Kat River catchment that enhance their wellbeing. This section also looked at the present and historical changes the community has observed in the benefits accruing from the ecosystem services. Additionally, the section looked at how such benefits are distributed among all social groups in the catchment. The section on drivers and pressure of ecological change aimed to help the respondents identify the historical and present drivers of ecological change in the Kat River catchment area, as well as the impacts of the ecological changes on the various ecosystem services the Kat River catchment provides. The section on procedural equity looked at fair participation of the stakeholders in the governance and management of water resources in the KRWUA. Lastly, the section on demographic data sought to elicit respondents' demographic information such as age, sex, and household size, among others. The interviews were conducted from 13 March–31 May 2023. A total of 31 people were interviewed.

## 3.4 Data Analysis

The PGIS mapping data were analysed using Microsoft excel. This allowed for the creation of graphs and other visuals used to identify patterns in the data. Excel's data analysis tools made it easier to visually interpret the data (Anderson et al., 2018). The interview data were analysed by the utilization of thematic analysis (Babchuk, 2019; Braun & Clarke, 2006). Thematic analysis allows the coding of patterns and the establishing of a framework for presenting hidden meaning within the data. The five phases of thematic analysis as summarized in Figure 3.6 were critically followed (Babchuk, 2019; Braun & Clarke, 2006). These steps are explained in Table 3.1.

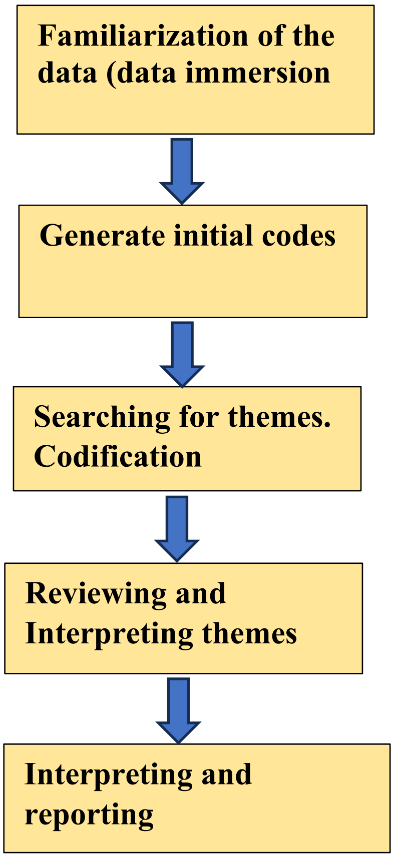


**Figure 3.5** Thematic analysis followed the thematic analysis procedure as per Babchuk, 2019; Braun & Clarke, 2006

**Table 3.1** Description of the phases of the thematic analysis process

| ***Phases*** | ***Description of the process*** |
|---|---|
| *Familiarization of the data (data immersion)* | After the interview process, with the aid of an interpreter and a transcriber, I transcribed the recorded data. Thereafter, I immersed myself in the data by reading the data several times. This provided me with insight into the data which enabled me to identify key initial patterns which could be explored in more depth. In addition, I gained a better understanding of the data which allowed me to gain a more comprehensive view and to better understand the underlying trends of ecological change and flow of ecosystem services. |
| *Generating initial codes* | Once again, I read through the data to gain better understanding and insights. This enabled me to begin generating initial codes. Initial codes such as ecosystem benefits, ecosystem services and so on were generated. I further moved to aligning and grouping information according to the codes. |
| *Searching for themes. Codification* | In this step, I read through the generated codes. Then I collated the codes into themes and gathered all data relevant to each theme, such as most benefited social groups and least benefited social groups. I then reviewed each theme and the relevant data to determine whether the data supported the theme, hereby permitting me to refine the themes and draw conclusions from the data. This process allowed me to determine which themes were supported by the data and which were not, and to develop a set of refined and well-supported themes based on the data. |
| *Reviewing and Interpreting themes* | In this stage of the analysis, I cross-checked the data again and grouped them into overarching themes such as distributive equity and knowledge and operation management of the KRWUA. |
| *Interpreting and reporting* | In this stage, I interpreted and reported the findings in conjunction with findings from literature. |

## 3.5 Ethical Considerations

This study received approval `from the Rhodes University Human Research Ethics Committee (RU-HREC) with approval No. 2023-6998-7441. A gatekeeper permission letter was received from the Kat River Catchment Management Forum to conduct the research. Participants' informed consent was sought before the start of the interview section. In addition, all participants voluntarily agreed to be interviewed. Ethical considerations were adhered to throughout the study. Permission was sought from participants who voluntarily agreed to participate and be recorded on tape. The gatekeeper permission letter was received to ensure that the research was conducted in accordance with local regulations. All participants provided informed consent and were aware that their interviews would be recorded and used for research purposes. Furthermore, to ensure that ethical considerations were met, only adults over the age of 18 were targeted for participation. Those who were not comfortable with the tape recorder were not recorded. None of the participants were mentioned by name in the interviews nor in the data interpretations and reports, to maintain their anonymity and confidentiality. This was done to ensure that the participants felt comfortable and secure during the course of the interview, as well as to protect their identities. Additionally, this helped to maintain the integrity of the data, as the participants' names and identities were not associated with the results of the research. All interviews were conducted from 13 March to 31 May 2023, at their homesteads and farms. Each interview lasted between 40 and 60 minutes. The interviews were conducted in a private setting to ensure that participants felt safe and secure in sharing their experiences and that their identities remained anonymous. Additionally, the duration of the interviews was kept to a minimum to ensure that the participants did not feel overwhelmed by the process.

# CHAPTER 4: PARTICIPATORY MAPPING OF KEY DRIVERS OF ECOLOGICAL CHANGE, AND ECOSYSTEM SERVICES IN THE KAT RIVER CATCHMENT

## 4.1 Introduction

Important drivers of ecological change in freshwater ecosystems, such as climate change, agricultural activities, pollution, and over-fishing, have profoundly impacted the structure and function of freshwater ecosystems, resulting in biodiversity loss, degraded water quality and altered habitat complexity (Carpenter et al., 2011; He & Silliman, 2019). Consequently, ecosystem services provided by freshwater ecosystems, including water purification, flood regulation and climate regulation, have been significantly compromised. Water management and conservation efforts face substantial challenges due to the severe impacts of these ecological changes (Strayer & Dudgeon, 2010). For example, increased water withdrawals, diversions, and pollution can diminish the availability of water to ecosystems, leading to species loss and disruption of critical ecosystem processes (Döll & Zhang, 2010; Meyer, J. L. et al., 1999).

Recent studies have highlighted the fact that ecological changes in freshwater ecosystems intensely affect the ecosystem services these systems offer (Carpenter et al., 2011; Daily, 1997; Strayer & Dudgeon, 2010). This highlights the need to preserve and safeguard freshwater ecosystems and the services they provide. Understanding ecological changes, their key drivers, and their long-term temporal and spatial dimensions and trajectories is essential for the development of effective and sustainable intervention strategies. Therefore, this chapter introduces a novel framework for a multidimensional, participatory mapping of key drivers of ecological change and ecosystem services within the Kat River catchment.

Using the participatory approach, perceived ecological change, ecological drivers of change and ecosystem services were mapped. The novelty of the approach adopted rested on i) participatory engagement, allowing stakeholders to reflect and internalise changes which had occurred over time and space, ii) strengthened stakeholder capacity in spatial and temporal analysis and reflection of changes, ecosystem services and the benefit they supplied iii) a multidimensional analytical means for reflecting on the significance and importance of key ecosystem drivers and ecosystem services over time and space, and iv) the offering of a critical reflection of the interactions between ecological change and ecosystem services. Overall, the objective of this chapter was to undertake a multidimensional, participatory, engaged mapping of ecological change and ecosystem services in the Kat River. This chapter thus fulfils objective 1 in **Chapter 1, Section 1.3**.

## 4.2 Material and methods

This study utilized PGIS mapping to actively involve stakeholders within the Kat River catchment in a two-day Participatory mapping workshop. The data collection process is described in **Chapter 3, Section 3.3**.

Purposive sampling was used to select the participants for the study; stakeholders were identified and selected according to their experience and knowledge of the Kat River catchment. These participants represented different institutional stakeholders of the catchment, such as members of the catchment management forum (CMF), youth representatives and formal ward councillors.

The study conceptual framework, discussed in **Chapter 3, Section 3.3.1**, informed the development of the participatory workshop question guide (Appendix 1) used for the mapping process. The question guide considered four dimensions on the mapping of ecological change and ecosystem services in the Kat River. The dimensions included, i) perceived severity of the ecological change; ii) perceived importance of the ecosystem services; iii) temporal dimension of ecological change and ecosystem services flow, and (iv) spatial dimension of ecological change and ecosystem services flow.

**Table 4.1** Dimensions considered during participatory GIS mapping.

| Dimensions of the PGIS mapping | Focus |
|---|---|
| Severity (ecological changes). | This is the perceived level of severity of the impact of the identified ecological changes both in the catchment and to households. |
| Importance (ecosystem services). | This is the perceived importance of the identified ecosystem services to households. |

| | |
|---|---|
| Temporal dimension | Observed conditions of ecological changes, ecosystem services and associated benefits and risks over time in the Kat River catchment. Stakeholders were asked to determine whether these changes were getting worse, improving or remain fairly the same over time. |
| Spatial dimension | This relates to spatial scale coverage of the identified ecological change, ecosystem services and associated benefits and risks. Research participants were asked to determine whether these changes were getting worse, improving or remained fairly the same over time across the space. |

The severity impact level of the perceived ecological changes on the Kat River catchment was explored (Appendix 1a). The participants were asked to reflect on how they perceived the severity of identified changes in the catchment; and whether they perceived these changes be very serious; moderately serious or not serious. i) Very serious was when the participants perceived the ecological change to have a detrimental impact difficult to manage/control on the catchment and households ii) moderately serious was when the ecological changes were perceived to be manageable, and iii) not serious was when the ecological changes were perceived not to have detrimental impacts on the catchment and households. The severity impacts stemming from the identified ecological changes on the catchment, and the health and well-being of the population were scored by the participants on a scale of code 1 to code 5, wherein 5 signified a *very serious* impact, 3 denoted a *serious* impact, and 1 indicated a *not serious* impact.

Research participants discussed the perceived ecosystem services from the Kat River with regards to the degree of importance to their day to day living in the households. The research participants were asked how important or impactful the ecosystem services (benefits) were to them (Appendix 1a). Responses were graded as Code 1 = very important; 3 = moderately important and 5 = not important (Appendix 1a).

Temporal dimension of the perceived ecological change and identified ecosystem services were reflected upon and explored by the research participants. Temporal dimension or progression signifies the perceived time or duration of the perceived changes. In this section the research participants were asked to reflect on how they perceived the ecological changes and ecosystem services to have been over the timeframes i) 0−5years (short-term changes), ii) 5−15 years (mid-term changes) and iii) more than 15 years (long-term changes). Participants were asked to specify whether the perceived changes were either improving, deteriorating or had no observed changes (not improving or deteriorating). These time frame in years were accorded numerical codes, where code 1 = less than 5 years, 3 = 5−15 years, and 5 = more than 15 years (Appendix 1a).

Spatial dimensions on the perceived ecosystem services were reflected upon and explored by the research participants. Spatial dimension or representation were areas on the Kat River map where they are perceived the services to be. In this section, participants were asked to indicate where they perceived the services to be on the Kat River map. The research participants also explored the perceived ecosystem services spatial progression changes. The research participants were asked to reflect on how they perceived the identified area coverage of each of the ecosystem services over time, whether they perceived the spatial area to be either increasing, decreasing or unchanged (where neither increase nor decrease had occurred). The reflection was done over the period of years 0–5 years (short term changes); 5–15 years (mid-term changes) and more than 15 years (long term changes) (Appendix 1a).

The PGIS mapping workshop was attended by 22 engaging participants. The breakdown, as shown in Figure 4.1, indicates that 59% were male and 41% were female participants. During the first day of the PGIS mapping workshop the overall scope of the study was introduced to ensure a shared understanding among the research participants. Clarity was key, enabling participants to pose questions when necessary. Moreover, it helped to keep the discussions in-track and participants well informed about the study's anticipated outcomes. This opportunity allowed me to gauge their comprehension and interest, influencing the approach I took during the discussions.

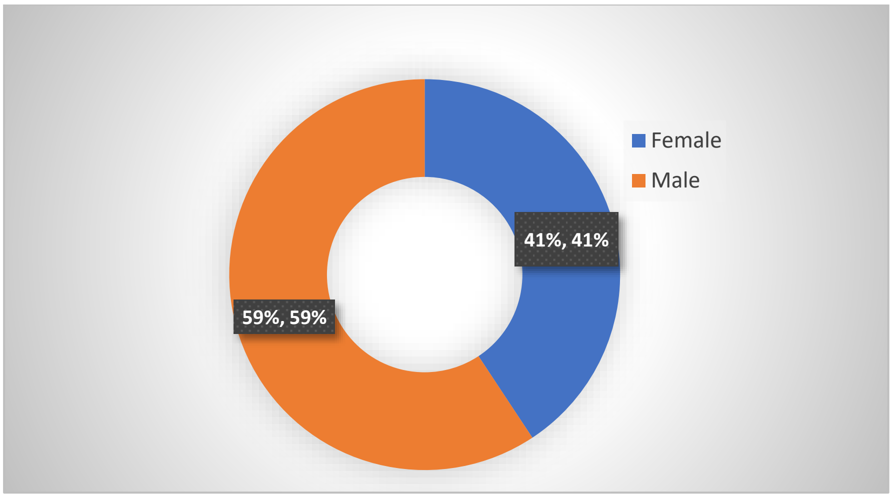


**Figure 4.1** Gender percentage distribution of the PGIS mapping participants

**Part 1** of the PGIS mapping guide (Appendix 1a) focussed on exploring and mapping the perceived historical and current ecological alterations within the Kat River catchment, coupled with their key drivers. We compiled a comprehensive list of these ecological changes and proceeded to explore their spatial representations and temporal elements. Each perceived ecological change underwent meticulous mapping, accentuating their key drivers. This step deepened our understanding of the intricate interplay between drivers such as climate change, land conversion, and water management, vis-à-vis the spatial and temporal trends of these transformations. Figures 4.2 and 4.3 show photographs of research participants taken during the PGIS mapping workshop.

**Figure 4.2** Research participants mapping key drivers of ecological change in the Kat River catchment. The participants gave their consent for their photo to be published.

The second day of the PGIS mapping workshop focussed on **Part 2** of the PGIS mapping workshop guide (Appendix 1a). This focussed on the perceived ecosystem services and social-economic burdens/concerns in the catchment. We explored the spatial and temporal dimension of the perceived ecosystem services on the catchment map, and temporal dimensions of the perceived social-economic burdens/concerns. The research participants explored the level of importance of each on these perceived ecosystem services (Figure 4.3). In doing so, the research participants were asked to reflect on how important the perceived ecosystem services were to their households and the communities. The PGIS mapping method employed in this study is innovative. The systemic-relational framework used in this study was essential because it allowed the conception and mapping of multi-relational actors or components. In addition, it enabled a multidimensional mapping approach.

**Figure 4.3** Research participants mapping ecosystem services in the Kat River catchment. The participants gave their consent for their photo to be published.

## 4.3 Results

### 4.3.1 Perceived ecological change of the key drivers

Throughout the participatory mapping process, stakeholders identified flooding, soil erosion, droughts, water pollution, invasive alien species and water scarcity as important ecological change (Figure 4.4) within the catchment. Flooding and invasive alien species were perceived to mostly occur in the upper and middle part of the catchment, whereas water pollution and drought were perceived to be mostly concentrated within the middle part of the catchment.

