INTEGRATING GEOSPATIAL, HUMAN, AND SOCIO-ECONOMIC APPROACHES FOR PROFILING THE AGROECOSYSTEM NEXUS IN UMSUNDUZI FLOODPLAINS: A GUIDE FOR SUPPORTING THE TRANSFORMATION OF COMMUNITY FARMING PRACTICES

Report to the

Water Research Commission

By

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WRC report no. 3265/1/26
ISBN 978-0-6392-0806-0

July 2026

This is the final report of WRC project no. C2023/2024-01462.

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EXECUTIVE SUMMARY

Wetlands are important and productive ecosystems that are renowned for the ecological and socio-economic services they provide. Specifically, wetlands play a critical role in maintaining the regional ecological balance, mitigating floods and droughts, providing habitats for diverse flora and fauna, and supporting human well-being through essential services, such as carbon sequestration and water purification. Wetlands tend to vary in terms of their types, size, and location. They include estuarine, riverine, lacustrine, palustrine and constructed wetlands. However, wetlands are constantly being degraded by human activities, so that some can no longer offer ecosystem services. Considering the importance of these ecosystems and their extensive degradation, numerous research efforts have been exerted towards understanding, identifying and addressing the factors that drive the change and degradation. However, fewer research efforts tend to be directed towards riverine or floodplain wetlands, especially in developing regions such as southern Africa. Most of these research efforts tend to be categorised either into physical quantitative approaches, which focus on the spatial quantification of the extent of wetlands and their land cover types, or qualitative approaches, which focus on the human and socioeconomic aspects that shape the perceptions and activities of community members who live within these environments.

The challenge with these distinct approaches is that they are exclusive and not complementary, yet they both seek to address the same environmental problem. In this regard, very few integrative research efforts have been conducted in developing countries, such as South Africa, to understand the phenomenon of floodplain wetland degradation. Therefore, the focus of this Water Research Commission (WRC)-funded project (2023/2023-01462) is to evaluate the integration of geospatial, human and socio-economic approaches for profiling the agroecosystem nexus in the flood plains of the uMsunduzi River, so as to guide efforts supporting the transformation of community activities. To address the overarching objective of the project, the following specific objectives were drawn up: (i) to conduct a systematic review of the literature on the successes and failures of agroecological practices in wetland areas in the Global South, (ii) to map the spatial extent of wetlands around the uMsunduzi confluence, and (iii) to examine the perceptions of the key stakeholders (the smallholder farmers and wetland park authorities) on the current and alternative forms of livelihood around the uMsunduzi confluences. These objectives were addressed in three working packages. The first working package addressed Objective 1, which was split into three systematic literature reviews. The second work package addressed Objective 2 by characterising the changes in the spatial extent of wetlands, on a land use and land cover scale, within the uMgeni catchment and within the floodplain of the uMsundizi River during the period from 2000 and 2024. The third working package addressed Objective 3 by examining the perceptions of the key stakeholders (the smallholder farmers and wetland park authorities) on the current and alternative forms of livelihood around the uMsunduzi confluences. The following specific objectives were drawn up, to address the outlined work packages:

(i) to systematically review the literature on the successes and failures of agroecologically sound practices in wetland areas in the Global South;
(ii) to systematically review the literature on community perceptions regarding the utilisation and management of wetlands;
(iii) to assess the LULC changes, focusing on the floodplain wetlands in the uMngeni catchment (DWS U20), KwaZulu-Natal, South Africa, by using Landsat ETM+ and Landsat OLI satellite data;
(iv) to systematically review the literature on governance challenges and policy effectiveness in

wetland management;

(v) to delineate the spatial distribution and extent of wetlands (vegetation) along the uMsunduzi River floodplain and within the uMngeni catchment (DWS U20), in KwaZulu-Natal, South Africa, by using Landsat ETM+ and Landsat OLI satellite data and Random Forest;

(vi) to examine the community perspectives and policy effectiveness: floodplain wetland management and its socio-economic impacts in the Msunduzi River Basin;

(vii) to assess the perceptions of key stakeholders on current and alternative livelihood forms around the uMsunduzi confluence;

(viii) to explore and analyse community perceptions of the human activities that contribute to the decline of the Umsunduzi floodplain wetlands, using interview insights; and

(ix) to integrate geospatial and socio-economic data to assess the relationship between spatiotemporal changes between 2000 and 2024 in wetland spatial extent and community perceptions along the uMsunduzi River Floodplains.

The study initially proposed covering both the uMfolozi and uMsunduzi floodplains. However, considering the revisions to the project proposal and the allocated budget, the study focused only on the uMsunduzi floodplains. The project set out to use action-research techniques so that people in the target communities could participate fully and see real benefits. The land use land cover component was first conducted at the uMgeni catchment and then zoomed to the floodplains of the uMsunduzi River. All qualitative data were collected within the uMsunduzi catchment, with a special focus on the villages along the river. GIS shapefiles for the administrative boundaries of provinces, districts, wards, catchments, rivers and roads were downloaded from the Department of Forestry, Fisheries and the Environment website. The National Wetland Map 6 (NWM6), which was produced by the South African National Biodiversity Institute (SANBI) project in 2024, was utilised to guide the mapping of wetlands. The classification ground reference sampling points were derived from fine spatial imagery in the Google Earth domain and existing landcover types. The older versions of the NWM were then utilised to guide the mapping of wetlands for the previous years. Earth observation data, such as Landsat and Shuttle Radar Topography missions, were accessed through the widely available Google Earth Engine platform, combined with various machine learning algorithms. When conducting systematic literature reviews, the PRISMA framework and checklist were used to develop the key search terms and to retrieve relevant studies from databases, such as the Web of Science, Scopus and ScienceDirect.

In conducting a systematic review of the literature (n = 51) on the successes and failures of agroecological practices in wetland areas in the Global South, the results showed that the most extensively mentioned agricultural practices were in the context of water, soil, crop, tillage, livestock and pest management. The review showed an uneven distribution of research efforts across developing countries. Particularly, 75% of the studies were associated with positive ecological outcomes and focused on the implementation of sustainable agricultural practices. The positive outcomes were associated with the optimal management of soil, crop, land, tillage, water and aquaculture, in the order of their scores. The most sustainable agricultural practices were associated with the pans and marshes, whereas those that were least successful were mostly in the floodplains and constructed wetlands. Meanwhile, the management of tillage, fisheries, water and soil management practices was associated with negative outcomes, in order scores. These agricultural practices were associated with floodplains, marshes, pans and constructed wetlands. The failure of agroecological practices in the wetlands was attributed to various factors, including an insufficient understanding of wetland ecology among the farmers, a lack of adequate training in wetland management, ineffective management policies, traditional beliefs, policy constraints, as well as

adverse climate conditions, such as droughts. However, there is still a need to extend our understanding of sustainable agricultural practices in wetlands, including their significant impact on agricultural production, environmental preservation and food security in developing countries.

When systematically assessing the literature (n= 56) on the perceptions of community members regarding the sustainable management of wetlands in developing countries, the findings indicated that wetlands are primarily exploited for crop farming and fishing, and the communities acknowledge their importance; however, some challenges, including extensive agriculture, population growth, infrastructure development, climate change and limited resources, impede sustainable practices.

Meanwhile, when systematically evaluating the literature (n= 30) on the effective wetland management policies and associated governance challenges in Africa, the findings demonstrated that, while wetland management policies do exist in countries across the continent, their implementation is inconsistent. Their effectiveness is hindered by governance fragmentation, weak enforcement and institutional gaps. Most countries do not have a stand-alone wetland policy; instead, they rely on sectoral environmental legislation that provides partial protection. While wetland policies exist, their implementation is not effective, as they disregard the local needs and customary knowledge, which results in low compliance and continued wetland degradation. Developing national wetland policies, allocating resources and personnel to monitor and enforce them, as well as including local stakeholders in the policy designs, are critical for ensuring that wetlands are adequately protected, while the local livelihood needs are met. Overall, insights from the reviewed literature imply that joint and coordinated efforts by policymakers and communities are imperative for effective wetland management.

When delineating the extent of floodplain wetlands extent and land use/land cover changes in the uMngeni catchment (2000-2024) by using Landsat data, seven key land cover classes were classified by using the Random Forest (RF) algorithm, combined with image transformation techniques on Google Earth Engine (GEE). These classes included agriculture, bare land, built-up areas, forest, grassland, wetlands and water bodies. The overall accuracies for the respective years were 88.98% (2000), 91.23% (2010), 84.21% (2020) and 86.55% (2024), with corresponding Kappa coefficients of 0.82, 0.84, 0.78 and 0.80. The findings show a significant 37% decline in the wetland area from 2000 (2 978 ha) to 2024 (1 874 ha), with the most pronounced loss (46%) occurring between 2000 and 2010. The built-up areas increased by 38% over the same period, while agriculture peaked in 2010 (9 312 ha), before declining to 7 632 ha by 2024. The dominant transitions involved wetlands and grasslands being replaced by urban land and bare surfaces, particularly along the edges of the floodplain. These patterns reflect the intensifying human pressure on wetland ecosystems.

To understand how the communities perceive wetland sustainability, a mixed-method approach was used, which included 60 randomly distributed questionnaires, field observations and an applied statistical analysis. The results showed that most respondents relied on the wetland for a range of activities, including fishing, crop farming, grazing and domestic use. However, several human-related pressures, such as sand mining, water pollution, soil erosion, limited awareness, exclusion from decision-making and poor waste management, were making it difficult to use the wetland sustainably. Despite these challenges, respondents generally understood the value and importance of the wetland. The study highlighted the need for stronger collaboration between the local communities and policymakers in order to ensure the protection and long-term health of these essential ecosystems.

To gauge the community's understanding of wetland management policies and their perceived effectiveness in shaping agricultural practices and socio-economic development, based on a mixed-methods approach, 60 randomly distributed questionnaires and interviews with key stakeholders were

employed. The results suggested a marked deficiency in community awareness regarding existing floodplain wetland management regulations, accompanied by widespread scepticism about their effectiveness. This lack of awareness was further exacerbated by perceptions of ineffective community participation in policy decision-making, which highlighted a substantial disconnect between the intention of these policies and the lived experience of the residents. These insights suggest that without meaningful engagement and the transparent dissemination of information, the potential for effective floodplain management remains severely compromised, thereby jeopardising both environmental sustainability and socio-economic development within the region.

After adopting semi-structured interviews to probe the understanding of the Traditional Authorities (TAs) and a few key community members (n = 9) regarding the degradation of the river's floodplain wetlands, the results also highlighted a transition from it being a sacred "*lifeblood*" at the heart of their religious and cultural life to a deadly "*polluted liability*". Community members highlighted several catastrophic impacts, including severe water pollution that was linked to skin diseases, flooded mining pools that pose a drowning risk for children, and extensive damage to their local fishery and traditional reed-gathering livelihoods. The most lamented challenge was that of governance failure. While the Traditional Authorities (TAs) maintain local regulatory systems, their limited financial and institutional capacity prevents them from enforcing these rules against external polluters, which renders the existing environmental laws largely ineffective on the ground. This disconnect has left the TAs and their communities feeling abandoned and their primary natural resource unprotected. However, the residents shared a clear vision for its restoration. Their appeal for collaborative partnerships, for their inclusion in local river management committees, and for the increased financial backing of the traditional authorities, presents a compelling framework for achieving sustainable wetland management. The results underscore the urgent need for improved communication strategies and inclusive engagement processes in order to empower the local communities in floodplain management.

Finally, in order to address the dearth of literature that integrates geospatial and socio-economic data to assess the relationship between the spatiotemporal changes in the spatial extent of the wetland and the community perceptions along the river floodplains, the project engaged a mixed-method approach, by integrating Landsat remotely sensed data with household surveys (n = 60) to map and assess the wetland spatial variations between the year 2000 and 2024. The findings showed a strong alignment between the community perceptions and the geospatial analysis. The wetland areas declined by 50.98% between 2000 and 2024, which is a trend that the community members were well aware of. The land-cover classification performed reliably, achieving an overall accuracy and kappa values above 80% and 0.80, respectively. These results highlight the value of using a mixed-methods approach in environmental research. Combining remote-sensing data with socio-economic information provided a more complete and nuanced understanding of the changes that are taking place, and it underscores the importance of integrating both types of data in spatial assessment studies.

New knowledge and innovation

Although significant progress has been made in applying advanced geospatial techniques to map the spatial distribution of wetlands and their changes, as well as in conducting qualitative socio-economic research to understand the drivers of wetland transformation, particularly in developing countries, very few studies integrate both approaches, especially in the context of floodplain wetlands. This research went beyond the general baseline data that were generated through GIS and the remote sensing mapping of land use and land cover changes, as it incorporated the perceptions of community members and their traditional leaders regarding the factors that are driving the decrease in the spatial extent and distribution of floodplain wetlands. It was interesting to note that agriculture was not

extensive in the study area, whereas activities, such as sand mining, water pollution, soil erosion, fishing and the gathering of reeds were conducted within the floodplains of the uMsunduzi River. Nevertheless, the project provides a clear pathway and approach for integrating spatially-explicit data and socio-economic data for profiling the context of the wetlands. Notably, there is a strong association between the findings derived from the geospatial data and the qualitative insights that were gathered by means of questionnaires and interviews. This implies that these two approaches are appropriate for profiling the agroecosystem nexus within the floodplain wetlands, and that they support the transformation of various community activities and practices within these ecosystems. Meanwhile, this could also assist policymakers in making informed decisions about how to reduce the extent of wetland degradation.

Capacity Building

To comprehensively address its capacity-building mandate, the project recruited two Honours and three Master's students, two early-career researchers and one mid-career researcher to enhance both the institutional and their individual capabilities. All Master's and Honours students have completed their studies. Both Honours students who earned distinctions in their research projects have been earmarked to continue with their Master's studies in 2026. Postdoctoral fellows actively participated in the supervision of students, alongside early-career researchers. They, in turn, benefited from the mentorship of mid-career and senior researchers, particularly in developing the skills related to project conceptualisation and management. Eight manuscripts were generated from this project, and one of them was published. The students presented their findings at several conferences.

Conclusion

The main objective of this project was to assess the integration of geospatial data and the qualitative insights gathered through questionnaires and interviews for providing baseline information that could be used to guide the transformation of community farming practices and livelihoods that are dependent on floodplain wetlands, in order to facilitate their restoration. Based on the systematic literature reviews, it was concluded that farmers and community members in developing countries use different environmentally-friendly agroecological practices to manage soil, water, crops, livestock, pests and tillage. The literature indicates that these methods are good for the environment when they are done properly, especially in areas like soil, crop, land, water and aquaculture management. In addition, these practices worked best in wetlands, such as pans and marshes, but they did not work as well in floodplains and constructed wetlands. The reviewed literature demonstrates, to a larger extent, that although community members support conservation, they still have mixed attitudes, which highlights the need for better engagement and education. The literature also highlighted a gap between the strong policies on paper and the weak implementation, due to the limited resources and fragmented governance across multiple sectors. Top-down approaches were noted in the literature for their failure, while locally grounded bylaws led to better compliance and less degradation. Overall, the findings imply that effective wetland management requires integrated governance that aligns the national policies with the local reality, that strengthens institutions and that includes community participation. This is essential for protecting wetlands, while it also supports the livelihoods of the people who depend on them. Based on the empirical studies, the project concludes that there has been a great decrease in the spatial extent and distribution of wetlands within the floodplains of uMsunduzi and the greater uMngeni Catchment. Despite the existence of legal protection and planning instruments in South Africa, the wetlands in the uMngeni Catchment remain highly vulnerable to encroachment. The geospatial data and the qualitative insights that were gathered through questionnaires and interviews both demonstrate that floodplain wetlands are being degraded along the uMsunduzi River. Based on these findings, it can be concluded that integrating geospatial

data and qualitative insights is an effective approach for profiling the agroecosystem nexus within wetland ecosystems.

Recommendations

Although different wetlands are associated with different contexts, several research gaps remain with regard to the integration of geospatial data and the qualitative insights gathered through questionnaires and interviews in profiling the health, spatial extent, sustainable utilisation and conservation of floodplain wetlands. These include the following:

- The project showed that geospatial and qualitative data can profile the link between human activities and wetlands; however, due to its complexity, a follow-up study is needed to develop a model that integrates all the variables and simulates different scenarios.
- Integrated wetland management, particularly in peri-urban and rural areas, should be strengthened with overlapping regulations, by routinely combining geospatial and socio-economic data to monitor the wetland conditions, the human pressures and the livelihoods of the local communities. Community awareness and capacity can be enhanced through education on wetland ecology, sustainable practices, pollution prevention, as well as training in climate-smart, wetland-friendly farming and support for livelihood diversification, in order to reduce the pressure on natural resources. Traditional authorities should be empowered as key co-managers; they should be fully informed of the regulations, supported financially and logistically, and they should be actively included in collaborative platforms with municipal and environmental agencies.
- Although there is a functional community catchment forum that covers the uMgeni and uMsunduzi, this governance forum does not actively involve community members, including women's groups and youth networks. There is a need to enforce inclusivity within this forum, so as to coordinate planning, enforcement, monitoring and data sharing, to overcome fragmented governance, as well as to strengthen accountability and policy implementation for wetland conservation.
- There is a need for locally relevant awareness programmes that are focused on wetland policies, ecological functions and sustainable utilisation practices. These could be implemented by the public governance organs, in conjunction with traditional leaders and existing NPOs. This approach will address the critical issue of limited awareness, which reduces their compliance and contribution to ongoing wetland degradation.
- While the political sensitivities and context-specific nature of this work limit a broad generalisation of the findings, this study presents a genuine and much-needed model for effective rehabilitation. The overriding message is that the future of the uMsunduzi River depends on moving beyond policy abstraction and grounding the solutions in local empowerment, while actively involving the communities who live along its banks.
- Future research should build on these findings by integrating high-resolution geospatial and socio-economic data, by incorporating participatory governance approaches, and by linking household-level qualitative information to precise locations, in order to better assess the health, use and conservation of floodplain wetlands.

ACKNOWLEDGMENTS

The research presented here was a component of an unsolicited project that was initiated, funded, and overseen by the Water Research Commission (WRC) in the Key Strategic Area of Water Utilisation in Agriculture. The project team expresses its sincere gratitude to the WRC for its funding and project management. The project team also wishes to sincerely thank the following members of the Reference Group for their valuable contributions and guidance:

Dr L Nhamo	:	Water Research Commission (Project Manager)
Prof S Mpandeli	:	Water Research Commission
Dr S Hlophe-Ginindza	:	Water Research Commission
Dr B Madikizela	:	Water Research Commission
Dr H van Deventer	:	Council for Scientific and Industrial Research
Dr N P Majozi	:	Council for Scientific and Industrial Research
Dr L Mugwedi	:	University of Venda
Mr T Newby	:	GeoTerra Image
Dr B CE le Roux	:	Food and Water Research
Dr MS Magombeyi	:	IIWMI
B Ngcobo	:	(Private)
Dr A Nyamugama	:	Agricultural Research Council
Ms S Fritz	:	Water Research Commission

We would also like to thank the following individuals:

- the South African Research Chair (SARChI) in Land-use Management in the School of Agricultural, Earth & Environmental Science, Discipline of Geography; University of KwaZulu-Natal, for its logistical support and leverage funding;
- the uMsunduzi Catchment Management Forum, for accommodating the project team in their meetings;
- the postgraduate students who participated in the project: Abusiswe Rigala, Palesa J Mokgala, Nokwanda Nkabinde, Thabiso N Mavundla and Mihla L Ndlovu;
- the administrative staff from the Centre for Transformative Agricultural and Food Systems (CTAFS) and the Centre for Water Resources Research, for supporting the project;
- the community leaders and members of the uMsunduzi catchment, for permitting the field surveys to take place in their community; and
- The many stakeholders whose contributions laid the groundwork for the data used in this report.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANN-CA	Artificial Neural Network–Cellular Automata
DEM	Digital Elevation Model
DFFE	Department of Forestry, Fisheries and the Environment
ETM+	Enhanced Thematic Mapper Plus
GEE	Google Earth Engine
GIS	Geographic Information System
HAND	Height Above Nearest Drainage
IEEE	Institute of Electrical and Electronics Engineers
LULC	Land Use / Land Cover
LULCC	Land Use / Land Cover Change
MOLUSCE	Modules for Land Use Change Evaluation
MSE	Mean Squared Error
NDVI	Normalised Difference Vegetation Index
NDWI	Normalised Difference Water Index
NEMA	National Environmental Management Act
NFEPA	National Freshwater Ecosystem Priority Areas
NIR	Near-Infrared
OA	Overall Accuracy
OLI	Operational Land Imager
PA	Producer's Accuracy
PLUS	Patch-Generating Land Use Simulation
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
RF	Random Forest
RS	Remote Sensing
SANBI	South African National Biodiversity Institute
SDGs	Sustainable Development Goals
SRTM	Shuttle Radar Topography Mission
SWIR	Shortwave Infrared
TEEB	The Economics of Ecosystems and Biodiversity
UA	User's Accuracy
UWC	University of the Western Cape
WOS	Web of Science
WRC	Water Research Commission

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1 BACKGROUND AND SCOPE OF THE PROJECT

1.1 Brief Background

Despite their small land surface (around 6%), wetlands support about 40% of all the known plant and animal species, yet they are fragile and the most extensively threatened ecosystems (Hu et al. 2017, Jia et al. 2020, Wetlands 2025). These inland ecosystems consist of various types, including depressions, seeps and floodplain wetlands (Wetlands 2025). Floodplain wetlands that are situated in low-lying areas adjacent to rivers are typically formed through sediment deposition by the water (Kuiper et al. 2014, Yi et al. 2024). However, the unsuitable use of human resources threatens their long-term viability (Kuiper, Janse, Teurlincx, Verhoeven and Alkemade 2014, Yi, Huixin, Yaomin, Jinlian, Xingyu, Huize, Jiaxin, Zhenguo, Liping and Shudong 2024). Because of their high moisture content, floodplain wetlands have been widely utilised for agriculture across many countries (Dlamini et al. 2021). Research conducted in Africa underscores their significance in supporting the cultivation of rice, maize and different vegetable crops, for both subsistence and commercial purposes (Dlamini, Adam, Chirima and Hamandawana 2021). However, their rich natural resources attract extensive extraction activities, which make them highly susceptible to degradation (Barbier and Thompson 1998). Consequently, their agricultural potential and the diverse ecosystem goods and services that they offer place them at significant risk (Barbier 2000, Davidson 2014). This susceptibility is further exacerbated by the absence of effective routine monitoring systems and inadequate mechanisms to inform environmentally sustainable interventions.

In South Africa, only about 15% of the floodplain wetlands remain intact, following the encroachment by human activities (Skowno et al. 2019). The uMsunduzi and uMfolozi floodplain systems, which are located on the northern outskirts of South Africa's KwaZulu-Natal Province, are increasingly experiencing similar pressures. These wetland systems are linked to the iSimangaliso Wetland Park, which is a globally recognised World Heritage Site that is known for its rich environmental landscape and its role in supporting local communities by means of tourism (Cyrus et al. 2010). In addition, these wetlands sustain both commercial and subsistence agriculture, which further contributes to the local livelihoods. The

uMsunduzi/uMfolozi floodplain wetlands are integral components of the uMsunduzi and uMfolozi Rivers.

The uMsunduzi/uMfolozi wetland systems span approximately 19 000 hectares at the catchment level (Bate et al. 2011). However, since 1911, much of the floodplains have been converted for commercial forestry and small-scale sugarcane farming (Cyrus, Vivier, Owen and Jerling 2010). By the 1960s, the canalisation of both rivers for irrigation had already altered more than 50% of the floodplain (Cyrus, Vivier, Owen and Jerling 2010). These extractive activities have significantly compromised the ecological functions of the wetland system. Farmers utilising these wetlands play a critical role in these challenges, yet conservation regulations often alienate the local communities that depend on wetland resources for their livelihoods. The extent to which these communities recognise the long-term consequences of their actions, as well as the potential benefits of sustainable practices, remains unclear.

Given this context of the floodplain wetlands, preserving them while maintaining the region's agricultural productivity requires the adoption of environmentally sustainable farming techniques. To achieve this, agricultural and conservation policymakers need comprehensive data on the farmers' environmental awareness and they should prioritise efforts to enhance it. In addition, farmers must be at the forefront of future wetland conservation initiatives. Globally, sound agroecological practices have been implemented to sustain wetland resources, yet their effectiveness in strengthening the capacity of the community in sustainable resource management remains uncertain. A comprehensive literature review is therefore essential to assess the impact and successes of agroecological practices, to help communities in developing countries to manage their natural resources.

Quantitative and qualitative analyses of the impact of agriculture on wetlands in South Africa remain limited, with little information on the interactions between farmers and wetland ecosystems. Research has demonstrated that human activities negatively affect the functionality of wetlands (Galatowitsch, 2018; Zhang et al., 2019). Farmers who manage these fragile ecosystems often adopt a utilitarian perspective toward the environment (Kerubo, 2011). Understanding the relationship between agricultural practices and wetland conservation is crucial for promoting sustainable farming and implementing effective management strategies to preserve wetland resources. The current project examines the farmers' awareness of how community activities and practices influence wetland conservation in the uMsunduzi floodplain wetlands. In addition, geospatial data and techniques are utilised to analyse the land use and land cover

changes over time, in order to provide insights into the extent of wetland transformation and to inform sustainable management approaches.

1.2 Aims and Objectives

This project aims to provide baseline information that will guide the magnitude and form of the transformation of community farming practices and livelihoods in the uMsunduzi floodplain, in order to facilitate the restoration of wetland areas. This overarching objective will be achieved by using the following specific objectives:

(a) to conduct a systematic review of literature on the successes and failures of agroecological practices in wetland areas in the Global South;
(b) to map the spatial extent of wetlands around the uMsunduzi confluence; and
(c) to examine the perceptions of the key stakeholders (smallholder farmers and wetland park authorities) on the current and alternative forms of livelihood around the uMsunduzi confluence.

1.3 Scope and the Overview of the Report

1.3.1 Study area

The geographic scope of this project comprised the uMgeni and uMsunduzi catchments in KwaZulu-Natal, South Africa. The Msunduzi region is located in the province of KwaZulu-Natal, South Africa. Its focus was on general wetlands within the uMgeni catchment and the floodplain wetlands of the uMsunduzi River (29°37′0″ S and 30°23′34″ E). The uMsunduzi River, which is also known as the Dusi River, flows through Pietermaritzburg, and it serves as a significant tributary to the uMgeni River, which it joins below the Nagle Dam (Figure 1.1). Covering an area of 540 km², this river plays a critical role in the region's hydrology and ecosystem (Boakye and Akpor 2012). The uMsunduzi region falls within Pietermaritzburg, a city that is characterised by a marine west coast climate (Cfb). Summers are marked by warm weather and frequent rainfall, which is often accompanied by thunderstorms, while the winters tend to be dry and mild. The region’s topography, particularly in its high-lying areas, affects the local climate, which makes the uMsunduzi cooler and wetter than Pietermaritzburg. Rainfall in the region occurs in the summer months (mostly December to February), with a mean annual precipitation of 859 mm (Scott-Shaw & Davis, 2023). The floodplains are crucial for the livelihoods of local communities, as they rely on the wetlands for fishing, agriculture and access

to water resources. These wetlands provide essential services, including flood control, while the fertile floodplains sustain agricultural activities (Dlamini et al., 2021). In addition, the floodplains support a wide variety of plant and animal species, which adds to the ecological diversity of the region and strengthens the overall environmental resilience of the uMsunduzi catchment area (Sutherland et al., 2019).

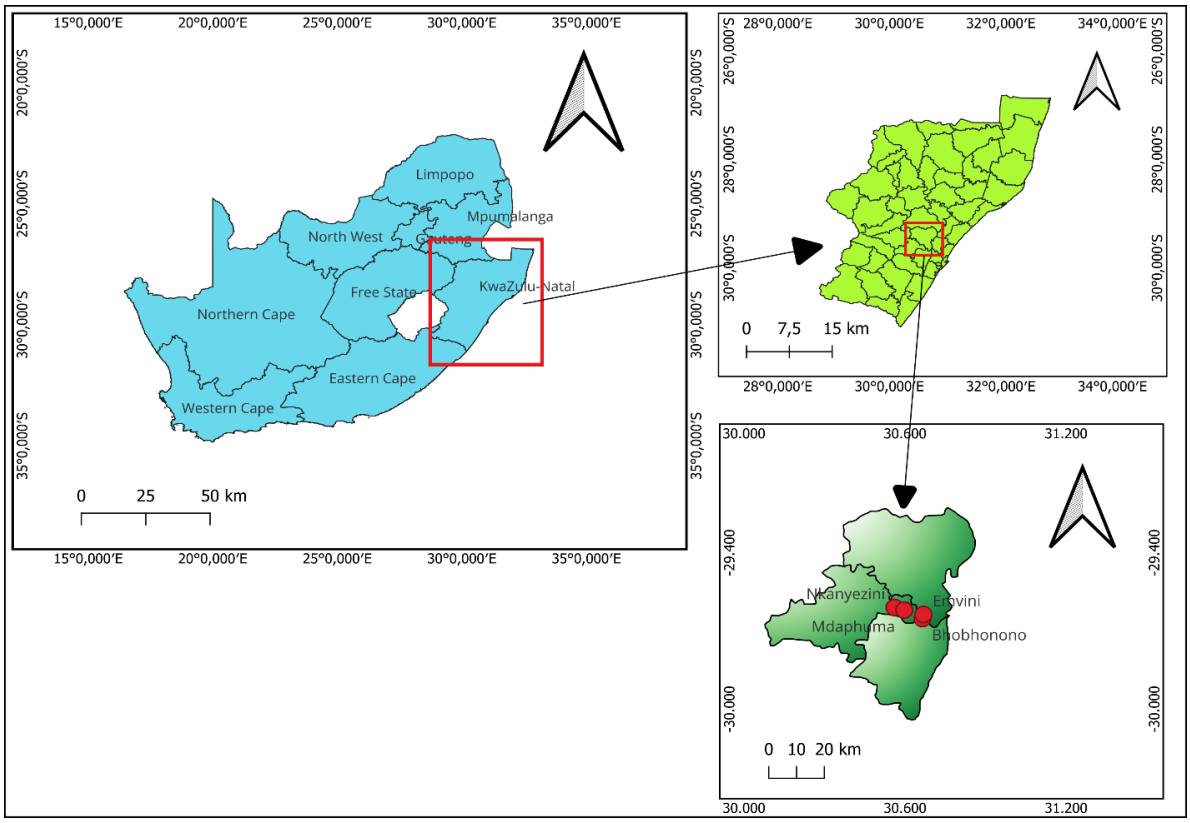


Figure 1-1: Location of villages where sampling was conducted in the KwaZulu-Natal Province, South Africa (Mokgala et al. 2026)

The uMsunduzi Municipality has seen considerable demographic changes between 2011 and 2022. According to Stats SA (2022), the total population increased from 621 715 in 2011 to 817 725 in 2022. The population is relatively young, with children (0-14 years) constituting 23.5% of the population in 2022, although this is a slight decrease from 26.7% in 2011. The working-age population (15-64 years) grew to 69.7% in 2022, from 68.3% in 2011, while the elderly (65+ years) segment increased to 6.8%, which was up from 5.0%. The dependency ratio improved by declining from 46.4 in 2011 to 43.4 in 2022, which indicates a gradual reduction in the number of dependents supported by the working-age population.

The gender balance in uMsunduzi has remained stable, with a sex ratio of 91.3 males for every 100 females in 2022, which was slightly up from 90.8 in 2011. The educational attainment has

improved, as reflected by the reduction in the proportion of adults aged 20-and-above with no schooling, dropping from 5.5% in 2011 to 4.0% in 2022. At the same time, the percentage of adults with higher education increased from 12.8% to 14.6%. The number of households in uMsunduzi rose significantly, from 164 757 in 2011 to 213 727 in 2022. Despite this growth, the average household size remained constant at 3.8 members per household. Infrastructure improvements are also evident, as formal dwellings increased from 73.5% of the total households in 2011 to 90.5% in 2022. Access to sanitation improved, with the proportion of households using flush toilets connected to the sewerage system rising from 56.7% to 63.0%. In addition, refuse disposal services reached 56.6% of households in 2022, which was up from 53.1% in 2011, and access to piped water in homes improved from 47.9% to 54.5%. Electricity for lighting was available to 98.0% of households in 2022, which was up from 91.9% in 2011, reflecting significant progress in the provision of basic services in the municipality.

1.3.2 Report overview

This report brings together the work of multiple authors within the project team, with each chapter being written to stand alone. Each chapter addresses one or more of the contractual objectives, as guided by WRC project managers and the technical reference group. Given this 'paper' format, the study area is presented in Section 1.3.1 and a separate, overarching methodology chapter is not included, as distinct approaches were used in each chapter. Consequently, there are inevitable overlaps, particularly in the methods sections across the report. This was considered to be acceptable, as it follows the main aim of each chapter. Some chapters have been adapted from previously published, peer-reviewed articles.