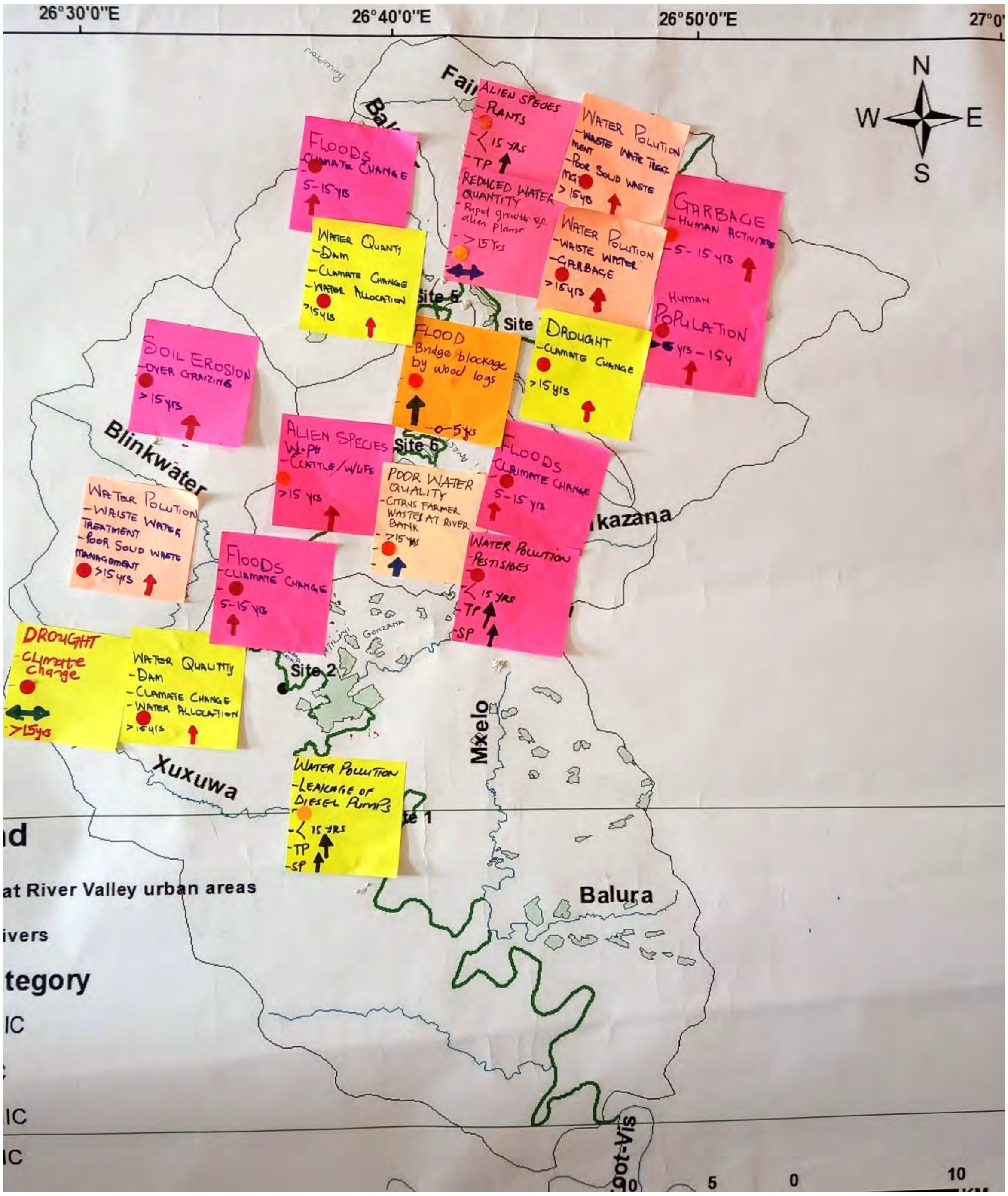


**Figure 4.4** Participants' input regarding the spatial distribution of the perceived ecological changes of the Kat River catchment

The stakeholders identified climate change and obstruction of bridges and water channels as the key drivers of flooding within the catchment (Table 4.2). Poor management of solid waste and wastewater treatment works were perceived to be the main contributors to the water pollution in the Kat River catchment. Regarding soil erosion, over grazing and over exploitation of natural resources within the catchment were perceived to be the main drivers by the participants. Climate change was perceived to be major driver of drought and invasive alien species. Finally, the research participants perceived water pollution to be the key driver of the decreased aquatic biodiversity.

**Table 4.2** Perceived ecological changes and their key drivers.

| Perceived ecological change | Perceived drivers |
|---|---|
| Flooding | Climate change, bridge blockage by wood logs |
| Water pollution and poor water quality | Wastewater treatment works (WWTWs), poor management of wastewater and solid waste; agricultural wastes (farming practices) |
| Soil erosion | Overgrazing and over exploitation of the nature resources |
| Drought | Climate change |
| Invasive alien species | Climate change |
| Decrease in aquatic biodiversity | Water pollution |

### *Flooding*

According to the research participants, floods are most prevalent in the Upper and Middle Kat regions, evident in four distinct spatial areas (Figure 4.5). Interestingly, no occurrences of floods are noted in the Lower Kat region. It is noteworthy that the majority of the participants resided in the Upper and Middle Kat areas, with only a few residing in the Lower Kat, which may have impacted the results.

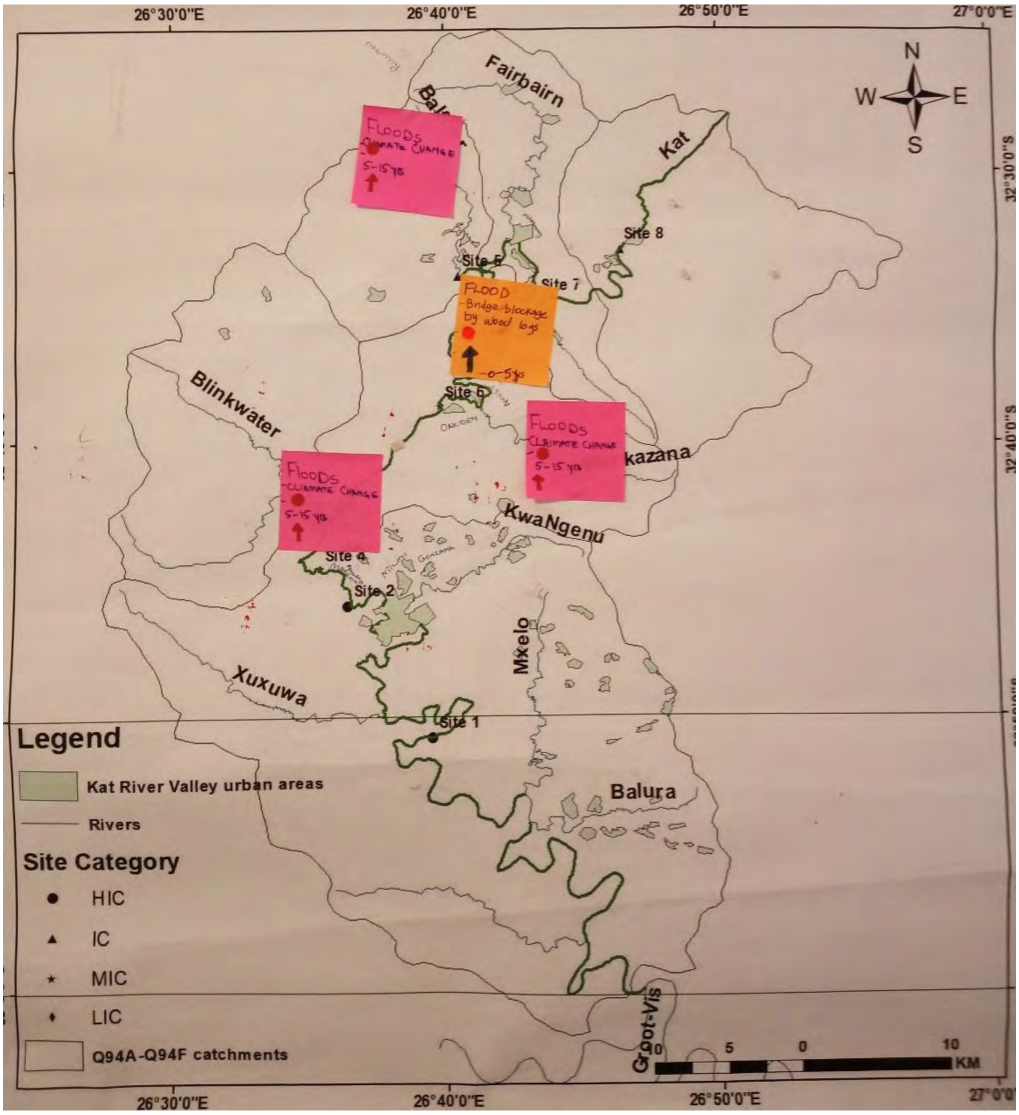

**Figure 4.5** Participants' input regarding the spatial distribution of the perceived flood occurrences in the Kat River catchment.

### *Water pollution*

Water pollution was one of the perceived ecological changes within the Kat River system. This perceived water pollution was spatially distributed across five distinct areas within the Upper and Middle Kat River catchment. It subsequently contributed to perceived poor water quality, also distributed across three different areas on the PGIS map (Figure 4.6).

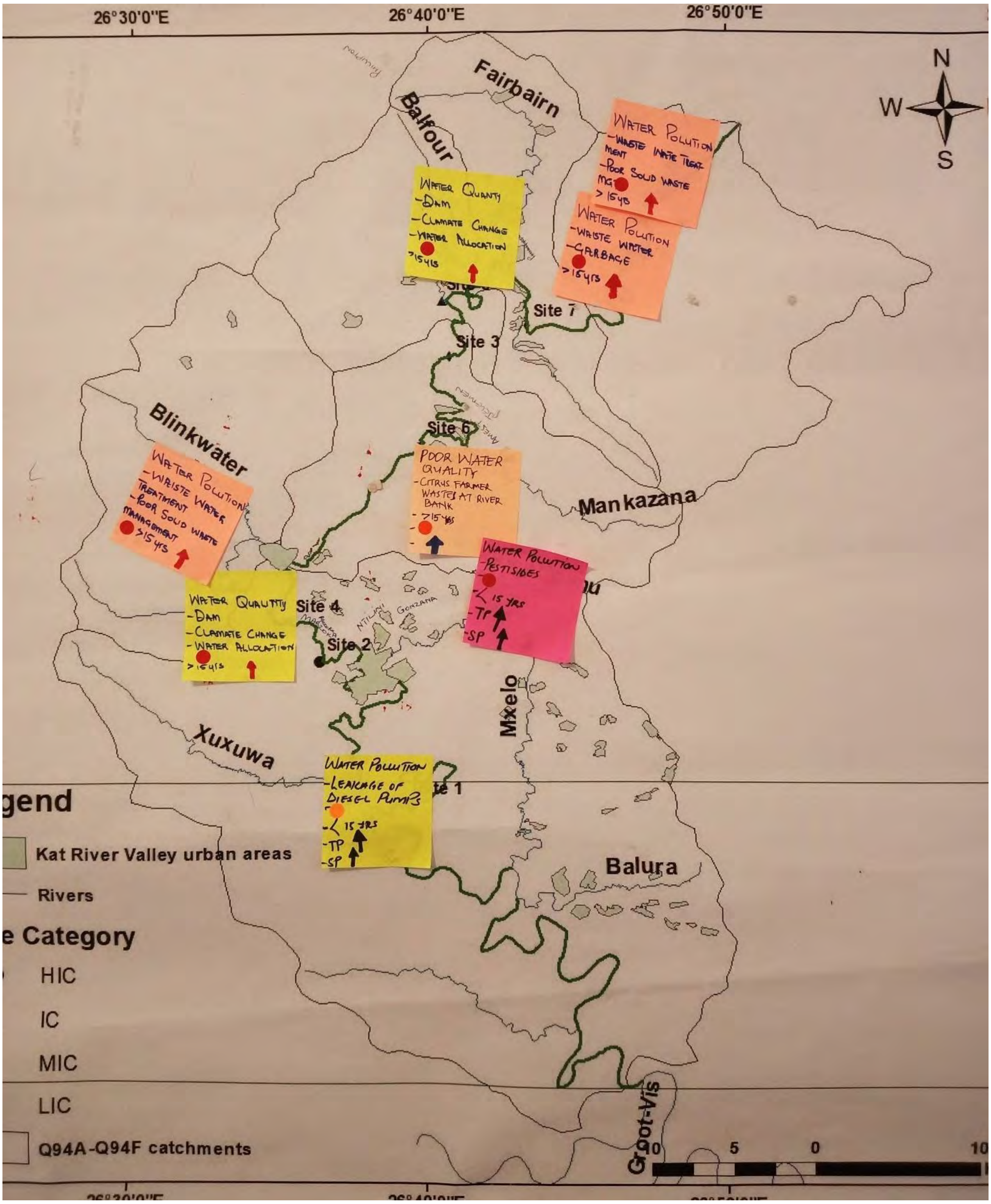


**Figure 4.6** Participants' input regarding the spatial distribution of the perceived water pollution in the Kat River catchment.

### *Soil erosion*

As indicated by the PGIS mapping results, soil erosion in the Kat River system primarily stems from overgrazing and the excessive exploitation of natural resources. Notably, this phenomenon was only reported to be observed within a single area on the Middle part of the Kat River catchment map (Figure 4.4/Appendix 2).

***Drought***

Drought was perceived in two distinct locations within the catchment (Figure 4.4), one in the Upper part with the other in the Middle part of the catchment. According to the PGIS mapping result, the perceived driver of drought in the Kat River system was climate change (Table 4.2).

***Invasive alien species***

The research participants reflected on the growth of invasive alien species and perceived this phenomenon to be spatially distributed in three places across the Upper and Middle parts of the Kat River catchment. Figure 4.4 shows the spatial distribution of the perceived ecological change.

### 4.3.2 Perceived severity of the identified ecological change

Notably, ecological changes such as floods, water pollution, soil erosion and a decline in aquatic organism populations were all associated with a severity level of 5, signifying a "very serious" impact on the river system and its catchment. Overall, with the exception of invasive alien species, which was awarded a severity score of 3, changes were given a severity score of 5 (Figure 4.7).

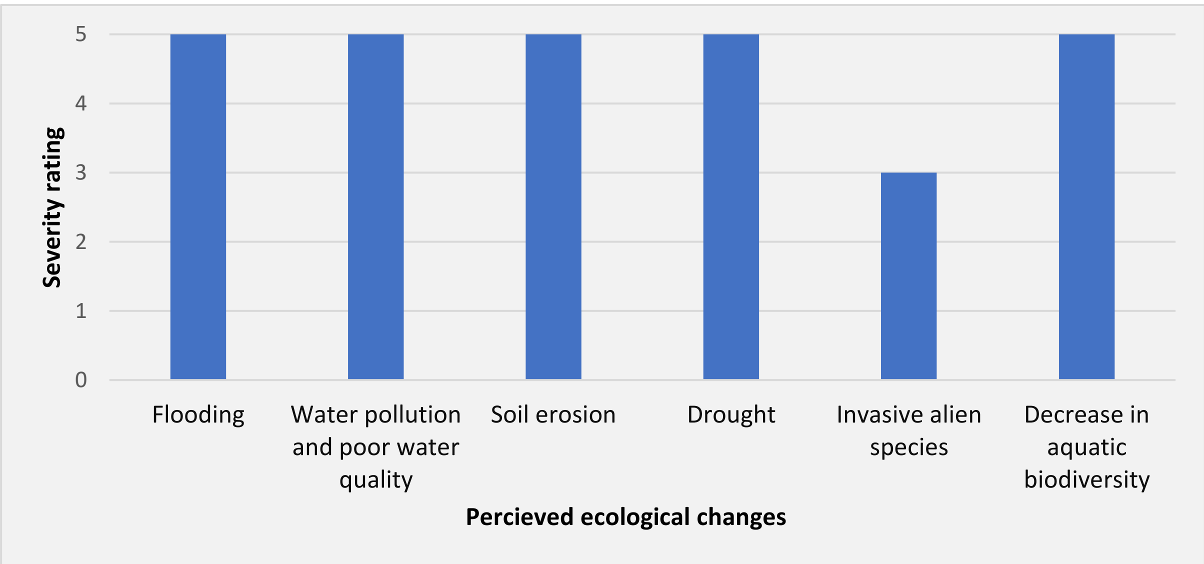

**Figure 4.7** Perceived severity of the impact of the identified ecological change. Rating score: 1= not serious, 3 = moderately serious, and 5 = very serious.