The report is structured to logically meet the project's objectives, with the following chapter sequence:

Chapter 1 provides a comprehensive introduction to the study by covering the background, conceptual framework and project rationale. It outlines the overarching goals and specific contractual objectives, which establish the foundation for the detailed work presented in the preceding chapters.

Chapter 2 is a scoping systematic review of the literature on the successes and failures of agroecologically sound practices in wetland areas in the global South. This chapter directly addresses contractual Objective Number 1.

Chapter 3 is a comprehensive systematic review of literature on wetland utilisation practices in

developing regions, with a particular focus on community perceptions and the sustainable management of wetlands. This chapter addresses contractual Objective Numbers 1 and 3.

Chapter 4 is an analysis of the governance systems and the effectiveness of the policies related to wetland management across the African continent. The chapter systematically reviews published literature on governance systems and the effectiveness of policies related to wetlands in Africa. This chapter is also in partial fulfilment of contractual Objective Numbers 1 and 3.

Chapter 5 is a geospatial study that maps the changing extent of landcover types in the uMngeni catchment, as well as within the floodplains of the uMsunduzi River at selected intervals over 24 years, by using satellite imagery and guidance from the National Wetlands Map, Version 6. This chapter addresses contractual Objective Number 2.

Chapter 6 is a combined socio-economic study that assesses the local community's views and the real-world effectiveness of policies for managing wetlands in the UMsunduzi River basin. This chapter partially addresses contractual Objective Number 3.

Chapter 7 is a targeted stakeholder analysis that explores the current livelihoods and the potential alternative livelihood options for community members living along the floodplains of the uMsunduzi River. This chapter also addresses contractual Objective Number 3.

Chapter 8 is a qualitative, interview-based investigation into how local communities perceive the degradation of the uMsunduzi floodplain wetlands and the human activities driving it. This chapter also addresses contractual Objective Number 3.

Chapter 9 presents an integrated analysis that combines the geospatial data from Chapter 5 with the socio-economic perception from later chapters to explore connections between physical wetland changes and community views over time. This chapter addresses contractual objectives 2 and three as well as the overarching aim.

Chapter 10 is the synthesis chapter that discusses the overall findings of the project. It presents the final conclusions and provides the key recommendations. The chapter also delivers conclusions and suggestions for future research.

Chapter 11 presents supplementary materials that document the skills and knowledge transfer activities that were conducted as part of the project's capacity development.

2 A SCOPING SYSTEMATIC REVIEW OF LITERATURE ON THE SUCCESSES AND FAILURES OF AGROECOLOGICAL SOUND PRACTICES IN WETLAND AREAS IN THE GLOBAL SOUTH

2.1 Introduction

Wetlands are widely renowned for supporting a variety of agricultural activities on millions of hectares of different types of wetlands. According to the Ramsar Convention on wetlands, wetlands are "*areas of marsh, fen, peat, and/or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters"* (Secretariat 2016). Wetlands are referred to as the kidneys of the landscape, given their hydrological and chemical recycling activities. They are also viewed as biological supermarkets because they support and sustain a wide range of food webs and biodiversity. From an agricultural perspective, wetlands provide water for crops, livestock and aquaculture, as well as ponds for fisheries. According to GRID-Arendal (2016), over a billion individuals across the globe earn their livelihoods directly from wetlands, by engaging in activities such as fishing, rice cultivation, or crafts. Meanwhile, 1.5 to 3 billion people globally depend on wetlands as a source of drinking water, food and livelihood security. Most people whose livelihoods are anchored on wetlands are rural farmers in developing countries. For example, in the Mahakam Delta, Indonesia, 40% of the households are reported to to be dependent on mangrove wetlands (Lamsal et al. 2015). Meanwhile, in Uganda, the Pace Wetland generates 50% of the dependent population's monthly income.

Despite the significant contribution of wetlands to poverty reduction and food security in many developing countries, they are significantly threatened by these agricultural practices, which modify the hydrological and other natural regimes on which they depend. This reduces their ability to sustain their ecological role and their agricultural potential. However, as the human population grows exponentially, the management of water and other natural resources becomes increasingly challenging, which puts pressure on the value of wetlands. Despite this, their extent, their value to rural communities, and their future potential remain largely unrecognised.

In the context of agriculture, a variety of sound agricultural practices have been widely implemented to promote food and nutrition security, while safeguarding the natural resources of wetlands. Environmentally-sound agricultural practices refer to farming and cultivation techniques that are designed and implemented in a manner that minimises the negative impacts on the environment, while promoting sustainable and efficient food production. These practices aim to balance agricultural productivity, environmental conservation and the long-term ecological health. To prescribe and recommend specific, environmentally-sound agricultural practices and solutions in wetland areas, it is

imperative to make an inventory of the documented agricultural practices that have been successfully implemented in wetland areas. In this regard, this study systematically reviewed the literature on the successes and failures of agroecologically sound practices in wetland areas in the Global South.

2.2 The principle of environmental sound agricultural practices

As previously mentioned, 'environmentally-sound agricultural practices' refer to farming techniques that are designed and implemented in a way that reduces the negative impacts on the environment, while promoting sustainable and efficient food production. These practices seek to balance agricultural productivity, environmental conservation and the long-term ecological health in the light of the growing global population. Several environmentally sound agricultural practices relate to wetland environments, as shown in Figure 2.1. In theory, the adoption of sound agricultural practices by farmers in developing countries should empower them to strive for a more sustainable and resilient future. Simultaneously, these practices should help to address the environmental challenges and ensure food security. While many of these practices have been implemented in various wetland areas, it is crucial to evaluate their success and failures in terms of balancing their social, economic and environmental aspects. This evaluation ensures that both the present and future generations can thrive in a healthy environment. If these areas are exploited without sustainable management, communities will face increased risks, such as resource depletion, reduced livelihoods, health vulnerabilities and a heightened exposure to environmental hazards.

Figure 2-1: The priorities, selected principles and practices of sound agricultural practices

2.3 Materials and Methods

2.3.1 Literature search methodology

The study adopted the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol for the literature search (Page et al. 2021). The literature search was conducted in the Institute of Electrical and Electronics Engineers (IEEE), Web of Science (WOS) and Scopus databases. An all-inclusive search was performed in the databases by using the following search string: ((agroecology* OR sustainable farming OR regenerative farming OR cropping OR crop farming OR farming practice OR agriculture OR livestock farming) AND (wetland* OR wetland ecosystem* OR swamp* OR marsh* OR peatland) AND (local ecological knowledge OR traditional ecological knowledge OR indigenous knowledge OR participatory GIS OR GIS OR remote sensing)). The literature search was conducted without constraints relating to the year of publication.

The search string retrieved 157, 2 328 and 888 articles from IEEE, WOS and Scopus, respectively. For the acquisition of relevant studies, all the retrieved literature (n = 3373) was imported into EndNote software, in preparation for screening. The articles eligible for the meta-analysis had to meet the inclusion criteria:

(i) The study is conducted specifically within wetland ecosystems,

(ii) The study includes or mentions sound agroecological practice(s),

(iii) The study reports the outcome of the agroecological practice,

(iv) The study reports the methods and datasets utilised (either qualitative or quantitative),

(v) The study is published as a peer-reviewed article or academic book, or book chapter,

(vi) The full text is accessible in English,

Figure 2.2 illustrates the literature selection flow diagram. The first exclusion procedure was the removal of duplicates, considering that the key search terms used in all databases were similar. In total, 918 duplicates were removed. The remaining articles (n = 2 455) were subjected to title screening to check whether the study was carried out within wetland ecosystems. Upon title screening, 876 papers were excluded. The abstracts of the remaining list of articles (n = 1 579) were screened, excluding those that did not report specific sound agroecological practice(s) and outcomes (n = 1 523). Before the abstract screening, studies that only stated the agricultural activities practised in wetlands were excluded, as these were out of the research scope. After assessing the remaining 56 articles, 12 of them were unavailable in English and were full-length, and they were therefore excluded from the EndNote library. The remaining 44 articles were assessed for their eligibility, and additional studies (n=7) were

identified by using a backwards reference-searching strategy (Jalali and Wohlin 2012). These were retrieved by using the Google Scholar web search engine. In total, the final analysis comprised 51 articles, which were used to retrieve the data for meta-analysis.

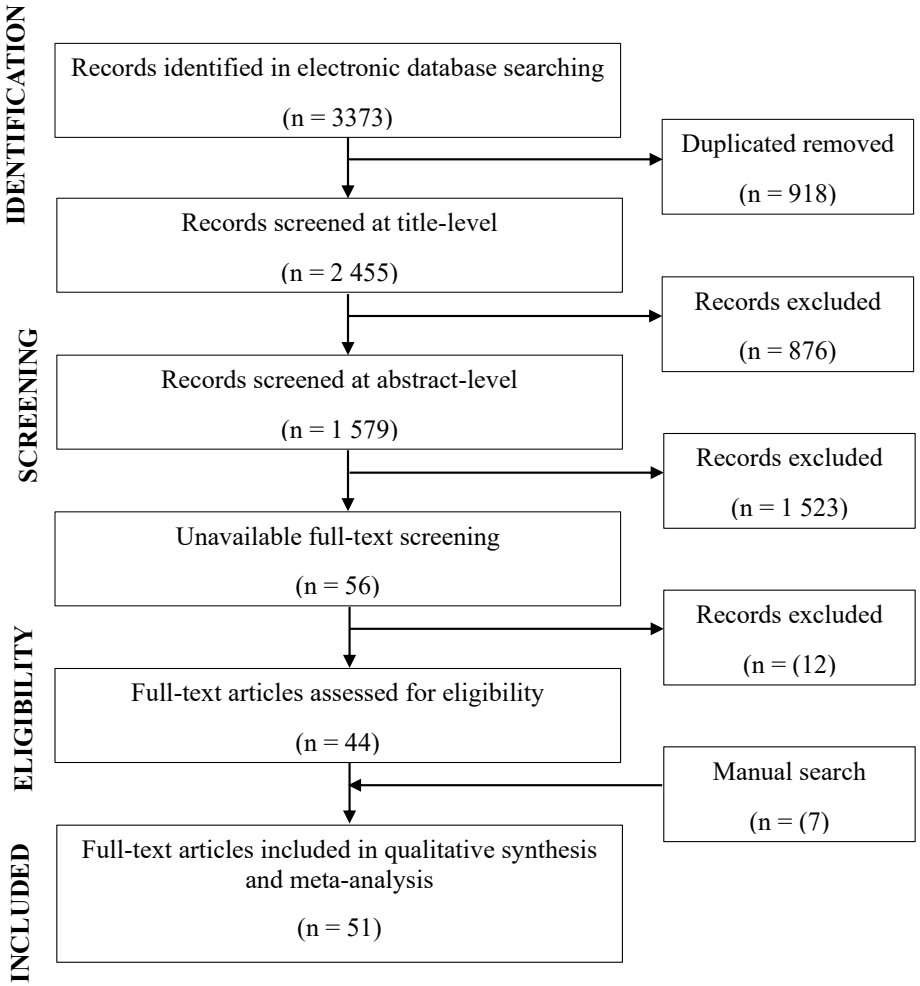


Figure 2-2: PRISMA flow diagram showing the selection of literature used in this review

2.3.2 Data extraction and analysis

The selected articles were exported from EndNote and imported into an Excel spreadsheet for extracting data. Before exporting, EndNote was set to retrieve bibliometric information, such as the author's name, journal name, digital object identifier, publication year, article title, abstract and keywords. In addition, information, such as the study area location (country and continent), the twetland type, he sound agroecological activity mentioned, the type of practice (traditional/modern), the outcomes in terms of benefits/failures, barriers to implementing sound agroecological activities, supporting framework/policy for implementing sound agroecological activities, the methods used in the study, as well as the overall results, were extracted from reading through each article. The extracted data were then converted and recorded as numerical variables in preparation for the data analysis.

The selected 51 studies were analysed qualitatively and quantitatively. Specifically, the data analysis

method adopted in this study is detailed in Sibanda et al. (2021). The agroecological practices were categorised based on a compiled set of practices proposed by Wezel et al. (2014) and Kerr et al. (2021).

2.4 Bibliometric Analytical Outputs

2.4.1 Literature search characteristics

In evaluating the topical concepts of studies on agroecological sound practices in wetlands, the bibliometric network map in Figure 2.3 categorised the retrieved literature into six clusters. The co-occurring key term from the first cluster (red) is “farmer”, which relates to the inclusion of farmers in the methodology framework of most studies used in this review. In addition, the cluster had key terms such as “smallholder farmer”, ‘agricultural practice”, “cultivation technique” and “manure”. This directly relates to the practice of sound agricultural practices, such as the application of manure by smallholder farmers. The blue cluster included “traditional ecological knowledge”, “traditional farming practice”, “organic farming”, “biodiversity & conservation”, “sustainable use” and “floodplain” as its key terms. This relates to the successful implementation of organic farming techniques (traditional ecological knowledge-based farming systems) in achieving biodiversity conservation, as well as for the sustainable use of floodplain wetland environments.

The third cluster (purple) had “wetland” as its co-occurring key term, which directly implies that the reviewed studies had a specific focus on wetland ecosystems. In addition, the key terms of the cluster were “mixed cropping”, “farming practice”, “food security”, “household food security,” and “sustainable utilisation”, which indicated a mixed cropping system as one farming practice for sustainable utilisation of wetland, which can also contribute to household food security. The yellow cluster categorised terms such as “agriculture”, “conservation practice”, “ecosystem service”, “water quality”, “drainage”, “watershed”, which relate to agricultural conservation practices for maintaining ecosystem services related to water management. The fifth cluster (green) categorised terms such as “GIS”, “remote sensing”, “soil”, “water”, and “irrigation”. Geographical Information Systems (GIS) and remote sensing are the methods used mostly for studies that focus on agroecological sound practices related to soil amendment and water management. The last cluster (orange) has “sustainability” as its co-occurring key term. Sustainability is the major focal point for agroecologically sound practices.

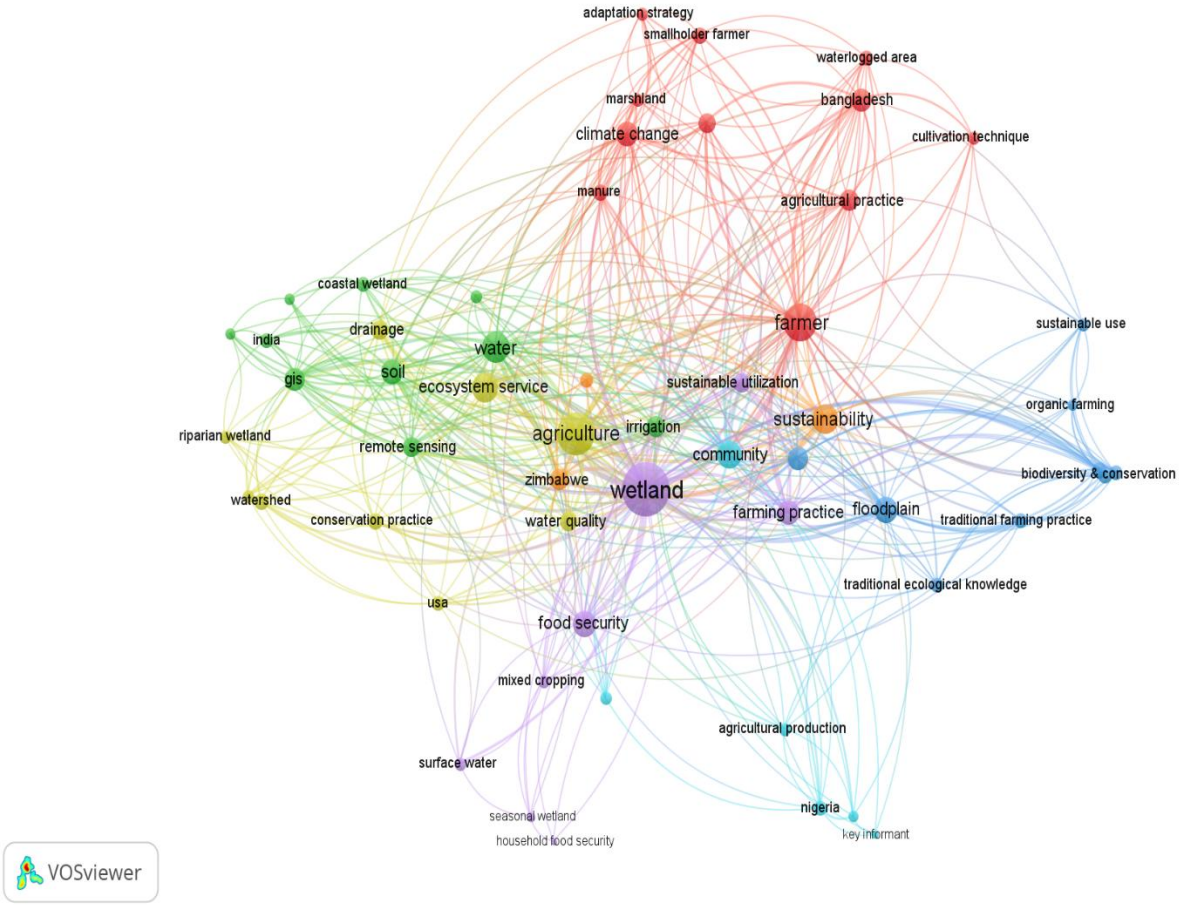


Figure 2-3: Topical concepts for agroecologically sound practices were derived using titles, abstracts, and keywords

2.5 Agroecologically-sound Practices identified in the Literature

The results showed that 31 agroecologically sound practices were mentioned in the retrieved literature (Figure 2.4). The most reported agroecologically-sound practices, in the context of wetland ecosystems, focused on soil management, crop diversification and tillage management. This finding concurs with that of Kerr, Madsen, Stüber, Liebert, Enloe, Borghino, Parros, Mutyambai, Prudhon and Wezel (2021), who reported crop diversity and organic soil amendments as some of the key agroecological practices with positive outcomes in the context of food security and nutrition. Specifically, the results of this review illustrated that most of the studies (n = 37) focused on organic soil amendments, of which the application of organic manure had the highest frequency of studies. Thirteen studies focused on crop diversification practices, such as crop rotation (Sun et al. 2019, Svotwa et al. 2008), mixed cropping (Gadzirayi 2006, Hiyama 2014), intercropping (Marambanyika 2017, Nawarathne et al. 2020) and agroforestry (Rotinsulu 2022). For studies that reported tillage management practices (n = 11), four studies reported the use of ridge and furrow farming practices (Mandishona 2022, Marambanyika 2017). In addition, two studies reported the use of raised fields (Comptour 2018, Nawarathne, Dissanayake and Ginigaddara 2020) and at least one study mentioned conservation tillage (De Laporte

et al. 2010), minimum tillage (Marambanyika 2017), zero tillage (Nawarathne, Dissanayake and Ginigaddara 2020), as well as basin tillage and contour farming (Marambanyika 2017) practices. Other agroecologically sound practices mentioned within the retrieved literature are shown in Figure 2.4 below.

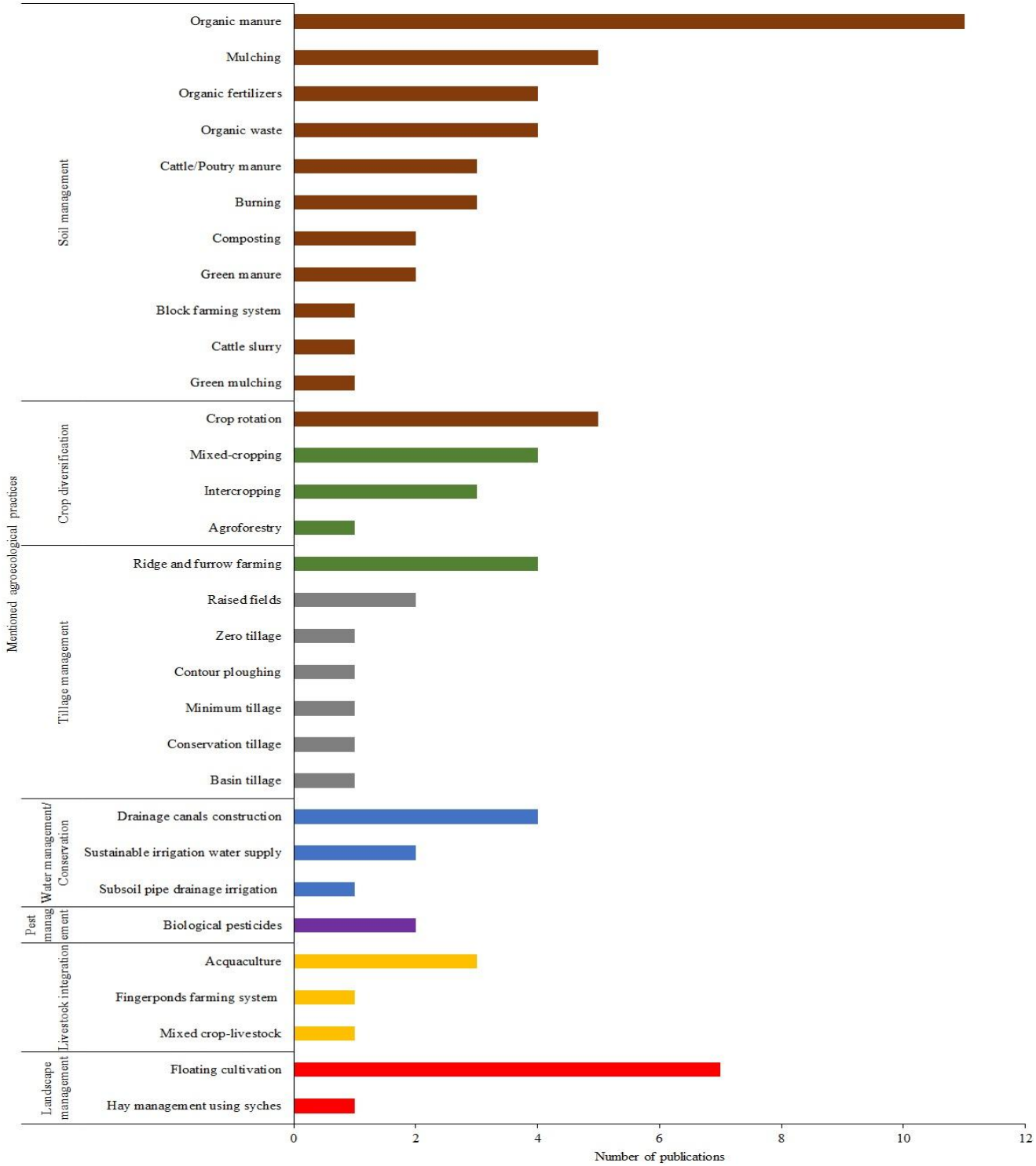


Figure 2-4: Agroecologically-sound practices are mentioned in the retrieved literature. Studies that mentioned more than one practice are counted several times

Eight wetland types were identified in the retrieved literature harbouring the agroecologically sound practices, illustrated in Figure 2-5. In particular, these were palustrine (25), marine (9), floodplain (9), lacustrine (4), coastal swamps (3), artificial wetlands (2), estuaries and peatland (Figure 2.5). In the African countries, the palustrine wetlands (i.e., dambos) were the most studied in relation to agroecologically sound practices. The major ecosystem services that were derived from these wetlands were predominantly related to food production, soil and water management. Floodplain wetlands were primarily renowned for their food production, followed by soil management, crop diversification and water management-related ecosystem services.

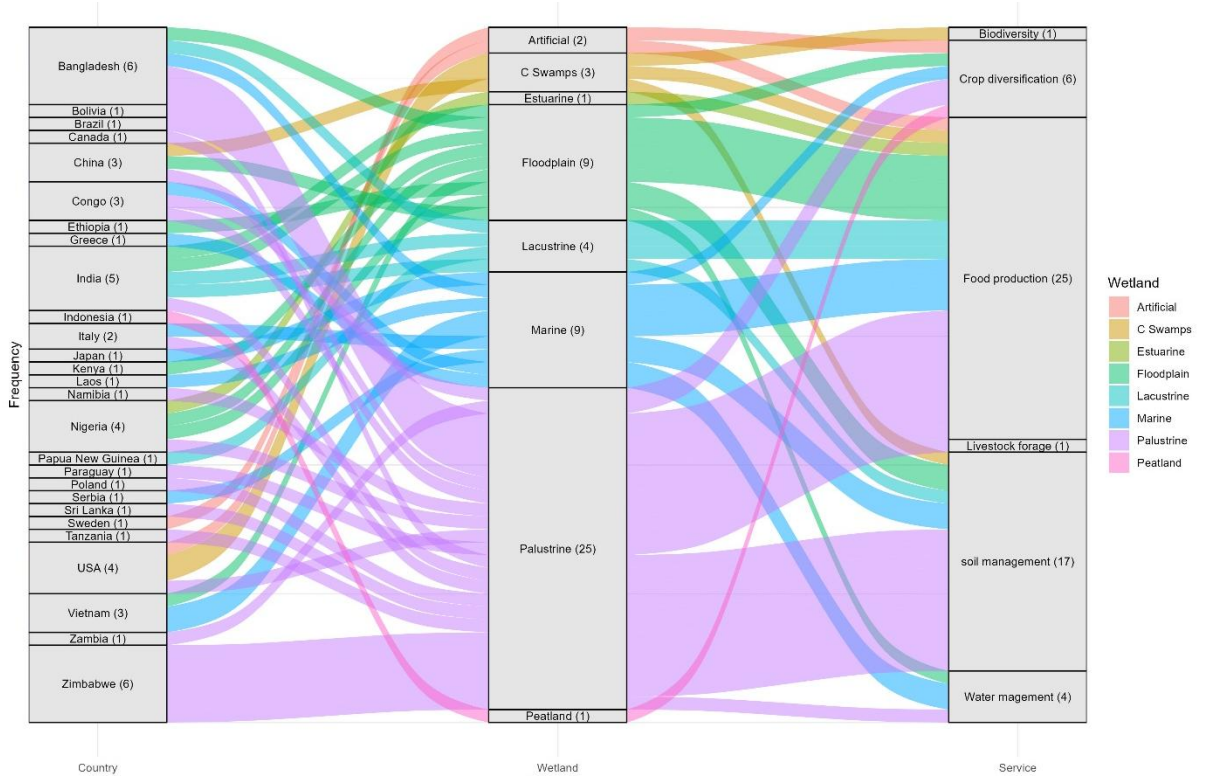


Figure 2-5: Location and type of wetland where agroecological practices were conducted and their associated ecosystem services. Studies which mention more than one ecosystem service or type of wetland are counted several times.

From the retrieved literature, the dominant ecosystem services derived from the agroecologically sound practices studied in the retrieved literature were provisioning (23) and regulating (23), followed by supporting (21) and cultural services (Figure 2.6). Provisioning services studied in the literature included the optimisation of agricultural production, food provision, the selling of agricultural products and crop diversification. This is associated with the rapid increase in the population in developing countries, which is associated with an increased food demand. The regulating services included water management, followed by erosion control, climate regulation and pest control. The supporting services were dominated by soil fertility, conservation and formation improvement, followed by biodiversity support. Again, this reflects the soil as the basis for agriculture and food production. Interestingly, the

cultural services, being the least, included cultural beliefs and indigenous ecological knowledge. This implies that fewer research efforts are exerted in assessing cultural ecosystem services.

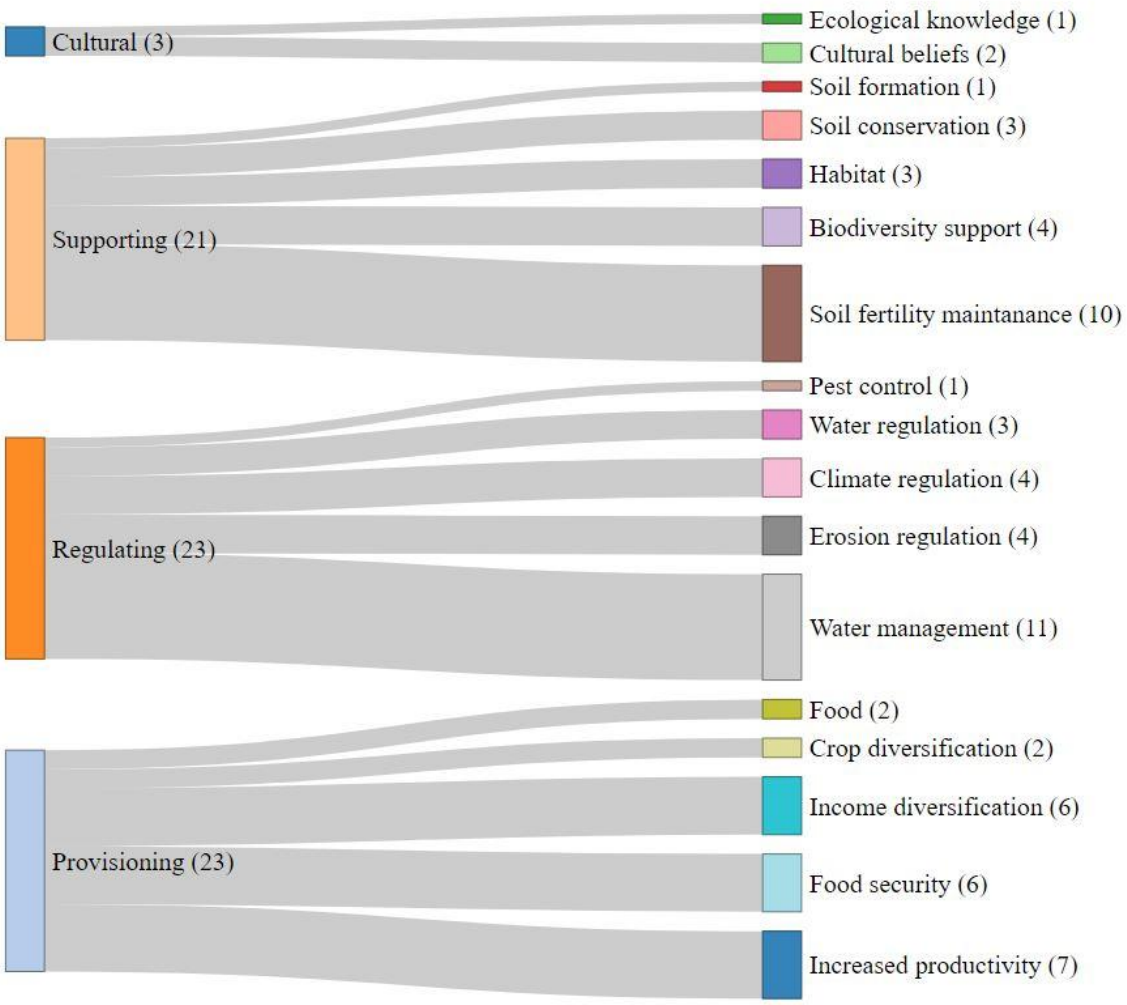


Figure 2-6: Goods and services derived from ecosystem services are discussed in the retrieved literature

2.6 Spatio-temporal Distribution of Studies

Figure 2.7 below depicts the spatial distribution of the studies included in this review. The results of this review illustrated that the studies were conducted in 27 different countries. From a country-level spatial point of view, Bangladesh and Zimbabwe yielded the highest number of publications (12% each), followed by India (10%), Nigeria (8%) and the USA (8%) (Figure 2.7). At least one to two studies were carried out in most of the countries, as illustrated in Figure 2-7. When assessing the frequency of publications per continent, the results showed that studies on agroecological sound practices in wetlands were conducted on six continents. Asia constituted the highest number of publications (39%), about 33% of the studies were conducted in Africa, 14% in Europe, 10% in North

America, 2% in South America and 2% in Oceania. From the geographic distribution of published articles, it can be observed that most studies have been conducted in the Global South. However, more research efforts need to be made towards understanding agroecologically sound practices in other parts of southern Africa, such as South Africa.