***Flooding***

Flooding within the Kat River catchment was perceived to be widespread and very severe (Figure 4.7), with serious detrimental impact to the catchment area. These impacts related mainly to loss of lives and livelihoods, inability to access school and loss of school items as indicated in participants' comments:

*"The flood affects the community very much because the people, and school pupils that crosses the river end up losing their lives or school items."*

*"Two of my uncles drowned in the river. And this prevents farm workers from going (to) their farms because they cannot cross."*

According to the participants, during prolonged heavy rainfall, a small bridge within the catchment becomes flooded and overflows. This obstructs people from crossing to the other side, disrupting their daily routines including commuting to schools, farms and workplaces. Figures 4.8 and 4.9 depict the small bridge in the middle Kat catchment before and during flooding.

**Figure 4.8** Small bridge before a heavy rainfall in the Kat River catchment

**Figure 4.9** Small bridge overflowing during a heavy rainfall in the Kat River catchment

The flooding of this bridge poses serious threats to lives and livelihoods as indicated by comments from the research participants:

> *"The bridge is very small, and people are unable to go across the river to the opposite (side) for work, business schools, and other activities."*

> *"Flood especially during heavy rainfall, which makes the river overflow. The Bridge is very low, so when there is a heavy pour down of rain, the villagers are unable to cross to the other side." (Two people were during a flood.)*

***Water pollution***

The perceived severity rating of water pollution was 5 (Figure 4.7). This indicates a "very serious" impact. From the PGIS mapping result, the key drivers of water pollution were perceived to be agricultural wastes, wastewater treatment works and poor management of wastewater and waste solids. The comments provided by one of the participants reflect their perception of the primary drivers of poor water quality and pollution, along with the ensuing repercussions.

> *"The present government contributed to the cause of pollutant in the water body because in 2010, there was a sewerage tank from Hogsback that dumped sewage directly into the river. This led to the outburst of sickness in the village."*

> *"Pollution in water hinders rituals."*

*"We lack adequate resources to adapt, (and so there is a) high (rate) of death. People die like house flies."*

"*In the past, the river pollution has been caused by natural occurrences only. But in the present day, the river pollution is caused by anthropogenic activities. From the people in the village and the pedestrians, (and) also the pollution from upstream.*"

***Soil Erosion***

The participants reflected on the severity rating of soil erosion and perceived it to have a very serious impact on the catchment with severity code 5 (Figure 4.7).

*"Some plant(s) have become extinct along the riverbanks. For example, the mints (which is used as a natural tea) and the long grass plants (Marram, this grass is used for thatching)."*

***Drought***

The severity rating of drought is also perceived to be 5 (Figure 4.7), indicating a very serious impact in the catchment as perceived by the research participants.

*"Drought; no water in the river during summer."*

***Invasive alien species***

Invasion of alien species in the Kat River catchment was reflected on and perceived to be serious by the research participants, with a severity code of 3, (Figure 4.7). The participants also reflected on the drivers of the invasive alien species and perceived the key driver to be climate change.

### 4.3.3 Temporal dimension of identified ecological changes.

The participants were asked to reflect on and map the temporal dimension of each of the identified ecological change in terms of whether these changes had been improving or deteriorating over the years. They were also asked to indicate the time frame if they identified the changes as either improving or deteriorating. Many of the identified changes have been occurring in the catchment over the past 15 years and indicate increasing deterioration (tp+) (Figure 4.10). Invasive alien species, water pollution and poor water quality, drought and soil erosion were all identified as having occurred in the catchment for over 15 years, with continuing deterioration over these years. Flooding and a decrease in aquatic biodiversity were perceived as only having occurred over the past 5–15 years. None of the identified changes were perceived as a recent occurrence (0–5 years).

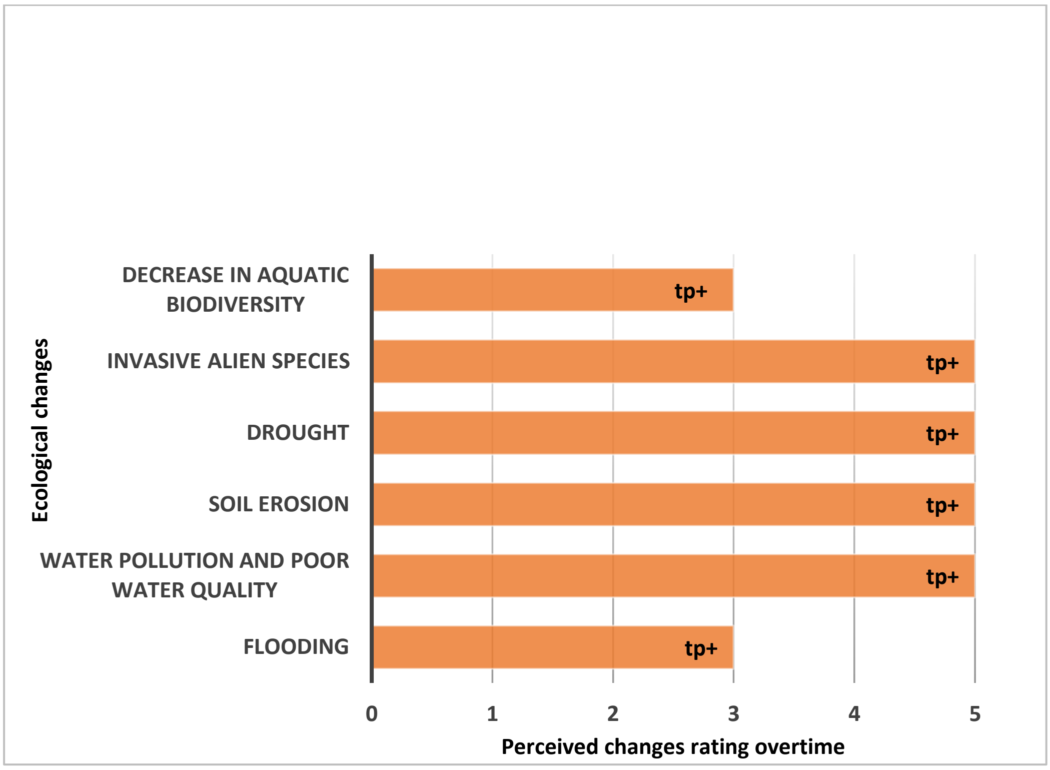


**Figure 4.10** Perceived ecological change occurrence and progression (improving or deteriorating) over time in years. Code: 1 = 0–5 years, 3 = 5–15 years, 5 = >15 years; tp+ = increasingly deteriorating, and tp- = improving.

### *Flooding*

The research participants reflected on the occurrence of floods over time in years and perceived it to have occurred between 5 and 15 years (Figure 4.10) with a recent (0−5years) increase which has led to loss of lives in the catchment. These are some comments from the participants.

> *"The floods became worst these 2022/2023 and three peoples were swept away by the flood."*

> *"Flood especially during rainy season and the water becomes dirty."*

> *"The floods wash away the farmers crops, and the water pumps also get eroded too."*

***Water pollution***

As perceived by the research participants, the temporal progression sign (tp+) for water pollution (shown in Figure 4.10) signifies a deteriorating trend in the Kat River system. Participants perceived that changes have been taking place over a period of more than 15 years. Below are quotes perceived by research participants.

> "The Kat *River is polluted in the midstream which results in health issues*."

> "There is *poor water quality in the Kat River which is due to pollution."*

> *"There is poor water quality now but when the Whites were here the water from the Kat River was of good quality. The Whites left in 1883."*

***Soil erosion***

Soil erosion in the Kat River catchment was perceived by the research participants to have occurred for more the 15 years. The changes over the period were perceived to be getting worse tp+ (increasingly deteriorating) (Figure 4.10).

***Drought***

The research participants reflected on the drought in the catchment and perceived it to have occurred for more than 15 years and gave it a code 5 (Figure 4.10). The temporal progression of drought was perceived to be increasingly deteriorating with the sign tp+. Here are some of the comments from the research participants.

> *"In the past they (did) experience drought, people walk(ed) across the river on dry ground. Also, the citrus farmer business gets affect(ed) during drought periods."*

> *"During drought, traditional healer(s) lack water to perform their activities, especially with the nature of the job."*

***Invasive alien species***

The growth of invasive alien species was perceived by the research participants to have occurred for more than 15 years in the catchment area, with an increasingly deteriorating temporal progression tp+ (Figure 4.10). The participants mentioned the growth of Black Wattle trees (*Acacia mearnsii*) along the bank of the river in the catchment. Figure 4.11 shows a Black wattle found in the Middle part of the catchment.

**Figure 4.11** Invasive alien species *Acacia mearnsii*, common name Black Wattle tree. The photo was taking from the Kat River Catchment.

### 4.3.4 Perceived ecosystem services in the Kat River catchment

The research participants identified several ecosystem services within the Kat River catchment area (Table 4.3; Figure 4.12). These services included water, wood, sand, reeds, spiritual activities, fishing, and sites for recreation. Following the Millennium Ecosystem Assessment (MEA) classification scheme, these services can be classified as provisioning (e.g., fishing, water) or cultural (e.g., spiritual benefits, recreation). Interestingly, the research participants did not perceive regulatory and supporting functions to be services supplied by the Kat River catchment.


**Figure 4.12** Participants' input regarding the spatial distribution of the perceived ecosystem services on the Kat River catchment map.

**Table 4.3** Perceived ecosystem services, importance, temporal progression, spatial progression, and perceived changes in years

| Perceived ecosystem services | Importance | Perceived spatial progression (sp) | Perceived time progression (tp) | Perceived time frame (years) |
|---|---|---|---|---|
| Water for irrigation | Very important | ↔ | ↓ | >15 |
| Water for food, crop & livestock | Very important | ↔ | ↓ | >15 |
| Water for drinking & domestic use | Very important | ↔ | ↓ | >15 |
| Wood | Very important | ↔ | ↔ | |
| Sand for building | Very important | ↓ | ↓ | 0−5 |
| Fishing | Very important | ↓ | ↓ | 5−15 |
| Recreational benefits | Moderately important | ↓ | ↓ | >15 |
| Medicinal plants | Very important | ↔ | | 0-5 |
| Water (sacred pool) | Very important | ↔ | ↓ | 5−15 |
| Traditional purposes | Moderately important | ↓ | ↔ | 0−5 |
| Reeds | Very important | ↓ | ↓ | >15 |
| Spiritual purposes | Moderately important | ↔ | ↓ | 5−15 |

***Water***

The research participants reflected on the area on the Kat River catchment where they collected water for their wellbeing. They reported that water for various purposes such as drinking, domestic use, irrigation and livestock survival were collected from five distinct areas in the catchment (Figure 4.12). The five distinct area are distributed in the Upper and Middle Kat in the catchment. The participants also reflected on the mode of water collection from the river. For irrigation, water is abstracted by use of pumping machines. For domestic use, which includes direct consumption, water is collected using buckets. Livestock are permitted to graze freely along the banks of the river and can drink water directly from the river.

***Reeds and Wood***

Reeds and wood were perceived to be particularly present in four distinct areas in the Upper and Middle sub-catchments, as illustrated in Figure 4.12. The research participants reflected on the importance of the reed collection areas along the banks of the Kat River which provide for house construction and building activities.

***Sand***

The participants reflected on areas where sand is harvested in the Kat River catchment area. The research participants perceived that the sand is harvested in the Upper part of the catchment (Figure 4.12), which used for multiple purposes, including house construction and trading.

***Spiritual and traditional values***

As reflected on and perceived by the research participants, there were two areas where spiritual and traditional activities were carried out in the Kat River, and they are located in the Upper and Middle part of the catchment (Figure 4.12). Traditional rituals and practices are closely intertwined with the river, reflecting its spiritual importance. Indigenous leaders and traditional healers perceive a unique connection with their ancestors through the river, believing that it serves as a medium of communication with the spiritual realm.

***Fishing***

The participants reflected on the areas where they caught fish in the Kat River catchment area. The participants observed three distinct areas in each part of the catchment, Upper, Middle, and Lower, where they caught fish (Figure 4.12).

***Recreational benefits***

Recreational benefits were perceived to be performed in two distinct areas in the Upper and Middle parts of Kat catchment (Figure 4.12).

### 4.3.5 Perceived importance of the identified ecosystem services

The research participants were asked to rate the importance of the benefits provided by the identified ecosystem services to their well-being. The results indicate that cultural services such as traditional benefits, recreation and spiritual values were accorded moderate importance compared to provisioning services, which were rated as very important to the well-being of the participants (Figure 4.13).

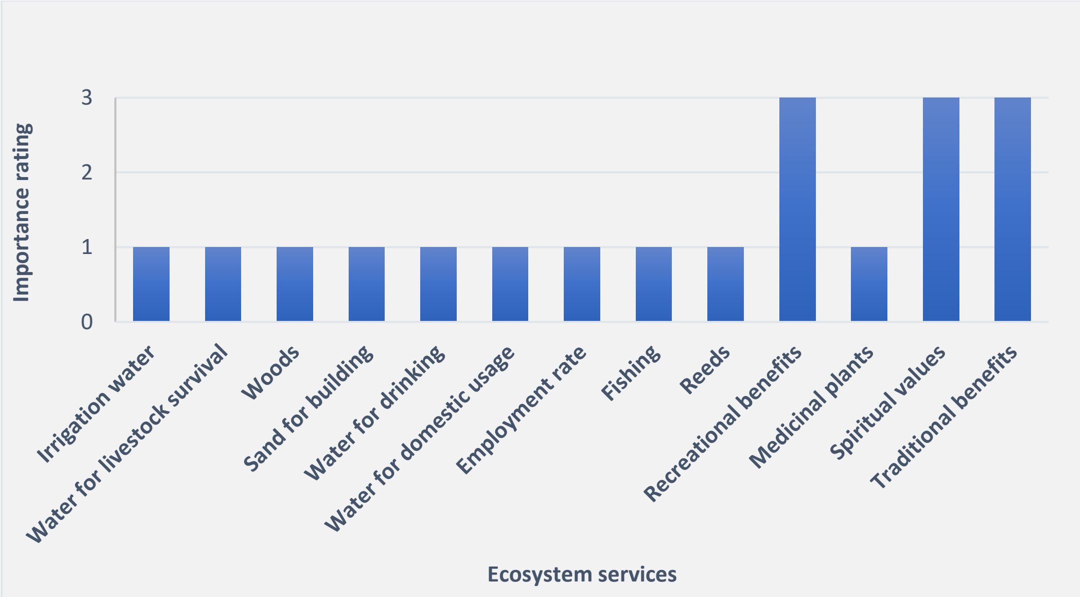


**Figure 4.13** Perceived importance of the identified ecosystem services within the Kat River catchment. Importance rating: 1 = very important, 3 = moderately important, 5 = not important.

### 4.3.6 Temporal direction of the identified ecosystem services

The research participants were asked to reflect on the quality and availability of the identified ecosystem services over time. The participants were also asked to reflect on whether these ecosystem services have been improving or deteriorating over the identified period. Water for drinking, water for domestic usage (other than drinking), water for livestock watering, recreational benefits, reeds, and irrigation water were perceived to have been deteriorating (in terms of quality and quantity) over the past 15 years within the catchment (Figure 4.14). Recent changes (0–5 years) were observed for medical plants and sand for construction, and these ecosystem services supplied were perceived to have been deteriorating over time. Ecosystem services whose quality were perceived to have been deteriorating over the past 5–15 years included fishing and spiritual benefits (Figure 4.14). Traditional benefits and wood were perceived to have remained mostly the same over time (neither improving nor deteriorating) (Figure 4.14).