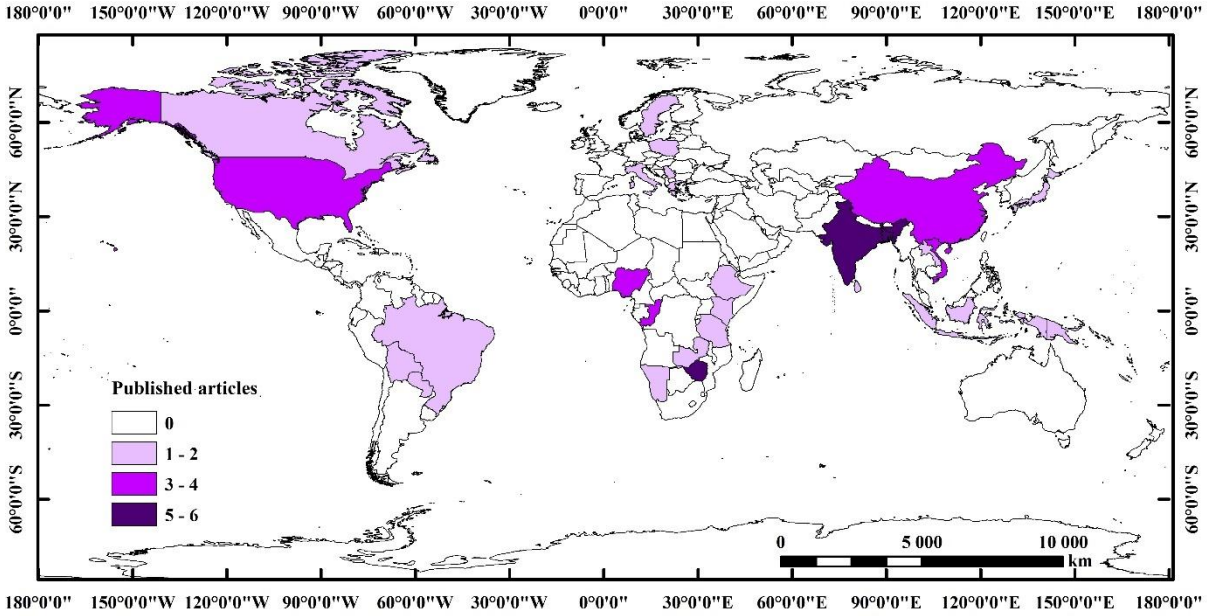


Figure 2-7: Spatial distribution of studies on agroecological practices in the context of wetlands

The literature search results show that the oldest article included in this review was published in 1992, and three articles were published within the 1990s (Figure 2-8). Only two studies (Musacchio 2002, Okoji 2002) were published between 2000 to 2005. The number of published articles was constant between 2006 and 2016, with about one to two publications per year. The results showed that the number of publications has attracted increased attention since 2017, with an increased range of two to six articles per year (Figure 2.8).

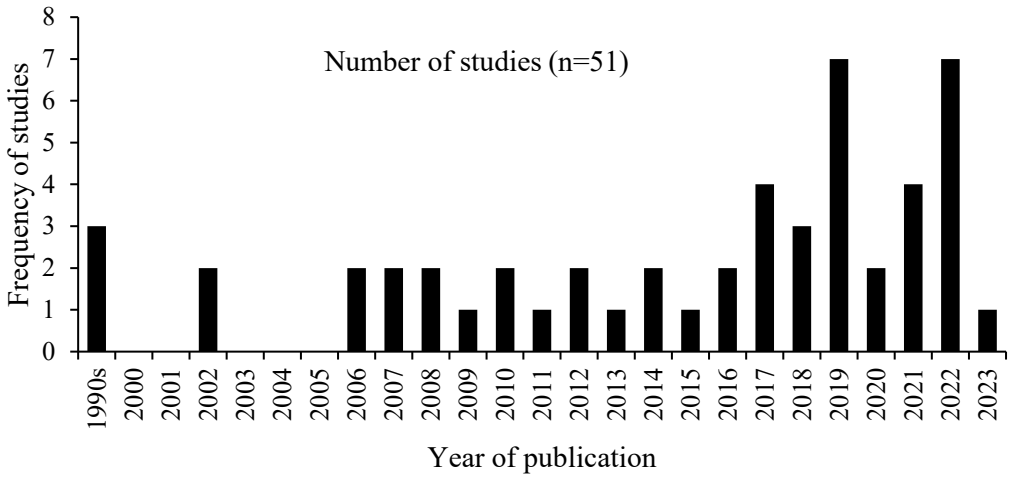


Figure 2-8: Frequency of studies that mentioned agroecologically sound practices(s) in wetlands

2.7 Successes of Agroecological Sound Practices in Wetland Areas

This study sought to conduct a systematic review on assessing the successes and failures of agroecologically sound practices in wetland ecosystems. The results of this review showed that 75% of the studies reported positive outcomes of the agroecologically sound practices mentioned within the retrieved literature. Specifically, the positive outcomes were associated with the optimal management of soil, crop, land, tillage, water and aquaculture, in the order of their positive scores. The most ecologically successful applications of sound agricultural practices were associated with the pans and marshes, whereas the least successful were mostly in floodplains and constructed wetlands (Figure 2-9 (a)). Meanwhile, the management of tillage, fisheries, water and soil management practices was associated with negative outcomes, in the highest order of negative outcomes. These agriculturally sound practices were associated with floodplains, marshes, pans and constructed wetlands (Figure 2-9 (b)).

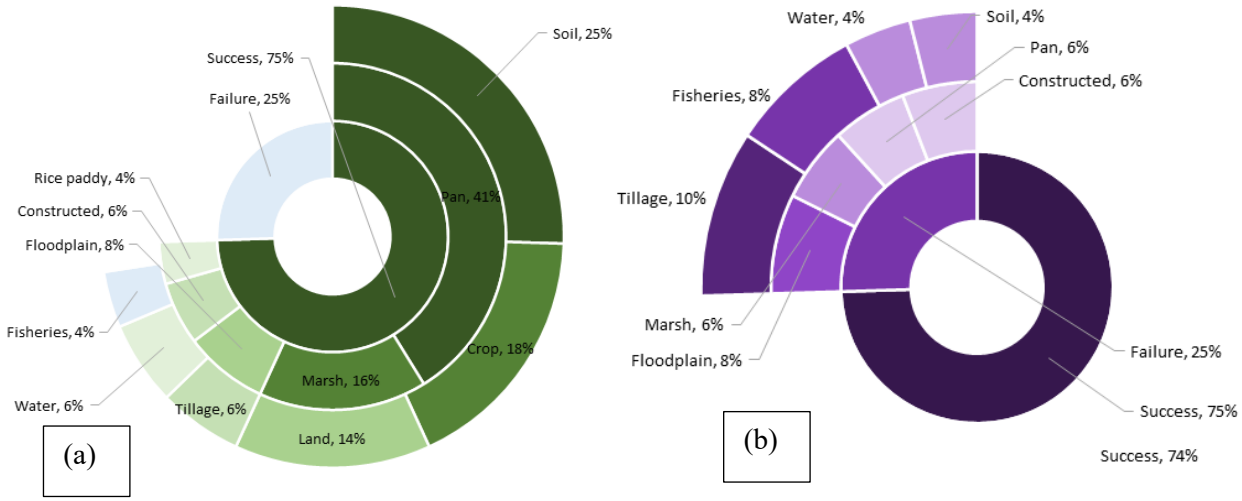


Figure 2-9: Proportions of success and failures of sound agricultural practices in different types of applications and wetlands are reported in the gathered literature

2.7.1 Organic farming practices

The most commonly adopted agroecologically sound practice in the retrieved literature is the use of organic manure. The application of organic manure was reported as an important traditional wetland cultivation practice that is used by small-scale farmers (Gadzirayi 2006, Mandishona 2022, Molnar 2021). This points out the importance of traditional and indigenous knowledge in achieving sustainable wetland agricultural practices. Despite organic manure, a study by (Okoji 2002) also revealed that the application of organic waste and the implementation of block farming are sustainable strategies that can reduce wetland flooding and improve soil fertility. In addition, the use of locally available soil amendments, like cattle/poultry and composting using crop residue, is considered to be affordable, eco-friendly wetland cultivation practices that replenish the soil nutrients and increase agricultural productivity, whilst protecting the ecosystem (BijaySingh 1997, Marambanyika 2017, Nawarathne, Dissanayake and Ginigaddara 2020). In a seasonal wetland located in Zimbabwe, Nyamadzawo (2014) reported that the burning of vegetation in preparation for tillage is a low-cost source of fertiliser, which increases the soil nutrient content, thereby increasing the soil fertility.

Another successful agroecologically sound practice mentioned in the reviewed studies is mulching. The use of mulch is reported as being a successful soil and moisture conservation practice (Nawarathne, Dissanayake and Ginigaddara 2020, Svotwa, Manyanhaire and Makombe 2008), as well as a climate change adaptation strategy (Balasha 2023). Interestingly, the use of green mulching is a sound agroecological practice that can maintain the soil's fertility and prevent the proliferation of weeds without the use of chemical herbicides or fertilisers (Dominici 2022).

The results showed that four studies mentioned the use of organic fertilisers as a successful, sound agroecological practice in wetlands. For instance, a study by Sun, Yang, Yao and Chen (2019) showed that the combined use of organic fertilisers, such as biochar and fulvic acid, has the potential to achieve agroecological benefits by improving soil and food productivity, as compared to the use of nitrogen fertilisers. Biochar stays in the soil for a longer period, and it helps to enhance soil carbon sequestration, moisture retention, nutrient availability, fertility, quality and crop productivity (Nawarathne, Dissanayake and Ginigaddara 2020). In Zambia, Kuntashula (2006) found that the use of *Gliricidia sepium* leafy biomass, as an alternative to commercial fertilisers, is a sound soil fertility management practice that increases vegetable productivity. Moreover, the study showed that *Tephrosia* leaf extract and *Achook* neem seed extract are effective crop protection biological pesticides, which can be used as alternatives to chemical pesticides to ensure the sustainable utilisation of wetlands (Kuntashula 2006).

The findings revealed that floating agriculture has proved to be a sustainable traditional agroecological practice in different wetland areas in Bangladesh. Floating agriculture is a soilless cultivation method that depends on harvesting and decomposing available aquatic plants, such as water hyacinth, to create floating beds in a water body for growing vegetables and seedlings during periods of waterlogging (Bala et al. 2020, Kabir et al. 2022). As such, it is considered a sound agroecological technique for climate change adaptation (Alam and Chowdhury 2018, Kabir, Sarker, Uddin, Leggette, Schneider, Darr and Knierim 2022), by sustaining livelihoods (Alam and Chowdhury 2018, Bala, Ghosh, Kazal, Rahman, Sultana and Sujan 2020, Islam and Atkins 2007, Mohsin and Ferdousi 2019) as well as in enhancing food security (Irfanullah 2008), while also protecting the ecosystem.

A study by Sadananda et al. (2022) compared the environmental impacts of organic and conventional farming systems within a wetland located in India. The results showed that organic farming had a higher concentration of soil nutrients when compared to conventional farming. In this regard, it can be concluded that the use of organic elements is important for sustainable agricultural farming in wetlands. Organic farming techniques are sound agroecological practices that have less environmental impact, and they exhibit the capabilities of retaining healthy soil conditions, as well as increasing crop productivity.

2.7.2 Crop diversification practices

Results showed that a mixed cropping system, such as mixing crops and vegetables, is a sound agroecological practice that can increase income generation, while maintaining the balance between soil nutrients, water and light, as well as reducing pests and diseases (Marambanyika 2017). In the context of seasonal wetlands, the mixed-cropping of flood- and drought-adaptive cropping systems, such as rice and millet, is essential for conserving the water environments of these ecosystems (Hiyama 2014). In addition, practices such as crop rotation and intercropping are essential for optimising soil

nutrients, enhancing soil structure and controlling weeds, pests and diseases (Marambanyika 2017, Nawarathne, Dissanayake and Ginigaddara 2020, Svotwa, Manyanhaire and Makombe 2008). Agroforestry systems that are developed specifically by local communities can be adopted as a wetland rehabilitation strategy, which can also provide an income and sustain food security in the face of climate change (Rotinsulu 2022).

2.7.3 Tillage management

In terms of tillage, the results of this study showed that raised beds, ridges and furrows are sustainable cultivation practices for water management (Nawarathne, Dissanayake and Ginigaddara 2020). Consequently, ridges also allow farmers to sustainably use the limited space available for planting crops, which leads to practices such as intercropping and mixed cropping (Mandishona 2022). Conservation tillage is also a lower-cost practice for reducing sediment delivery, mostly in agricultural wetlands, which, in turn, improves the water quality (De Laporte, Weersink and Yang 2010). Basin tillage is another sound agroecological practice that can effectively manage soil erosion and the rate of water abstraction and wastage during crop irrigation (Marambanyika 2017).

2.7.4 Water management

The results of this study showed that about 6% of the studies that reported positive outcomes were based on sustainable and smart water management strategies that could be implemented in wetland ecosystems. For instance, Zalidis (1998) developed a water management system that could schedule the water supply to irrigation schemes, thus saving enough water to maintain discharges, as well as keeping water salinity within an acceptable range. The utilisation of subsoil pipe drainage for irrigation is another effective strategy that creates a freshwater lens, which can effectively counter the capillary rise of saline water and salt accumulation in agro-wetland soils (Masina 2019). In addition, to effectively manage water use conflicts between agriculture and wetlands, adaptive wetland techniques such as precise water recharge, as well as agricultural management techniques such as water-saving irrigation and planting, need to be coupled (Zou 2018). In other studies, drainage construction was successfully implemented to remove excess water without destroying the hydrological functioning of wetlands (Balasha 2023, Svotwa, Manyanhaire and Makombe 2008).

2.7.5 Livestock integration

The integration of aquaculture and agriculture is a sustainable wetland farming technology for improving food security (Kipkemboi 2007), and it provides a balance in the economy, environment and farmers' health (Berg 2017). However, the study by Dang (2021) reported that the creation of aquaculture ponds in the Mekong Delta was at the expense of the forests, paddy fields and wetlands,

which significantly affected the ecosystem services and sustainable development in the region.

2.8 Failures or Challenges faced by Agroecologically-sound Practices in Wetland Areas

In terms of the failure of agroecologically sound practices in wetlands, 25% of the studies reported negative outcomes. Of these studies, about 8% reported that practices, such as the use of organic matter and organic manure, increase crop production, which, in turn, has resulted in wetland degradation due to over-cultivation (Chuma 2021, Desta 2022, Malik 2019, Mwakaje 2009). Although the tillage system of ridges and furrows is an effective and sound agroecological practice in soil erosion control, it can also disrupt the hydrological functioning of the ecosystem (Marambanyika 2017).

One of the factors contributing to the failure of agroecologically-sound practices mentioned in the retrieved literature is an inadequate knowledge of farmers regarding wetland ecological functionalities among (Chuma 2021, Taiwo 2013). Inadequate training on wetland management (Malik 2019), the lack of effective management policies (Lynch et al. 2016), traditional belief systems (Mwakaje 2009), hindering policy frameworks (Chiaravalloti 2017, Taiwo 2013), as well as the climatic conditions, such as droughts (Kimmage 1992).

According to Lynch, Kalumanga and Ospina (2016), the lack of effective management policies in developing countries could also hinder the success of sound agricultural practices in wetland areas. Developing countries are constantly experiencing substantial development pressure and difficulties in attaining food and nutrition security. In evaluating the agricultural practices in three internationally significant wetlands in Tanzania, Colombia and Papua New Guinea, Lynch, Kalumanga and Ospina (2016) noted that the Malagarasi-Muyovozi, Las Hermosas wetland complex and the Lake Kutubu, respectively, were affected by rapidly increasing population growth rates, which resulted in more poor communities that were relying on the natural capital from the wetland areas. The over-exploitation of natural resources in these wetlands was compounded by the poor regulatory and planning processes and their implementation in these developing countries.

Similarly, Kimmage and Adams (1992) also noted that development projects and activities, such as the construction of dams and large-scale irrigation schemes, also result in adverse impacts on the application of sound agricultural practices in wetland areas. Kimmage and Adams (1992) noted that the development in the floodplain wetland of the Hadejia-Jama'are rivers in northern Nigeria was hampered by the former large-scale irrigation schemes upstream, which resulted in a limited water supply. Subsequently, the smallholder farmers relied on the water from the wetlands for dry season cropping.

Furthermore, basing the decision-making process on anecdotal evidence and scant data has been identified as another challenge associated with the negative outcomes of agricultural sound practices in wetlands. Some wetland resources in developing countries lack adequate inventories, monitoring and

management. This again is a result of developmental pressures, which result in environmental resources, such as wetlands, receiving limited attention, compared to other environmental and socioeconomic aspects of a country. Lynch, Kalumanga and Ospina (2016) also noted that there was limited knowledge in the Las Hermosas wetland complex, Colombia, and Lake Kutubu, Papua New Guinea, and that only a few surveys were conducted on the presence of species, their status, range, biology, ecology, and possible rapid recent declines in endemics, among others. The people living around these wetland areas had limited knowledge and understanding of the need to conserve the wetlands and associated resources. In addition, there were no accurate spatially explicit assessments on delineating the wetland boundaries across their natural hydrological cycles, which further complicated the management efforts. Consequently, the application of sound agricultural practices in the field of aquaculture faced many barriers.

Above all, the major setback arises from the limited knowledge held by local communities and natural resource managers regarding the various benefits that wetlands offer and how they can be sustainably utilised for agriculture (Kangalawe and Liwenga 2005). For instance, there is limited consensus on the implications of the sustainable utilisation of wetlands. This generally results in tensions and disconnects that occur between the development and conservation approaches and agendas, which often actively discourage or ignore wetland agriculture and its importance to the rural communities. Most often, based on limited scientific evidence, the conservation agenda and agricultural activities of the surrounding communities are brought to a halt. In some instances, this raises conflicts between the resource managers, conservationists and the rural communities who are dependent on these wetlands. For example, in the Kilombero Valley, Uganda, conflicting interests were reported by Kangalawe and Liwenga (2005) between environmental conservation and the livelihoods of local communities, where Udzungwa National Park, Selous and Kilombero Game reserves imposed restrictions on the natural resources used by surrounding communities. Similarly, in the Pantanal Wetland, Brazil, due to the lack of knowledge and community engagement, policymakers enforced top-down fishing policies that limited the local people and denied their local knowledge and management practices (Chiaravalloti 2017). This illustrates that there is a need for multidisciplinary integrated efforts and approaches, which will make sure that the interests of the various stakeholders are adequately addressed.

Bureaucratic governance systems, which seldom support and incorporate all stakeholders in their decision--making, are another force that impedes the success of agroecologically sound practices in wetlands. According to Kimmage and Adams (1992), the government did not invest in the Hadejia-Jama'are floodplain wetland to improve the sustainable utilisation of water among all stakeholders. Furthermore, the study notes that, for the project to be a success, there was a need for changes in the perceptions of the political leaders who were driving the development agenda in the country. Kimmage and Adams (1992) noted that without any changes in the dominant ideologies and the culture of development, no confidence-generating scientific evidence, cost-benefit economic information or

environmental data could influence their decision making.

2.9 Challenges and Gaps in the Reviewed Literature

Most studies on agroecological practices in wetlands appear to be concentrated in specific regions, with Bangladesh, Zimbabwe, India, Nigeria and the USA receiving more attention. However, there remains a gap in understanding how these practices are implemented in other parts of the Global South, particularly in countries like South Africa, where diverse wetland systems and unique socio-economic contexts require more localised, context-specific research.

Overall, there were no studies that explored the relationship between sound agricultural practices and their impact on resilience, capacity building, adaptation and the mitigation of the effects of climate change. Furthermore, there were very few studies that highlighted and emphasised the importance and benefits of indigenous knowledge systems, farmer participation, or community engagement in co-designing and implementing sound agricultural practices that are suitable for specific communities and for the wetlands that they live in.

The gathered literature does not clearly highlight the standard procedures that could be used to assess the relative contribution of different sound agricultural practices. Subsequently, it is very challenging to generate specific key assessment variables and criteria. Much of the literature used different aspects to report on the environmental concerns associated with various agricultural practices in the wetlands covered.

Furthermore, despite the absence of standardisation, the criteria used in the collected literature tend to be more qualitative than quantitative, and they often lack a multidisciplinary perspective. For instance, spatially-explicit techniques, like GIS and earth observation science, were not extensively utilised in the gathered literature to assess the successes and failures of various sound agricultural practices. Most of these studies did not even consider the application of geospatial data and technologies. In this regard, the techniques discussed in the retrieved literature are not extensively spatially explicit.

2.10 Opportunities and the Way Forward

After analysing the retrieved literature, the following opportunities and suggestions are proposed for future studies:

- There is a need to expand the geographical scope of research on agroecological practices in wetlands, beyond the commonly studied regions like Bangladesh, Zimbabwe, India, Nigeria, and the USA, and to include the under-represented parts of the Global South. The focus should be on understanding these practices in other areas, particularly in southern Africa, including South Africa.

- Future studies should investigate the relationship between sound agricultural practices and their impact on resilience, capacity building, adaptation and the mitigation of the effects of climate change. This will provide valuable insights into the role of agroecology in climate change adaptation.
- There is a need to emphasise the importance and benefits of indigenous knowledge systems, farmer participation and community engagement in co-designing and implementing sound agricultural practices. Case studies in which these approaches have been successful in specific communities and wetland ecosystems should be highlighted.
- All stakeholders should develop and promote standardised assessment procedures that can be used to evaluate the relative contribution of different sound agricultural practices. Key assessment variables and criteria should be established to facilitate consistent and comparable research outcomes.
- There is a need to encourage the use of quantitative methods and multidisciplinary perspectives in future research. This includes exploring the integration of spatially-explicit techniques, such as geographic information systems, spatial modelling and earth observation science, to assess the success and failures of various sound agricultural practices comprehensively.

By addressing the abovementioned points, future studies could contribute to a more integrated and holistic understanding of the sound agricultural practices implemented in wetland areas, along with their far-reaching implications for sustainable agriculture, environmental conservation, as well as food and nutrition security.

2.11 Conclusion

The objective of this study was to conduct a systematic literature review that focused on the outcomes of agroecological practices in wetland areas across the Global South by following the PRISMA approach and checklist. The extensively implemented agroecological practices in developing countries were in the context of water, soil, crop, tillage, livestock and pest management. A skewed distribution of research efforts between the developed and developing countries was noted, and 75% of the studies were associated with the positive ecological outcomes of implementing sound agricultural practices. The positive outcomes were associated with the optimal management of soil, crop, land, tillage, water and aquaculture, in the order of their positive scores. Their successful application of sound agricultural practices was mostly in pans and marshes, whereas the least-successful application was mostly in flood plains and constructed wetlands. The management of tillage, fisheries, water and soil management practices was associated with negative outcomes. An inadequate understanding of the farmers regarding wetland ecology, insufficient training in wetland management, ineffective management policies, traditional beliefs, policy constraints and adverse climate conditions, like droughts, were among the most significant factors that contributed to the failure of these agroecological practices in the wetlands

of developing countries. However, there is still a need to improve our understanding of sound agricultural practices in wetlands, including their significant impact on sustainable agriculture, environmental preservation and food security.

3 COMMUNITY PERCEPTIONS AND SUSTAINABLE MANAGEMENT OF WETLANDS: A SYSTEMATIC REVIEW OF LITERATURE ON WETLAND UTILISATION PRACTICES IN DEVELOPING REGIONS

3.1 Introduction

Wetlands are increasingly recognised as crucial water sources, particularly as many countries in arid regions grapple with rising food insecurity and water scarcity. These ecosystems serve as vital water reservoirs for supporting farmers, local communities and the environment (Paul & Pal, 2024) and they provide numerous ecological and socio-economic benefits, including fisheries, agriculture and recreational opportunities. Moreover, wetlands are integral to the cultural identity and food and nutrition security of many communities. Community members and their activities impact the spatial extent, condition, and quality of wetlands. Consequently, they play a critical role in influencing how biodiversity conservation initiatives change (Klebl et al. 2024). A deep understanding of these local ecosystems positions them well to support the sustainable utilisation of these systems. Scientific research shows that many local and smallholder communities understand and recognise the importance of the wetlands, not only for their economic benefit, but also for their long-term ecological health (Libala et al. 2022, Wood 2017).

However, there is still a need to extend these studies to the perspectives of community members on the sustainable management of wetlands (Chan et al. 2012, Jax et al. 2013, Martín-López et al. 2014). Understanding and integrating the perspectives of the community can help to improve planning and decision-making for inclusive and sustainable wetland management. This is important because wetlands are often degraded due to poor management, which may stem from a lack of ownership or mismatched priorities among the stakeholders. The effective management of shared resources, such as wetlands, requires several key elements, including management strategies from different collaborative stakeholders, appreciating the local perceptions, and aligning them with ecological conservation and the needs of the community.

Incorporating community perceptions into management strategies is very important because it ensures that the main beneficiaries of the shared resources are involved in the decision-making. This approach not only fosters a sense of ownership but also helps to align the priorities of management with the community's needs. Several studies provide context-specific insights on

the perspectives of smallholder community members in the sustainable utilisation of wetlands (Kansuntisukmongkol 2007, Nxele 2007, Saluja et al. 2023). For example, Marambanyika et al. 2017 conducted a study in Zimbabwe that examined how human actions and management approaches affected the wetlands across rural districts. The study revealed that the active involvement of local leaders and communities contributed to the conservation of wetlands, whereby local traditional leaders created rules and adapted customs to manage the natural resources by using their indigenous knowledge (Marambanyika and Beckedahl 2017). Areas in which there was participation with the local leaders showed minimal soil erosion and water alterations, which highlighted the positive impact of community-led conservation (Marambanyika and Beckedahl 2017). Similarly, Shrestha 2011 conducted a study that highlighted the role of communities in wetland management. In this study, locals contributed their indigenous knowledge to management efforts, which led to a better condition of the wetland. They also participated in user groups, which helped in the effective management of the resources. In addition, communities used the wetland sustainably, which supported their economic well-being. The results showed that this helped to maintain an ecological balance, it raised the community's awareness, and promoted self-reliance, while demonstrating a willingness among the households to pay for the conservation efforts.

However, there is a notable lack of comprehensive assessments of these studies, particularly regarding the perceptions of smallholder and local communities on the sustainable use of these vital resources. Most of the existing literature reviews focus on ecological assessment or policy frameworks. For example, one review focused on the framework for South Africa, and the other examined South Africa's environmental policies and legislative framework (Dini & Everard, 2016; Sinthumule, 2024). Understanding how diverse smallholder farmers/communities perceive the sustainable use of wetlands is crucial for developing effective strategies that align with both ecological and human wellbeing. While there are studies that explore community-led conservation efforts and the importance of local knowledge in managing wetlands (Marambanyika et al. 2017), there remains a gap in understanding how diverse smallholder farmers and communities perceive the sustainable use of these resources. This gap is not solely due to a lack of literature reviews; rather, it reflects a broader need for more comprehensive studies that focus on community perceptions and their implications for sustainable management. For instance, research in Rwanda has shown that farmers have valuable insights into agricultural wetland management, as they highlight the constraints, such as water shortages and the high cost of fertilisers (Nabahungu and Visser 2013). Similarly,

studies on the perception of smallholder farmers on climate change and adaptation strategies underscore the importance of integrating local knowledge into management strategies (Muleke et al. 2022).

Therefore, this study systematically reviewed the literature on community perceptions regarding the utilisation and management of wetlands. In order to address this aim, this review assessed the progress and challenges and it identified critical gaps in the literature. Understanding these perceptions is crucial for developing effective, sustainable management strategies that align with both ecological conservation and community needs. In addition, the findings of this study will serve as a foundational resource for future studies that aim to enhance the resilience of both the floodplain ecosystems and the communities that depend on them.

3.2 Materials and Methods

3.2.1 Data collection

This systematic review was conducted by following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach and guidelines. PRISMA improves transparency and completeness in its systematic reviews and meta-analyses by providing minimal evidence-based items, which facilitates a clearer methodology and findings assessment by the readers (Page et al. 2021). The literature was searched in May 2024 from three databases, including the Web of Science, Springer and Scopus. The key search terms, including (wetland management) AND (wetland agriculture) AND (decision making) AND (communities), were used to retrieve literature in databases. These key search terms were selected to reflect the key themes that are relevant to the review, by focusing on wetland management practices, agricultural practices, decision-making processes and community involvement. Recognising that different databases cater to various disciplines, the search string was modified for each database to enhance its retrieval effectiveness. Tailoring the search strings for each database, according to its requirements, enhanced the capture of a wide range of perspectives, while maximising the relevance of the retrieved articles. A comprehensive strategy was used across multiple databases to minimise any selection bias. In addition, predefined inclusion and exclusion criteria were put in place to ensure that only relevant studies were included. Article selection was based on a review of titles and abstracts that prioritised studies that addressed community perception regarding the sustainable use and management of wetlands.

Thirty-two documents were identified for the Scopus database. Twenty-two relevant articles were then imported to EndNote, based on the key search terms. The Web of Science yielded seventy-three documents when filtered for all fields. After excluding the review articles, sixty-three articles remained. Twenty-one articles were imported to EndNote. The initial search of the Springer database returned 19 150 articles. After filtering it to include only articles, this number was reduced to 1 927, and further refinement to research articles yielded 1 645 articles. From this subset, 33 articles were imported for further screening. The total number of articles imported to EndNote from these different databases was 81. These articles were then imported to Covidence for screening, and six duplicates were removed, resulting in 75 articles for screening. Covidence was utilised because it minimises the need to use different applications, thereby saving time and reducing the likelihood of errors (Babineau 2014).

3.2.2 Data Screening

The title- and abstract-screening process was then conducted on a total of seventy studies. Each article was assessed based on its title and abstract by voting on its eligibility, using three distinct options namely: "Yes," indicating that the study satisfied the inclusion criteria and should proceed to full-text screening; "No," meant that the study did not meet the criteria and should be excluded; and "Maybe" suggested that the eligibility of the study was uncertain and required further evaluation during the full-text screening stage. In addition, studies that did not meet these criteria, particularly those lacking the integration of the community perspective on sustainable utilisation, were excluded from the review. Consequently, 22 did not meet the inclusion criteria, while 53 were eligible (Figure 3-1).

Following this initial screening, full-text screening followed, and only 53 studies were accessible in full-text *.pdf format documents for review (Figure 3.1). Each of these documents retrieved from different databases was examined thoroughly with the predefined inclusion criteria. The inclusion criteria focused on the integration of the key components, specifically studies that addressed the intersection of wetland management, agriculture, decision-making, and community engagement.

Of the 53 studies reviewed, two were found to be not eligible, resulting in 51 retrieved studies, and nine studies were excluded from further consideration. Forty-two studies were deemed eligible for review, and an additional 14 were incorporated as back-search references that were sourced from the existing literature (Figure 3.1). The back search references consisted of the papers that were encountered while reviewing other articles that were not identified during the

initial search in the three selected databases. This approach is common in academic research, as it allows for the discovery of relevant literature that may not have appeared in the primary database searches (Jalali and Wohlin 2012). Identifying these additional sources underscores the importance of a thorough literature engagement, and it results in a more comprehensive overview of the existing research and perspectives (Kotze 2007). In total, 56 studies were eligible for review, which were then subsequently exported and downloaded in a *.csv format before being converted for data extraction. The data from these studies, including the titles, abstract, publication year, and country of origin, were then imported into a Microsoft Excel Spreadsheet. This organised data facilitated the generation of frequency graphs that examined the sustainable use of neighbouring wetlands by local farmers and communities.

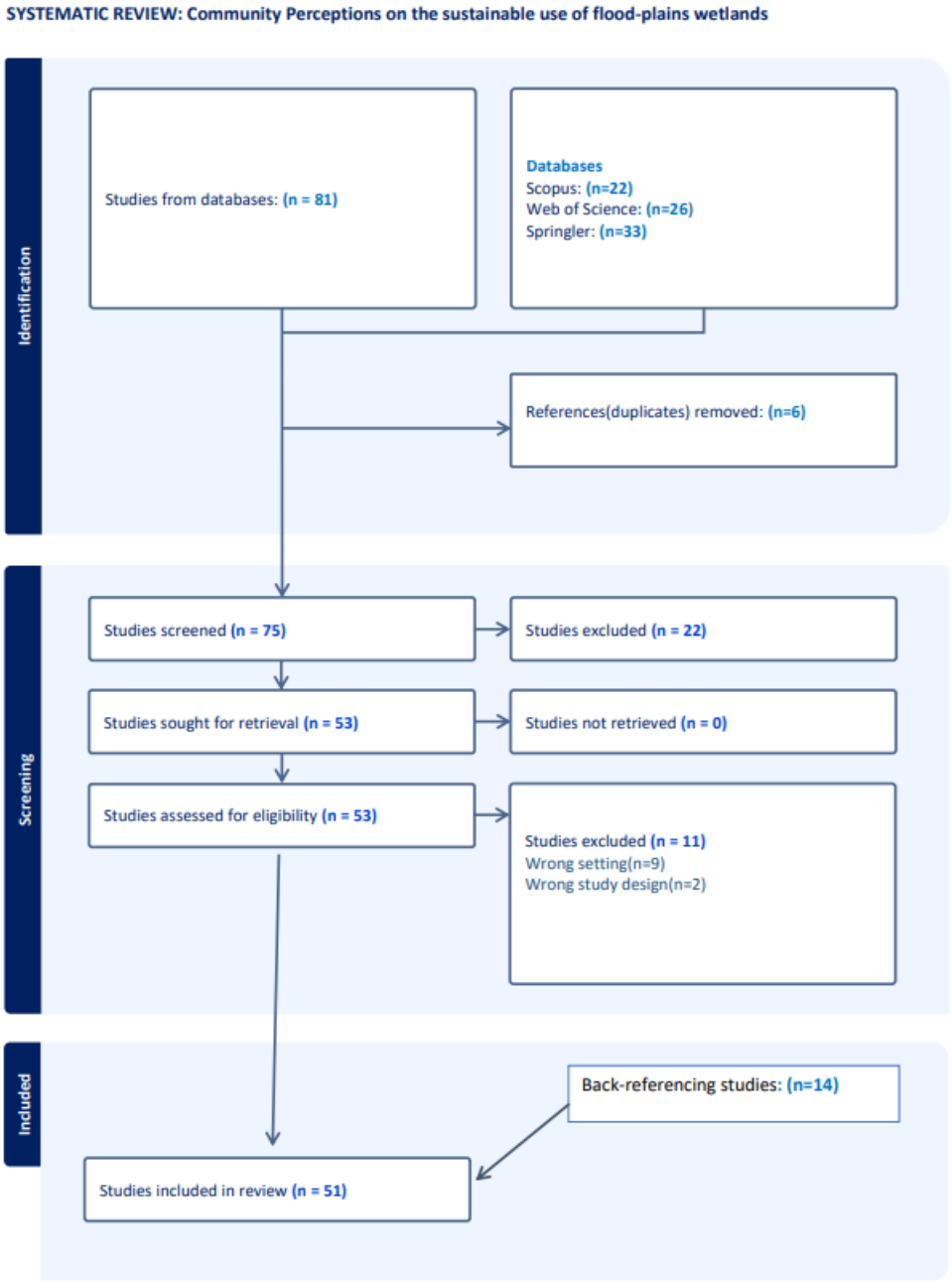


Figure 3-1: Systematic review flow chart. Flow chart created using the Covidence tool.