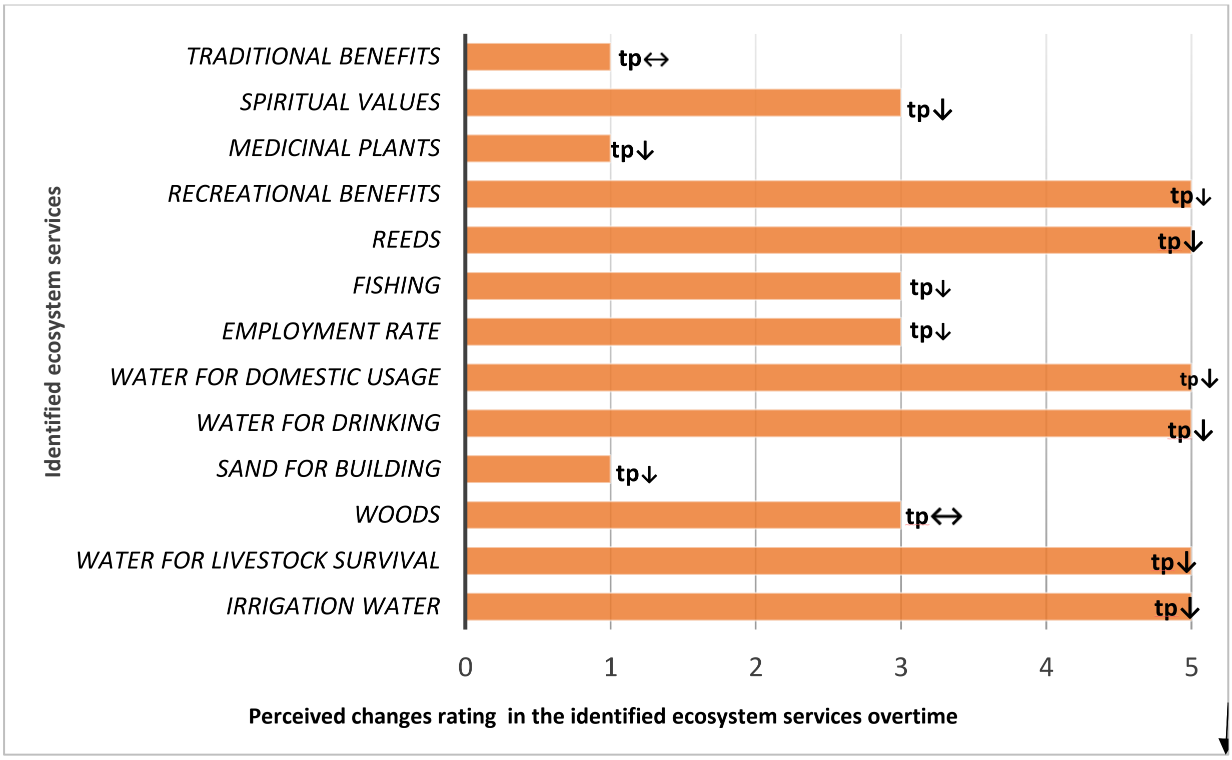


**Figure 4.14** Perceived changes of ecosystem services over time. Code: temporal changes (tp) in years1 = 0–5 years, 3 = 5–15 years, 5 = > 15 years. tp↓ = deteriorating (i.e. changes are getting worse over time) tp↔ = no changes, tp↑ = changes are improving over time.

***Water***

Water quality and availability were perceived to be deteriorating over time by the research participants (Figure 4.14). The participants were asked to reflect on the water quality and purification methods before direct consumption (such as drinking water for households). Their comments mostly indicated a fear that the water was not safe for drinking.

> *"No, it is not safe. We drink the water like that."*
>
> *"No, it is not safe. We drink the water like that (but) sometimes boil before drinking."*

***Reeds and Wood***

The participants perceived the supply of reeds to be deteriorating, while wood was observed to be neither deteriorating nor improving over time in the catchment (Figure 4.14).

> *"Changes both in the quality and the availability. Fewer reeds and herbs."*
>
> *"Fewer reeds in the river."*

***Sand***

The quantity of sand was perceived by the research participants to be deceasing over the recent time (Figure 4.14). This is possibly due to its concentrated demand.

***Spiritual and traditional benefits***

The participant reflected on the changes observed in the spiritual and traditional benefits over time (Figure 4.14). The participants reported deteriorating changes in the spiritual benefits (poor water quality in the sacred pool where the spiritual activities are performed). There were no perceived or observed changes to traditional benefits.

***Fishing***

The research participants reflected on the availability of fish in the river over time (Figure 4.14). The participants perceived the availability of fish to be deteriorating in the Kat River over time in years (5–15 years).

> "*There (were) fishing activities before but now they are not (here) anymore*."
>
> "*No fishes (the participant suspected that there were no fish because 5 years ago fishermen came frequently for fishing, but they no longer do so)."*

***Recreational benefits***

Changes to recreational benefits (such as swimming and boating/paddling) over time in the Kat River catchment were reflected upon by the research participants. The research participants perceived benefits to have deteriorated over the last 5–15 years (Figure 4.14).

### 4.3.7 Spatial direction of the identified ecosystem services

The research participants were asked to reflect on the changes in the observed spatial distribution of the identified ecosystem services in the catchment. They were asked to reflect on whether the area coverage of the ecosystem services was expanding, reducing or had remained unchanged in size over time. As observed in Figure 4.15, no changes (not increasing or reducing) were observed in spiritual values, medicinal plants, water for drinking, irrigation or domestic use, or in livestock survival area coverage over time. Traditional benefits, recreational benefits, reeds, fishing and sand spatial coverage were observed to be reducing. Communities such as Balfour, Fairbairn and Blinkwater were affected. No identified ecosystem services spatial coverage was observed to be increasing in size.

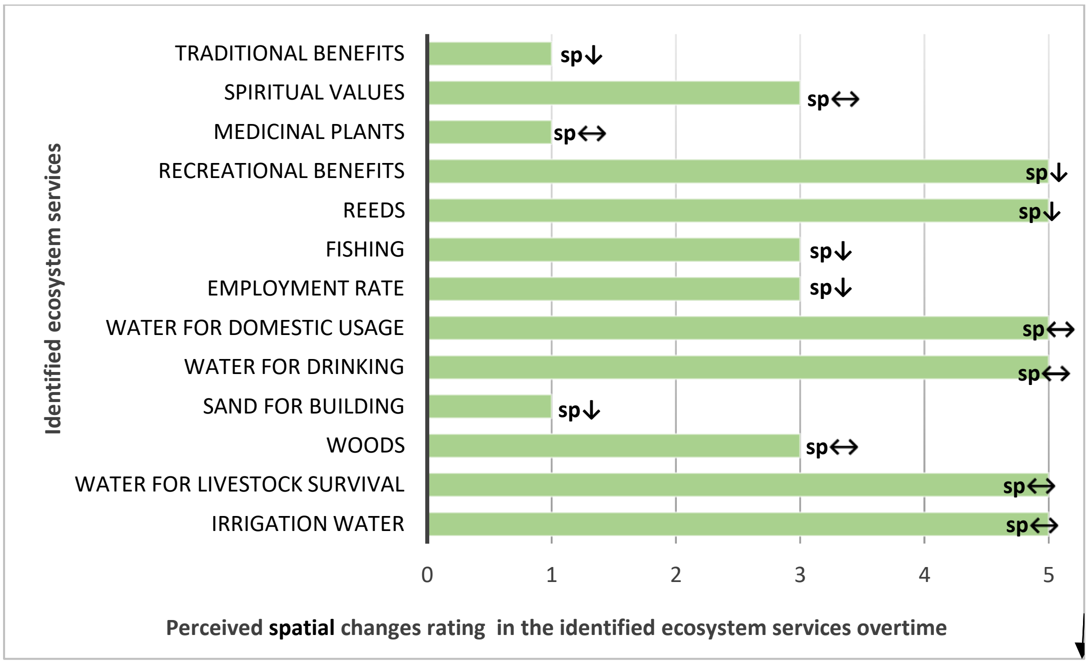


**Figure 4.15** Perceived changes the ecosystem services over time. Code: spatial progression (sp) in years 1 = 0–5 years, 3 = 5–15 years, 5 = > 15 years. sp↓ = decreasing (spatial changes decreasing over time) sp↔ = no changes, sp↑ = changes observed to be increasing over time.

### *Water*

The spatial area coverage of water collection in the Kat River catchment area (Figure 4.15) was perceived by the research participants to be neither increasing nor reducing (no observed change).

### *Wood and Reeds*

The research participants reflected on changes in the spatial coverage areas of wood and reeds. Wood areas coverage in the catchment was perceived to have remained unchanged (neither increasing nor reducing), while the spatial coverage of reeds was perceived to have decreased (Figure 4.15).

### *Sand*

The spatial coverage of sand in the catchment was reflected upon (Figure 4.15) and perceived to be decreasing over recent years (0–5 years).

### *Spiritual and traditional values*

The research participants reflected on and perceived changes in the spatial coverage of the spiritual and traditional benefits in the catchment (areas where spiritual and traditional rituals are carried out). The participants perceived decreasing changes in the spatial coverage of the spiritual benefits for the period of 5 to 15 years, and a decrease for the last 0–5 years for the traditional benefits (Figure 4.15).

***Fishing***

As reflected upon by the research participants, the spatial coverage of fish in the Kat River was perceived to have decreased in area for more than 15 years in the catchment (Figure 4.15).

***Recreational benefits***

The participants reflected on and perceived the area coverage for recreational activities in the Kat River to have been decreasing for more than 15 years (Figure 4.15).

### 4.3.8 Perceived social-economic burdens/concerns arising from the ecological changes in the Kat River catchment.

As a consequence of the ecological changes occurrence trends in the Kat River catchment area, the research participants identified burdens or concerns affecting their well-being (Table 4.4). Of the identified burdens, water-borne diseases, sharing of water sources with animals, scarcity of reeds and cultural concerns (such as submerged graves) were perceived to be the most serious concerns by the research participants. Concerns perceived as moderately serious included fewer fishes as well as fewer medicinal plants (Figure 4.16).

**Table 4.4** Perceived social-economic burden/concerns arising from the ecological changes in the Kat River catchment.

| **Perceived social-economic burden/concerns.** | **Severity impact** | **Time progression changes** | **Timeframe (year)** |
|---|---|---|---|
| River co-sharing with animals | Very serious | ↑ | 5−15 |
| Scarcity of reeds | Very serious | ↑ | 0−5 |
| Culture Burden (Grave) | Very serious | ↑ | > 15 |

| | | | |
|---|---|---|---|
| Low Medicinal plants | Moderately serious | ↑ | 0–5 |
| Fewer fish | Moderately serious | ↑ | 5–15 |
| Water-borne diseases | Very serious | ↔ | 5–15 |

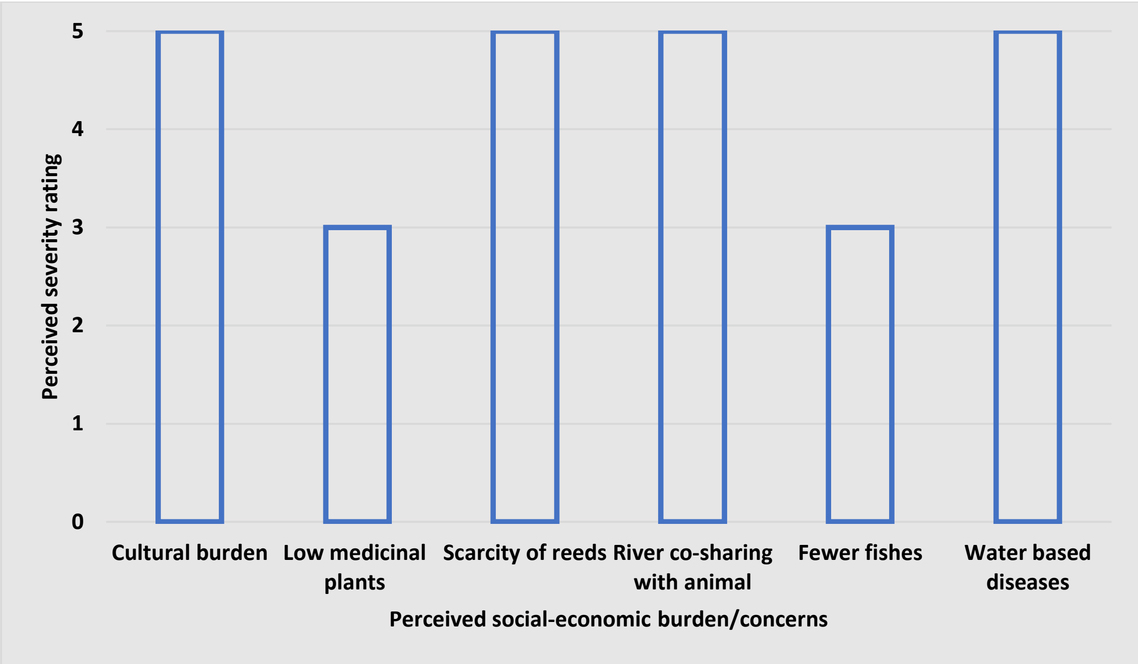


**Figure 4.16** Perceived severity of the identified concerns/burden on well-being. Severity rating: 1 = represents not serious, 3 = represents moderately serious, 5 = represents very serious.

All the identified concerns were perceived by the research participants to be becoming worse over time (Figure 4.17). For more than 15 years (Figure 4.17), concerns regarding submerged graves due to the construction of the Kat River dam (that is cultural burden) have continued to plague the communities. These graves mostly belong to Black people, and the communities feel abandoned and unfairly treated as the government has not made any reparation in this regard. This sense of indignity and inhuman treatment arising from the construction of the Kat River dam within the catchment area is best captured in the comments of one of the research participants.

"*In April 2004 the Water Affairs & Forestry' former minister visited the Kat valley upon invitation by the CMF to investigate the plight of indignity that plagues the residents of the entire "Kat". The apartheid regime neglected an existing graveyard for black people during the building of the Kat dam in 1969. As a result, this burden still haunts the families of the* *deceased each time they have to visit and pay homage to their loved ones as the graves are always submerged under the water. The CMF took this upon itself as their program since this also affected those downstream. The former minister declared this as a gross violation of human dignity. She committed her government to exhumation of the bodies and fencing of the Kat dam as a restoration of the lost dignity. The CMF added that it wanted reparation as one of the other means."*

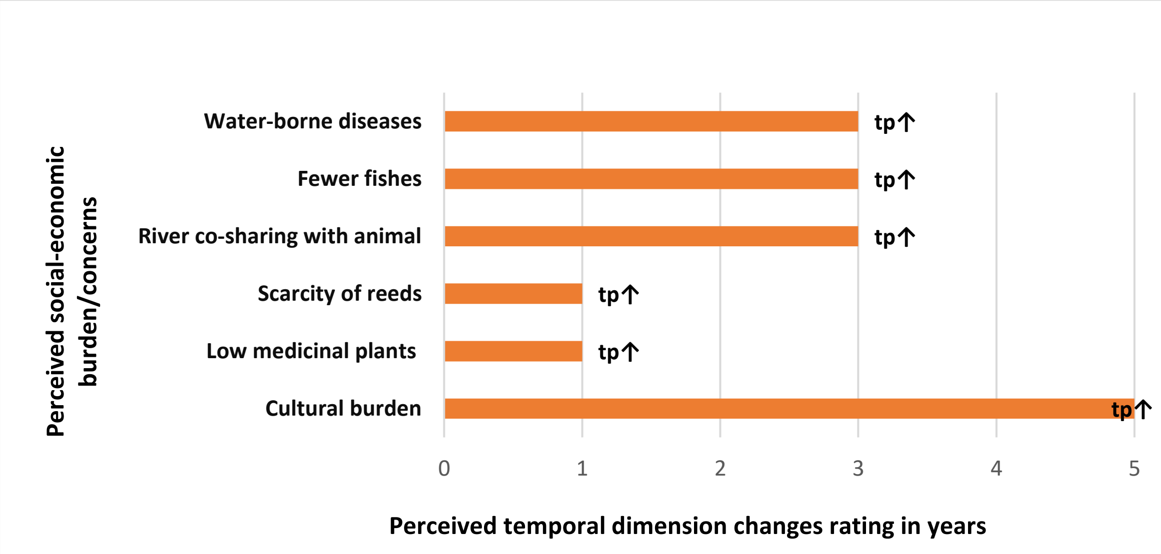


**Figure 4.17** Perceived temporal dimension changes on the identified concerns/burden. Code: 1 = 0–5 years, 3 = 5–15 years, 5 = >15 years. tp↓ represents improving, tp↔ represents no changes, and tp↑ represents deteriorating.

The research participants perceived deteriorating temporal dimension changes in water-borne diseases, fewer fish and co-sharing the Kat River with animals over the period of the last 5–15 years (Figure 4.17).

There were concerns regarding the water quality, which might have affected the aquatic biodiversity of fish in the river. Here is a comment from on the research participants.

> "*I suspect that there are no fishes in the river because like 5 years ago fisherman do come for fishing, but they stopped.*"

The issues of water-borne diseases and co-sharing the Kat River with livestock were explored. The participants perceived the co-sharing of the river with animals to be a major concern, because it impacts the river quality and poses a potential health risk, particularly to households who directly consume the water. Participants had many comments regarding the water quality with regard to sharing the water with livestock.

*“We experience health issues, such as running stomach which may be as a result of the poor water quality. We also share the water with animals.”*

*“We even share the river with the animals. The animal goes to the river to drink water.”*

Of the recent temporal dimension changes (0–5 years), the research participants reflected and perceived the abundance of reeds and medicinal plants to be deteriorating, leading to their scarcity in the Kat River catchment area (Figure 4.17).

On discussion, the participants perceived that the decline may be attributed to a combination of factors such as climate change, human activities, and environmental pressures, as well as overgrazing in the catchment area.

### 4.4 Discussion

The Kat River system is a valuable resource for the inhabitants of the catchment, owing to the close link between the people and the river. Climate change was identified as a key driver of certain perceived ecological changes, with high severity impacts on the catchment. Changing climatic patterns may have adverse effects on freshwater ecosystems. Additionally, anthropogenic activities such as degradation, and urbanization, have also been identified as key drivers of observed ecological changes, with high severity impacts on ecosystems. Recent studies in South Africa have shown that, due to existing anthropogenic impacts, freshwater resources in South Africa are under severe stress, and climate change exacerbates that stress even further (Selby, 2022; Strayer & Dudgeon, 2010). Lerotholi et al. (2004) concluded that agricultural runoff from informal settlements and wastewater effluent discharges from the Kat River wastewater treatment facility are the principal contributors to the poor water quality within the Kat River. These issues have been further exacerbated by climate change, which has brought about more frequent extreme weather events such as intense rainfall, leading to floods which in turn promotes soil erosion.

Perceived ecological changes such as drought and invasive alien species, were each given a severity rating code of 3, indicating a 'serious' impact. These factors have substantial and detrimental influences on ecosystems. Drought can lead to crop failure, causing food scarcity. Invasive species can disrupt the ecology of the system and may lead to a decline in the native species population. For example, i) invasive species can compete with native species for food and habitat and can also introduce diseases or parasites that can harm the native population (Havel et al., 2015); ii) they can also lead to economic consequences, as they can damage crops and livestock (Bennett, 2014); and iii) they can be difficult to control and may require long-term management strategies and can affect the capacity of ecosystems to deliver goods and services (Woodford et al., 2017). The research participants perceived climate change to be a major driver behind the emergence of alien plant species in the Kat River catchment area, such as. *mearnsii* (Black wattle tree)*,* which is predominantly found at riparian zones. The invasion of this plant threatens riparian zones in South Africa as they outcompete native species and increase the occurrence of water loss in these zones (Moyo & Fatunbi, 2010).

Floods are a critical issue in South Africa, known for their intense and prolonged nature. For example, the Eastern Cape region has been significantly affected by climate change-induced unstable weather patterns, resulting in floods, droughts, and extreme temperature variations. These events have had severe repercussions on agricultural output, causing food insecurity and increased poverty (Grab & Nash, 2023; Wright et al., 2021). According to the PGIS mapping results, soil erosion within the Kat River catchment is a significant concern. Overgrazing by animals and the excessive exploitation of natural resources by humans were identified as key drivers. Notably, this issue has been a recurring seasonal problem for over a decade within the catchment. The removal of vegetation results in the loss of essential organic matter crucial for soil structure. Consequently, the soil's porosity diminishes, impairing its ability to absorb and retain water (Or et al., 2007). The cumulative effect of overgrazing and human overexploitation further depletes organic matter and essential nutrients in the soil. A similar situation in the 19th-century Great Plains of the United States illustrates the consequences of these actions. The Great Plains experienced a period of overgrazing, leading to soil erosion and reduced soil fertility. This caused a major decline in agricultural productions and population in the region (Cunfer, 2005).

Water pollution can disrupt the ecosystem's balance, leading to heightened algae growth and a decline in the aquatic organism population. As highlighted by Lerotholi et al., (2004) and Mgaba (2018), pollutants originating from runoff, waste and sewage are major sources of nitrogen and phosphates, which are crucial nutrients for algae growth within the Kat River system. Algae blooms consume oxygen, suffocating aquatic organisms, particularly fish. Pollutants like toxins and heavy metals in runoff, waste, and sewage can negatively impact fish

populations. Moreover, these pollutants can foster disease and parasites, further impacting fish populations. Elevated levels of nitrogen and phosphorus in water can result in the excessive growth of algae, which can deplete the oxygen supply for fish living in the water body. This, in turn, can lead to a significant decline in fish populations over time. Therefore, it is essential to monitor and control the levels of nitrogen and phosphorus in water bodies to maintain a healthy aquatic ecosystem(Hallegraeff, 2003). A significant number of participants voiced their discontent with the government's apparent apathy towards enforcing environmental laws and regulations. This perceived lack of enforcement seems to have led to increased water contamination and a decline in water quality.
A more proactive approach from the government was desired, implementing substantial measures to safeguard the environment and the well-being of local communities.

The benefits derived from the services supplied by the Kat River catchment include water for drinking, cooking, cleaning, irrigation water and providing water for livestock, as well as facilities for the recreational and spiritual needs of the local community, and lastly, the catchment area as a whole enhances the overall quality of life of its inhabitants. This ecosystem service offers a multitude of benefits for the community, as research participants reflected on and highlighted the diverse usage of the water from the Kat River system. For irrigation purposes, water is abstracted by use of pumping machines; For domestic use, which includes direct consumption, water is collected by buckets from the Kat River. The research participants also reflected on the poor water quality and ways to purify the water before drinking in households and discussed the consequences of direct drinking without adequate water treatment measures. This shows that inhabitants are aware of the potential health risks associated with directly consuming untreated water from the river and highlights the need for better water treatment.

The Kat River system has an abundant availability of wood and reeds, making it particularly well-suited to construction using such building materials. The versatility of reeds is worth noting, as they are lightweight, durable, and easily moulded into various forms. They possess excellent insulation properties, contributing to cooler interiors during hot seasons and warmer interiors during colder periods (Puttegowda et al., 2018). The river mud, functioning as a binding agent, enhances the structural integrity of the reed-based construction, making it resilient to environmental conditions. Interestingly, this practice of utilizing natural materials such as reeds for construction is not limited to the Kat River area. Similar sustainable building practices involving reeds and other plant materials are observed in various regions world-wide, such as some rural areas in China (Knapp, 2012). The research participants reflected on the uses and availability of reeds in the Kat River catchment. Reeds are a key material used for building of houses in the catchment and are found in the riparian zones of the river. The abundance of reeds in the catchment area, however, has become impacted by various factors including overexploitation and climate change, and the spatial distribution is decreasing over time. This has caused a decrease in the availability of reeds for housing construction, forcing people to use alternative materials. This has a negative impact on the wellbeing of people (such as lacking shelter) mostly who rely on reeds for construction and other purposes. It is therefore essential to take steps to conserve and manage reed resources in the Kat River catchment area.

The research participants reflected on the importance and availability of sand in the Kat River catchment area. The benefit of sand is its role in forming a protective barrier along riverbanks. This barrier helps shield the banks from the erosive forces of flowing water, thus playing a vital role in preventing bank erosion. River sand collection contributes to the local economy by serving as a marketable resource. Its availability and suitability for construction purposes makes it a valuable commodity for trade within the community (Jordaan et al., 2009; Li et al., 2013).

Cultural ecosystem services such as spiritual and recreational activities were identified and discussed. Some sacred pools carry immense spiritual meaning, serving as a conduit for connecting with the world of spirits and gaining spiritual insights. This ritualistic use of the sacred pool is believed to purify the spirit and facilitate a closer alignment with the river's spiritual energies (Falayi, 2017; Jordaan et al., 2009; Motteux, 2000). The workshops showed that The Kat River system serves not only as a natural resource bank, but also as a source of profound spiritual guidance and connection, fostering a sense of unity between people, nature, and the spiritual world. Recreational activities such as swimming were not exercised by the communities owing to the poor water quality of the river. Overall, the participants' cautious approach to recreational activities in the Kat River system highlights their awareness of the existing challenges and their commitment to avoiding potential dangers while still benefiting from the river's resources (Büchele et al., 2006; Merz et al., 2021).

It is fascinating to note that the research participants did not perceive that they received regulatory and supporting ecosystem services in the Kat River catchment area. This may be due to a number of reasons, such as (i) limited knowledge of the categories of ecosystem services classification, (ii) lack of public awareness of the importance of ecosystem service categories and services they provide, and (iii) lack of recognition of the role played by ecosystem services in the sustainable management of natural resources. These issues could be addressed by implementing measures such as awareness campaigns and targeted educational programs, to better inform and involve the public in the sustainable management of these natural resources. This could lead to better decision-making and the improved management of ecosystem services in the catchment.

Poor waste management poses a significant threat to the environment and public health. It leads to the release of harmful toxins and pollutants into the ecosystem, causing serious repercussions. Addressing waste management is crucial to safeguarding the environment and public well-being. Proper waste disposal practices, treatment of chemicals and sewage, and initiatives to reduce plastic use are essential steps toward maintaining the health and balance of freshwater ecosystems (Adeleke & Bezuidenhout, 2011; Dumbili & Henderson, 2020).

Water-borne diseases like cholera, typhoid fever and diarrhoea are caused by microorganisms such as bacteria, viruses, and protozoa. These pathogens thrive in contaminated water sources. Inadequate waste management, poor sanitation, and lack of proper sewage disposal contribute to the contamination of water sources. In Ethiopia, inadequate access to clean water and sanitation has been linked to a higher prevalence of intestinal parasites. Contaminated water can lead to infections through ingestion, inhalation, or skin contact. Illnesses such as cholera, dysentery and typhoid fever can result from consuming or coming into contact with polluted water. Poor sanitation can also increase the risk of vector-borne diseases like malaria and dengue fever (Aschale et al., 2021; Tigabu et al., 2019; Wassie, 2020).

Co-sharing the river with animal such as livestock is a health hazard. This situation could pose risks on multiple fronts. Animal waste introduced into the river can pollute the water, posing health threats to both animal populations and humans who rely on the river for drinking water. The waste can also stimulate excessive growth of algae, depleting oxygen levels in the water and disrupting the ecosystem's balance. To address this issue, implementing proper waste management strategies, such as creating intensive animal husbandry practices where animals are watered and fed, and raising awareness among local communities about the risks of co-sharing the Kat River with animals are crucial steps. This can help protect both the environment and human health, ensuring a sustainable and healthy coexistence between humans and animals in the catchment area.

The overexploitation of medicinal plants for various purposes such as food and medicine, can deplete their populations, leaving the riverbanks susceptible to soil erosion. Invasive species, which can outcompete native plants, pose another threat to medicinal plant diversity. The presence of invasive species can reduce the overall biodiversity of medicinal plants, making it harder for native species to survive and thrive  (Rai & Singh, 2020). To address the decline of medicinal plants, sustainable practices are essential. This includes proper land management to prevent overgrazing, as well as conservation efforts to protect natural habitats  (Chen et al., 2016).

## 4.5 Conclusion

This study employs a novel framework for multi-dimensional mapping of perceived ecological changes, ecosystem services, and the perceived social-economic burdens/concerns in the Kat River catchment, making a valuable analytical contribution to the ecosystem services literature.

Using the PGIS mapping method, the study explored i) the perceived ecological changes and their spatial representation in the Kat River catchment, their perceived respectively drivers, the severity impact to wellbeing and the temporal dimensions (whether the perceived ecological change is deteriorating, improving or remains the same over time in years), ii) the perceived ecosystem services and their spatial representation in the Kat River catchment area, the importance of the services to wellbeing, and their the temporal dimensions (whether the perceived ecosystem services are improving, getting worse or remain the same over time), and the changes on the spatial area coverage over time (whether the area coverage is increasing, decreasing or remains the same), and lastly iii) perceived severity impact on wellbeing, from the perceived social-economic burden/concerns arising from the ecological changes in the Kat River catchment area, and the temporal dimensions (how the participants perceived the changes on their wellbeing over time).

Sustainable conservation strategies such as wetland restoration, riparian buffer zone protection and controlling invasive alien species should be implemented to safeguard freshwater ecosystem services for future generations.

The findings of this study can inform decision-making regarding ecosystem protection to sustain the critical services they provide. It also sheds light on the impact of ecological changes on key ecosystem services, offering insights that may aid in management decisions to minimize their impacts.

# CHAPTER 5: ANALYSING EQUITY DIMENSIONS OF ECOSYSTEM SERVICES FLOW IN THE KAT RIVER CATCHMENT

## 5.1 Introduction

Equity is foregrounded in the governance and institutional arrangements around water, particularly given the history of South Africa, in which the majority of the people were excluded from access to the benefit of water resources (Lotz-Sisitka & Burt, 2006). In South Africa, equity is one of the foundational values guiding the management, development, and protection of water resources (RSA, 1998). However, a reflection of the conceptualization of equity in the National Water Act (Act No. 36 of 1998) suggests two dimensions of equity, distributive and procedural (Odume et al., 2021). Odume et al. (2021) indicated that this conceptualization leaves out two other important dimensions, namely, recognition and contextual equity. All four dimensions of equity are critical to ensure fully realized equity imperatives as intended in the management, governance, and development of water resources in South Africa.

Distributive equity dimension focuses on fairness in the allocation and access to the benefits of water resources, including ecosystem services, and fairness in the sharing of the associated risks, burden, and costs (Leach et al., 2018). About ecosystem services discourse, this raises an important equity question: who gain access to the benefits flowing from ecosystem services, and who carries the costs, risks and burden of ecological changes resulting from access to ecosystem services? This is an important question given that in many parts of South Africa, the societal groupings benefiting from ecosystem services are often different from those carrying the costs and burden arising from the activities of those who are benefiting, e.g., irrigation return flows which impact on water quality for downstream users (Hotes, 2013). This raises the need to apply fair rules in governing the benefits and costs arising from access to ecosystem services, whilst paying attention to the outcomes of the applications of the rules (Leach et al., 2018; Loft et al., 2017; McDermott et al., 2013). Thus, both rule-based and consequence-based theories are critical in analysing the distributive equity dimensions of ecosystem services flow.

While distributive equity emphasizes fairness in the allocation of benefits and costs, procedural equity concerns itself with how decisions are made, and who has or does not have access to the decision-making processes, and who is able or not able to influence the decisions that impact on resource allocation and distribution (Sovacool & Dworkin, 2015). Procedural equity pays attention to matters of power dynamics, as power in many ways determines who influences resource allocation decisions (McDermott et al., 2013). Procedural equity is a critical dimension of equity in ecosystem services governance, due to its emphasis on decisions that may impact on who gets to benefit from ecosystem services and who may be excluded (Odume et al., 2021). In this study, procedural equity was analysed in terms of how stakeholders within the catchment participated in key governance structures and decision processes, particularly with reference to the KRWUA and KRCMF, as well as other decisions that influence activities which may affect the Kat River catchment area as a social-ecological system.