3.2.3 Data extraction and analysis

The Microsoft Excel spreadsheet created in the previous stage served as a tool for data extraction to evaluate the progress and to identify gaps, limitations and opportunities related to the perceptions of local farmers and the community on the sustainable utilisation of neighbouring wetlands. This phase concentrated on collecting data from the selected articles (n=56). The spreadsheet contained information about each study, including the year of publication, the study area country, the type of study, the anthropogenic factors, the

methodologies employed, and the perceptions reported.

The extracted data were systematically reviewed to facilitate the analysis. Subsequently, graphs were generated to visually represent the results associated with the above-mentioned essential information. This approach not only enhanced the clarity of the findings but also provided a comprehensive overview of the various elements influencing the local perceptions regarding sustainable wetland management. By leveraging the capabilities of Excel, the review process was streamlined, which enabled a more effective examination of the data that was collected from the literature.

3.3 Results

To ensure a comprehensive analysis, several key aspects were extracted from each study. These included the year of publication (to track research trends over time), the study area (to account for geographical variations in perception), the type of study (qualitative, quantitative or mixed method) to acknowledge the different insights, the perceived benefits (to inform management strategies) and the perceptions of the communities.

3.3.1 Spatial data distribution and frequency of studies

The global spatial distribution of studies has evaluated the perceptions of local farmers and communities regarding the sustainable use of the neighbouring wetland (Figure 3.2 (a)). The data indicated that most of these studies were conducted in India and Uganda (9.8%), followed by Greece, Nepal and South Africa (7.3%). This pattern suggests a concentrated research focus on these regions, influenced by the ecological significance and the socio-economic context that drives community engagement in sustainable practices. Figure 3.2 (b) represents the frequency of the studies that focused on community perceptions of wetland management over the years. The analysis indicated that, over the years, there has been a significant increase in research that is focused on wetlands, which reflects a growing acknowledgement of their ecological importance and the detrimental effects of human activities on these ecosystems.

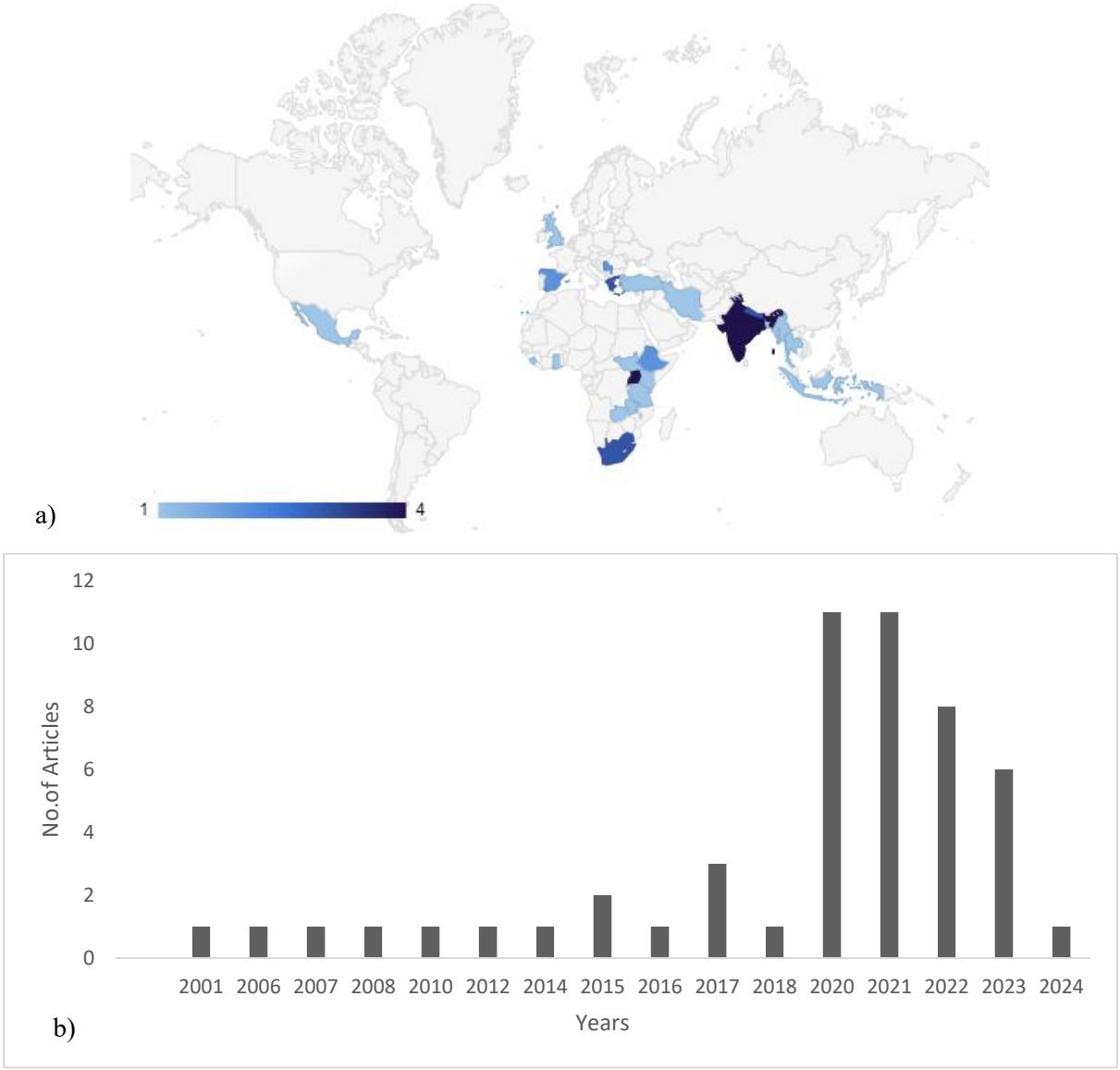


Figure 3-2:(a) Global spatial distribution of studies on wetland management and community perceptions, and (b) frequency of studies conducted on wetland management and community perception over the years.

3.3.2 Approaches and methodologies used in the reviewed literature

The major approaches that were employed in the retrieved studies to evaluate community engagement in wetland management are summarised in Figure 3.3. Most of the evaluated literature used the mixed-method approach. Out of 56 studies, 44 employed a mixed-methods approach, while ten utilised a qualitative method, and the remaining two used a quantitative approach. The predominance of mixed methods research can be attributed to its capacity to provide a more holistic understanding of the phenomena under investigation (Zina, 2021). This

approach effectively addresses the limitations that are inherent in singular methodologies by leveraging the strength of both qualitative and quantitative techniques, thereby enriching the overall analysis and findings (Creswell & Plano Clark, 2023). Most reviewed studies used a combination of interviews and questionnaires, together with surveys and focus groups, for gathering data. This trend indicates the preference for mixed-methods research designs when assessing community involvement in wetland management. A mixed-method approach is used to provide a comprehensive insight into the community dynamics, and it contributes to more effective wetland management strategies that align with the local needs and values (Creswell & Clark, 2017).

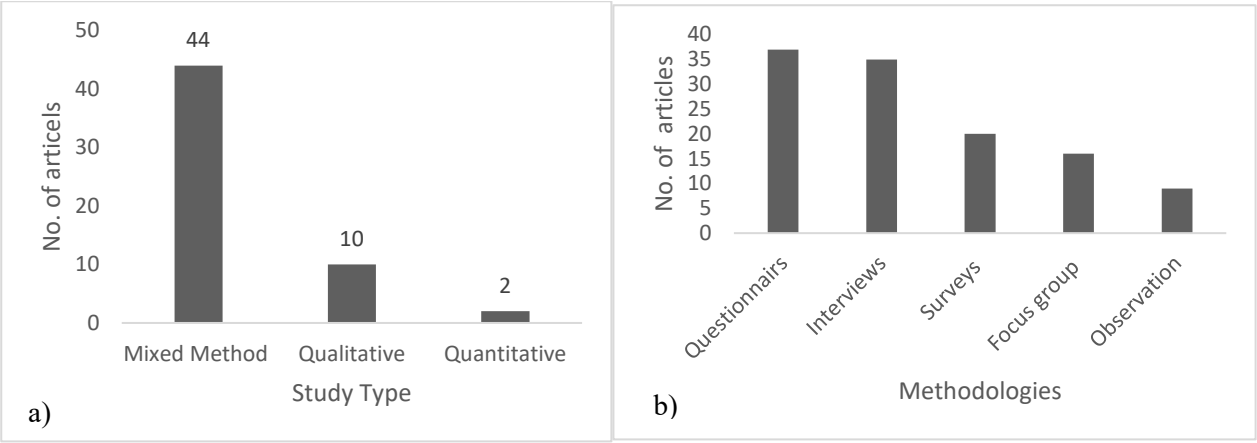


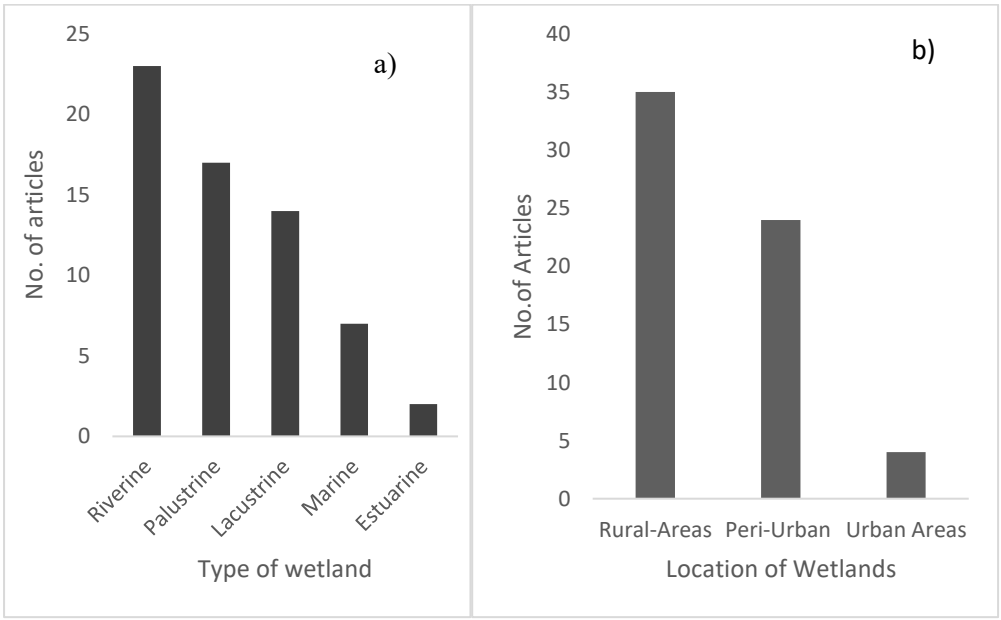
Figure 3-3:(a) Approaches and (b) data gathering instruments utilised in the retrieved literature to evaluate community perceptions and engagement in wetland management

3.3.3 Types of wetlands in literature and their associated utilisation patterns

Figure 3.4(a) depicts the types of wetlands that were covered by the retrieved literature (56 studies). The analysis of wetland types across 56 studies shows a distinct ranking in their frequency of study. Some of the studies adopted a broader approach by examining more than two types of wetlands simultaneously. Riverine wetlands situated along rivers and streams, as well as palustrine wetlands, were the most frequently examined types of wetlands of the 56 studies reviewed. More specifically, 23 of these studies focused on riverine wetlands, while 17 centered on palustrine wetlands (inland wetlands/marshes). In addition, 14 of the studies investigated lacustrine wetlands (associated with ponds), seven focused on marine wetlands (where the river meets the ocean), and two studies addressed estuarine wetlands (coastal areas). This distribution highlights the predominant interest in riverine and palustrine wetlands, when compared to other wetland types; this can be attributed to the fact that communities often rely

on riverine and palustrine wetlands for their various livelihoods (Zingstra et al. 2010). Figure 3.4(b) shows the anthropogenic activities that were occurring in the wetlands evaluated in the retrieved literature. Agriculture was the most significant driver of wetland degradation, followed by population growth, overexploitation, climate change and pollution. While agricultural activities remain the most significant anthropogenic drivers affecting wetlands, a comprehensive understanding of all the contributing practices is essential for developing effective conservation strategies. These findings underscore the complex interplay between human activities and wetland health, which highlights an urgent need for sustainable management practices.

Figure 3.4(c) shows that most of the studies focused on wetlands that were located in rural areas, followed by peri-urban areas, and lastly, urban areas. This can be attributed to the fact that rural populations are more dependent on wetland ecosystems for their livelihoods, which leads to more focus on sustainable practices (Gardner and Finlayson 2018). In addition, rural communities often engage in agriculture and fishing, which makes them more likely to be concerned if these ecosystems are managed sustainably, and it makes their perceptions relevant in sustainability discussions. Peri-urban wetlands, where rural and urban influences meet, face unique challenges due to rapid development, which has led to studies that explore how communities adapt to these changes (Alikhani et al. 2023). Furthermore, urban wetlands are often degraded and overlooked, which has resulted in fewer research studies on the perceptions of the communities in these areas.



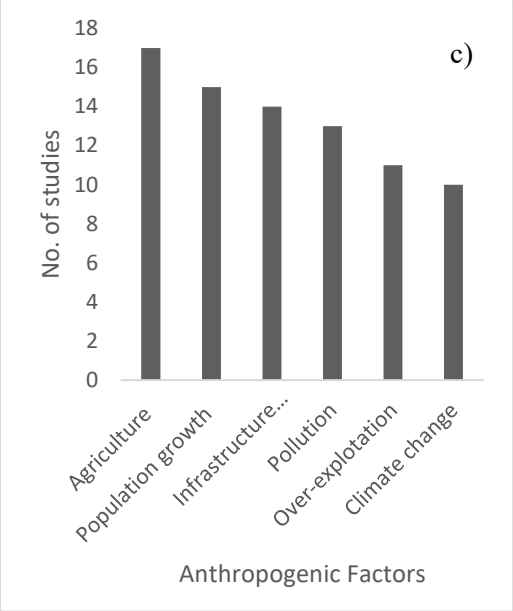


Figure 3-4: (a) Different types of wetlands, (b) their location, and (c) the dominant anthropogenic activities surrounding them, as identified in the reviewed studies

Figure 3.5 illustrates the agricultural practices that were identified in wetlands that were covered in the retrieved studies. Crop farming was the most prevalent activity among local communities, with fishing and grazing also playing a crucial role in their livelihoods. These activities illustrate an interconnection between human activities and wetland ecosystems (Zedler and Kercher 2005), and they highlight the importance of sustainable management approaches that consider both the ecological health and the community needs. Crop production and fishing are often seen as primary sources of their food security, income and employment.

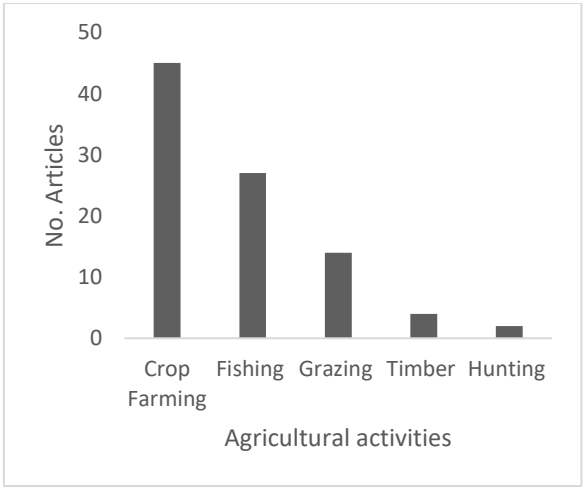


Figure 3-5: Agricultural practices in wetlands are dominant around the wetlands studied in the reviewed literature

3.3.4 Community perceptions on wetland conservation in reviewed studies

The analysis was of the community perceptions regarding wetland management across 51 studies. Figure 3.6(a) shows the demographics of the participants, which reveal that most of the reviewed literature focused on the general local community members, followed by farmers (smallholder or commercial), and lastly, various stakeholders, such as Non-Governmental Organisations (NGOs), government officials and specialists. This trend can be attributed to the local communities relying on these ecosystems for their livelihoods and cultural practices (Bhattacharya et al. 2024). In addition, they are more directly dependent on them for essential resources, such as water, food security and materials for shelter.

Figure 3.6(b) below shows the ecosystem services that were perceived to be derived from the wetlands in the retrieved literature. The ecosystem service most recognised by the communities surrounding wetlands included the provision of food through fishing and crop farming. Most studies showed that local communities benefit mostly in terms of crop farming and fishing from the wetlands, which is vital for both their diets and the economy (Berg et al. 2017, Everard 2016, Shah 2023, Sumatra). Wetlands provide fertile soil, which supports small-scale and subsistence agriculture. For instance, crops such as cabbages and indigenous plants, such as sweet potatoes, thrive in the moist soils found in wetlands (Biebighauser 2015). Agriculture is important for improving the households' food security.

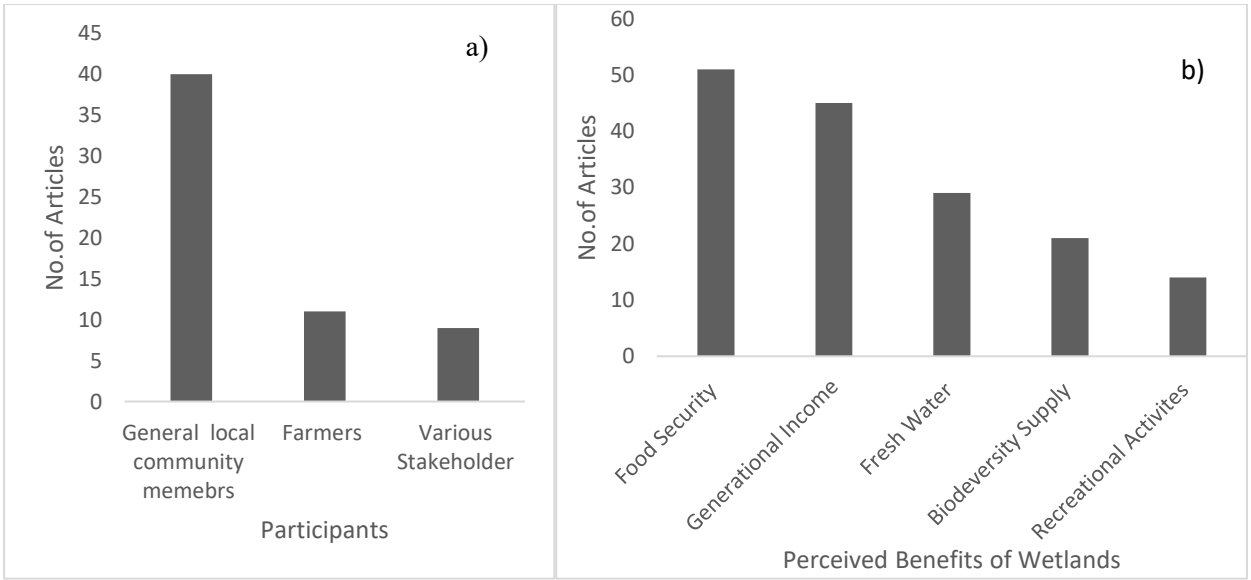


Figure 3-6: (a) Demographics of participants, (b) ecosystem services or benefits perceived by community members in the retrieved literature

Regarding the level of awareness of wetland degradation and conservation, most of the community members in 30 studies were highly aware of this and expressed their positive perceptions towards the sustainable utilisation of wetlands (Figure 3.7(a)). In contrast, 14 studies reported a neutral attitude. Twelve studies indicated negative perceptions towards the conservation methods. For example, one community believed that their livelihoods were unlikely to be affected by changes in the wetlands, and they viewed the wetlands as wastelands or unused spaces (Dalu et al. 2022). Furthermore, communities are primarily focused on the benefits that they receive from wetlands and do not consider their degradation to be a significant concern (Rebelo et al. 2010). This may stem from a lack of involvement or understanding of how wetlands function ecologically, which can lead to indifference towards the conservation methods. Such detachment often occurs when a community is not actively involved in or dependent on wetlands due to development, which results in a disconnect between their daily lives and the need for conservation (Røskaft 2018). For example, Sinthumule and Netshisaulu (2022) highlighted that while rural communities in South Africa recognise the importance of wetlands in their daily livelihoods, many still hold a neutral or indifferent attitude, due to their limited engagement in conservation efforts. Furthermore, negative attitudes arise from various issues, including past conflicts over land use, misunderstandings about the importance of wetlands, and competing economic interests that focus on short-term profits rather than long-term sustainability. In addition, other factors influence their perceptions, including their education level, socio-economic factors, demographic characteristics and competing economic interests (Figure 3.7(b)).

The majority of the studies reviewed demonstrated that education and socioeconomic factors (income levels, employment status and food security) are the most influential factors that shape the perceptions of communities on the sustainable utilisation of wetlands (Dalu, Mukhuwana, Cuthbert, Marambanyika, Gunter, Murungweni and Dalu 2022, Gómez Aíza et al. 2021, Zafeiriou et al. 2020). Formal education is crucial, as communities with a higher education levels are more aware of the benefits of wetlands and the importance of conservation, which results in a more positive attitude. Conversely, those with lower education levels lack access to knowledge about sustainable practices and the importance of conservation, which leads to their neutral or negative attitudes concerning conservation (Shrestha 2011). Furthermore, their economic status also plays a crucial role (Aazami and Shanazi 2020, Al-Amin et al. 2021) . Communities that depend solely on the wetland for their livelihoods often prioritise their immediate financial needs over conservation, which creates a conflict of interest (Kadoma et

al. 2023).

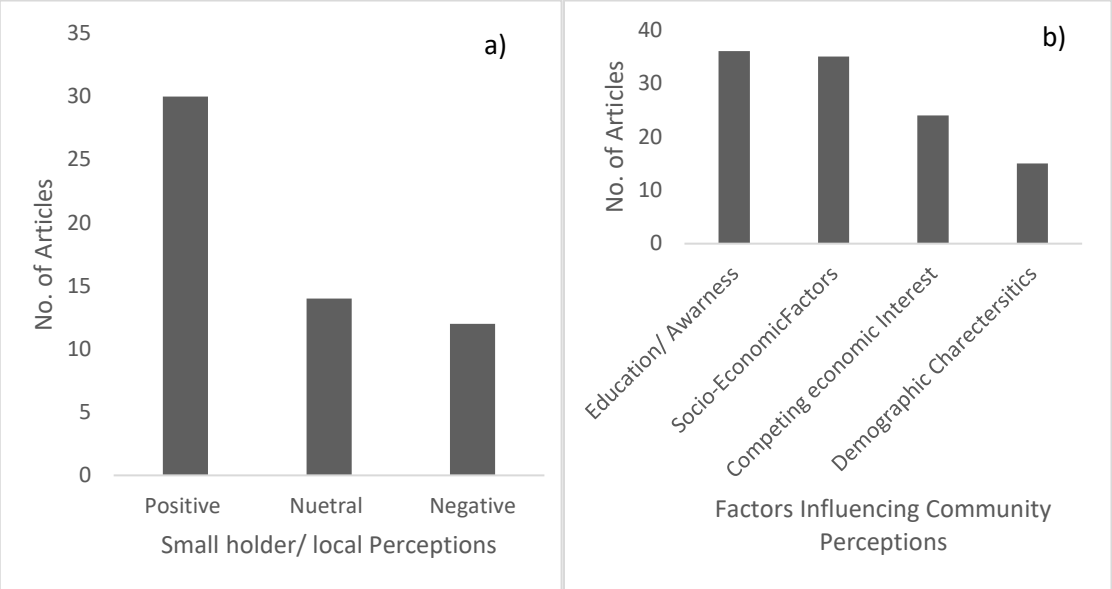


Figure 3-7: (a) Communities' attitudes and perceptions regarding wetland conservation and degradation, and (b) the factors influencing these perceptions, as reported in the reviewed literature

With regard to perceived challenges/anthropogenic factors that were pointed out in the reviewed literature (Figure 3.8), agricultural expansion was perceived to be the primary challenge to the sustainable use of the wetlands, followed by population growth, climate change, infrastructure development and pollution from waste dumping. These results can be attributed to agricultural activities, which often lead to land conversion, which results in habitat loss and the degradation of wetland ecosystems. Furthermore, research indicates that agriculture is the major driver of wetland loss globally (Kundu et al. 2024, Villar 2014). In addition, population growth increases the demand for food and land, which puts more pressure on wetlands, as the communities seek to expand their agricultural production to meet their needs (Alavaisha 2020). Climate change is a contributing factor to those communities that practise unfriendly eco-farming, and it poses a threat by altering the hydrological patterns and increasing the vulnerability of the wetlands to extreme weather conditions (Verhoeven and Setter 2010). Collectively, these challenges highlight the urgent need for collaborative management strategies that balance the agricultural demand with the preservation of wetland ecosystems.

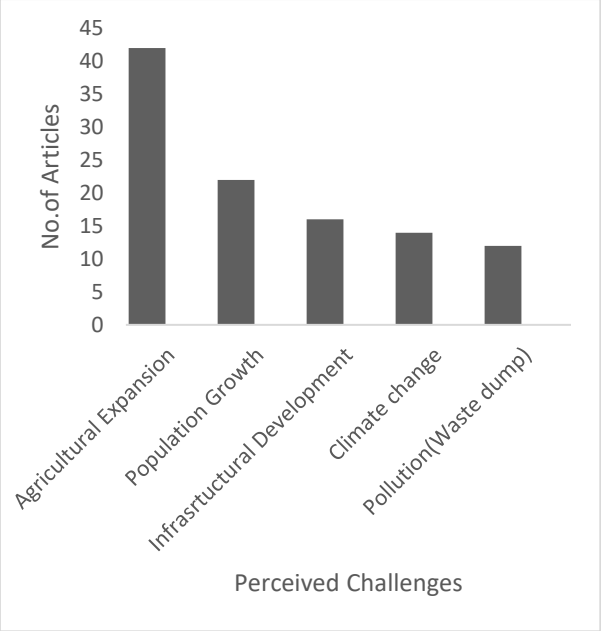


Figure 3-8: Perceived challenges to wetland conservation as reported in the reviewed literature

Figure 3.9 shows the management strategies that were pointed out by the communities that were examined. In most of the reviewed literature, communities indicated that wetlands could be managed by means of effective government regulations, increased agroecological awareness, education and community-based initiatives. Government regulations are perceived to be essential because they provide a structured framework for wetland management, which will ensure that conservation efforts are enforced and that local communities are aware of these regulations (Truong 2021). Most retrieved studies indicated that community members often lacked formal education about agroecological practices. Therefore, they revealed that the communities perceived education and awareness as crucial strategies for effective wetland management. They advocated for integrating the traditional knowledge of local communities and actively engaging with local community members in decision-making processes, which will lead to improved conservation outcomes (Sinthumule 2021).

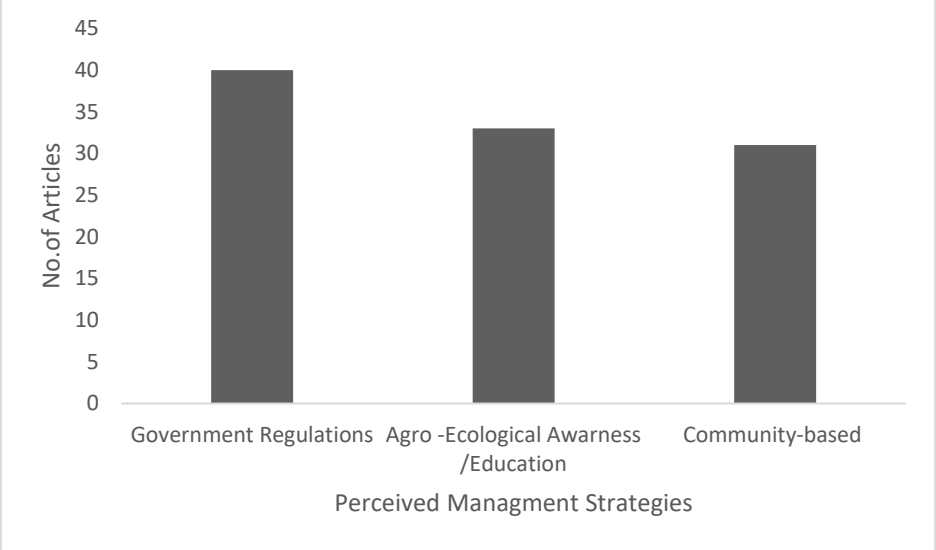


Figure 3-9: Perceived management strategies

3.4 Discussion

The objective of this study was to systematically review the literature on wetland utilisation practices in different regions by focusing on the community perceptions and strategies for sustainable management.

3.4.1 Progress in the literature on wetland utilisation practices and community perceptions for sustainable management.

Results showed that most of the studies that evaluated community engagement in wetland management, particularly where communities depend on these wetlands for agricultural activities and food production, were conducted in developing countries such as India and Uganda. This can be attributed to the fact that India and Uganda are home to significant wetland ecosystems that play a critical role in supporting diversity, agriculture and local livelihoods. For instance, wetlands in Uganda are essentially for community sustenance, and they offer vital resources, such as fish, water and fertile soil for agricultural practices (Kadoma, Perry and Renaud 2023). Research conducted in the Wakiso District revealed that these ecosystems are facing over-exploitation, due to the escalating human demands. Therefore, the lack of alternative livelihoods makes the community heavily reliant on the wetlands. Agricultural expansion, due to population growth and food demand, frequently results in the drainage of the wetlands for crop production, which significantly alters the hydrological regimes and leads to biodiversity loss (Galatowitsch 2018). In additionally, agricultural practices often lead to land conversion, nutrient loss and habitat destruction. Meanwhile, the high population density in

Myanmar has led to an increased food demand, which has resulted in the improper management of the wetlands, as communities strive to sustain their livelihoods (Saluja, Prasad, Lwin, Soe, Pottinger-Glass and Piman 2023). According to Kugonza (2023), this reliance on agriculture leads to increased pressure on the wetlands, particularly through practices such as land conversion, pesticide use and nutrient runoff, which eresults in habitat destruction and the loss of biodiversity. These findings highlight the significant reliance of these communities on agricultural activities for their sustenance and economic stability.

Furthermore, the results demonstrated that there has been a significant increase in the frequency of studies that focus on the perceptions of communities regarding the utilisation of wetlands in developing countries. This can be attributed to a growing concern over wetland degradation, a growing environmental awareness, and an increasing number of policy and conservation initiatives (Frenken and Mharapara 2000). In order to better understand and manage our wetlands, lessons can be drawn from developed regions by researching how they manage their wetlands properly and integrate their strategies locally.

3.5 Evaluation of Wetland Types and their Utilisation Patterns

The results illustrated that the dominant wetlands covered in the literature were floodplain wetlands (riverine and palustrine). This could be attributed to their exceptional ecological productivity and significance. Floodplains are among the most productive ecosystems globally, because they support a rich biodiversity and provide essential services, such as water filtration, flood regulation and a habitat for various species (Dixon and Carrie 2016, Shah and Atisa 2021). In addition, their fertile soils and high moisture content make them suitable for agriculture, which further highlights their importance. This combination of ecological and agricultural value makes them a focal point in research and conservation efforts (Waltham et al. 2019).

Meanwhile, the major anthropogenic activities that drive their utilisation patterns were noted to be agriculture, population growth and the subsequent development of infrastructure. In such contexts, communities often rely heavily on wetlands for their survival and livelihoods. The significant focus on Uganda and India in the wetland studies in this review reflect the pressing socio-economic challenges that these developing nations face. Developing countries experience a substantial population growth, which results in an intensifying dependency and pressure on natural resources, including the wetlands. More especially, agriculture is the primary driver of wetland degradation, as communities engage in intensive crop farming, fishing and grazing (Gardner and Davidson 2011). Furthermore, the conversion of wetlands for

agricultural use is concerning, because it not only reduces the biodiversity, but it also disrupts the essential ecosystem services (Sandhu 2016). In addition, the studies show that the process of developing wetlands for agricultural use can result in pollution from pesticides, fertilisers, and wastewater, which disrupt the normal functioning of wetland ecosystems and deplete the water resources in the surroundings (Gu and Jiang 2023). For example, wetlands in Uganda have been subject to high levels of conversion, due to increasing agricultural demands, with reports indicating a reduction in the wetland area from 15% in 1994 to less than 9% by 2018 (Kadoma, Perry and Renaud 2023).