Contextual equity is centred around considering the various pre-existing conditions that can either enable or hinder people's access to decision-making procedures, resources, burdens, costs, and benefits (McDermott et al., 2013). It is important to create a truly fair and sustainable system which considers all social groups' unique characteristics, such as the specific social, cultural, economic, and ecological context of a particular area or community. Promoting contextual equity to ensure a fair outcome in the management of ecosystem services includes the consideration of: (i) a deep understanding of the local context, i.e. the social and economic structures and characteristics (Rodríguez-Robayo & Merino-Perez, 2017); (ii) involving local communities in decision-making processes; (iii) all members of a community, including marginalized or vulnerable groups, should have fair access to and benefit from ecosystem services; and (iv) contextual equity encourages a holistic understanding of the interconnectedness of social, economic and ecological factors in a given context (Gudi-Mindermann et al., 2023).

While contextual equity pays attention to social, economic, and ecological structures and characteristics in the fair access and distribution of ecosystem services, recognitional equity pertains to acknowledging and respecting the diverse knowledge systems, values, and perspectives of different individuals and communities regarding ecosystem services (Bennett et al., 2020). It involves recognizing the unique contributions and needs of various groups, especially those traditionally marginalized or whose knowledge might not have been historically acknowledged (Meerow et al., 2019). For example, indigenous peoples and women often have specialized knowledge, languages, and skills that can contribute to environmental decision-making, yet their voices are often excluded from decision-making processes (Friedman et al., 2018). Considering the conceptual framework of the study, we focused on distributive and procedural equity of ecosystem services, because these ensure that all social groups participate in decision-making and have fair access to the distribution of ecosystem services. In addition, there have been few studies on equity and ecosystem services flow in the Kat River catchment area.

Despite the relevance of the concept of equity to ecosystem services governance and management, not much attention has been paid to the nexus between equity and ecosystem services in the literature (McDermott et al., 2013; Pascual et al., 2014). An explicit analysis of the equity dimension of ecosystem services flow is critical for several reasons. First, it brings to sharp focus the cost-benefits arising from ecosystem services for different societal groupings, and the implications of these. For example, the societal groupings that benefit from a particular ecosystem service such as using a river as a waste disposal channel, may externalize the associated costs such as water borne diseases to other societal grouping. Second, it can shed light on the adaptive capabilities of the different societal groupings in light of the burden carried by these groups as a result of ecological change (Daw et al., 2011). One important question about fairness is whether marginalized groups have the capacity to adapt to the costs they face.. Third, policies and management strategies can be better designed in ways that are more equitable over time. Fourth, such an analysis can advance the science and practice of ecology, especially in relation to the equitable governance and management of ecosystem services.

Given that the Kat River catchment is a complex socio-ecological system within a semi-rural landscape, with various social and economic activities such as agriculture, industries and livestock production, and high levels of poverty, unemployment and inequalities, an equity analysis in relation to ecosystem services flow is a critical exercise. For example, an equity analysis can shed light on the winners and losers within the catchment, with a view to contributing to advancing equitable strategies for ecosystem services governance within the catchment. Therefore, the objective of this chapter was to analyse the equity dimensions of ecosystem services flow within the Kar River catchment. This objective fulfils Objective 2 stated in **Section 1.3** of **Chapter 1**.

## 5.2 Materials and methods

A series of semi-structured interviews were conducted across a triad of distinct villages within the confines of the Kat River catchment area. These villages were identified as Cathcartvale, Fairbairn and Picardy. The full details of the data collection are discussed in **Chapter 3**.

The study adopted a purposive sampling technique to recruit interview respondents. The interviewees were selected from four social groups, namely, non-farming households, commercial farmers, subsistence farmers and members of the Kat River Catchment Management Forum (KRCMF). These groups were selected due to their variety of interactions with water resources in the Kat River catchment area. The study aimed to examine the concepts of distributive and procedural equity in the flow of ecosystem services, as well as procedural equity in stakeholder participation in local water resource management institutions such as the Kat River Water User Association (KRWUA) and the KRCMF.

The selection of these social groups was essential to ensure that the study captured a wide range of perspectives and experiences related to water resources management in the Kat River catchment. The non-farming households were selected because they were not directly involved in farming activities but relied on water resources for domestic use. Commercial farmers were included because farmers use water resources for large-scale agricultural activities, while subsistence farmers were included due to the significant role, they play in the local food system. Finally, members of the KRCMF were included due to their inclusion in local water resource management institutions and because they have a direct influence on decision-making processes related to the water resources management.

To foster interaction during the interviews, an interview question guide (Appendix 2a) was used. The guide focussed on three areas, namely, the distribution of benefits/costs derived from ecosystem services among different social groups within the Kat River catchment, participation and decision-making processes in key water related institutions within the catchment, and the demographic of the research participants.

The first aspect of the interview questions sought to elicit from the research participants their perceptions and experiences regarding the ecosystem services (benefits) they derived from ecosystem services, the challenges they faced in accessing these services, and the costs/risks associated with ecological changes within the catchment. The second aspect of the interview questions explored the notion of fairness in the participation of stakeholders in decision-making procedures related to water resources management. The questions were designed to elicit responses from the interviewees on their experiences with the local water management forum (KRWUA), their level of participation, and their perception of fairness in the decision-making processes within key water-related structures and institutions.

The third aspect of the interview questions sought to elicit responses regarding the research participant demography such as their age, gender, educational level, occupation, and income level. This information was essential in understanding both distributive and procedural equity dimensions.

To facilitate the data collection process, the semi-structured interview process for this study was conducted over a period of three months (March−April 2023). To navigate through the villages in the Kat River catchment area, the researcher employed two research field assistants to assist with data collection. This approach allowed the team to cover a wide area within a short period and quickly gain a better understanding of local knowledge and information about the villages, such as population size, language, and customs. Having two research assistants also allowed the team to gather more data, as it was easier for them to cover more ground. The assistants were trained on the interview question guide and were familiarized with the study's objectives. They also received training on ethical research practices and the importance of confidentiality and informed consent. The use of two research assistants was beneficial in ensuring that the data collection process was efficient and effective. The team was able to gather a wealth of data and insights on the perceptions and experiences of different stakeholders regarding the concept of equity and ecosystem services in local water resource management institutions. The assistants were also able to provide valuable local knowledge and insights which enriched the data collection process.

## 5.3 Results

This section discusses the results of the data analysis regarding the fairness of the distribution of ecosystem services and the participation of stakeholder in decision-making procedures or processes related to water resources management in the Kat River catchment area. Additionally, the section presents the socio-demographics of the research participants.

### 5.3.1 Descriptive statistic of the socio-demographic data of research participants

The data indicate that 61.2 percent of the research participants were male while 38.9 percent were female (Table 5.1). Moreover, 58 percent of the research participants had lived and worked in the catchment area for over three decades, which suggests that they had extensive knowledge and experience regarding the catchment. The majority of the research participants, accounting for 70.9 percent, belonged to the age group 36 to 65 years. The main sources of income for the research participants were farming and social grants.

**Table 5.1** Demographic profiles of the research participants in the Kat River catchment

| **Variables** | | **Number** | **Percent** |
|---|---|---|---|
| Gender | | | |
| | Male | 19 | 61.2 |
| | Female | 12 | 38.7 |
| | **Total** | **31** | **100** |
| | | | |
| Age range | | | |
| | 18−35years | 3 | 9.7 |
| | 36−65years | 22 | 70.9 |
| | 66>years | 6 | 19.3 |
| | Prefer not to say | 0 | 0 |
| | **Total** | **31** | **100** |
| | | | |
| Years range lived in the catchment | | | |
| | 1−5years | 1 | 3.2 |
| | 6−15years | 5 | 16.1 |
| | 16−25years | 2 | 6.5 |
| | 26−35years | 5 | 16.1 |
| | 35>years | 18 | 58 |
| | Prefer not to say | 0 | 0 |
| | **Total** | **31** | **100** |
| | | | |
| Employment status | | | |
| | Not employed | 16 | 51.6 |
| | Employed | 9 | 29.1 |
| | Retired | 6 | 19.3 |
| | Student | 0 | 0 |
| | Prefer not to say | 0 | 0 |
| | **Total** | **31** | **100** |
| | | | |
| Head of household | | | |
| | Yes | 19 | 61.2 |
| | No | 12 | 38.7 |
| | **Total** | **31** | **100** |
| | | | |
| Main income source | | | |

| | | | |
|---|---|---|---|
| | Social grants | 12 | 38.7 |
| | Farming | 14 | 46 |
| | Retirement pension | 1 | 3.2 |
| | Handcraft | 0 | 0 |
| | Business | 2 | 6.5 |
| | Others | 2 | 6.5 |
| | **Total** | **31** | **100** |

### 5.3.2 Distributive equity and ecosystem services in the Kat River catchment

The research participants were asked to reflect on the ecosystem services they received from the Kat River system in accordance with their importance in the household. The research participants mentioned a diverse range of ecosystem services such as water (for drinking, domestic and agricultural uses), fishing, and the collection of reeds under provisioning ecosystem services, and spiritual and traditional benefits, as well as recreational activities under cultural ecosystem services. A word cloud (Figure 5.1) visually represents the various ecosystem services mentioned by the respondents. The word cloud represents in font sizes the perceived importance of ecosystem services to the research participants. Water for drinking, water for irrigation, water for domestic use, water for livestock survival, reeds, medicinal plants, wood, and fish (larger font size) were the most important as perceived by the research participants. Other ecosystem services (represented in smaller font size) such as recreational activities, swimming and river mud also appeared to be important to the research participants, albeit to a lesser extent.


**Figure 5.1** A word cloud showing participants' perceived ecosystems services from the Kat River catchment.

The word cloud presented in Figure 5.1 highlights the various benefits which stakeholders in the Kat River catchment area derived from the ecosystem. The benefits included irrigation water, drinking water, reeds, swimming, recreational activities, spiritual and traditional activities, among others, encompassing both tangible and intangible ecosystem services. These benefits are essential for the health and well-being of the communities residing within and around the catchment. Of the ecosystem services listed, water, reeds, medicinal plants, wood, fish, and sand emerged as the very important, as perceived and mentioned by the research participants. However, water appeared to be the most important (Figure 5.1), which implies that it was perceived as a service by all the research participants. A focus on the most commonly received ecosystem services in the catchment also prompts further investigation into which social groups or individuals benefit the most and the which the least.

***Perceived most and least benefitting social groups.***

In the semi-structured interview, we sought to gain insight into which social group benefitted the most and least from these ecosystem services.

The responses obtained from the semi-structured interview interestingly show that 28 percent of the research participants perceived and stated that all social groups within the Kat River catchment enjoy the ecosystem services mentioned (Figure 5.2).

> Question: The benefits (ecosystem services) you have mentioned, who else in your village also enjoys them? (e.g., farmers, households, traditional healers and so on.)
>
> "*All social groups are enjoying the benefits*."
>
> "*All social groups including the schools, and the pedestrian*."

Fifty-eight (58) per cent of respondents believed that social groups such as farmers benefit the most.

> "*Crop farmers, livestock farmers"*
>
> *"Livestock farmers and crop farmers"*
>
> *"Livestock and crop farmers"*
>
> *"Mostly the livestock and crop farmers"*

Thirteen (13) per cent perceived that traditional healer, people who often use the river for spiritual activities, and households benefit the most (Figure 5.2).

> *"Children, Churches, Traditional healer"*
>
> *"Traditional healers"*
>
> *"The youth (because they do go fishing in the river), women (also go to the river to get medicinal plants and fetch water if the taps run dry)"*

This finding highlights the importance of ecosystems in providing benefits to all social groups, and efforts should be made to ensure that these benefits are shared equitably. It also recognizes the significance of ecosystems in providing spiritual benefits, and that collaborative efforts should be made to ensure that the benefits of ecosystem services are shared among all stakeholders.

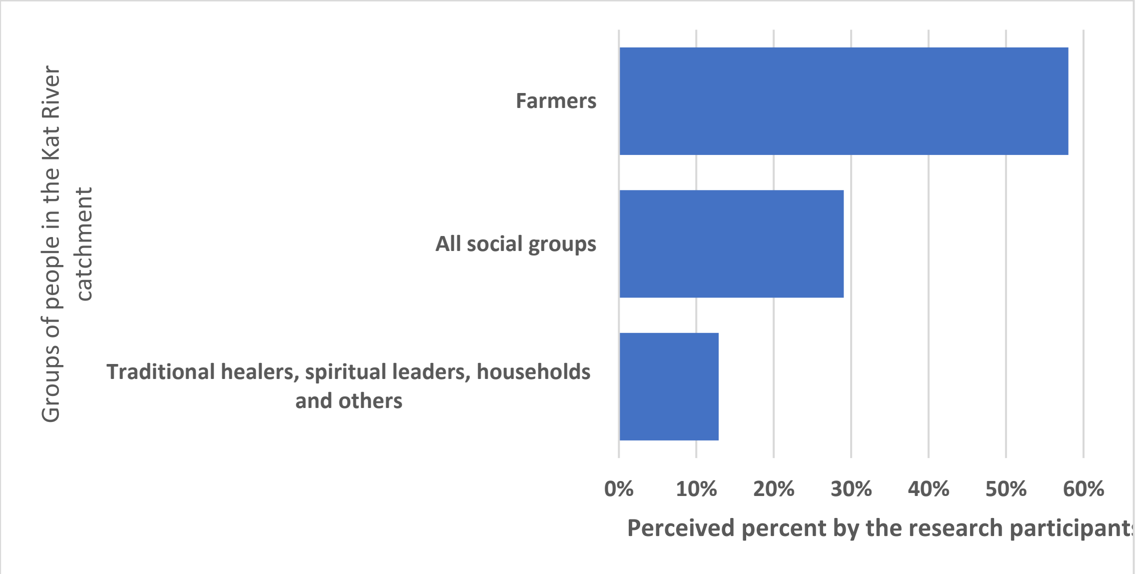


**Figure 5.2** Participants perceptions regarding societal groupings that benefits the most from ecosystem services within the Kat River catchment.

Despite the recognition that all social groups benefit from the ecosystem services provided by the Kat River catchment, respondents highlighted that particularly crop farmers (citrus farmers) benefit the most:

The following statement *"Citrus farmer"* was resonated by the majority of participants.

This is because people perceive that the farmers have the ability to abstract water from the river in large quantities using pumps, which enables them to irrigate their land more extensively, resulting in higher crop yields. However, the excessive abstraction of water from the river by these farmers may cause depletion in the river's water levels, and may also impact on water quality, affecting other users dependent on the river, as suggested by some of the research participants:

*"Non-farming households are affected because the farmers can use their pump and generator to abstract water leading to low water levels."*

*"Nonfarming households are affected because they do not have engines to pump water to their households, but farmer have water pumps."*

To gain insight into societal groupings that may have benefited the least from the identified ecosystem services the following question was posed to the research participants:

> *Question: Please tell us whether other groups of people would like to get these benefits but cannot do so. And why?*

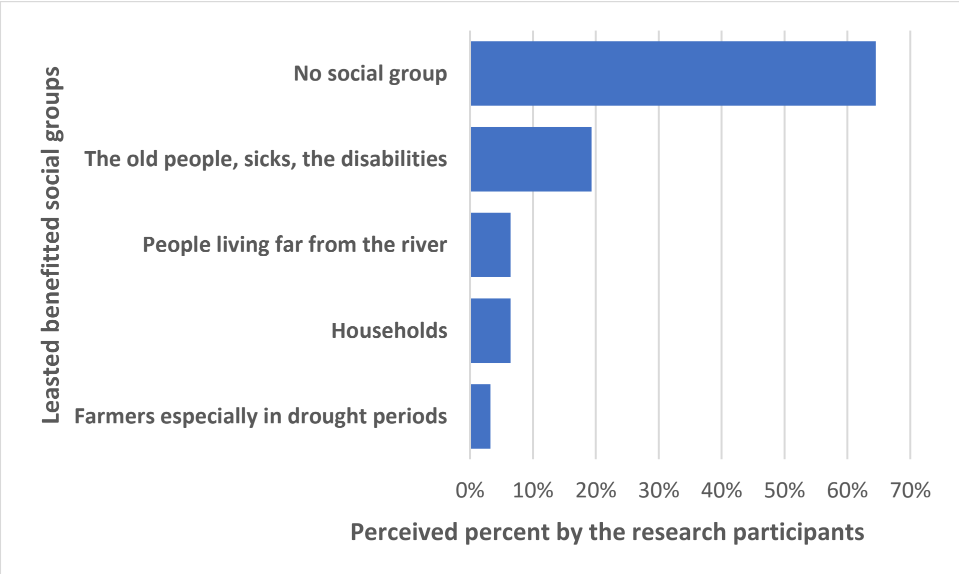


**Figure 5.3** Participants perceptions regarding societal groupings that benefit the least from ecosystem services within the Kat River catchment.

Remarkably, 65 percent of research participants perceived and stated that no particular social group benefitted the least from ecosystem services (Figure 5.3). This implies that there are no perceived social groups left out of receiving ecosystem services, particularly water resources. However, 19 percent of the participants perceived that old people, the sick and the disabled benefitted the least.

> *"Yes. The old people, sicks, and the disabilities".*
>
> *"Yes, the disabled people."*
>
> *"No social group."*

The group of people living furthest from the river and households were perceived by 6 percent of the research participants to benefit the least. Lastly 3 percent of the participants perceived farmers to benefit the least, especially in drought periods.

*"People living far from the river."*

*"Households."*

*"Farmers especially in drought periods."*

The research participants reflected on the least benefitted social groups and perceived that those group of people may lack means or access to navigate the Kat River to fetch water for their use. This suggests that although the majority of respondents believe that everyone benefits from ecosystem services, some groups, such as the elderly and disabled, may not receive the same benefits as others due to a lack of resources or lack of access to certain services.

***Perceived groups of people who suffers the costs/burdens.***

The research participants reflected on the social groups that are most negatively affected as a result of the benefits other groups derive from ecosystem services. The participants perceived that households directly drinking water carry the cost/burdens of actions not done by themselves. For example, the returns of agricultural activities such as diesel leakage from the water pump in the river are externalities caused by the farmer, of which households carry the cost/burdens.

*"There are leakages of diesel from the pumps into the river. Also, fertilizers wash off into the river."*

*"Pollution from upstream to downstream too. They sometimes find dead donkey in the river and dumping of diapers and plastics litters"*.

The research participants also reflected and perceived the group of people living downstream of the Kat to carry the costs/burdens as a result of the services other groups derive from the river. The participants perceived that the upstream groups of people benefit from the use of water for irrigating their land, while the downstream groups suffer from the pollution caused by the irrigation. Pollution by groups of people upstream of the Kat River would not affect the upstream groups and would be carried to another group lower down.

### 5.3.3 Procedural equity and water resource management in the Kat River catchment

Procedural equity involves providing meaningful stakeholder engagement, consultation, and participation to ensure equitable outcomes. The research participants were asked to reflect on their participation/involvement in the existing Kat River Water User Association (KRWUA) that governs and manages the water resources in the catchment area. Presented in Figure 5.4 is the participants perception.

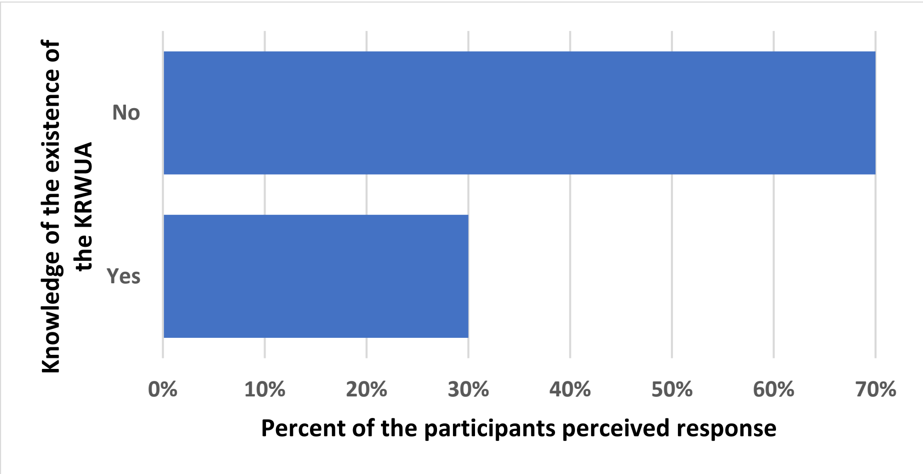


**Figure 5.4** Participants perceptions regarding their knowledge of the existing Water User Association in the Kat River catchment.

The existence of the KRWUA was known to 30 percent of the participants (Figure 5.4). Participants reflected the roles of the KRWUA.

> *"Yes, as the National Water Act states, the platform is to assist the community in the usage and management of the water in the Kat River catchment area."*

> *"Yes. For the people to have fair access to the water in the Kat River."*

> *"Yes. The association is for the usage of irrigation water by the citrus farmers."*

Remarkably, 70 percent of the research participants did not appear to be aware of the presence of the KRWUA in the catchment but speculated on its roles (Figure 5.4).

> *"No. Guessing… they used to manage and monitor the usage of water and take precautionary measures and actions when necessary."*

> *"No. Guessing… they are people who are in charge of water management in the catchment area."*

*"No. The association ensures that the river is clean and make it accessible to the people."*

Then the research participants were asked to reflect on fair access to water for all social groups in the Kat River catchment area (Appendix 2a).

Question: Do you think the Kat River Water User Association rules allow for fair water access by all groups of people (e.g., farmers, non-farmers, women, youth etc.) who live within the catchment?

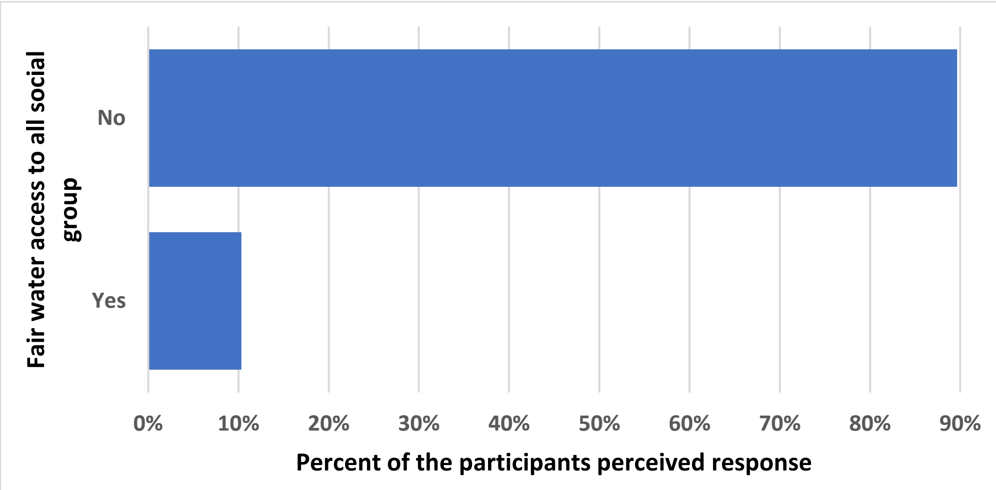


**Figure 5.5** Participants perceptions regarding fair water access to all social groups within the Kat River catchment.

The results present 90 percent of the research participants' reflection and perception, which is that not all social groups in the catchment receive fair water access and allocations (Figure 5.5).

*"No. due to non-functionality of all stakeholders in the catchment."*

*"No, Farmers have more access than others."*

*"No, I think everybody should have access to the water in the Kat River."*

10 percent of the participants reflected and perceived that the KRWUA rules allow for fair water access by all social groups (Figure 5.5).

*"Yes, there is not enough water resource (it is scarce resource) in essence there is restriction for irrigation use. But there is not restriction for domestic use (this covers stock farming and garden use."*

Furthermore, the research participants were asked to reflect, (Appendix 2a) on how they would see the KRWUA run water management and how they would ensure fair participation of all stakeholders if they were the KRWUA chairperson.

1. Question: How best would you like to see the Kat River Water User Association govern water in this catchment?

   *"There should be equity in the management. I would like an equitable and fair participations by all stakeholders. And the reviving of the structure of the KRWUA."*

   *"I would like to see that the water is clean, and the people should be well informed."*

   *"Collaboration with the small-scale farmers then ensure fair participations by all small farmers."*

2. Question: If you were the chairperson of the Kat River Water User Association, what would you do to ensure fair participation by all people in matters of water governance in this area?

*"I would ensure communication among all social groups. Community awareness. And enable that the small-scale farmers are represented in the association."*

*"Organise meetings in the community for the awareness and the community to air their concerns."*

*"Awareness meeting to get all stakeholders informed about the association. Water abstraction regulated timeframes for all social groups."*

*"I will organize meetings with the community to notify people about the association."*

*"Awareness campaign to get all stakeholders informed about the association."*

## 5.4 Discussion

This study represents the perceived perceptions of stakeholders regarding equity in ecosystem service flow and the management of the water resources in the Kat River catchment area. Equity in water resource management is a crucial issue in South Africa. Due to the country's historical context, certain societal groups have been unfairly allocated the benefits or costs of ecosystem services (McDermott et al., 2013). However, Act No. 36 of 1998 of the National Water Act aims to address this by ensuring that water resources are accessed in an equitable manner, while also protecting and preserving these resources (Fanadzo & Ncube, 2018). The implementation of this act requires two dimensions of equity in water resources governance and management.

The research participants reflected on i) the perceived ecosystem services flow which benefits them from the Kat River catchment; ii) the social groups which benefit the most and least; iii) the social groups which carry the costs/burdens; iv) the Kat River stakeholders awareness of the presence of the KRWUA; v) the perception of the fair water access to all groups of people in the catchment, and vi) the perception on how best they want the KRWUA to govern and manage water resources. The focus on distributive and procedural equity within the context of ecosystem services and the management of water resource in the Kat River catchment is essential. Distributive equity deals with the fair allocation of ecosystem benefits and costs, ensuring that no community or group is disproportionately affected (McDermott et al., 2013). Procedural equity, on the other hand, involves providing meaningful stakeholder engagement, consultation, and participation to ensure equitable outcomes (Pollard & Du Toit, 2008). These two dimensions of equity are essential for effective and sustainable water resource management.

The study's research participants reflected on the perceived benefits they receive from the Kat River catchment. These include water and reeds, swimming, recreational activities, and spiritual and traditional activities, which are essential for the well-being of communities in the area. This finding is consistent with Adekola et al. (2012), who showed the impact of various provisioning ecosystem services (such as fish, water and medicinal plants) in the Ga-Mampa wetlands and their impacts on local livelihoods in South Africa. This suggests that the Kat River catchment provides important ecosystem services for local communities, and it is crucial to protect these benefits and ensure that all social benefits are distributed fairly. The research participants' perception (Section 5.3.2) is that the distribution of the benefits, costs, and burden to all group of people in the Kat River catchment is unfair. This suggests that there may be inequities in not only the quality of ecosystem service but also the accessibility of services. For example, some social groups have access to more benefits than another social groups, while other social groups suffer the costs/burdens as a result of another social group's benefits. The study by Osman & Faust, (2021) proves that the availability of water does not guarantee fair distribution and access to safe water for everyone.

An attempt to implement distributive equity in water resource management aims to ensure more sustainable and equitable ecosystem services allocation. According to Erdiaw-Kwasie et al., (2020), this can be achieved by stakeholder's involvement in decision-making procedures related to water resources and related initiatives. It is worth noting that the South African Water Legislation (NWA, 1998) advocates for inclusiveness and participation of citizens through the decentralisation of water resources at the catchment level. This study identified that water institutions such as WUAs play a crucial role in promoting procedural equity when it comes to discussing water-related issues in the catchment. By bringing together all water users, stakeholders, and government representatives, WUAs provide a platform for everyone to participate in the conversation and have their voices heard. However, the research participants' reflections and perceptions revealed (Section 5.3.3) the ineffectiveness of the awareness and participation of stakeholders in the KRWUA. This suggests inequities in policies and decisions regarding water resources, as the stakeholders upon whom the decisions are made are absent from the decision-making table. The participation and inclusiveness of stakeholders is crucial in achieving efficient and responsive management, conflict management, informed decisions through a diverse range of perspectives, social enhancement, and institutional capacity in handling complex water challenges. It is essential to consider different viewpoints and opinions to address complex issues effectively. By involving all stakeholders, we can create a more inclusive and sustainable future for everyone (Margerum & Robinson, 2015). In addition, this study revealed that the research participants had a keen interest in inclusion regarding matters related to water resource management in the existing KRWUA.

Achieving equity in water resources management is essential. Behbahani et al., (2019) and Litman (2002) suggested that it can be achieved in two ways., horizontally and vertically. It is important to ensure that all social groups receive fair distribution of goods and services, regardless of any factors such as geographical region, physical ability, or socio-demographic composition. The horizontal equity application is indeed crucial as it requires all groups to be treated equally according to their identity. However, vertical equity takes into account the differing needs and abilities of people and communities, ensuring that goods and services are distributed accordingly. By so doing all social groups could be equally involved and represented in the governance and management of water resources in the catchment area.

## 5.5 Conclusion

This chapter explores the perceptions of research participants (stakeholders) on the distributive equity of ecosystem services among the various social groups in the Kat River catchment. Participants' reflections on procedural equity regarding the water resources management in the KRWUA were also explored. The chapter presents perceived concerns and inequities in the distributive equity of benefits, costs, and burdens to all groups of people. In particular, the social groups that benefitted the least, and the social groups who suffered the costs and burdens caused by other benefiting groups were explored.

The chapter also explored the role of procedural equity in managing water resources in the KRWUA. The involvement and inclusion of stakeholders in the KRWUA is elusive, as there is a very low awareness of the KRWUA by the research participants in the catchment. This study highlighted the importance of ensuring that all stakeholders are consulted and that their rights and interests are taken into account. Therefore, it is vital to increase public awareness of the KRWUA's roles and responsibilities, to ensure that all stakeholders are actively involved in the conservation and management of water resources in the catchment.

# CHAPTER 6: SYNTHESIS, CONCLUSION LIMITATIONS OF STUDY AND RECOMMENDATIONS

## 6.1 Synthesis

The intention of this research was to better understand perceived ecological changes in the Kat River Catchment area over space and time, as well as their key drivers as identified by catchment stakeholders, and the impact of these changes on the flow of ecosystem services. The study also sought to analyse the equity implications of ecosystem services flow and the impact of ecological changes, as well as stakeholder participation in an important water governance structure in the KRWUA. The study drew on the conceptual framework developed by Odume and de Wet (2019) for distilling the systemic relational social-ecological equity concerns in social-ecological system (SES). The framework also drew on insights from the ethics and water governance literature (Groenfeldt & Schmidt, 2013), social-ecological interactions and ecosystem (dis)services flow (Kandziora et al., 2013) and the link between biodiversity, ecosystem (dis)services and human wellbeing (Haines-Young & Potschin, 2010).

Chapter 4 of the study focused on the first objective, which was to map the perceived key drivers of ecological change and ecosystem services flow in the Kat River catchment area. The chapter also assessed the spatial and temporal dimensions of perceived ecological changes and ecosystem services flow, as well as the perceived social-economic burdens/concerns arising from ecological changes. Flooding, water pollution and poor water quality, soil erosion, drought, invasive alien species and decrease in aquatic biodiversity were perceived as the key ecological changes and drivers that have occurred over time and space in the catchment. Water pollution and poor water quality, flooding, soil erosion, a decrease in aquatic biodiversity and drought were perceived to be serious in terms of their impact on the river system and on human well-being within the catchment. The results suggest that the severity of the impact of the changes has progressively increased over time, which means that interventions are needed to reverse or mitigate this trend. Interventions which can be taken may include increased public awareness of the issues, infrastructure development, improved wastewater management and public awareness campaigns, as well as investing in more sustainable water management and restoration. Implementing these interventions can contribute to reducing the impact of the identified ecological change on the quality, quantity, and reliability of the flow of ecosystem services, which will in turn contribute to human well-being within the catchment system.