In addition, the high unemployment rates increase the situation further, as communities seek an alternative means of sustenance through activities, such as agriculture and fishing (Shrestha 2011). A study conducted by Marambanyika, Beckedahl and Ngetar (2017) that examined methods for the sustainable use of wetlands within communities, highlighted the significance of participatory management strategies that are cost-effective and adapted to the local requirements. The results indicated that a majority of households (91.9%) depended on wetland agriculture to ensure their food security, particularly due to the absence of formal employment opportunities (Marambanyika, Beckedahl and Ngetar 2017). The reliance on wetlands for food security and economic stability underscores the importance of understanding the local perceptions and practices concerning wetland management.

The results also showed that most of the reviewed studies used a mixed methods approach when evaluating the perceptions of the communities regarding wetland management. The use of mixed methods in studies combining qualitative interviews and quantitative questionnaires and surveys has been demonstrated to be effective in capturing a comprehensive understanding of the community's perceptions and their behaviours toward wetland management. This is supported by the studies of both Zina (2021) and Pole (2007), who stated that the mixed method approach provides a holistic understanding of the topic, as the limitation of one method can be balanced by the strength of the other. This method also helps researchers to address both confirmatory and exploratory questions simultaneously.

3.6 An Evaluation of Community Awareness and Perceptions of Wetland Degradation and the Need for their Sustainable Utilisation

Furthermore, the results reveal that most communities that were studied were aware of wetland degradation and had a positive attitude toward wetland management. This implies that community members are aware of the importance of wetlands, which suggests that there is a

strong connection between the community and the wetlands, which motivates them to adopt practices that are aimed at preserving their wetlands (Baylan 2023, Gosling et al. 2017, Nelson et al. 2017). This aligns with a study by Shrestha (2011), which highlights the critical relationship between community engagement and effective wetland management. The findings suggest that when communities are informed about the ecological and economic benefits provided by wetlands, they are more likely to participate actively in conservation efforts (Dixon and Carrie 2016, Obradović et al. 2023) This is supported by other studies that revealed a generally positive perception among smallholder communities regarding wetland management. For instance, a study conducted by Truong (2021) in Vietnam demonstrated that local villagers typically had a positive attitude and perception towards wetland management, largely due to their awareness of the benefits that these ecosystems provide, which results in their improved livelihoods and the resilience of these ecosystems. One example of their positive perception was when they expressed that they would preserve and protect the wetland because they want their children, grandchildren and future generations to benefit as they have benefited from the wetland (Truong 2021). The study highlighted that when communities recognise the direct benefits of wetlands, such as sustainable fishing opportunities and enhanced agricultural productivity, they become more inclined to engage in conservation practices (Truong 2021).

Meanwhile, in Uganda, community members perceived wetland ecosystems as critical natural resources and fertile land for agriculture (Kadoma, Perry and Renaud 2023). These results foster a sense of ownership of these ecosystems, which motivates local communities to advocate for their conservation. Kadoma, Perry and Renaud (2023) revealed that community members did not view these ecosystems as mere resources to exploit, but rather as assets. This suggests that they truly supported the conservation initiatives. In addition, a study by Saluja, Prasad, Lwin, Soe, Pottinger-Glass and Piman (2023) that was conducted in Myanmar noted that community-based conservation strategies were more effective when they aligned with the local needs and expectations. This suggests that community-based conservation strategies should be advocated for, as they are not only inclusive, but they also cultivate a sense of ownership and responsibility to the community. In addition, the positive attitudes and perceptions in the retrieved literature stem from an understanding of the importance of wetlands, including the floodplain wetlands, with active involvement in the decision-making process. Such engagement not only enhances the community support for conservation efforts, but it also fosters a deeper connection between the local communities and their natural environment.

However, the presence of neutral and negative perceptions raised important considerations for wetland management. Neutral responses implied a lack of understanding regarding wetland conservation. This suggests that there is a need and opportunity for enhanced education and outreach efforts to inform communities about the benefits and necessities of conservation (Truong 2021). For instance, Sinthumule and Netshisaulu (2022) observed that, while many respondents acknowledge the importance of wetlands, a portion remained neutral in their attitude, due to insufficient knowledge of the wide renage of the ecosystem services provided by wetlands, such as water purification, flood regulation nutrient cycling and support for the biodiversity. This lack of awareness hinders the community's engagement in conservation efforts, as individuals may not fully understand how these ecosystem services directly contribute to their livelihoods and overall well-being (Sinthumule and Netshisaulu 2022).

On the other hand, the negative perceptions in the literature stem from previous negative experiences with conservation policies that were perceived as ineffective or exclusionary, and which have led to disruption among community members (Kadoma, Perry and Renaud 2023). In this regard, Røskaft (2018) highlighted that the negative perceptions often come from historical conflicts between local communities and policymakers. As reported by Røskaft (2018), many local respondents felt excluded from the decision-making processes regarding wetland management. Consequently, they did not see the value of preserving the wetlands, which has led to their desertification and the disruption of conservation initiatives (Røskaft 2018). Overall, studies that reported negative and neutral community perceptions regarding the sustainable utilisation of wetlands underscored the lack of awareness and information about the importance of wetlands, the conflicting economic interests and past grievances, as the causes of the negative perceptions among community members. Addressing these challenges is crucial for fostering collaboration between local communities and policymakers. In addition, addressing these issues requires comprehensive education programmes, inclusive decision-making processes, as well as policies that balance the economic needs with environmental sustainability.

3.7 Factors Influencing Perceptions of Community Members

Education and awareness were demonstrated to be among the key factors that influence the community's perceptions or attitudes toward wetland management in the retrieved literature. The findings of this study indicated that higher education correlated with an increased

awareness and positive perception of wetland management, which significantly influenced the conservation initiatives. The results of the study suggest that education enhances knowledge about the ecological importance of wetlands, which leads to more initiative-taking community engagement. A study conducted in the upper Chiwdin Basin of Maynar noted that educational programmes significantly impacted the respondents' awareness regarding local wetland conservation. Specifically, those with a higher education level demonstrated a greater understanding of the effectiveness of conservation measures, and they were reported to be more likely to support penalties for activities that are harmful to wetlands (Saluja, Prasad, Lwin, Soe, Pottinger-Glass and Piman 2023). In addition, Shah and Atisa (2021) highlighted that both formal and informal education were important in fostering community awareness and management of wetlands in Kenya. Furthermore, the lack of education was reported to often result in a negative attitude and misconception about wetlands, which contributed to the degradation of wetlands. Furthermore, a study conducted in South Africa revealed that respondents with a tertiary education were less reliant on wetlands for their basic needs, compared to those with a lower educational background (Sinthumule and Netshisaulu 2022). Thus, this indicates that educated individuals may have alternative resources or income sources, which allows them to prioritise wetland conservation over the immediate exploitation of wetland resources (Sinthumule 2021). Overall, the evidence suggests that enhancing educational opportunities related to wetland ecosystems can lead to improved community attitudes or perceptions toward conservation.

Competing economic interests were another factor influencing how local communities perceived the sustainable use of wetlands in the reviewed studies. In many areas, wetlands are vital for providing essential consumable resources, such as fish, crops, fresh water and resources (Rebelo, McCartney and Finlayson 2010, Zebardast et al. 2021). When these resources are prioritised for economic gain, communities may overlook the long-term benefits of wetland conservation, and they may manage the pressures to avoid extreme and negative impacts. For instance, a study from Chott Merouane in Algeria reported that local communities often found themselves in a struggle between different economic activities, such as agriculture, livestock production and salt mining (Demnati et al. 2012). This competition created tension among the community members, which led to conflicts over resource allocation. It was reported that this ultimately resulted in these ecosystems being viewed as sources of immediate profits, which compromised the health of the wetland ecosystems due to their overexploitation and degradation (Fatma et al. 2012). For instance, private landowners often convert wetlands to

agricultural or urban uses for higher short-term benefits, thereby ignoring the broader public benefits that wetlands provide (Heimlich 1998). Moreover, in areas where there were other activities, such as tourism or industrial development, communities viewed wetland conservation as a problem for economic growth (Ramachandra et al. 2005). This perception, or attitude, may lead to resistance against conservation initiatives and a lack of engagement in their sustainability. Therefore, these dynamics highlight how varying economic interests shape the local attitudes and perceptions of the sustainable use of wetlands. For instance, if a community perceives the wetland primarily as a challenge to farming or urban development, it may resist conservation initiatives, and it may have a negative perception or attitude concerning the sustainable utilisation of these ecosystems (Oellermann 1994). On the other hand, when the community recognises the wetlands as valuable resources that offer essential services, they are likely to have a positive attitude toward wetland conservation initiatives.

Another factor that influences the perception of locals regarding the sustainable utilisation of wetlands is the socioeconomic factors, such as their income levels and demographic characteristics (Biswas et al. 2010). Higher-level incomes are often linked to resilience and resourcefulness, which result in an increased awareness of environmental issues and a positive attitude toward the sustainable utilisation of wetlands. Communities with more financial resources typically have better access to education and information about the ecological benefits of wetlands. For example, a study conducted in rural India found that participants with a higher education level were more aware of the functions of wetlands and their significance to the local economy (Biswas, Samal, Roy and Mazumdar 2010). This awareness fosters supportive and positive attitudes or perceptions, as these individuals recognise the long-term advantages of preserving the wetlands for future generations (Ake 2023). However, economically disadvantaged communities with a limited income may prioritise their survival needs over environmental concerns. In areas where wetlands are essential for livelihoods, such as fishing and crop farming, economically disadvantaged communities may view conservation initiatives as barriers and a threat to their economic survival. This perspective is often associated with conservation efforts that restrict access to vital wetland resources, which potentially increases poverty and limits economic opportunities. For example, a study conducted Ntupwa et al. (2012) in the little Ruaha sub-catchment in Tanzania, noted that community members relied heavily on wetland resources for their daily subsistence, which generated a negative attitude and perception towards conservation methods that restricted their access to these ecosystems (Brander and Schuyt 2004).

Demographic characteristics, such as age, gender and household composition, were also highlighted in the literature as factors that influence an individual's perception regarding the sustainable utilisation of wetlands. The literature highlighted that young people are seen as key drivers of change in conservation, that they are capable of proposing innovative approaches and engaging their peers in sustainability initiatives, as well as generating effective educational campaigns (Aprile and Punzo 2023). This stands in contrast with the older generation, who often prioritise the traditional methods that have served them well in the past. While their methods may have been effective historically, they might need to be integrated into the recent advancements in order to effectively address a new and current era of ecological challenges, thus resulting in resistance against new conservation initiatives. This generational difference highlights how varying experiences and values may influence the community's attitudes toward sustainable wetland utilisation. In addition, gender plays an important role in wetland management, as women are often directly involved in managing the resources from these wetland ecosystems, but they frequently lack representation in the decision-making (Abillah et al. (2021). This lack of involvement in decision-making leads to the exclusion of their invaluable insights. For example, Nigussie et al. (2024) noted that when women are included in the decision-making process, they tend to have a more positive attitude toward sustainable wetland management, as they are being recognised and valued. However, without their voice, communities may miss important perspectives that could improve resource management and positive attitudes and perceptions in wetland management. In a related study in the Vhembe Biosphere Reserve, Dalu, Mukhuwana, Cuthbert, Marambanyika, Gunter, Murungweni and Dalu (2022) noted that gender and educational attainment effectively explained the community's knowledge and attitudes toward wetlands. Similarly, Chuma Basimine et al. (2024) in South Kivu, the Democratic Republic of Congo, demonstrated that the perspectives of the community varied in relation to their gender and religion, as well as their seniority in wetland use, land tenure and educational level. These findings highlight the importance of incorporating demographic aspects when developing and implementing wetland conservation strategies.

Findings from the review of literature highlighted challenges, such as a lack of information, historical grievances and competing economic interests as contributing factors to negative attitudes and perspectives. Saluja, Prasad, Lwin, Soe, Pottinger-Glass and Piman (2023) noted that 97% of participants in Myanmar's Chindwin Basin reported that they were not aware of any existing laws or regulations that protected wetlands, and 87% were of the view that the

government did not effectively promote awareness regarding wetland conservation in rural community areas. In another study, Demnati, Allache, Ernoul and Samraoui (2012) noted that economic activities, including crop and livestock production and salt mining, conflicted with the wetland conservation efforts, influenced the communities to prioritise the immediate economic benefits over the long-term environmental sustainability in Algeria's Chott Merouane region. To foster a positive attitude and sustainable practices, specific education and inclusive management strategies should be implemented. Furthermore, promoting sustainable wetland management that strikes a balance between ecological sustainability and economic needs requires an understanding of the socioeconomic dynamics. Therefore, these results underscore the importance of incorporating community perspectives into wetland management strategies. Engaging local stakeholders not only deepens their understanding but also cultivates a sense of ownership regarding the conservation efforts (Kadoma, Perry and Renaud 2023). Successful wetland management requires a collaborative approach that considers the needs and values of local communities, while promoting sustainable practices. Furthermore, more success and sustainability can be attained by conservation programmes by actively including community members in the decision-making and giving them the tools and training that they need (Shrestha 2011).

3.8 Recommendations

Based on the findings from the systematic review of community perceptions and behaviour regarding wetland management, the following recommendations can be made to enhance the effectiveness of conservation efforts and to address the identified gaps:

- It is essential to foster greater community involvement in wetland management decision-making;
- Given that some studies revealed neutral and negative perceptions towards wetland management, it is recommended that targeted outreach and education programmes are developed, which focus on raising awareness about the ecological and economic benefits of wetlands, as well as the existing laws or regulations, to ensure their protection;
- There is a need to generate educational materials that are presented in the local languages and designed to dovetail with the existing indigenous knowledge systems, beliefs and cultures;

- There is a need for longitudinal studies that will track the changes in community perceptions and behaviour over time. Such research efforts will provide an insight into how attitudes change in response to conservation initiatives, socio-economic changes and environmental impacts;
- Collaborative approaches that respect and integrate traditional knowledge into wetland practices can enhance sustainability initiatives;
- Addressing socio-economic challenges, such as unemployment and food insecurity, through alternative livelihoods and sustainable agricultural practices can improve a community's attitude towards wetland management and reduce pressure on the wetlands; and
- Policymakers must provide the resources and funding to address challenges that hinder the sustainable practices of wetland management in local communities.

3.9 Conclusion

In conclusion, this systematic review has emphasised how important community perceptions are in guiding sustainable wetland management practices. While many communities show a positive perception toward conservation efforts, the existence of neutral and negative attitudes highlights the need for focused initiatives that promote engagement and education. Furthermore, it is crucial to also focus on the factors that influence community perceptions and to develop strategies that encourage a positive attitude towards conservation. Most studies concentrated on developing countries, which points to a significant gap in research from other areas, which calls for a broader focus in future studies. By addressing these gaps and following the recommendations that are outlined, stakeholders can strengthen community involvement in wetland conservation, which will result in the more effective and sustainable management of these essential ecosystems.

Overall, addressing these concerns will require a balanced approach that integrates and considers environmental conservation with the socio-economic needs of the local population. Involving communities in the decision-making processes and developing alternative livelihood strategies will also help to ensure that conservation initiatives are both effective and equitable. This approach fosters community support and promotes the sustainable management of wetland resources.

4 GOVERNANCE CHALLENGES AND POLICY EFFECTIVENESS IN WETLAND MANAGEMENT: A SYSTEMATIC REVIEW ACROSS AFRICA

4.1 Introduction

In Africa, wetlands provide a wide range of benefits, such as water for domestic use and agriculture, a location for fishing and animal grazing, as well as supporting cultural and ecotourism activities, which makes them an important ecosystem for supporting millions of people (Musasa et al., 2023). Despite their importance, wetlands across several African countries are increasingly under stress, as they are threatened by climate change and human activity, such as urbanisation, overgrazing, overcultivation, pollution and the over-extraction of vital natural resources (Mwakaje 2009). Wetlands, particularly in Africa, experience immense pressure from drainage for agriculture and human settlement (Garba et al., 2025), with this pressure being expected to increase further as the population continues to grow. Wetlands will continue to face threats, unless strategic plans are adopted to conserve and protect this vital ecosystem.

In response to these challenges, several African countries have introduced laws, policies and management frameworks that are focused on protecting wetlands and promoting their sustainable use and management. However, whether these policies are achieving their intended goals remains unclear. While wetland policies exist across several countries, such as South Africa, Ghana, Ethiopia and Tanzania, they are often reported as being poorly implemented, inadequately enforced or disconnected from the local reality. Other studies have identified multiple factors that hinder the successful implementation of policies across regions (Saluja, 2023; Nyumah & Brambilla, 2025). Taken together, these studies suggest a need for a systematic understanding of how the policies are implemented and experienced across different contexts.

Despite the existence and general idea of policies for protecting and managing wetlands, their successful implementation and effectiveness are yet to be seen. Although several studies and a growing body of research have examined the governance and management of wetlands in Africa (Ostrovskaya et al., 2013; Mkonda, 2022), most of this research does not systematically analyse the effectiveness of policy and governance across different African countries. There have been limited systematic analyses of policy efficacy, as most research focuses on specific

wetlands and countries, which makes it difficult to draw broader conclusions on the performance of wetland management policies in Africa. To address this gap, this study systematically reviews the existing literature on wetland management in Africa. It aims to assess the efficacy of the wetland management policies and laws. The aim of this review is to synthesise the existing literature in order to comprehend how wetland management is governed across different levels, what barriers hinder the implementation of policies and how stakeholder involvement influences the management outcomes. By synthesising these findings and gaining insights into this nuanced subject, this review paves the way for understanding the complexity of the policy landscape that surrounds African wetlands, while informing future research by providing evidence-based recommendations that support effective and sustainable wetland management policies.

4.2 Materials and Methods

This systematic literature review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) as a guideline for collecting data, as it is the standard methodology that ensures a quality review and replication process (Tedja et al., 2024).

The main online databases with large academic study repositories were selected to search for relevant literature, namely Scopus, the Web of Science and PubMed. Firstly, relevant keywords were identified and then combined with Boolean operators to produce search strings that were utilised to search for the relevant literature. The keywords used were “floodplain”, “wetland”, “polic(y)”, “strategy (y)” and “framework”, the Boolean operators “AND” and “OR”, along with the listing of all 54 African countries to restrict the search to studies within the African continent. The search strings (Figure 4.1) were adapted to each database in order to align with the specific indexing systems of each database.

Scopus

((("Floodplain" OR "Wetland") W/5 (polic* OR strateg* OR framework)) AND ("Algeria" OR "Angola*" OR "Benin" OR "Botswan*" OR "Burkina Faso" OR "Burundi" OR "Cabo Verde" OR "Cameroon" OR "Central African Republic" OR "Chad" OR "Comoros" OR "Democratic Republic of Congo" OR "DRC" OR "Djibouti" OR "Egypt" OR "Equatorial Guinea" OR "Eritrea" OR "Eswatini" OR "Swaziland" OR "Ethiopia" OR "Gabon" OR "Gambia" OR "Ghana" OR "Guinea" OR "Guinea-Bissau" OR "Ivory Coast" OR "Côte d'Ivoire" OR "Kenya" OR "Lesotho" OR "Liberia" OR "Libya" OR "Madagascar" OR "Malawi*" OR "Mali" OR "Mauritania" OR "Mauritius" OR "Morocco" OR "Mozambique" OR "Namibia" OR "Niger" OR "Nigeria" OR "Republic of Congo" OR "Rwanda" OR "Sao Tome and Principe" OR "Senegal" OR "Seychelles" OR "Sierra Leone" OR "Somalia" OR "South Africa" OR "South Sudan" OR "Sudan" OR "Tanzania" OR "Togo" OR "Tunisia" OR "Uganda" OR "Zambia" OR "Zimbabwe"))

Web of Science

(((("Floodplain" OR "Wetland") NEAR/5 (polic* OR strateg* OR framework)) AND ("Algeria" OR "Angola*" OR "Benin" OR "Botswan*" OR "Burkina Faso" OR "Burundi" OR "Cabo Verde" OR "Cameroon" OR "Central African Republic" OR "Chad" OR "Comoros" OR "Democratic Republic of Congo" OR "DRC" OR "Djibouti" OR "Egypt" OR "Equatorial Guinea" OR "Eritrea" OR "Eswatini" OR "Swaziland" OR "Ethiopia" OR "Gabon" OR "Gambia" OR "Ghana" OR "Guinea" OR "Guinea-Bissau" OR "Ivory Coast" OR "Côte d'Ivoire" OR "Kenya" OR "Lesotho" OR "Liberia" OR "Libya" OR "Madagascar" OR "Malawi*" OR "Mali" OR "Mauritania" OR "Mauritius" OR "Morocco" OR "Mozambique" OR "Namibia" OR "Niger" OR "Nigeria" OR "Republic of Congo" OR "Rwanda" OR "Sao Tome and Principe" OR "Senegal" OR "Seychelles" OR "Sierra Leone" OR "Somalia" OR "South Africa" OR "South Sudan" OR "Sudan" OR "Tanzania" OR "Togo" OR "Tunisia" OR "Uganda" OR "Zambia" OR "Zimbabwe")))

Pubmed

(((("Floodplain" OR "Wetland") AND (polic* OR strateg* OR framework)) AND ("Algeria" OR "Angola*" OR "Benin" OR "Botswan*" OR "Burkina Faso" OR "Burundi" OR "Cabo Verde" OR "Cameroon" OR "Central African Republic" OR "Chad" OR "Comoros" OR "Democratic Republic of Congo" OR "DRC" OR "Djibouti" OR "Egypt" OR "Equatorial Guinea" OR "Eritrea" OR "Eswatini" OR "Swaziland" OR "Ethiopia" OR "Gabon" OR "Gambia" OR "Ghana" OR "Guinea" OR "Guinea-Bissau" OR "Ivory Coast" OR "Côte d'Ivoire" OR "Kenya" OR "Lesotho" OR "Liberia" OR "Libya" OR "Madagascar" OR "Malawi*" OR "Mali" OR "Mauritania" OR "Mauritius" OR "Morocco" OR "Mozambique" OR "Namibia" OR "Niger" OR "Nigeria" OR "Republic of Congo" OR "Rwanda" OR "Sao Tome and Principe" OR "Senegal" OR "Seychelles" OR "Sierra Leone" OR "Somalia" OR "South Africa" OR "South Sudan" OR "Sudan" OR "Tanzania" OR "Togo" OR "Tunisia" OR "Uganda" OR "Zambia" OR "Zimbabwe")))[tiab:~5]

Figure 4-1: Search strings used in literature search

The results were produced after inputting each string into its respective database. Scopus retrieved 131 articles, the Web of Science retrieved 78 and PubMed had 165 articles, which amounted to a total of 383 studies for the initial literature search (see Figure 4.2). All obtained material from the databases was extracted and imported into Covidence, an online tool that is used for conducting efficient literature reviews. The following steps of the review were conducted within Covidence: title and abstract screening, as well as full-text screening and data extraction. After the import of articles, a total of 66 duplicates were eliminated, which left 317 studies, which were then taken to the next phase of title and abstract screening, where the studies were deemed suitable by reading the title and abstract of each article.

For studies to be considered for this review, the articles had to meet the following criteria:

- they had to be examined the effectiveness, governance or implementation of wetland management policies;
- they had to be published in peer-reviewed journals;
- they had to be available in full text; and
- they had to be written in English

Studies were excluded if they focused on wetlands outside the African continent and were not accessible. To ensure a comprehensive overview of the effectiveness of wetland policy across the African continent, the review included studies from all African countries, regardless of their regional grouping. This extensive scope was necessary to capture the diversity of wetland governance, to highlight the regional differences and to allow for comparisons across the different countries. This allows for the review to examine the policy effectiveness across Africa, and not just one subregion. In addition, this search was not restricted to a specific time-frame. This was done to avoid excluding studies that analysed policies that remain currently relevant. Most African countries remain under old legal regimes or that still struggle with long-standing governance issues that were first identified in earlier studies. Including a range of publication dates enables the review to track not only the current policy dynamics, but also the persistent challenges and evolving governance over the years.

After the title and abstract screening of the 317 studies, 275 were excluded, leaving a total of 42 studies that were assessed for eligibility and passed through to the full text screening phase. For the full-text screening, the articles were downloaded as PDFs and uploaded into Covidence. Of the remaining studies, 12 were excluded from the review.

A total of five studies were manually selected and included through citation searching, a process in which additional studies are identified by examining the reference lists of studies that are already included in the systematic literature review. After the full text screening, a final number of 30 studies were selected for review. Thereafter, a data extraction template was developed and used to collect key information from each study, such as the author's name(s), the year of publication, the title of study, the country of study, the methodological approaches, the effectiveness of wetland policies and the barriers to successful implementation, among others. The extraction template was then used to extract the data, and was downloaded and stored on Excel. The steps undertaken in this review are presented in Figure 4.2 below.

During the data extraction phase, the data were organised neatly into categories in Excel. Using a descriptive and thematic synthesis approach, the data that were extracted were analysed. In order to summarise and report the publication trends, the location of the studies, the methodologies, governance levels and policy effectiveness, a descriptive analysis was utilised. A thematic synthesis, a method that is used to synthesise findings from multiple qualitative studies (Nicholson et al., 2016), was applied to the qualitative findings on the challenges to policy implementation, governance dynamics and more. The results were presented in charts, tables and maps to provide a clear visual summary of findings.

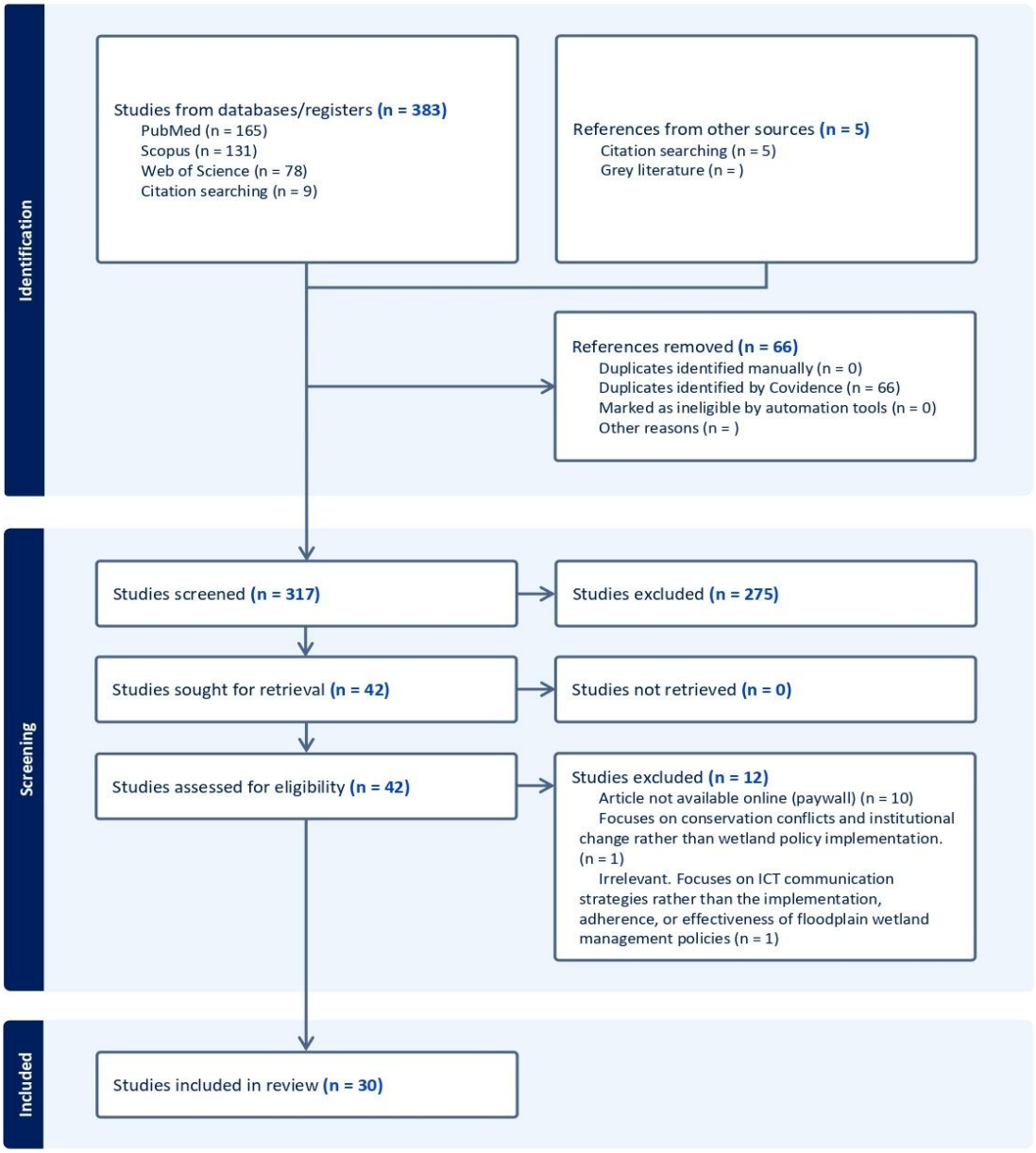


Figure 4-2: PRISMA flow diagram followed in the selection of the studies included in this review

4.3 Results

4.3.1 Geographic distribution of studies

The studies included in the systematic review originated from nine African countries, namely Ethiopia, Ghana, Malawi, Nigeria, South Africa, South Sudan, Tanzania, Uganda and Zimbabwe. As illustrated in Figure 4.3, the studies were geographically concentrated in specific regions, with southern Africa (South Africa, Zimbabwe and Malawi) and eastern Africa (Ethiopia, Tanzania, and Uganda) being featured most prominently. In contrast, there are limited studies stemming from West and Central Africa.

The country with the most studies is Zimbabwe, with seven studies (Mandishona & Knight, 2022; Marambanyika & Beckedahl, 2016; Marambanyika & Beckedahl, 2017; Marambanyika, et al., 2017; Mwonzora, 2022; Matamanda et al., 2018; Musasa et al., 2023), which accounts for 23% of the total publications. It is closely followed by Ethiopia (Dechasa et al., 2020; Dixon et al., 2021; Gebrehiwot, 2022; Odote, 2019; Tuji et al., 2024; Wondie, 2018) and South Africa (Banda et al., 2024; Dalu et al., 2022; Lemine et al., 2022; Libala et al., 2022; Ostro et al., 2013; Sinthumule, 2024), which both have six studies each, which account for 20% each. Just behind them is Tanzania with five studies (Hamisi et al., 2012; Lynch et al., 2016; Materu et al., 2018; Mwakaje, 2009; Ngowi & Mwakaje, 2020), which account for 17%. The number of studies published from these four studies accounted for 80% of the total retrieved articles. The other 20% is shared among Nigeria with two studies (Adekola et al., 2012; Akpabio & Umoh, 2021) and one study each in Ghana (Asomani-Boateng 2019), Kenya (Odote, 2019), Malawi (Kosamu, 2012), South Sudan (Mulatu, 2022) and Uganda (Turyahabwe et al., 2017).

Figure 4-3: Map showing the geographic distribution of studies

4.3.2 Publication trends

This review revealed a fair amount of academic attention given to wetland management and governance in Africa over the past decade, with a consistent number of studies being published between 2016 and 2021, with three studies in 2016, 2018, 2020 and 2023, and two from 2017 and 2019. A peak occurred in 2022 with a total of five studies published, as illustrated in Figure 4.4. Interestingly, between 2009 and 2015, only 5 studies were published across those years, with one study each in 2009 and 2013, and zero studies in 2010, 2011, 2014 and 2015.

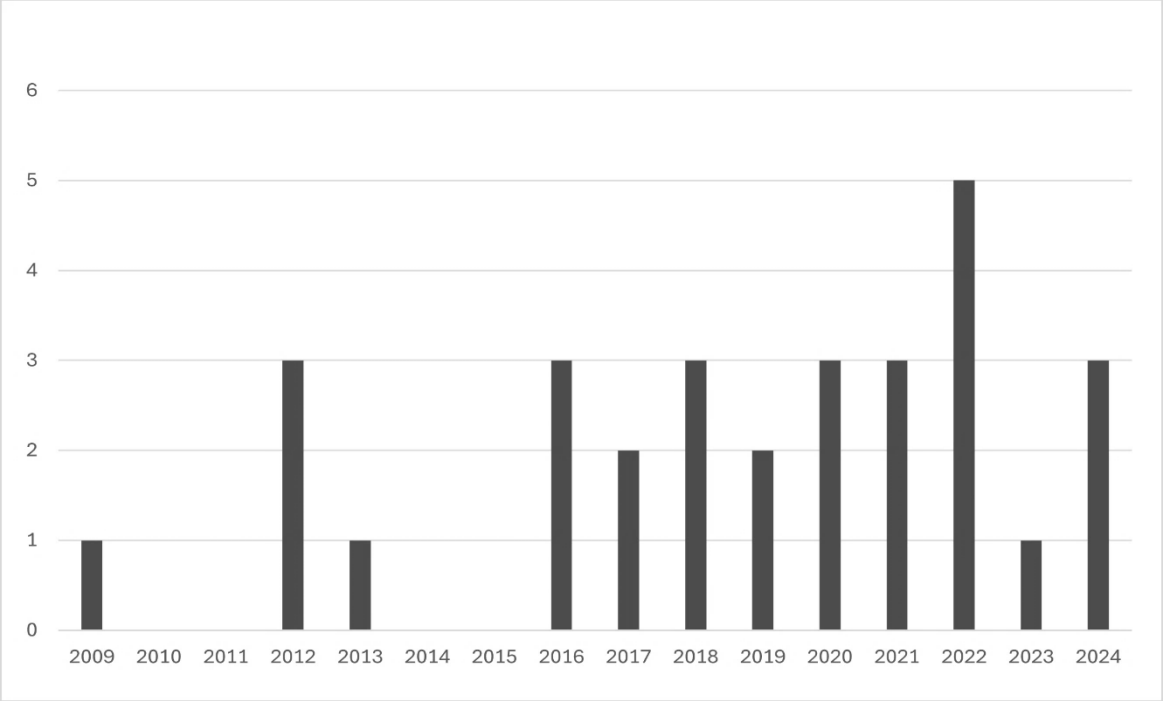


Figure 4-4: Chart revealing the number of studies published each year from 2009 to 2024

4.3.3 Research approaches utilised in literature

Based on Figure 4.5, a variety of methods were employed in the included studies. A mixed methods research approach was predominantly utilised out of the 30 studies that were selected for this review, which accounted for 53% (n=16) of the total literature. A mixed methods approach combines the quantitative and qualitative techniques, which allows for a more comprehensive understanding of the issues concerning wetland management (Saraswati and Devi 2023). Most of the studies that used a mixed methods approach blended the qualitative methods, such as in-depth interviews, focus groups or observations, with the quantitative methods, like land use cover and a change analysis.

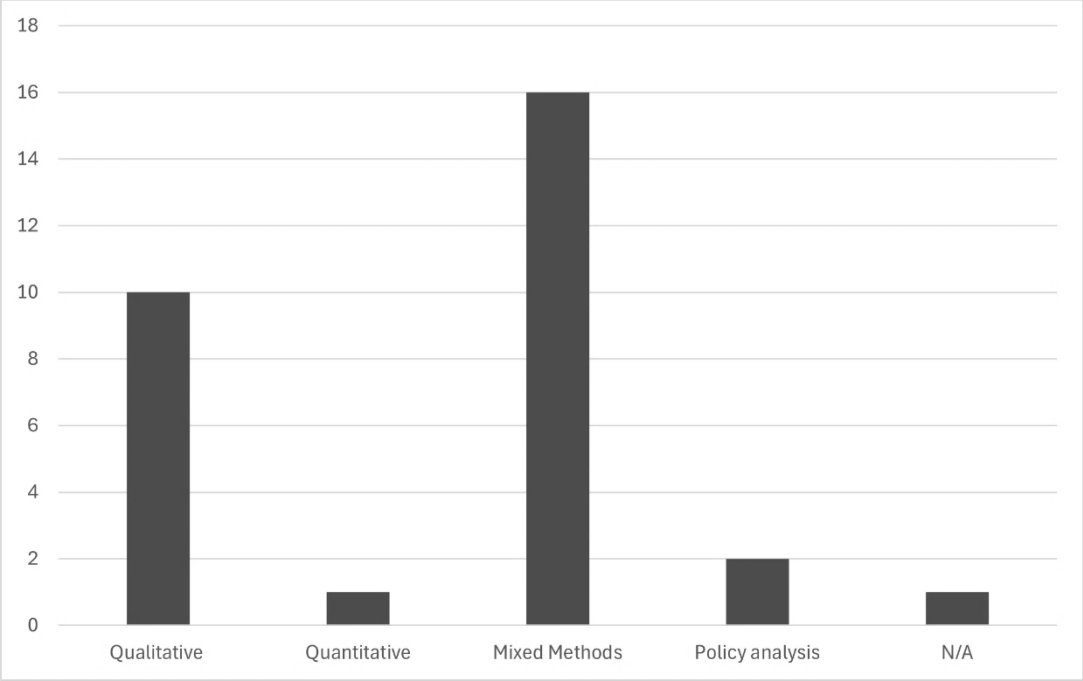


Figure 4-5: Research designs utilised in studies

The qualitative approaches also featured prominently, where studies using mainly interviews, focus groups, or discussion groups, accounted for 34% (n=10) of the total included studies. Semi-structured interviews were the most-used data collection method, with 15 studies opting for this method, which reflected a strong preference for research that is in-depth and context-specific and which focused mainly on the perceptions of policy effectiveness and policy dynamics.

Fewer studies employed a quantitative methodology, with only 3% (n=1) of the studies utilising only surveys or Geographic Information Systems (GIS) as the key methodology for the collection of data, which highlighted a relative gap in the large-scale analysis within the field of wetland management. In addition, a small set of studies focused primarily on policy analysis (7%), where only two studies utilised a document-based approach to analyse and assess wetland legislation, policy frameworks and governance structures. A diversity of methodologies was evident in the selected studies.

As illustrated in Figure 4.5, one article did not provide an explicit description of the methodology that was utilised, and as such, it was grouped in a 'Not Available' (N/A) category. The paper did not employ any specific methodology, which left it unclear as to whether the findings were based on interviews or document analysis. Nevertheless, this article was included in the review due to its relevance to wetland policy discussions, and including it provided a broader view of the discourse surrounding wetland management.

4.3.4 Governance levels

Wetland governance is a complex and multi-faceted phenomenon that is often comprised of multiple levels of governance. Figure 4.6 illustrates that the selected studies addressed multiple levels of governance, which highlights the intricacy that exists within the management of wetlands.

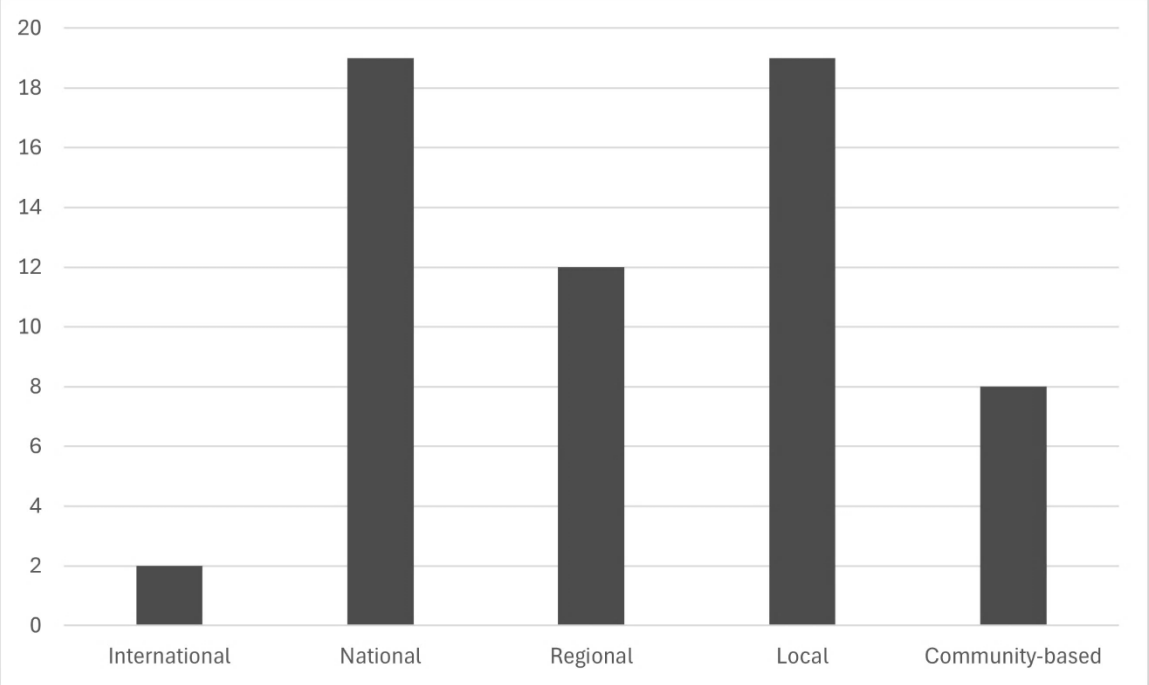


Figure 4-6: A chart illustrating the multiple levels of governance that are involved in wetland management

Across the 30 selected studies, governance on a national and local level was mentioned the most frequently (n =19). Figure 4.6 reflects a balance between national and local governance in wetland management. National governments were featured prominently in discussions on legislation, regulatory frameworks and environmental policies, while local governments were mostly featured in the context of interaction between the local communities and wetlands. Community-based governance also featured significantly (n=8); it was mostly mentioned in relation to customary and traditional knowledge systems, informal rules or co-management.

Significantly, several studies (n=25) addressed the multiple levels of government simultaneously, which showcased the fact that wetland management requires coordination and collaboration across the multiple levels of authority.

The reviewed studies illustrate a diverse range of governance instruments that were used at a national, regional, local and community level. This reveals several key patterns on how policy tools are utilised and where they fall short.

At a national level, most instruments were formal and regulatory in nature. For example, environmental legislation, national wetland strategies, water acts and national planning frameworks were mentioned, including Malawi's National Parks and Wildlife Policy (Kosamu, 2012), the Zimbabwean wetland legislation (Marambanyika & Beckedahl, 2016), as well as the National Environmental Management Act (NEMA), the National Water Act (NWA) and the Conservation of Agricultural Resources Act (CARA) (Lemine & Kanyerere, 2022). Such instruments were common in research across countries like Zimbabwe, Nigeria, Malawi, Kenya and South Africa. However, although these tools were prevalent, their use normally lacked critical coordination and resource support across the sectors, which reduced their impact. For example, although Kenya and Zimbabwe had national wetland Acts or environmental policies in place, the ecological effects were still largely negative, with evidence of further degradation, the conversion of wetlands and a loss of biodiversity (Odote, 2019; Marambanyika & Beckedahl, 2016). This, in turn, had largely negative socioeconomic implications, such as conflicts over the resources and the impact on the livelihoods of those who depend on the ecosystem services that the wetlands provide.

In contrast, regional (sub-national) tools, such as municipal by-laws, urban planning regulations (Mwonzora, 2022) and land use plans (Asomani-Boateng, 2019) were less commonly reported, and when they were referenced, they were typically fragmented. In South Africa and Zimbabwe, the corresponding tools included plans for wetland regulations (Mwonzora, 2022) and wetland masterplans (Matamanda, 2018). However, a lack of coordination between the national policies, and the lack of necessary financial resources hindered the regional governments from effectively implementing their strategies. Surprisingly, however, some studies (Lemine, 2022; Matamanda, 2018) have found that the fragmentation of laws at a regional level can destabilise rehabilitation efforts in wetlands by generating institutional overlapping responsibilities.

At a community level, it was noted that customary by-laws, co-management arrangements and participatory arrangements were commonly utilised, more so in parts of Zimbabwe, South Africa, Ethiopia and Tanzania. These tools were often aligned with the local practices and ecological knowledge (Ostrovskaya, 2013; Libala et al., 2022), which enabled a greater acceptance across communities. Cases such as Hamisi (2012), Marambanyika & Beckedahl

(2016) and Ngowi & Mwakaje (2020) demonstrated that, by having community-level tools supported by formal recognition, such as partnerships with NGOs or incentive-based approaches (Ngowi & Mwakaje, 2020), it meant that they had relatively positive socio-ecological outcomes, such as increased stewardship and reduced degradation.

Community-driven initiatives that are backed by formal support, tended to report more positive results. For example, farmers in the Bake Chora wetland of Ethiopia were trained under the Ethiopian Wetlands Research Programme (EWRP), which allowed them to learn how to drain and cultivate fields (Dixon et al., 2021). Once such practices were adopted, the farmers reported that their once compact soil became smooth and fertile. This mirrors the work of Musasa et al. (2023), who emphasised that including indigenous practices and providing wetland users with decision-making power avoids conflicts and contributes to successful management.

A second case is Ethiopia's Wichi Integrated Watershed programme, which was discussed by Dixon et al. (2021), where a non-governmental organisation collaborated with a wetland council to enforce the conservation rules. During this project, the community's own by-laws reduced the rate of ploughing in the wetland, which resulted in a drop in the destructive use of the wetland. However, farmers reported that these gains eroded when the external support ended. These cases demonstrate how wetland degradation reduces, and local stewardship rises, when community governance structures are formally supported (through either training or partnerships), thereby producing positive socio-ecological outcomes.

This review found that multi-stakeholder arrangements were more commonly associated with a positive environment and social effects, than with top-down regulations alone. For example, Musasa (2023) documented the successful conservation of the Monavale Vlei in Harare (Zimbabwe) by means of a combination of community engagement and formal institutional support.

Meanwhile, cases that relied on top-down control without local involvement often reported institutional failure, low compliance and continued wetland degradation (Fitsum, 2020; Akpabio, 2021). For example, in Ethiopia (Dechasa et al., 2020) and Tanzania (Hamisi et al., 2012, institutional arrangements lacked the flexibility to integrate community strategies into management, which resulted in policies that remained detached from the local reality and that were ineffective in practice. In addition, evidence from Ghana indicates that despite policies advocating for stakeholder participation and promoting the participation of local communities in wetland management (Asomani-Boateng, 2019), the actual implementation was limited,

which resulted in the exclusion of local communities in the decision-making processes.

In Uganda, the top-down approach was highly associated with escalating conflicts among the stakeholders and with continuous wetland degradation (Turyahabwe et al., 2017). In this study, low compliance is exemplified by local wetland users who continue to partake in activities that harm the wetland, due to their dependency on the wetland for their livelihoods. Formal wetland policies exist in Uganda (Turyahabwe et al., 2017); however, respondents feigned an ignorance of such policies because the policies did not align with their needs. These cases demonstrate how exclusionary wetland governance not only undermines policy enforcement, but it also erodes a community's trust in the governments and its policies (Dalu et al., 2022; Gebrehiwot, 2022; Libala et al., 2022). Overall, while the frequency of instruments shows a strong national dominance, their design, application and comprehensiveness either determine their support or undermine the sustainability of a wetland. Policies that failed to link the community-level protocols to national mandates, or that ignored the socioeconomic pressures that determined wetland use, were less likely to succeed or achieve positive outcomes.

4.3.5 Effectiveness of policies

The actual effectiveness of wetland management policies was a major concern across all the selected studies. As shown in Figure 4.7, none of the reviewed studies came to the conclusion that the wetland management policies that they examined were completely successful in producing the desired ecological or socioeconomic objectives. The majority of the studies, about 80% (n=16), implied that the policies were ineffective, with most of them pointing to poor enforcement, a policy-practice disconnect and institutional fragmentation (see Figure 4.8), which were barriers to effective policies.

Meanwhile, 20% of studies (n=4) suggested that the policies were somewhat effective. In these cases, this effectiveness was mostly partial, and it was often driven by the local authority (Dalu, et al., 2022) or community-based initiatives (Marambanyika et al., 2017). Figure 4.7 highlights a challenge with policy implementation across several African countries.

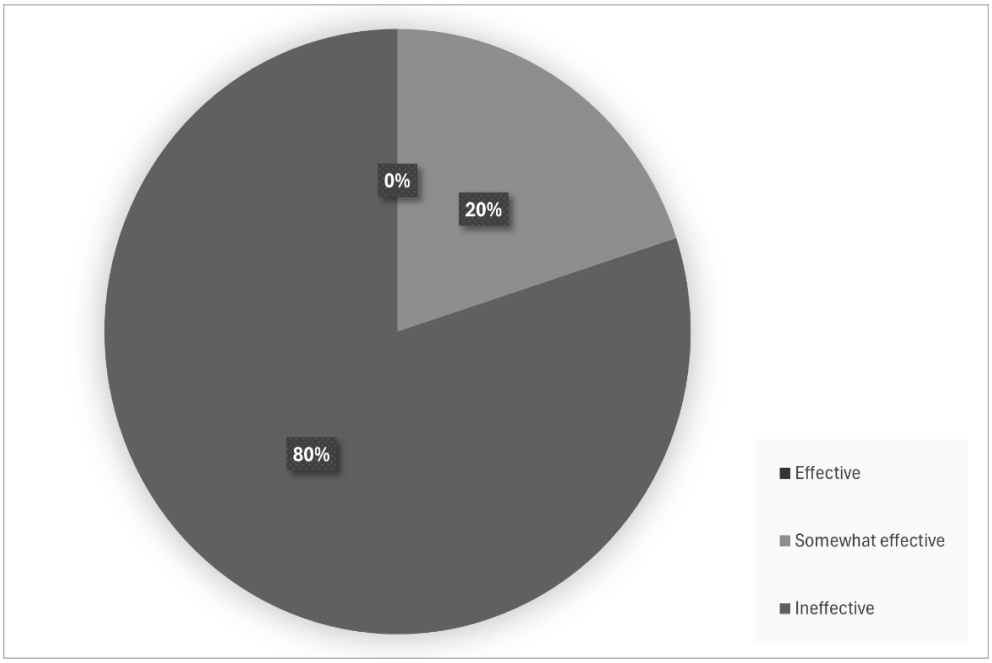


Figure 4-7: Chart illustrating policy effectiveness in studies

An analysis of the governance levels among the reviewed studies revealed a common trend in the distribution of institutional involvement in wetland management. Most of the studies did not focus on a single governance level, but examined wetland management across multiple, interacting levels of authority. Notably, the national and regional governance level was found in six studies. This reflects a common trend in the wetland policy, where the national government sets broad policy agendas, while regional governments aim to interpret or implement these on a sub-national scale. Despite such a multi-level engagement, most cases reported ineffectiveness, citing issues of coordination (Adeloka et al., 2012; Asomani-Boateng, 2019; Dechasa et al., 2020; Marambanyika & Beckedahl, 2017; Materu et al., 2018), capacity (Lynch et al., 2016; Marambanyika & Beckedahl, 2016) or implementation (Adekola et al., 2012; Gebrehiwot, 2022; Materu et al., 2018). In addition, where national governance was reported, it was associated with ineffective outcomes, which illustrates a gap between the policy formulation and its implementation on the ground.

Despite the layered governance that exists within the management of wetlands, the frequency of involvement was not necessarily followed by successful outcomes. Numerous studies that had looked at policies at multiple tiers (local, regional and national) have still reported ineffective policy performance. This would mean that the mere presence of policies is not enough, but that coordination through tiers (Odote, 2019; Musasa, 2023; Sinthumule, 2024; Tuji, 2024), clear mandates (Lemine, 2022), and support through resources (Marambanyika &

Beckedahl, 2016) are essential to ensure that government collaboration yields tangible ecological and socioeconomic benefits. Overall, the evidence indicates that simply involving multiple tiers of governance is not enough; rather, wetland policy effectiveness depends on how well these tiers interact and communicate with each other, what policy instruments are used, and whether local stakeholders are involved in the management of wetlands.

4.3.6 Barriers/challenges to policy implementation

As illustrated in Figure 4.8 below, several common factors pose as a barrier to effective wetland policy implementation across the selected studies that have been identified, and they have been grouped into seven themes.

The most frequently reported challenge was institutional weakness and fragmentation, which appeared in 29 out of 30 studies. This included factors such as poor coordination among the stakeholders, weak enforcement structures and the unclear responsibilities of governments, across multiple levels. Several studies indicated that fragmented and weak institutional arrangements undermined wetland management governance. For instance, in Nigeria, the management of wetlands is affected by fragmented organisation, which means that the responsibilities were unclear and coordination was lacking, which ultimately led to duplication, conflict, or the neglect of management functions (Adekola et al., 2012). This weakness of institutions did not occur in isolation, but was consistently highlighted across several studies (Asomani-Boateng 2019, Dalu et al. 2022, Gebrehiwot 2022, Hamisi et al. 2012, Kosamu et al. 2012, Materu et al. 2018, Ngowi and Mwakaje 2020) as a barrier to effective implementation.

Other major barriers included socio-economic pressure (n=18), which occurred particularly in communities that rely on wetlands for their livelihoods and well-being. This was illustrated by Turyahabwe et al. (2017) in Uganda, where wetland policies focus on conservation, but fail to offer alternative livelihood options, which results in community resistance and low compliance with policies. Socioeconomic pressures outweighed existing formal regulations, as communities prioritised food security and income over any conservation efforts. A study in Tanzania (Hamisi et al., 2012) highlighted that current institutional arrangements do not consider adaptive management, despite the wetlands providing vital resources for their livelihoods. In the context of high poverty and limited livelihood options, wetland abuse will persist, even when formal wetland policies exist, which will ultimately weaken management.

Another frequently reported theme was the policy and legal gaps (n=16), which included an absence of wetland laws (Materu et al., 2018) and the poor harmonisation of governments. Insufficient community engagement surfaced as another recurring theme across 13 studies, with research in Ethiopia (Dixon et al., 2021), South Africa (Dalu et al., 2022) and Zimbabwe (Marambanyika & Beckedahl, 2016) indicating that very low levels of public participation and the minimal inclusion of traditional knowledge systems hinder effective implementation. Funding and resource constraints also appeared to be important (n=9), where the lack of funds, as well as human or technical resources, hinders the enforcement of regulations or their monitoring (Asomani-Boateng 2019).

Climate variability (n=4) and corruption and political interference (n=4) appeared in a few studies. It is important to note that many of these barriers appeared simultaneously within the same study. No study reported that the failure of wetland management policies was due to a single issue.

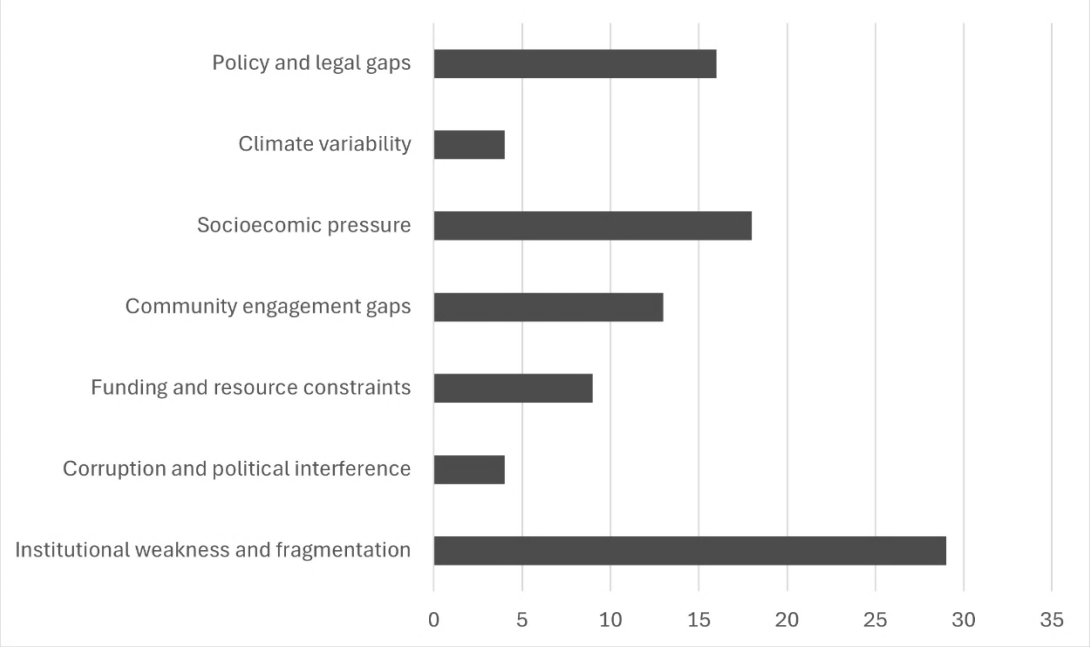


Figure 4-8: Barriers to policy implementation across selected studies

4.4 Discussion

4.4.1 Fragmentation in wetland governance

Across the African continent, governments have recognised wetlands and their importance in legislation. However, in several cases, wetlands have not been recognised in a dedicated stand-

alone policy. For instance, Ethiopia does not have a separate wetland policy; instead, it relies on multiple sectoral laws for the protection of its wetlands (Gebrehiwot 2022). The author notes that the conservation and management of Ethiopian wetlands are partly dealt with in the Ethiopian water resources management policy, the water resources management proclamation and the national conservation strategy, among others. These strategic documents cover some aspects of wetlands management, but they do not deal with wetlands as a separate entity.

A similar occurrence was recorded by Sinthumule (2024), who highlighted that South Africa has no stand-alone wetland policy. Instead, the country relies on an array of acts and government legislation for the legal protection of wetlands. The objectives of the management of wetlands are scattered across the Agricultural, Environmental and Water Acts and legislation. For example, the Conservation of Agricultural Resources Act 43 of 1983 (CARA) has control over the utilisation of natural agricultural resources to promote the conservation of water resources.

In addition, the National Water Act 36 of 1998 (NWA) has a mandate to promote the wise use and management of South Africa's water resources. The Act does not necessarily allude to wetlands, but they are a 'water resource', which grants them protection through this Act. Lastly, NEMBA provides for the governance and management of the country's biodiversity. Although wetlands are not specifically mentioned, they do host a large area of biodiversity, which indirectly receives protection under the Act, while some wetlands receive partial protection from South Africa's environmental legislation.

Wetlands are thus classified under different contexts, either as biodiversity hosts, water resources or agricultural land, which leads to inconsistent management. This, in turn, contributes to the ineffectiveness of wetland legislation. A similar case occurs in Malawi, which also does not have a national wetland policy. Kosamu et al. (2012) mentioned that wetland issues in Malawi appear briefly in the National Parks and Wildlife Policy and in the National Fisheries and Aquaculture Policy. This also highlights the reliance on sectoral laws. In essence, the fragmentation of wetland governance implies that wetlands are governed without a cohesive policy framework or clearly defined institutional responsibility. Sinthumule (2024) states that such a multiplicity of legislation is the root cause of incoherence, which leads to ineffective policy frameworks.

In contrast, Asomani-Boateng (2019) has praised the wetland management in Ghana, where wetland management policies, plans and a legal framework exist, and he has emphasised its

impressive approach to the protection of wetlands. Unlike the previously mentioned countries, Ghana has an explicit wetland policy (Asomani-Boateng, 2019). In addition, a National Wetlands Conservation Strategy has been developed as a means of integrating wetland management into the everyday activities of multiple stakeholders. According to Asomani-Boateng (2019), Ghana has many acts and policies, including, but not limited to, the National Environmental Policy (1995), the Forestry and Wildlife Policy (1994) and the National Land Policy (1999).

Despite having impressive and abundant legal policy instruments, including a stand-alone national wetland policy, Ghana's wetlands continue to face an alarming rate of destruction and degradation (Asomani-Boateng, 2019). The disconnect between the presence of wetland policies and their actual performance can be attributed to several weaknesses in the governance structures. Sectoral legislation often has the propensity to spread its responsibilities across different government departments or agencies, which creates overlaps and contradictions and weakens the accountability of management. Thus, implementation is fragmented across those sectors that lack clear coordination. Even where policies are well formulated and strong on paper, limited monitoring systems and weak enforcement reduce their impact.

In addition, the formulation of wetland policies on a national level tends to marginalise local communities that are dependent on wetlands, which results in them being out of sync with the local context. Without local buy-in, compliance with the policies will remain low, and wetland degradation will continue. These factors, therefore, explain how the presence of policies does not necessarily equate to improved wetland management.

Regional wetland management has therefore been shown to be largely included in other frameworks, rather than as a separate unified policy. Although a plethora of legislation exists to manage and protect wetlands, their effectiveness is diluted, as wetlands are not generally the main focus and priority of these sectoral Acts. Wetlands are treated as an afterthought and as by-products, and they are relegated to secondary status under the water, biodiversity and agricultural statutes. Wetlands should either have their own policy that identifies them as their own entity, or they should be classed under one legislation or Act to avoid conflicting or overlapping mandates.

4.4.2 Gaps in institutions

In addition to the gaps in implementation that have been highlighted above, there are prevalent

institutional constraints. Quite a few studies have highlighted the capacity shortages in conservation, as well as the weak coordination and limited resources for wetland management. These issues exist across several countries and governance levels. For example, although their intention is to protect wetland goods, Ghana's policies have failed in practice, as they have failed to showcase any positive impacts. Asomani-Boateng (2019) highlights several agencies that have put forward measures that can protect and preserve the wetlands in Ghana, including the prevention of development in wetlands. However, these have failed, as evidenced by the continuous wetland degradation. The good intentions illustrated by the plans and policies are undermined by insubstantial monitoring systems, which are further exacerbated by a lack of resources. Asomani-Boateng (2019) found that although development is not allowed in wetlands, it has still occurred, with an alarming rate of respondents in the study building on the wetlands. The author remarks that if monitoring and enforcement were established, these offenders would have been caught. This article illustrates how well-intentioned policies cannot work without efficient enforcement.

Similarly, Zimbabwe's environmental and regulatory agencies are cited as lacking financial resources and manpower to constantly monitor the wetlands (Marambanyika and Beckedahl 2016). A lack of manpower is exemplified by each district only having one officer who enforces the environmental law; thus, wetlands are sidelined. It was also noted that one vehicle is shared amongst eight districts (Marambanyika and Beckedahl 2016), which highlights a lack of resources for policy enforcement. Without adequate personnel, finances and resources, even the best policies and regulations will not be monitored and enforced, rendering them ineffective in practice.

Studies highlight that many institutions deal with conflicting mandates with inadequate specialisation. Wetlands fall under the confines of several environmental departments, authorities and local governments (Adekola et al. 2012, Asomani-Boateng 2019, Mandishona and Knight 2022, Marambanyika and Beckedahl 2016, Matamanda et al. 2018, Materu, Urban and Heise 2018, Ostrovskaya et al. 2013, Sinthumule 2024). The fragmentation that is prevalent in countries, such as South Africa, Zimbabwe and Tanzania, means that no single agency particularly 'owns' wetlands. This leads to an unclear mandate among the organisations, which consequently affects the enforcement of laws and policies. As a result, vital tasks, such as the environmental impact assessments of wetlands, as well as the monitoring and enforcement of wetland laws and regulations, are not prioritised.

The authors have noted that wetland management government departments are under-

resourced. For instance, Sinthumule (2024) highlighted inadequate monitoring resources and manpower across the departments, which contribute to an ineffective legal framework. His study found that capacity shortages in skills and knowledge are problematic for the enforcement and implementation of policies. This view is shared by Mandishona & Knight (2022), who noted that the Environmental Management Agency (EMA) of Zimbabwe, which is responsible for environmental management, lacks the financial and human resources that arenecessary for the implementation of wetland management strategies. The existing legislation can therefore not be implemented effectively, due to the EMA not having skilled personnel to monitor the use of wetlands and their impacts.

A similar case was observed in South Sudan by Mulatu et al. (2022), where the country lacks adequately resourced institutional frameworks to manage the wetlands effectively. The institutional set-up of the Ministry of Environment and Forestry is ill-equipped to implement its mandates, due to inadequate financial and human resources; thus, their responsibility for policy design cannot be seen through. Limited technical expertise and insufficient funding are listed as the reasons why sustainable wetland management is undermined.

All in all, these studies indicate that the constraints in human, financial and technical resources are a major barrier to policy implementation. This suggests that although wetland management legislation exists in countries, its effectiveness is affected by not having the necessary resources to ensure and monitor that they are implemented.

4.4.3 Ecological and socioeconomic outcomes

The reviewed studies expose a mixed picture of the environmental and socioeconomic outcomes of policies. Ecologically, some evidence indicates continued wetland degradation, in spite of the existence of wetland policies and legislation. Matamanda et al. (2018) reported that ongoing degradation of wetlands in Harare, Zimbabwe, still occurs, despite them being Ramsar sites. It is also reported that wetlands are losing their biodiversity, which is evidenced by the reduction of flora and fauna found in the wetland. The authors emphasise some national and international policies and legislation that govern the wetlands of Zimbabwe, which are said to be ‘sound and detailed’ (Matamanda, Chirisa, Mukamuri, Kaduwo and Mhlanga 2018). This suggests that policies that are strong in wording do, in fact, exist; however, they have not prevented the degradation and destruction of wetlands. Similar concerns are reflected by Marambanyika & Beckedahl (2017), where inconsistencies that exist in wetland management policies, due to different institutions partaking in wetland management, leave wetland users

confused, which results in the users engaging in activities that lead to their degradation. Overall, it seems that the impact of policies on wetlands has been limited to date.