Chapter 5 explored equitable flow of ecosystem services viz-a-viz ecological change within the catchment. Two dimensions of equity formed the basis of the analysis. The first dimension was distributive equity, which is concerned with fairness in the allocation of resources; it sheds light on how benefits and risks/costs are distributed among different societal groups (Rohde & Rohde, 2015). In the context of this research, this can be interpreted to better understand how human activities within the catchment impact on ecosystem services, and how these mediate who benefits from ecosystem services flow and who carries the costs of ecological change that impact on ecosystem services flow. The results suggest that commercial and livestock farmers may be the main benefactors of ecosystem services in the Kat River catchment. Their farming operations impact on the quality of the river water. The elderly and disabled, as well as those who share the river as a drinking water source with animals are the most impacted, thus carrying the costs of ecological change. The results shed light on the need to bring distributive equity analysis into the ecosystem services discourse as well as into the general management of water resources and associated ecosystem services.

The second dimension of equity analysed in this study was procedural equity (Hartman et al., 1999; McDermott et al., 2013; Leach et al., 2018). This dimension of equity concerns itself with fairness in the participation of people in key decision-making processes that impact on water resource management and the associated benefits and costs. In the context of this study, the main concerns relate to participation in the KRWUA, an important decision structure within the Kat River catchment area. The results suggest that there is a poor level of awareness and knowledge of the KRWUA, and this has led to low participation by all concern stakeholders within the catchment. Fair involvement and engagement of stakeholders is essential for sustainable water resource management. Inclusiveness and broad-based participation in water management decisions have been identified as crucial in addressing issues such as river pollution, as this provides an opportunity to draw on diverse knowledge systems in addressing water pollution, which aligns with catchment priorities (McDermott et al., 2013). The research participants expressed a keen interest to be well-informed about the KRWUA and wished to engage in affairs relating to the management and governance of water in the Kat River catchment. It is vital to ensure that stakeholders are adequately represented and included in water management processes to promote fair and equitable practices which benefit all catchment stakeholders. Effective awareness campaigns regarding the activities of the Water User Association could help deepen stakeholder participation and accelerate procedural equity imperatives.

## 6.2 Conclusion

This study explored a multidimensional mapping of the identified key drivers of ecological change and ecosystem service flow over space and time in the catchment, as perceived by the research participants. The study also explored the perceived socio-economic burdens/concerns arising from the ecological change impacting human well-being in the catchment. As perceived by the research participants, the identified ecological changes were rated as serious, and explored negative impacts on the quality, quantity, and reliability of ecosystem services flow, which affect the well-being of both humans and the environment. Results from the study suggest the need for the application of ecological interventions and conservation schemes to ensure sustainable water resources management.

In addition, the analysis of two dimensions of equity (distributive and procedural equity) on ecosystem service flow were explored in this study. The research participants revealed certain perceptions of inequity in the distribution of benefits, costs, and burdens from the river services among all societal groupings in the catchment. Some groups (such as farmers in the upper areas) may enjoy more benefits such as increased access to water for irrigation, and other groups (e.g., households and the elderly in areas lower down) who drink the river water after it has been used for irrigation may suffer the costs and burdens. The second equity dimension analysed in the study was procedural equity. As perceived by the catchment stakeholders, representation, and participation of all societal grouping in decision-making and management of the KRWUA is unclear; this is mainly due to lack of awareness of the KRWUA. The results of this study could be used to inform decision makers about equitable and effective ways to manage ecosystem services in the catchment. Furthermore, the study can provide valuable insights into how to address water resource challenges in the catchment.

## 6.3 Limitations of study

The major limitation of the study was that some stakeholders did not respond to or participate in the semi-structured interviews. For example, some commercial farmers' stakeholders declined the interview invitation because of agricultural/business commitments. Other stakeholders declined due to fear of revealing sensitive information. Additionally, some stakeholders were unaware of the study or were not interested in participating. This limited the scope of the study and prevented us from obtaining valuable data. As a result, the study was unable to gather comprehensive feedback from all stakeholders and this limitation may have affected the robustness of the results.

## 6.4 Recommendations for further study and management

- The study presents a multidimensional mapping of perceived ecosystem services flow, ecological change, and perceived social-economic burdens/concerns, which is a valuable contribution to the ecosystem literature, underscoring the need for further research on ecosystem disservice and changes and their impacts on society at large.
- This study introduces equity analysis into the ecosystem services debate. The study showed that the flow of ecosystem services, in terms of who benefits from these services and who does not benefit, is an equity concern. Further study on this subject is critical, particularly in varying contexts such as urban, peri-urban, and rural catchment systems.
- The spatial and temporal dimensions results from the PGIS mapping of ecosystem services and ecological changes can help to inform decision-makers, policymakers, and services management on how to create protection and intervention strategies that can help minimize the negative impacts of ecological changes and sustain ecosystems and the services they offer. Utilizing this information can lead to the development of effective strategies which promote sustainable management practices and ensure the long-term health and well-being of the Kat River catchment. Effective strategies such as comprehensive watershed management plan, restoration of riparian areas, and the implementation of sustainable fisheries and aquaculture practices.

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# APPENDICES

**Appendix 1a** Participatory GIS mapping workshop guide.

**PARTICIPATORY GIS WORKSHOP AGENDA OF KAT RIVER CATCHMENT**

Let's collaboratively gain a better understanding of the Kat River Valley catchment by identifying and discussing the key drivers of ecological change, ecosystem benefits (services) and burdens/concern.

**Aim**

The aim of this workshop is to map out the spatial and temporal elements of perceived ecological changes (and their key drivers), ecosystem services, and perceived social-economic burdens/concern from ecological changes in the Kat River catchment. It is going to be an interactive session with the stakeholder and members of the Kat River Catchment Management Forum (KRCMF).

**Background**

We will be looking at ecological changes you have observed in the Kat River catchment and their respective key drivers, and the ecosystem benefits (services) and burden/concerns you get from the Kat River catchment.

Key drivers of ecological change are actors\factors responsible for causing environmental changes. Please, we would like you to help us spatially identify some environmental changes (by indicating them on the map) and their key drivers in the Kat River valley catchment.

***A topographical map of the catchment will be made available. At the end of each section, a photograph of the map will be taken after identification and placement.***

**PART 1**

| S/N | Sections | Interactive Discussion |
|---|---|---|
| **1** | The observed ecological/environmental changes in the Kat River Valley catchment.<br>(Spatial element) | Looking and observing the past and present state of the Kat River Valley Catchment, have you noticed any environmental changes?<br><br>If yes, then please write on the sticky note the changes you have observed. (Please write at least 3-4 environmental changes, one each on a sticky note). |

| | | |
|---|---|---|
| | | Now, going to the Kat River Valley map, where exactly in the catchment are the environmental changes found?<br>***Stick the sticky notes to the map area you pointed out.*** |
| **2** | Key drivers of environmental change<br><br>Drivers (Spatial element) | Now, we are going to identify the key drivers of the environmental changes you have mentioned. **Drivers are any factor/actor that is responsible for causing environmental changes.**<br><br>What are the key drivers of each of the environmental changes you have mentioned? (Please indicate it next to the ecological change earlier mentioned). |
| | Severity | How serious are these environmental changes? (Very, Moderately or Not?). *Green/Orange/Red respectively*.<br>**Appropriately place the colour stickers on the sticky notes on the maps.**<br>**Using the small round stickers:**<br>**Red colour: Very serious,**<br>**Orange colour: Moderately serious and**<br>**Green colour: Not serious**. |
| | Time progression (Temporal element) | How do you perceive the identified environmental changes, are they getting worse, getting better, or remain the same?<br>**With the time frames 0-5years, 5-15years and > 15 years.**<br>Can you please indicate the time you started to notice these changes?<br><br>***Draw the arrows on the appropriate changes on the placed stick notes.***<br>⬆ **= increasingly deteriorating**<br>⬇ **= improving**<br>⬌ **= remains the same**<br>**Please, pause take photo of the map** |

**PART 2**

Ecosystem services are benefits nature provides us human beings and our communities which improve our well-being. In this part 2, we would like to ask you about the benefits you and your household receive from the Kat River catchment. Both the benefits you are getting now and the ones you used to get in the past.

| | | |
|---|---|---|
| **3** | **Ecosystem services (benefits)** | **Now let's discuss the benefit you get from the Kat River Valley catchment.** |

| | | |
|---|---|---|
| | Benefit (spatial representation)<br><br><br><br><br><br><br><br>Importance | Thinking about the Kat River catchment, what are the historical and current benefits you (or someone in the community or elsewhere that you are aware of) get from the catchment? Please write each ecosystem benefit on a sticky note.<br><br>Looking at the map of the Kat River Valley, where exactly in the catchment do you think the benefits are found?<br>***Stick notes to the map location you think the ecosystem benefit is found.***<br><br>How important or impactful are the benefits to you? **(Very, Averagely or Not important).**<br>**Using the small round stickers:**<br>**Green colour: Very important,**<br>**Orange colour: Moderately important and**<br>**Red colour: Not important**.<br><br>**Place the round sticker notes appropriately on the identified ecosystem benefit on the maps.** |
| | Time progression (Temporal element) (TP)<br><br><br><br><br><br><br><br><br><br><br><br><br>Spatial progression (SP) | **With the time frames 0-5years, 5-15years and > 15 years**:<br>For each of the benefits you have identified, have you noticed any change in them? If YES.<br>When did you start to notice the change?<br>Are you noticing it to be improving, deteriorating, or no changes?<br><br>***(Draw the arrows on the appropriate benefits on the placed stick notes).***<br>⬆ **= Improving**<br>⬇ **= deteriorating**<br>⬌ **= No change**<br>How did you perceive the **identified area coverage of each of the benefits,** are you perceiving the area to be increasing, reducing, or unchanged?<br><br>***(Draw the arrows on the appropriate benefits on the placed stick notes).***<br>⬆ **= Increasing**<br>⬇ **= Reducing**<br>⬌ **= Unchanged** **Please take photo of the map** |

**PART 3**

We will reflect and discussion the social-economic burdens/concerns arising from the ecological changes that put our lives in danger and make us unhappy. In this Part 3 of the workshop, we would like to know the social-economic burdens/concerns that are of major concerns to your wellbeing in the Kat River Catchment.

| **4** | Social-economic burdens/concerns | We will discuss the both historical and current social-economic burdens/concerns you get from the Kat River Valley catchment. |
|---|---|---|
| | Severity | Think about the state of the Kat River catchment, what are the historical and current social-economic burdens/concerns that have negatively affected the community, your household, or any social group in the catchment?<br><br>How serious would you consider each of these social-economic burdens/concerns to be?<br>(Very, Moderately or Low?)<br>**Using the small round stickers:**<br>**Red colour: Very serious,**<br>**Orange colour: Moderately serious and**<br>**Green colour: Not serious**.<br><br>**Place the round sticker notes appropriately on the identified social-economic burdens/concerns.** |
| | Time progression (Temporal element) (TP) | For each of the social-economic burdens/concerns you have identified, have you noticed changes in the seriousness over time?<br>If YES<br>**With the time frames 0-5years, 5-15years and > 15 years**:<br>Can you please indicate the timeframe?<br>And is it getting worse, or getting better, or same level (i.e., no changes)?<br><br>⬆ **= Getting worse (deteriorating)**<br>⬇ **= Getting better (Improving)**<br>⬌ **= On the same level (neither deteriorating nor improving)**<br><br>**Draw the arrows by the appropriate social-economic burdens/concerns in front of them each** |

**Appendix 2a** Semi-structures interview questions guide

## SEMI-STRUCTURED INTERVIEW QUESTIONS GUIDE

### A. Ecosystem Services/Benefits and distributive equity

Ecosystem services are benefits nature provides us human beings and our communities which improve our well-being. In this section of the interview, we would like to ask you about the benefits you and your household derive from the Kat River catchment. Both the benefits you are getting now and the ones you used to get in the past.

1. Please tell us the benefits that your household gets from the Kat River catchment.
2. In what ways do you consider these benefits important to your household?
3. Since you started getting these benefits from the Kat River catchment, have you noticed any change in these benefits, whether in terms of quality or availability?
4. If you have noticed any changes, which of these benefits have changed and when did you start to notice these changes?
5. The benefits you have mentioned, who else in your village also enjoy them? (e.g., farmers, households, traditional healers etc.)
6. Please tell us whether other groups of people would like to get these benefits but cannot do so. And why?
7. Please let us know whether other groups of people may also have been negatively affected as a result of another group's benefit from the ecosystem services.

### B. Drivers and pressure of change

These are actors or factors that cause environmental changes. Please we would like you to help us identify some key factors that are causing environmental changes in the Kat River valley catchment. In this section of the interview, we will be Looking at the current and historical changes you have observed in the Kat River catchment and what may have been responsible for the change.

1. Based on your experience and knowledge, what are some of the most important changes you have observed in the Kat River system?
2. When did you start noticing these changes?
3. What or Who do you think might have caused these changes?
4. Which groups of people in your view are most affected by these changes?
5. Why are these groups of people most affected?
6. Who do you think is benefiting from the changes?

7. How seriously are the changes affecting your household?

## C. Procedural equity

In this section of the interview, we would like to talk about procedural equity. Procedural equity is the fair participation of stakeholders in the management and governance of the natural resources. We will talk about how you and your fellow community/village members have been participating in the governance of water within the Kat River catchment.

3. Do you know about the presence of the Kat River Water User Association?
4. What is the role of the Kat River Water User Association?
5. From your understanding, which groups of people are members of this Kat River Water User Association?
6. Do you think the gender balance factor is considered when selecting the Kat River Water User Association committee members?
7. Do you think the Kat River Water User Association rules allow for fair water access by all groups of people (e.g., farmers, non-farmers, women, youth etc.) that live within the catchment? Explain your answer, please.
8. How best would you like to see the Kat River Water User Association govern water in this catchment?
9. If you were the chairperson of the Kat River Water User Association, what would you do to ensure fair participation by all people in matters of water governance in this area?

## D. Demographic data

We would like you to answer the following questions by ticking one or more boxes applicable to you.

1. Can you tell us your sex, please?

☐ Male

☐ Female

☐ Non-binary

☐ Prefer not to say.

2. In which age category are you?

☐ 18 - 35yrs

☐ 36 - 65yrs

☐ 66>yrs.

☐ Prefer not to say.

3. For how long have been living in this village?

☐ 1 – 5 years

☐ 6 – 15 years

☐ 16– 25 years

☐ 26 – 35 years

☐ >35 years

☐ Prefer not to say.

4. Can you tell us your marital status, please?

☐ Single

☐ Married

☐ Divorced

☐ Separated

☐ Prefer not to say.

5. Please tell us your employment status

☐ Not employed

☐ Employed

☐ Retired

☐ Student

☐ Prefer not to say.

6. Can you tell us the size of your household, please?

☐ 1-4

☐ 5-10

☐ >10

☐ Prefer not to say.

7. Are you the head of your household?

☐ Yes

☐ No

8. Can you tell us your main source of income?

- [ ] Social grant
- [ ] Employment income
- [ ] Farming
- [ ] Retirement pension
- [ ] Handcraft
- [ ] Business
- [ ] Others, please specify ______________________

9. Please tell us your average monthly income

- [ ] R1 – R480
- [ ] R481 – R3 500
- [ ] R3 501 – R6 500
- [ ] R6 501 – R10 000
- [ ] R10 001 – R20 000
- [ ] R20 001 – R40 000
- [ ] R40 001 – R60 000
- [ ] >R60 000
- [ ] Prefer not to say.

10. What is your highest level of education obtained?

- [ ] No formal education
- [ ] Primary School
- [ ] High School
- [ ] Vocational certificate Diploma
- [ ] Bachelor's Degree
- [ ] Master's Degree
- [ ] PhD
- [ ] Prefer not to say.