Socioeconomically, wetlands are heavily dependent on the local communities and households that reside on and near them. In South Africa, wetlands have benefited local communities by providing them with resources (Dalu, Mukhuwana, Cuthbert, Marambanyika, Gunter, Murungweni and Dalu 2022), while Marambanyika et al. (2016) highlighted how local households in Zimbabwe depend on wetlands for income generation, mainly through agricultural produce. These instances demonstrate how wetlands are the main source of food security and income for households that live on or near wetlands. Successfully promoting the conservation and sustainable management of wetlands can sustain income generation, and it can alleviate poverty without harming or degrading wetlands that support the households (Dixon et al. 2021). Mwakaje (2009) emphasised the need for support services, such as credit provision and stronger local institutions, in order to avoid agricultural activities that will threaten wetlands and livelihoods.

The ecological and socio-economic outcomes reported across the literature can be understood as a direct result of the patterns of policy effectiveness and the barriers that have been identified previously. Although many national policies contain a strong conservation intent, the majority of studies found that these policies were ineffective or only somewhat effective in practice. The disconnect between policy and practice helps to explain why wetland degradation and uneven livelihood outcomes persist across the regions. Essentially, poor outcomes are not usually the result of the absence of policies, but of the failure of the policies themselves. These failures stem from weak enforcement, fragmented mandates, limited resources and skilled personnel, and the exclusion of local wetland users.

The persistence of wetland drainage, encroachment and pollution in wetlands reflects the failure of wetland management policies, rather than being due to unavoidable environmental consequences. Where enforcement is weak and monitoring systems are absent, the legal protection of wetlands is nominal, and the land-use pressures resume, even in protected sites.

Conversely, the small subset of studies that described partial ecological recovery (Banda et al., 2024; Dixon et al., 2021; Kosamu et al., 2012) reported features that reduce the barriers, such as clear institutional leadership, routine monitoring, or locally supported compliance mechanisms. Thus, the ecological outcomes depend on how effectively policies are implemented and if the institutions are equipped to enforce them.

Socio-economically, wetlands offer resources, such as grazing, fishing and agricultural services, which provide food security and an income for local communities. When wetland management policies ignore the livelihood needs, the intended social benefits of wetlands are not seen. Top-down management that is not accompanied by alternative livelihood options or meaningful collaboration results in non-compliance with policies or intensified vulnerability for poor households (Turyahabwe et al., 2017). These patterns illustrate how socioeconomic outcomes are contingent on whether the policies engage with local communities.

Interestingly, heterogeneity and contradictions exist in the literature. Several countries, such as South Africa (Sinthumule, 2024), Ghana (Asomani-Boateng, 2019) and Tanzania (Hamisi et al., 2012), possess sophisticated policy landscapes, but they yield uneven local outcomes, while some community-led initiatives in less-resourced settings demonstrate meaningful gains (Dechasa et al., 2020; Kosamu et al., 2012). This highlights how the presence of policies is not enough, but the removal of policy barriers and the inclusion of local wetland users and their knowledge on wetland management can translate into these policies having a positive impact on wetlands and on people's livelihoods.

4.4.4 Community awareness and participation

A theme that reoccurred often throughout the reviewed studies is the role, or the lack of consultation with, local communities in wetland management. Many studies highlight the exclusion of communities living near or on wetlands from wetland management policies. They are also often unaware or ignorant of the formal policies that are meant to protect the wetlands. Locals almost always utilise and interact with the wetlands; because of this, their needs should guide the management of the ecosystems that they depend on. Studies in Zimbabwe and South Africa reveal that most communities adjacent to wetlands acquire their food from the wetlands and generate an income from the resources provided by wetlands (Dalu, Mukhuwana, Cuthbert, Marambanyika, Gunter, Murungweni and Dalu 2022, Marambanyika and Beckedahl 2016, Marambanyika et al. 2017). Communities are thus aware of the fact that wetlands are beneficial for their livelihoods. Libala et al. (2022) revealed that livestock owners in the Tsitsa catchment in South Africa view the wetlands as important for their livelihoods; they were aware of their degradation and, along with the local community, were eager to involve themselves in the efforts to strengthen local wetland governance. A similar case is illustrated in Zimbabwe, where households embraced soil and water practices and local rules that resulted in their improved

livelihoods and the protection of the ecosystems (Marambanyika, Beckedahl and Ngetar 2017). These findings demonstrate that knowledge stemming from the local people can improve wetland health.

In contrast, Dalu et al. (2022) found that wetland users in the Vhembe Biosphere Reserve were aware of the benefits provided to them by the wetlands; however, they still partook in activities that threatened the wetlands due to their unawareness of the fragile nature of wetlands. This demonstrates the major gaps in awareness of wetland policies. In Zimbabwe, an alarming number of households were unaware of the existence of wetland management laws, while in Uganda, a greater number were aware of the national wetland policy, but a small percentage knew only of the traditional rules. An unawareness of the policies or regulations contributes to the degradation of wetlands, where some people see them as wastelands (Adekola, Whanda and Ogwu 2012, Dalu, Mukhuwana, Cuthbert, Marambanyika, Gunter, Murungweni and Dalu 2022, Mwakaje 2009) and use them to dispose of their waste (Adekola, Whanda and Ogwu 2012), or as areas that should be drained (Musasa et al. 2023).

An unawareness of communities of the wetland policies is problematic, as it hinders the conservation efforts. Without local awareness or buy-in, the implementation of policies will most likely be unsuccessful. This is corroborated by Turyahabwe et al. (2017), who found that although local communities were aware of the wetland policy in Uganda, they feigned ignorance of those policies or laws that they did not agree with. Ultimately, this demonstrates that policies are not enough; they need to serve the needs of the local communities while also conserving and protecting the wetlands. If wetland policies encroach on the communities' means of survival, degradation will still occur.

The enforcement of wetland policies, where they exist, will falter when the local realities are ignored. Wetland policies are not implemented effectively in Uganda because local communities do not support them (Turyahabwe et al., 2017); this is because their policies focus solely on wetland conservation, without offering alternatives to support communities' livelihoods. Marambanyika & Beckedahl (2016) supported this claim; they found that policy implementation and enforcement will not improve unless alternative livelihood plans are offered to the communities.

Several studies emphasised the need for policies that are flexible and tailored to each community (Dalu, Mukhuwana, Cuthbert, Marambanyika, Gunter, Murungweni and Dalu 2022, Dixon, Wood and Hailu 2021, Gebrehiwot 2022, Marambanyika and Beckedahl 2016).

Wetland laws and policies are often designed to disregard the traditional tenure and the critical resources offered by wetlands to local communities (Dixon, Wood and Hailu 2021). Such policies will neglect the local realities and subsequently fail to reduce wetland degradation and destroy the trust that communities have in formal governance; this demonstrates the disadvantages of a top-down approach to wetland governance. The needs of locals are neglected in favour of sectoral interests, which creates tension between wetland conservation goals and the needs of communities. In retaliation, the local people have adopted wetland management practices that appeal to their needs, thereby disregarding the national laws (Marambanyika, Beckedahl and Ngetar 2017).

Community participation and awareness in wetland management are essential components for ensuring that wetland policies are supported and implemented, and thereby protecting wetlands from degradation. Sidelining the local realities and needs in such policies leads to the risk of worsening the degradation of wetlands, as communities will be forced to ignore the formal rules in order to support their livelihoods.

4.4.4.1 Customary tenure and traditional authority

In most of Africa, wetlands are often found on communal land, where traditional authorities and leaders are seen as custodians of the wetlands (Adekola, Whanda and Ogwu 2012, Kosamu, De Groot, Kambewa and De Snoo 2012). The Elephant Marsh of Malawi is managed by local governance, which means that rules and decisions are not often contested, as they are decided upon by traditional leaders like chiefs (Kosamu, De Groot, Kambewa and De Snoo 2012). In contrast, each wetland in Zimbabwe has adapted its own indigenous rules that are tied to local tradition. Marambanyika and Beckedahl (2017) argue that the top-down approach to wetland management is not enough, and that placing traditional leaders and local institutions at the centre of wetland governance should be the goal. Strong traditional arrangements often manage wetland governance more effectively compared to formal governance. For example, the lake in Nigeria is closed to fishing and other activities until permission is granted by the traditional leaders, and to break this rule is considered to be taboo (Adekola, Whanda and Ogwu 2012). In fact, the locals stated that they would honour these traditional rules over formal laws. This highlights how local and customary laws can be beneficial to wetland management if they are integrated into formal regulations.

Essentially, a top-down approach to wetland management that excludes the local needs will struggle to protect the wetlands effectively (Dalu, Mukhuwana, Cuthbert, Marambanyika,

Gunter, Murungweni and Dalu 2022, Marambanyika, Beckedahl and Ngetar 2017). The need for a bottom-up approach is emphasised by Dalu et al. (2022), where the planning processes and the designing of policies should involve local stakeholders from the outset and throughout. In addition, it should be built on the knowledge that indigenous leaders possess. The studies recommended participatory policy development and management that is community-based (Marambanyika and Beckedahl 2016, Marambanyika, Beckedahl and Ngetar 2017). Ultimately, coupling local governance, which adjusts the rules to the local realities, with formal governance, which sets the formal tone, will be beneficial to wetland management. Aligning the community needs and strategies within the formal laws means that local communities will be supported, while the wetlands are protected from further degradation.

4.4.5 Implications

The design of policies needs an integrated and holistic approach. There is a need for countries to merge their wetland management objectives into a coherent institutional framework. Ghana is an example of one country that has started this with its National Wetland Land Policy, but many countries continue to rely on 'ad hoc' laws. This study supports the need for stand-alone wetland policies. The existing sectoral laws, like those that exist in South Africa (Sinthumule 2024), should be blended with each other to explicitly recognise the wetland as their own separate entity. In practice, amendments to the environmental legislation may be necessary, in order to eliminate contradictory and overlapping mandates.

Local communities that are dependent on wetlands should be placed at the core of the wetland management policies. The evidence strongly suggests that a bottom-up approach works more effectively, compared to top-down governance. Traditional authorities and local communities need to be involved in the decision-making and policy design. Without proper enforcement and consistent monitoring, even the most well-written policies mean nothing. Sufficient funding and skilled personnel should be allocated to the goals of wetland management. Resource gaps can be filled by partnering with Non-Governmental Organisations (NGOS) or research institutions, to provide technical support.

4.4.6 Future research suggestions

A data gap exists with regard to policy impacts and wetland status. Very few studies exist that have assessed the ecological outcomes after the implementation of policies. Furthermore, very few analyses have been undertaken on how policies have changed the livelihoods of those

affected over time. Future studies could explore the consequences of policy implementation or the changes in livelihoods. Research can use field surveys or GIS technology to track environmental changes after the implementation of a policy. Research should continue to update this knowledge and to review the continuous changes. Policies are continuously updated and evolving and research should keep track of such changes. Grey literature can also hold useful information that is not found in journals, and synthesising it systematically would be beneficial.

4.4.7 Limitations of the study

Several limitations of this study should be acknowledged. Firstly, Africa is a large and diverse region; this study only used 30 studies, and as such, it may have left some countries and wetlands under-represented. Material on southern and eastern Africa was included in this review, but little to no material was available on northern and western Africa. This produces an uneven coverage of the wetland management policy landscape of Africa, which means that the conclusions might not hold in other countries, which limits the generalisability of the findings to other regions of Africa. In addition, articles were retrieved from three databases: Scopus, the Web of Science and PubMed. In conducting the review, grey literature or relevant studies found in other databases may have been missed. Furthermore, several studies not written in English were excluded from this review. Despite these limitations, this review reveals the significant trends and challenges that are integral to strengthening wetland management in Africa.

4.5 Conclusion

The objective of this study was to systematically assess the literature that examines the effectiveness of wetland management policies in Africa. By synthesising 30 studies on African wetland management policies, a complex pattern of strengths and weaknesses was found. A central finding is the gap that exists between the intentions of policies, on paper, and the resulting outcomes, in reality. In most cases, strong legislation exists in the reviewed literature, but its implementation is often hampered by limitations in resources and governance. Wetlands fall under multiple sectors (water, forestry, biodiversity and agriculture), which results in fragmented governance that leads to conflicting or overlapping responsibilities. Consequently, well-designed policies will be poorly enforced or insufficiently resourced, which weakens their effectiveness. Top-down approaches have failed due to their disconnect from the local

communities. Where local by-laws were followed, the wetlands demonstrated less degradation, and communities showed greater compliance with the laws. To achieve effective wetland management, an integrated governance framework should be adopted that balances the protection of wetlands with the needs of local communities. Coordinating the local realities with the national policies, strengthening the institutional capacity and allowing the participation of stakeholders are essential for achieving effective policy implementation. This review underscores the need to go beyond policies that only exist on paper and to focus on including the wetland beneficiaries in their implementation. Effectively conserving and protecting Africa's wetlands, while not ignoring the needs of its dependents, requires coordination and inclusivity across multiple sectors and governance levels. Achieving these goals is integral to ensuring that wetlands remain healthy ecosystems that will continue to provide important ecological and socio-economic benefits.

5 THE DELINEATION OF FLOODPLAIN WETLANDS EXTENT AND LAND USE/LAND COVER CHANGES IN UMNGENI CATCHMENT (2000-2024) USING LANDSAT DATA

5.1 Introduction

Wetland Ecological Infrastructure (EI) refers to ecosystems that operate naturally and can efficiently carry out functions while delivering valuable services to people and the health of the environment. Wetlands offer a diverse range of services that can be classified into the provisioning, regulating, cultural and supporting categories (Wetlands 2025). Provisioning services encompass the provision of food, such as fish, fresh water and raw materials; regulating services involve climate regulation, flood management, water filtration and erosion control; cultural services include opportunities for recreation, aesthetic pleasure and spiritual enrichment; and supporting services contribute to the biodiversity and nutrient cycling (Danley and Widmark 2016, Finlayson et al. 2005, Wondie 2018). Recognising and preserving wetland ecological infrastructure is essential for sustainable environmental management and the resilience of communities that depend on those services.

According to Mitsch and Gosselink (2000), the protection of wetlands by law is primarily motivated by their societal value, rather than the complex ecological processes that take place within them. While the perceived value of wetlands is derived from their functional ecological processes, it is also influenced by human perspectives, the specific location of a wetland, the level of human population encroachment, and the overall resource capacity. Valuing these services economically is essential for incorporating the environmental costs that are linked to wetland degradation. By attributing a monetary value to the advantages offered by wetlands, stakeholders can enhance their understanding of their significance in policymaking and resource distribution. The economic significance of wetlands is considerable. Research has estimated that healthy wetland ecosystems provide services that are valued at as much as $15 trillion around the world (De Groot et al. 2018). This assessment underscores the frequently neglected advantages of maintaining wetlands, as opposed to transforming them for agricultural or urban growth. For example, the destruction of a single hectare of coastal wetland can lead to an average annual decrease in ecosystem services worth roughly $33 000 (De Groot, Brander and Finlayson 2018, Finlayson, Cruz, Davidson, Alder, Cork, De Groot, Lévêque, Milton, Peterson and Pritchard 2005). Such statistics emphasise the importance of sustainable

management strategies that reconcile the developmental demands with environmental conservation.

Alterations in Land-Use and Land-Cover (LULC), particularly within floodplain wetlands, have a substantial effect on the ecological infrastructure of the wetland, which poses risks to both societal well-being and ecosystem functions. (Pielke Sr et al. 2011). Floodplain wetlands are particularly sensitive to hydrological changes and agricultural expansion. The primary causes of the LULC change are human activities, including the increasing population numbers, industrial development and the expansion of urban areas, which, in turn, impact the wetland ecological infrastructure (Moodley et al. 2023). These modifications diminish the ability of wetlands to offer essential services, while increasing the effects of climate change and reducing their resilience to environmental stresses (Mitsch and Gosselink 2000). The complexities associated with changes in the LULC require the application of tools and technologies that can comprehensively comprehend, analyse and simulate the dynamics of the LULC changes in a spatially explicit manner.

Remote Sensing (RS) and Geographic Information Systems (GISs), offer a valuable spatially-explicit framework for quantifying and assessing the LULC dynamics (Moodley, Toucher and Lottering 2023). Traditional techniques, such as data collection through censuses and environmental sample analyses, are insufficient for complex environmental research (Maktav et al. 2005, Mallupattu and Sreenivasula Reddy 2013). A recent advancement in these fields involves leveraging satellite data, in combination with GIS, to aid in data interpretation by utilising the growing volume of geographical information that is accessible (García-Mora et al. 2012). The Google Earth Engine (GEE) platform, which is designed to handle vast amounts of data over extended periods, while providing robust image analytical functions and algorithms, such as Artificial Neural Network (ANN), Support Vector Machine (SVM) and Random Forest (RF) (Amani et al. 2019), has emerged as a solution to the challenges associated with conducting big data LULC change analytics in RS. GEE offers one of the most frequently utilised datasets for spatially quantifying LULC changes in wetlands, namely, the Landsat imagery archives. These archives include the data acquired by Landsat 1–3 Multispectral scanner (MSS), Landsat 4 MSS/Thermal Mapper (TM), Landsat 5 TM, Landsat 7 Enhanced Thermal Mapper (ETM+) and the Landsat 8 and 9 Operational Land Imager (OLI). This makes GEE and Landsat data suitable for assessing the impact of LULC changes on wetland areas and to gain insights into their effects on the ecological infrastructure dynamics.

In this study, Landsat ETM+ and Landsat OLI satellite data were utilised to assess the LULC changes by focusing on floodplain wetlands in the uMngeni Catchment (DWS, U20), KwaZulu-Natal, South Africa. A LULC classification was conducted in GEE to identify and distinguish different land cover types within the catchment. This approach aimed to provide a comprehensive understanding of the spatial distribution of wetlands during the years 2000, 2010, 2020 and 2024, as well as their relationships with the surrounding land uses, and ultimately to inform conservation and management efforts. In addition, the study also sought to estimate the possible ecosystem services dynamics associated with the changes in wetland ecological infrastructure.

5.2 Methodology

5.2.1 Reference data

The first step in the study was to specify the Region of Interest (ROI) by using the uMngeni Catchment boundary and wetland boundaries within the catchment acquired from the Department of Forestry and Fisheries and the Environment (DFFE), as well as the South African National Biodiversity Institute SANBI website (Zwedzi and Tesfamichael 2020). The study's spatial boundaries were defined based on the National Wetland Map 6 (NWM6) produced by the South African National Biodiversity Institute (SANBI) project in 2024. Existing wetlands maps, inland waterbody datasets and land cover data were used to differentiate the wetlands from other surrounding land cover types.

5.2.2 Remotely sensed data

As a result of its longest-serving earth observation mission, Landsat data were acquired by using Landsat 7 Thematic Mapper Plus (TM+), Landsat 8 OLI and Landsat 9 OLI-2 during the years 2000, 2010, 2020 and 2024, which were accessed in GEE and used to map the wetlands and LULC changes in this study (Table 5.1). Specifically, Landsat surface reflectance first-tier (T1) products across the uMngeni Catchment were selected and processed in the GEE platform (https://earthengine.google.com/). In this study, the images acquired during the dry season were used, i.e. the months of May, June, July and August, which have less than 10% cloud cover. Dry season imagery was selected because croplands are typically harvested during this period; this results in reduced spectral noise and fewer vegetation-related disturbances, which enhances the reliability of land-cover discrimination. Due to the variations in cloud cover, the number of individual images per year varied. No additional preprocessing was necessary, as the available data in GEE is already pre-processed. GEE offers pre-processed Landsat data, which includes corrections for atmospheric, radiometric and geometric errors, as well as cloud masking. A median reducer was used to combine

various images into a single image for a specific year. Vegetation indices, such as the Normalised Difference Vegetation Index (NDVI) and the Normalised Difference Water Index (NDWI), which are effective in distinguishing vegetation and water bodies, were then computed and used in this study (Bian et al. 2021). The Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data (Rabus et al. 2003), with a spatial resolution complementary to Landsat data in GEE, was used for the topographic metrics. Specifically, topographic indices, which include the slope and aspect, were derived and used (Bian, Melesse, Leon, Verma and Yin 2021).

Table 5-1 Images covering the study area used in this study

Year	Landsat Satellite	Path/Row	Acquisition Date	Season	Preprocessing Steps
2000	Landsat 7 (ETM+)	167/79	2000-07-01 to 2000-08-30	Dry	Cloud masking, median composite
2010	Landsat 7 (ETM+)	167/79	2010-07-01 to 2010-08-30	Dry	Cloud masking, median composite
2020	Landsat 8 (OLI)	167/79	2020-07-01 to 2020-08-30	Dry	Cloud masking, median composite
2024	Landsat 9 (OLI-2)	160/93	2024-07-01 to 2024-08-30	Dry	Cloud masking, median composite

5.2.3 LULC classification

Initially, class labels and spectral bands from the Landsat imagery were established. The class labels included grasslands, wetlands, built-up areas, forests, waterbodies, bareland and farmland, which were merged into a single feature collection for training purposes. Landsat images from the years 2000, 2010, 2020 and 2024 were consolidated into a comprehensive image collection. The training data were then sampled from these images by extracting pixel values at the specified locations of the training data for the defined bands and class labels. These training data were subsequently divided into training (70%) and testing (30%) sets by incorporating a random column. An RF classifier was trained by using the training set and it was subsequently applied to the Landsat images to classify them into distinct LULC classes. RF is one of the proposed algorithms to be used because of its optimal performance in the literature (Ghosh and Das 2020, Saha et al. 2021). In this study, RF was used for classification. The classifier was initialised by using the following line of code: `var classifier = ee.Classifier.smileRandomForest (400, null, 1, 0.5, null, 0)`. An RF classifier was initialised in this study by calling the 'smileRandomForest' function from the 'Classifier;' class within the 'ee' object on GEE. The area covered by the wetlands was then masked out from the rest of the classes, to quantify the real extent

of the wetland.

5.2.4 Assessing the accuracy of classification models

To evaluate the classification accuracy, a confusion matrix was used, which compares the level of agreement between reference and classified samples (Foody 2020), and it was generated for the training dataset in GEE. A trained classifier was then applied to the test dataset, producing a second confusion matrix. From these matrices, various matrices were calculated, including the Overall Accuracy (OA), the User's Accuracy (UA), the Producer's Accuracy (PA) and the kappa statistics. Notably, the dataset consisted of (n = 4670) points across all. These points from all four years were visually checked across the images to ensure consistency in their classification and temporal variability.

5.2.5 Assessing the spatial extent of wetlands

To enhance the delineation of wetland areas within the uMngeni Catchment, a floodplain mapping technique was applied in GEE by utilising the MERIT Hydro Height Above Nearest Drainage (HAND; reference) dataset. Regions with HAND values of ≤5 m were selected as potential floodplains, indicating the low-lying zones that are susceptible to flooding. This dataset was confined to the uMngeni Catchment boundary to maintain regional relevance. Furthermore, river channels were extracted from the Joint Research Centre (JRC) Global Surface Water dataset, converted to the vector format, and buffered by 500 m to establish a floodplain mask (Pekel et al. 2016). The LULC maps that were classified from the years 2000, 2010, 2020 and 2024 were then confined to this buffered area in GEE, concentrating specifically on the wetland alterations within the hydrologically relevant floodplain. The LULC images that were masked by the floodplain were exported to Quantum GIS (QGIS) for additional analysis. This method refines the calculation of the extent of the wetland by ensuring that only changes in land cover within areas affected by fluvial dynamics are counted and excluding upland LULC changes that do not relate to floodplain hydrology. The extracted wetland category (Class 2) underwent further examination in QGIS by using the Raster Calculator and Reclassification tool to measure the wetland area over time. To calculate the wetland extent, the Zonal Statistics plug-in was used to determine the area in square meters, which was subsequently converted into hectares for uniformity. This approach improves the precision of wetland change evaluations by combining the floodplain delineation with the LULC classification, which facilitates a clearer understanding of the wetland transformation in response to hydrological and land use changes.

5.2.6 Ecosystem Services Valuation

Ecosystem Services Valuation (ESV) was incorporated into the evaluation of LULC changes to analyse the socio-ecological consequences of land-use shifts in the uMngeni Catchment. Relevant ESVs were

linked to each class, based on their ecological roles and provisioning abilities. The focus of the assessment was on the key ecosystem services, which included provisioning (e.g. food and raw materials), regulating (e.g. water regulation) and cultural services (e.g. recreation) (Daniel et al. 2012). The valuation of ESV was informed by the Economics of Ecosystems and Biodiversity (TEEB) framework and the work of Costanza et al. (1997), which provided monetary estimates for the ecosystem services. The formula used to determine the monetary values and calculate the ecosystem service value per hectare per year is as follows:

$$EV = \sum_{\{i=1\}}^{\{n\}} (Ai \times Vi) \qquad Equation\ 1$$

Where:

- EV: Total Ecosystem Value (ZAR per year);
- A_i: Area of land cover class (in hectares);
- V_i : Ecosystem service value for land cover class (ZAR/ha/year); and
- n: Total number of land cover classes considered.

Although site-specific values were unavailable for the catchment, values from the larger provincial context of KwaZulu-Natal were used to ensure their relevance to the local scenario. Wetlands, for instance, were primarily valued for their water regulation services (2,512.01 ZAR/ha/year), while agricultural lands were associated with food provisioning (2,870.99 ZAR/ha/year). The spatial mapping of ESV took place by overlaying the classified LULC maps for the years 2000, 2010, 2020 and 2024 with the corresponding ecosystem service values. Each pixel in the LULC class was allocated the relevant monetary values for its primary ecosystem services, which facilitated the generation of quantitative datasets that illustrated the temporal trends of ESV over the 24 years that were analysed. Descriptive statistics were utilised to detect the trends, as well as the gains and losses, in ecosystem service provisioning among the various LULC categories. The relationship between land use and land cover changes and the dynamics of ecosystem services was examined both qualitatively and quantitatively. For instance, the wetlands were evaluated for their function in water management, whereas forests were studied for their provision of raw materials and the preservation of genetic biodiversity (Costanza et al. 2014).

5.3 Results

5.3.1 Spatial distribution and extent of different landuse and land cover types

The classified land cover maps included in Appendix A offer an in-depth examination of the land cover changes within the catchment from 2000 to 2024 (Figure 5.1). Nevertheless, a more detailed analysis

conducted within the floodplain buffer (Appendix D) uncovers further details of the changes and trends in the LULC that are pertinent to floodplain wetland areas. This targeted evaluation is crucial for grasping the ramifications of land cover alterations on flood management, ecological balance and land use strategies. The wetland area that was covered mostly by vegetation in the catchment underwent a notable decline from 17 300 ha in 2000 to 11 500 ha in 2024, which reflected pressures such as urban sprawl and climate-induced changes (Li et al. 2022) (Figure 5.2). Similarly, wetlands within the floodplain buffer decreased from 2 977.9 ha in 2000 to 1 873.9 ha in 2024. This reduction points to a loss in the natural flood mitigation capability, which may elevate the flood risks and compromise vital ecosystem functions. Urban development was detected throughout the catchment, rising from 22 200 ha in 2000 to 27 200 ha in 2024 (Li et al. 2022). The floodplain buffer showed a similar pattern, with built-up areas expanding from 2 248.9 ha in 2000 to 2 412.3 ha in 2024. This expansion into flood-affected areas raises alarms about the heightened susceptibility to flooding, as impervious surfaces hinder water absorption and increase runoff. Forest cover within the catchment faced a significant drop from 92 400 ha in 2000 to 63 800 ha in 2024, which was driven by deforestation linked to agricultural development and urbanisation (Kumar et al. 2022, Levers et al. 2021). Within the floodplain buffer extent, forested areas also fell from 8 758.6 ha in 2000 to 4 909.8 ha in 2024, which highlighted the loss of vegetation essential for soil stabilisation, erosion control and local climate moderation. The coverage of water bodies expanded markedly within the catchment, rising from 9 500 ha in 2000 to 32 500 ha in 2024. A similar increase was noted in the floodplain buffer, where water bodies increased from 5 779.0 ha in 2000 to 9 675.8 ha in 2024. This trend may have resulted from hydrological shifts, heightened precipitation or human interventions, like dam construction and reservoir creation (Venter et al. 2020). Agricultural land in the catchment remained largely stable, experiencing a slight increase from 84 100 ha in 2000 to 89 500 ha in 2024. Conversely, in the floodplain buffer area, agricultural land decreased from 9 961.6 ha in 2000 to 7 631.9 ha in 2024. This change may be attributed to land conversion for urbanisation, soil degradation, or more frequent flooding, which made farming less feasible in those regions These results align with the findings of Moodley, Toucher and Lottering (2023), who indicated that it is probable that the forthcoming LULC trend will encompass substantial growth in urban and agricultural LULC categories in the world, which will lead to a reduction in the natural land-cover classes.

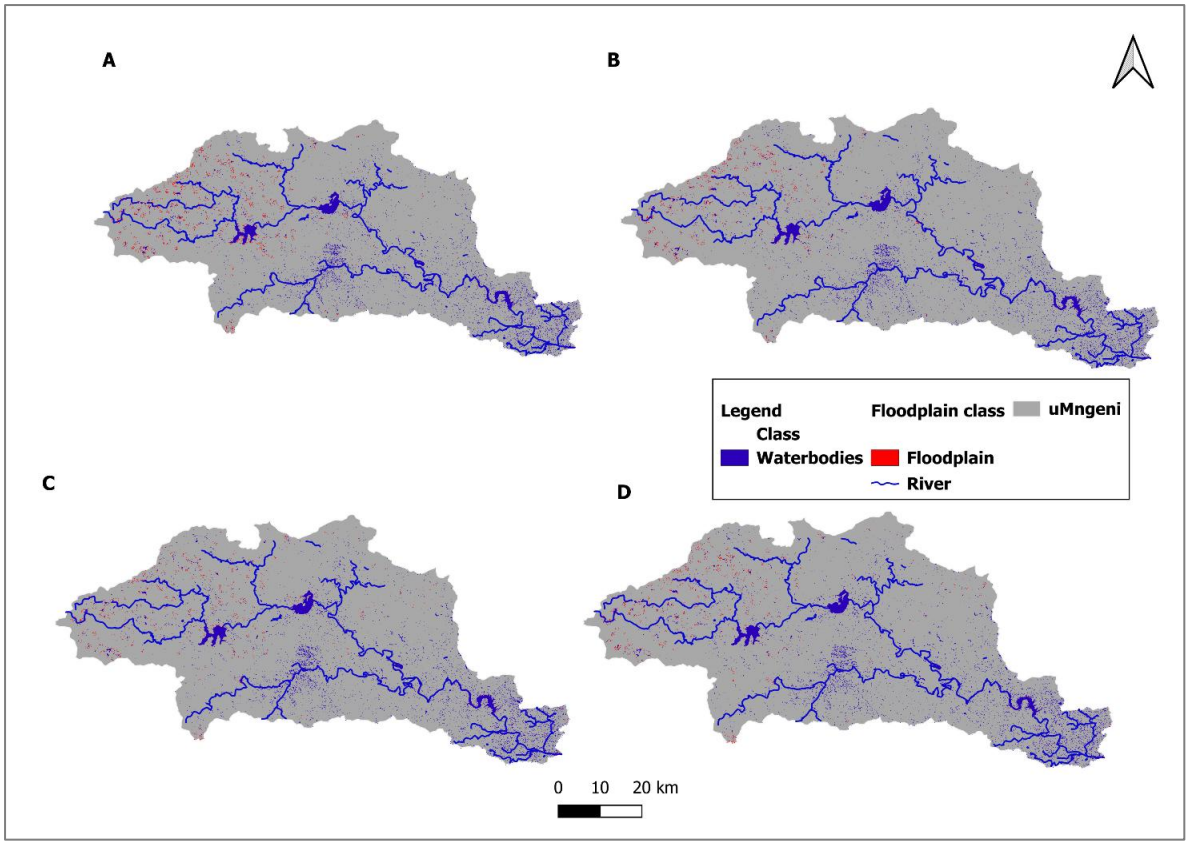


Figure 5-1: Wetland extents, waterbodies and rivers extracted from classified land cover maps using floodplain overlay within the uMngeni catchment:(DWS U20) (a) 2000; (b) 2010; (c) 2020; and (d) 2024

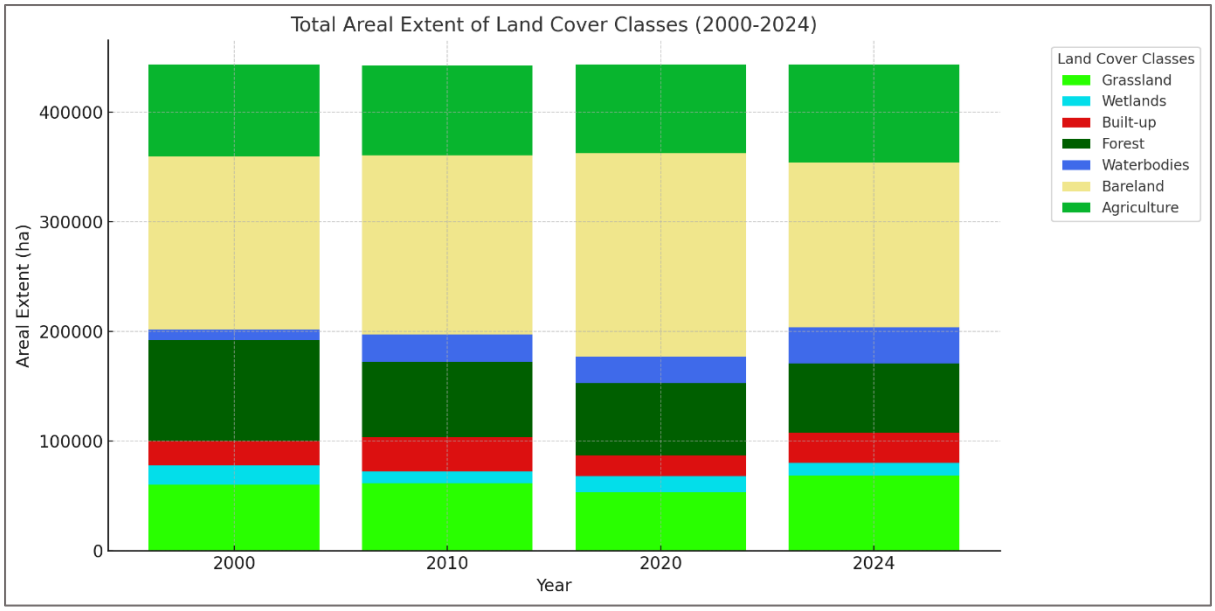


Figure 5-2: A stacked bar chart displaying the total areal extent of land cover classes from 2000 to 2024

5.3.2 Random Forest model accuracies

To assess the reliability of land cover classification, an accuracy evaluation was performed on all the classified images by utilising OA. The OA represents the proportion of accurately-classified pixels in relation to the total pixel count, whereas the kappa coefficient considers the agreement that arises by chance, which offers a solid metric for assessing classification reliability. The OA for each year and the kappa coefficient for the merged dataset are presented in Table 5.2.

Table 5-2 Overall accuracy for classified images and merged Kappa statistic

Year	Overall Accuracy (OA)	Kappa statistics
2000	88.98%	0.82
2010	91.23%	0.84
2020	84.21%	0.78
2024	86.55%	0.8
Average OA	**87.51%**	**0.81**

The results of the classification indicate a strong performance across various scenarios, with overall accuracies of between roughly 84% and 91%. The Kappa statistics ranging from 0.78 to 0.84 suggest a significant level of agreement between the predicted and reference datasets (Landis and Koch 1977). This stability in both the overall accuracy and the Kappa value emphasises the efficacy of the Random Forest model in differentiating multiple land cover types. These results correspond with the recognised methodologies in remote sensing accuracy evaluation, where the overall accuracy and the Kappa statistic act as complementary indicators of the classification performance (Congalton and Green 2019).

An analysis of the importance of the variables highlights the crucial role played by the Near Infrared (NIR) and Shortwave Infrared (SWIR) bands, which is consistent with earlier research that underscores their sensitivity to variations in the vegetation vigour and moisture levels (Jensen 2009) (Figure 5.3). The addition of vegetation indices, such as NDVI (Rouse et al. 1974) and NDWI (Gao 1996) enhances the class separability by recognising the subtle variations in plant health and moisture content. On the other hand, the visible bands (Blue, Green and Red) show a relatively lower importance; however, they still provide meaningful data for distinguishing certain land cover boundaries. Collectively, these findings reaffirm the effectiveness of multi-spectral data for LULC classification, and they demonstrate how ensemble methods like Random Forest (Breiman 2001) can adeptly utilise the diverse spectral

features of Landsat imagery.

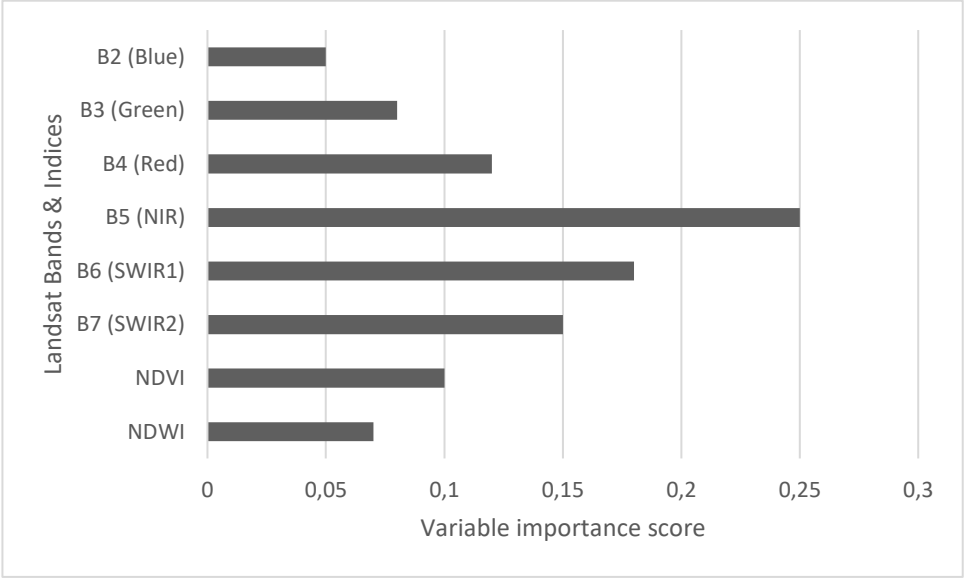


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Figure 5-3: Random Forest variable importance score

5.3.3 Temporal trends in ecosystem services provisioning

The findings highlighted considerable changes over time in the provision of ecosystem services from 2000 to 2024, which were driven by alterations in land use and land cover patterns (Table 5.3 and Figure 5.4). The wetlands, which are essential for regulating water, experienced a significant spatial reduction of about 22.4%, which resulted in a decrease of 3 115.21 ZAR/ha/year in their water regulation value. This trend indicates the heightened pressure from the expansion of agriculture and settlements, which often intrude upon ecologically valuable areas. Similar patterns have been noted in regional research, which stresses the vulnerability of wetlands in KwaZulu-Natal (Turpie et al. 2010). The expansion of agriculture, which rose by 17.4% during the study period, led to an increase of 1 497.63 ZAR/ha/year in food provision services. Nevertheless, this growth came at a cost to the natural ecosystems, such as wetlands and grasslands.

Grasslands, which are important for their recreational and aesthetic benefits, experienced a 15% decline, which amounted to a reduction of 526.15 ZAR/ha/year. These results correspond with the findings of Costanza, d'Arge, De Groot, Farber, Grasso, Hannon, Limburg, Naeem, O'neill and Paruelo (1997), who pointed out the compromises between agricultural growth and the sustainability of ecosystem services. Forests retained a relatively-stable spatial area, but made notable contributions to the raw material supplies (26.03 ZAR/ha/year) and gene pool conservation (486.82 ZAR/ha/year). The stability in the forest area likely reflects better management and conservation efforts in the province. Conversely, settlements increased by 23%, causing an extensive disruption of the natural ecosystems. While settlements offer limited ecosystem services themselves, they pose a growing risk to the regulating and

cultural services that are provided by wetlands and grasslands. The temporal analysis indicated a general decline in the regulating services, particularly those associated with water management. The deterioration of these services emphasises the rising vulnerability of the uMngeni Catchment to climate change and environmental degradation (Mantel et al. 2021).

Table 5-3 Temporal trends in ecosystem services provisioning

LULC Class	Ecosystem Service	Value in 2000 (ZAR/ha/year)	Value in 2010 (ZAR/ha/year)	Value in 2020 (ZAR/ha/year)	Value in 2024 (ZAR/ha/year)	% Change (2000–2024)
Wetlands	Water Regulation	2,512.01	2,300.50	2,100.75	1,950.80	-22.4%
Agriculture	Food Provisioning	2,870.99	3,000.50	3,150.25	3,368.62	+17.4%
Grasslands	Recreation	526.15	495.00	470.50	447.20	-15.0%
Forests	Gene Pool Preservation	486.82	500.00	515.75	530.00	+8.8%

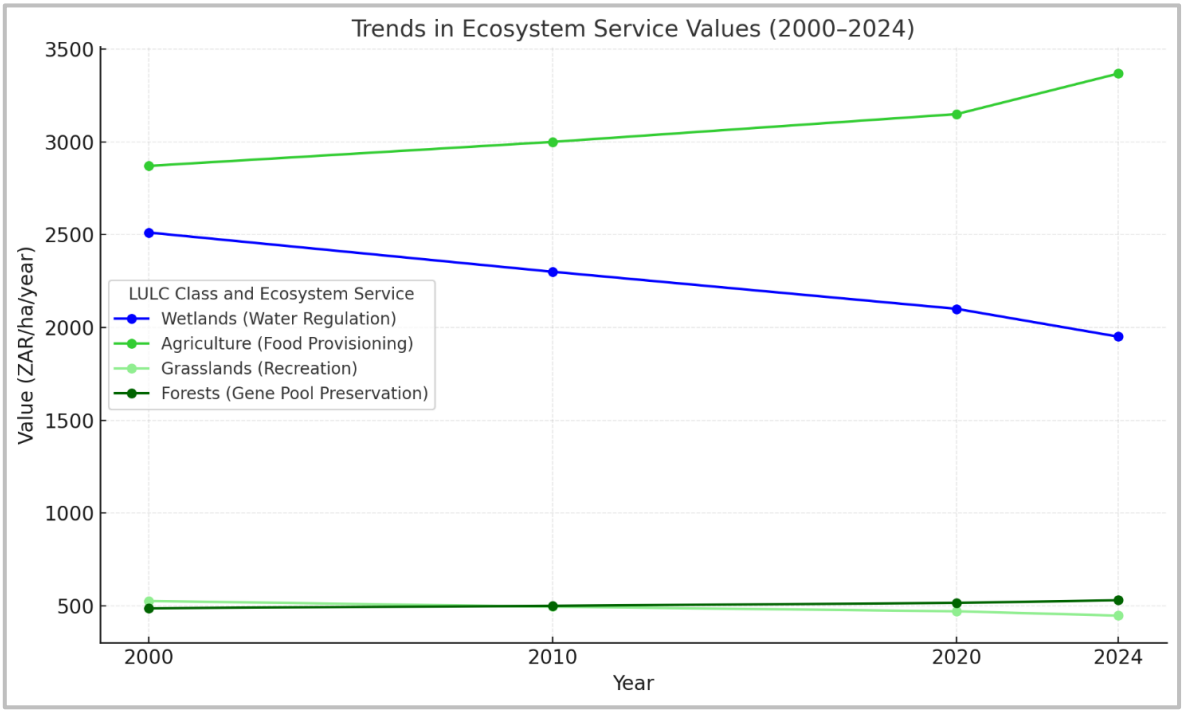


Figure 5-4: Trends in ecosystem service values from the year 2000-2024

5.4 Discussion

This research aimed to delineate the extent of the floodplain wetlands and to assess the LULC changes in the uMngeni Catchment from 2000 to 2024 by using Landsat data, with the specific focus being on the consequences for ecosystem services. The subsequent discussion consolidates the primary findings of the study, by investigating the intricate relationship between human actions and wetland behaviour. It also considers how alterations in the landscape influence the delivery of ecosystem services, thus providing valuable insights into the sustainable management strategies that are essential for alleviating the negative environmental effects and enhancing the resilience of the uMngeni Catchment.

5.4.1 Performance of Random Forest and remotely sensed data in mapping wetlands

The capabilities of the Random Forest classifier in wetland mapping are evidenced by its overall accuracies, which ranged from 84% to 91% and Kappa statistics of between 0.78 and 0.84, and which reflected its strong performance in addressing the intricate spectral variability that is typical of wetland areas. These findings align with prior research that emphasises the effectiveness of Random Forest within the remote sensing context, especially for varied and mixed types of land cover (Belgiu and Drăguţ 2016, Gislason et al. 2006, Rodriguez-Galiano et al. 2012). The ensemble methodology used in RF efficiently addresses the challenges associated with the high dimensionality and spectral noise that frequently occur in wetland classification, where detecting subtle variations in vegetation moisture and hydrological factors is essential (Mountrakis et al. 2011). Furthermore, the outcomes of this study are consistent with prior research that has indicated enhancements in the classification results when applying advanced machine learning techniques to remotely-sensed information, thereby emphasiszing the relevance of the approach for environmental observation and resource management (Maxwell et al. 2018).

In addition, the variable importance further highlights the effectiveness of combining multi-spectral remote sensing data with RF for identifying wetland areas. In this research, the NIR and SWIR spectral bands were revealed to be the most significant predictors, which reinforces prior studies that recorded the sensitivity of these bands to vegetation health and moisture variations (Belgiu and Drăguţ 2016, Jing et al. 2020). Furthermore, spectral indices, such as NDVI and NDWI, contributed valuable insights into the vegetation health and water presence, thus augmenting the model's proficiency in distinguishing the wetland perimeters from the neighbouring land types. These observations are bolstered by recent research which shows that integrating high-resolution spectral information with machine learning techniques not only enhances mapping precision, but it also boosts the clarity of the classification results (Janga et al. 2023). Collectively, these findings emphasise the collaborative potential between advanced remote sensing technologies and Random Forest classifiers, which

highlights their importance for precise wetland mapping and is crucial for conservation and management initiatives.

5.4.2 Changes in the extent of wetlands and other land cover types

The wetlands in the uMngeni Catchment significantly shrank from 17 00 ha in 2000 to 11 500 ha in 2024, which indicated a loss of 33.5% over the course of 24 years. This trend illustrates a mix of natural influences and human-driven pressures, such as urban expansion, agricultural intrusion and climatic shifts (Adeeyo et al. 2022). Similarly, wetlands within the floodplain buffer decreased from 2 977.9 ha to 1 873.9 ha, which highlights the global apprehensions that wetlands are among the most susceptible ecosystems to alterations in land use.

The rapid development of urban areas, which is marked by an expansion from 22 200 ha to 27 200 ha within the catchment and from 2 248.9 ha to 2 412.3 ha in the floodplain buffer, is most likely a significant contributor to the loss of wetlands. Wetlands that are located in close proximity to urban centres are particularly vulnerable, as they are often being drained or filled for the sake of infrastructure development. While agricultural land at the catchment level experienced a slight rise, the floodplain buffer saw a reduction from 9 961.6 ha to 7 631.9 ha, which may reflect a shift away from the flood-prone regions and is possibly due to heightened flooding risks or soil degradation (Adeeyo, Ndlovu, Ngwagwe, Mudau, Alabi and Edokpayi 2022, Verhoeven and Setter 2010). The drop in forest cover, from 92 400 ha to 63 800 ha in the catchment and from 8 758.6 ha to 4 909.8 ha in the floodplain buffer, indicates considerable deforestation, which is likely caused by land clearing for settlements and agriculture (Kumar, Kumar and Saikia 2022, Levers, Romero-Muñoz, Baumann, De Marzo, Fernández, Gasparri, Gavier-Pizarro, Waroux, Piquer-Rodríguez and Semper-Pascual 2021). Deforestation in the floodplains diminishes their natural ability to absorb floodwaters, which increases the flood hazards and contributes to erosion.

On the other hand, waterbodies experienced a significant increase, growing from 9 500 ha to 32 500 ha in the catchment, and from 5 779.0 ha to 9 675.8 ha in the floodplain buffer. This shift may be associated with climate fluctuations, alterations in hydrological flow or the expansion of artificial reservoirs (Venter, Scott, Desmet and Hoffman 2020). While the rise in waterbodies could enhance specific ecosystem functions, excessive growth may also indicate an escalating flood risk or modifications in land drainage patterns. From 2000 to 2020, the peak in bare land (185 500 ha) alongside a sharp decline in grasslands (53 200 ha in 2020) within the catchment underscores a phase of significant land conversion, which is most likely due to infrastructure or industrial development and changing hydrological regime cycles. Specifically, the year 2000 had a higher precipitation, compared to the other years. The later recovery of grasslands to 68 500 ha in 2024 suggests either active restoration initiatives or natural regrowth in abandoned lands. A comparable trend was observed in the floodplain buffer, where grasslands fell to 5 085.5 ha in 2020 before increasing to 5 641.6 ha in 2024.

South Africa is home to approximately 300 000 wetlands, with 48% being categorised as critically endangered and a mere 6% receiving formal protection (Van Deventer et al. 2019). As this study indicates, floodplain wetlands are particularly at risk, due to the competing land-use pressures. Conservation strategies need to tackle both the extensive catchment-wide and localised changes in the floodplains, in order to sustain their long-term ecological health.

5.4.3 Implications for ecosystem services

The variations in grassland coverage indicate its changing contribution to the ecosystem services. The expansion of grasslands, especially in rural regions, is expected to improve provisioning services, like forage for livestock, and to foster biodiversity preservation. Nevertheless, these advantages need to be balanced against possible challenges, such as overgrazing or land conversion that are driven by competing purposes. As Boval and Dixon (2012) noted, the effective management of grasslands is essential for preserving their multiple benefits. Subsequent research could investigate how these grassland changes relate to the regional economic activities and fluctuations in climate. The consistent increase in agricultural land reflects the region's dependence on food and fibre production, which aligns with global the agricultural trends. However, this expansion raises concerns about the potential trade-offs, including soil degradation, water resource depletion and biodiversity loss, due to monoculture practices (Jo et al. 2024, Li, Stringer and Dallimer 2022). While agriculture is essential for human sustenance, its intensification may undermine the long-term resilience of ecosystems.

The growth of water bodies is significant, as aquatic systems play a crucial role in cultural and supporting services. Lakes, reservoirs and expanded river systems offer recreational, aesthetic and spiritual benefits, while also nurturing the biodiversity and aquatic habitats. Nonetheless, these transformations may indicate underlying pressures, such as the fluctuating precipitation patterns, human activities (e.g., the construction of dams) or the impact of extreme weather events that lead to flooding, which can temporarily or permanently expand the water bodies (Beilfuss 2012). These changes require further exploration in order to determine whether they improve or undermine the overall performance of the ecosystem. The continual urban expansion highlights a growing human impact, which boosts the cultural and provisioning services like housing, infrastructure and economic prospects. Nevertheless, this urban development compromises regulating services, such as carbon storage and climate control, as the natural land cover diminishes. Urbanisation frequently causes the fragmentation of ecosystems, which adversely affects the biodiversity and habitat connectivity (Levers, Romero-Muñoz, Baumann, De Marzo, Fernández, Gasparri, Gavier-Pizarro, Waroux, Piquer-Rodríguez and Semper-Pascual 2021). The increase, and later the decrease in bare land, which reached its peak at 185 500 hectares in 2020, reflects the ongoing land degradation and desertification patterns. For example, increased bare land reduces the nutrient cycling and soil stabilisation capacity, which are critical services for maintaining agricultural productivity and ecosystem health (Venter, Scott, Desmet and Hoffman 2020).

The temporal dimension of these LULC changes provides important insights into the factors that influence ecosystem shifts. Similarly, the continuous expansion of urban areas highlights the economic growth and population demands, which are frequently accompanied by deforestation and wetland conversion, as demonstrated in this research. This observation is corroborated by Kumar, Kumar and Saikia (2022), who observed that urbanisation has a disproportionate effect on forest and wetland ecosystems, due to their proximity to developing urban centres.

The observed LULC trends highlight the trade-offs between the provisioning, regulating and cultural services. For example, although the expansion of agricultural and urban areas enhances food production and economic prospects, it adversely affects carbon storage, flood control and biodiversity. On the other hand, the increase in water bodies may create synergies by promoting cultural services, such as recreation, while also improving the availability of water for irrigation and domestic purposes. Recognising these trade-offs is crucial for informed decision-making, especially when trying to reconcile the immediate economic benefits with the long-term ecological integrity. Instruments like ecosystem service valuation and land-use optimisation models can assist in this process by measuring the trade-offs and pinpointing the synergies (Costanza, d'Arge, De Groot, Farber, Grasso, Hannon, Limburg, Naeem, O'neill and Paruelo 1997, Jo, Choi, Kweon, Son and Lim 2024).

5.4.4 Recommendations

Considering the increase in the LULC shifts demonstrated by the findings of this study and the vital functions that wetlands serve in supporting both the ecological and human systems, targeted strategies are being designed that tackle the challenges presented by the observed LULC changes. Given the persistent growth of agricultural land, alternative transformative and sustainable farming practices, such as crop diversification, agroforestry and soil conservation practices, should be emphasised in order to reduce land degradation and biodiversity loss, while boosting the productivity of ecosystems. The ongoing expansion of urban areas necessitates the integration of green infrastructure, wetland buffers, and sustainable urban drainage systems, including flood management and carbon storage, to reduce the negative effects on the regulatory services. Restoration initiatives concentrating on revegetation, erosion control and maintaining wetland hydrology must be conducted to reverse the trends of land degradation and to improve ecosystem services, such as nutrient cycling and water regulation. With the noted increase in waterbodies and grasslands, ongoing monitoring is crucial to safeguard their ecological health and to prevent their potential overuse or mismanagement. This might involve establishing biodiversity corridors and promoting sustainable grazing techniques. Considering the effects of changing the precipitation patterns and the dynamics of water bodies, adaptive management strategies should be developed to address the consequences of climate change on the LULC and wetland health, in order to ensure the long-term resilience of water resources and ecosystems.

5.5 Conclusion

The objective of this study was to analyse the land cover changes within the uMngeni Catchment and its floodplain, from 2000 to 2024, with a particular focus on wetland dynamics, urban expansion and agricultural shifts.

Based on the findings, it was concluded that:

- Landsat spectral variables, especially the NIR and SWIR bands, along with spectral indices like NDVI and NDWI, significantly enhance the accuracy of wetland and land cover classification when applied in a Random Forest model. The classifier attained high overall accuracy rates (84%-91%) and Kappa values (0.78-0.84), which indicated its reliability for delineating wetlands.
- Wetlands in the uMngeni Catchment have seen a decline of 33.5% between 2000 and 2024, mainly due to the expansion of agriculture and urban areas. Urban development has risen by 22.52%, while agricultural land has increased by 6.42%, effectively replacing wetland ecosystems and causing habitat fragmentation.
- These results indicate that the regulation of wetlands and the provision of ecosystem services are decreasing by 3 115.21 ZAR/ha/year, which indicates significant losses in the regulation of water and additional ecological functions. In the absence of focused conservation efforts, the ongoing degradation of wetlands will further compromise the resilience and sustainability of ecosystems.

By integrating floodplains and valley bottom wetlands into land-use planning and management frameworks, their ecological functionality can be preserved, which will contribute to the resilience of the broader catchment system. Future studies and policy frameworks should focus on the causes of wetland degradation and encourage approaches that enhance the resilience of natural ecosystems (Li, Ma, Gou, Hong, Fai and Xiong 2022, Moodley, Toucher and Lottering 2023). The safeguarding and rehabilitation of wetlands must take precedence, in order to uphold their ecological roles, to enhance water security and assist in achieving broader sustainable development objectives (Costanza, De Groot, Sutton, Van der Ploeg, Anderson, Kubiszewski, Farber and Turner 2014, Li, Stringer and Dallimer 2022). This research lays a solid groundwork for additional investigations into the relationship between land use changes and the provision of ecosystem services, providing practical insights to promote their long-term ecological and socio-economic sustainability (Mantel, Xoxo, Mahlaba, Tanner and Le Maître 2021, Rong and Fu 2023).

6 EXAMINING COMMUNITY PERSPECTIVES AND POLICY EFFECTIVENESS: FLOODPLAIN WETLAND MANAGEMENT AND ITS SOCIO-ECONOMIC IMPACTS IN THE MSUNDUZI RIVER BASIN

6.1 Introduction

Floodplain wetlands are critical ecosystems that provide a multitude of ecological, economic, social and cultural benefits globally (Dickens et al., 2003). These ecosystems function as natural buffers against floods, they facilitate water purification, support biodiversity and sustain the livelihoods of millions. However, despite their immense value, floodplain wetlands are increasingly threatened by human activities, land use changes, as well as the adverse impacts of climate change (Mandishona & Knight, 2022; Mooney et al., 2009). Such challenges complicate the efforts toward their sustainable management and conservation.

Globally, the vital ecological services offered by wetlands are increasingly being acknowledged, yet these fragile ecosystems remain under relentless pressure. The Ramsar Convention on Wetlands (1971), an international treaty that was aimed at conserving wetland resources, underscored the urgent need for their wise use and sustainable management. Despite the existence of such frameworks, wetlands continue to confront unprecedented challenges (Musasa & Marambanyika, 2020). While the Ramsar Convention has made significant strides in fostering international cooperation for wetland protection, the effective implementation of management strategies remains problematic. The challenge lies in reconciling the need for wetland conservation with the escalating demand for land and resources, particularly in Global South regions, where economic development is prioritised over environmental preservation.

In sub-Saharan Africa, wetlands play a crucial role in supporting agriculture and local livelihoods, yet they face unique conservation challenges that warrant further research (Raburu et al., 2012). The management of wetland ecosystems remains a pressing issue on the continent, as agricultural practices significantly contribute to wetland degradation through pollution, livestock overgrazing and habitat clearance (Marambanyika & Beckedahl, 2016). What compounds these issues is a weak institutional framework and a pervasive lack of awareness regarding wetland management policies, which hinder effective policy implementation. As a result, existing policies often fail to protect wetlands while adequately addressing the needs of local communities that depend on these vital ecosystems.

Despite the growing recognition of the ecological and socio-economic significance of floodplain wetlands, the existing literature predominantly emphasises ecological and economic factors, but largely neglects the socio-cultural dimensions that shape the interaction of local communities with these vital ecosystems. In sub-Saharan Africa, wetlands are often imbued with profound cultural significance, resulting in the development of traditional knowledge systems for their management (Laltaika, 2022). However, formal policies frequently overlook these cultural aspects, which creates discord between the traditional practices and regulatory

frameworks. This disconnect is exacerbated by a pervasive lack of community awareness regarding wetland management policies (Amadu, 2022; Turyasingura et al., 2022), which leads to utilisation practices that align more closely with the established traditions, rather than with the formal regulations (Matsiliza, 2024). Alarmingly, no studies have adequately evaluated the community awareness of wetland policies from the perspective of the local stakeholders, which highlights a significant gap in the research. Addressing this gap is essential for understanding the socio-cultural context of wetland management and for formulating policies that are both environmentally sustainable and relevant to the local realities.

Since South Africa became a contracting party to the Ramsar Convention in 1975, the critical state of its wetlands has been acknowledged. More than half of the wetland, river and estuarine ecosystems are now classified as critically endangered, endangered or vulnerable. According to SANBI (2025), over 60% of the river and wetland types are threatened, while less than 10% are well-protected. Despite the existing protective legislation, such as the 1984 Conservation of Agricultural Resources Act and the National Environmental Management Act, South Africa lacks a stand-alone wetland policy, which results in disjointed and incoherent governance (Sinthumule, 2024). The array of sectoral policies aimed at wetland conservation is often ineffective, and they fail to integrate proactive measures for maintaining healthy wetlands while addressing the urgent need to reverse past degradation (Sinthumule, 2024). Environmental law enforcement in South Africa is overseen by multiple agencies, including the Department of Forestry, Fisheries and the Environment (DFFE), the South African National Parks (SANParks), iSimangaliso Wetland Park, provincial environmental departments, conservation agencies and selected municipalities. Effective wetland management is crucial for both protecting ecosystems and supporting sustainable livelihoods. However, the limited capacity and resources of government entities pose a challenge for implementing environmental laws. Thus, assessing the impact of floodplain wetland policies on community farming practices has become imperative. Despite the enactment of numerous legal and regulatory instruments by the public sector organs, there is a limited understanding of how effectively these instruments are emphasised and presented to the community members.

It is in this regard that this article sought to explore the stakeholders' perceptions of the efficacy of current policies and legislation that are aimed at conserving wetlands in the Msunduzi floodplains, which are located in KwaZulu-Natal, South Africa. They exemplify the challenges faced by wetland ecosystems, as they strive to maintain ecological integrity while meeting the socio-economic demands of surrounding communities (Raburu et al., 2012). Specifically, the uMsunduzi floodplains are experiencing persistent degradation, despite the existence of laws and organisations to govern their usage. Therefore, this research sought to address the following objectives: (i) to identify the institutions, policies and implementation frameworks governing the utilisation of floodplain wetlands in uMsunduzi floodplains; (ii) to assess the magnitude of the communities' awareness of the policies and legislation governing wetland management; and (iii) to evaluate how these policies could be made more accessible to local communities, in order to be effectively implemented. By assessing the effectiveness of these frameworks in promoting sustainable livelihoods, the research aims to offer evidence-based recommendations for improving wetland management, thereby aligning them with the relevant Sustainable Development Goals (SDGs), particularly SDG 6 (Clean Water and Sanitation) and

SDG 15 (Life on Land).

6.2 Materials and Methods

This section provides an overview of the study area, and it focuses on the ecological and socio-economic significance of its floodplains, which are vital for local livelihoods, such as fishing and agriculture. This section also outlines the research methods that were employed in the study, detailing the mixed-methods approach, which integrates both qualitative and quantitative research. It describes how qualitative and quantitative methods were employed to assess the impact of these policies on local livelihoods and socio-economic outcomes. The section also covers the data collection process, the sampling strategy and the tools that were used for data analysis, which ensured a comprehensive approach to understanding floodplain wetland management in the Msunduzi region.

South Africa has an array of wetlands that provide environmental, socio-economic and cultural services. As a member of the Ramsar Convention since 1975 (Sinthumele, 2024), South Africa has a unique responsibility to protect and manage these vital ecosystems. Due to the dire need for woodland management and conservation, South Africa has several policies, legislation, and legal frameworks that aim to protect and manage wetlands (Elliot & Blackmore, 2019). The conservation of natural resources in South Africa is overseen first and foremost by the constitution of the Republic of South Africa, in which Section 24 states that reasonable legislative and other measures should be taken to prevent the pollution and ecological degradation of ecosystems (Republic of South Africa, 1996). The constitution does not mention wetlands specifically (Sinthumele, 2024), but several laws have been formulated to regulate the environment and natural resources (Elliot & Blackmore, 2019). It is important to note that none of them are specific to wetlands, which highlights the need for South Africa to either strengthen an existing statute or to formulate a legal framework that aims to specifically provide for wetlands.

The key policies and laws that govern the use of, and are aimed at protecting wetlands in South Africa, include the National Environmental Management Act (NEMA, No.107 of 1998), which provides an overarching framework for Environmental Protection, ensuring that decisions concerning sensitive ecosystems are adequately considered, in order to avoid extensive harm coming to them (Republic of South Africa, 1998a). Under the NEMA framework, Specific Environmental Management Acts (SEMAs) have been promulgated. The statutes that are relevant in the context of this paper are the NEMA: Biodiversity Act 10 of 2004 (NEMBA), the National Water Act 36 of 1998 (NWA), as well as the National Environmental Management: Protected Areas Act 57 of 2003 (NEMPAA).

NEMBA aims to conserve the biological diversity and protect the species and ecosystems (Republic of South Africa, 2004). This Act does not make any reference to wetlands, but given that wetlands are a type of ecosystem (Elliot & Blackmore, 2019), this Act is relevant. The NWA provides a legal framework for managing the water resources, although the Act mentions the word ‘wetlands’ no more than twice; wetlands are considered to be a water resource, which makes the NWA a relevant policy. The NEMPAA provides for the full protection and conservation of protected areas, including nature reserves, protected environments and World

Heritage sites, among others (Sinthumele, 2024). Again, this act does not refer to wetlands, but any water bodies that are located under protected areas will be given protection. This Act is relevant to the Msunduzi River Basin, as the uMsunduzi River falls under the iSimangaliso Wetland Park, which is both a World Heritage Site and a Ramsar Site, which provides for its protection under the NEMPAA. Lastly, the Conservation of Agricultural Resources Act 43 of 1983 (CARA) also plays an important role in wetland management, as it prevents the degradation or erosion of wetlands, preventing them from being harmed by cultivation or draining (Republic of South Africa, 1983). The abovementioned policies, legislations and frameworks work to conserve and protect wetlands; however, they cover multiple interests like water, biodiversity and agriculture, while not making direct reference to wetlands. This highlights the fragmentation of the policies and institutions that are meant to protect wetlands (MacFarlane et al., 2021).

The management of wetlands is not exclusive to policies and legislation, as there are various stakeholders that are also involved. The stakeholders in the Msunduzi River Basin include the national government, such as the Department of Forestry, Fisheries and the Environment (DFFE) which manages, protects and conserves the country's environment and natural resources, the Department of Water and Sanitation (DWS), which enforces the regulatory measures that ensure the provision and effective management of safe water, as well as the Department of Agriculture, Land Reform and Rural Development (DALRRD), which is responsible for the promotion of agriculture. At a provincial level, government departments include the KwaZulu-Natal Department of Economic Development, Tourism and Environment Affairs (EDTEA), the KwaZulu-Natal Department of Economic Development and Environmental Affairs and the KwaZulu-Natal Department of Agriculture and Rural Development (DARD), which are all responsible for implementing policies at a provincial level. Stakeholders also include the local government, which consists of the uMgungundlovu District Municipality and the Msunduzi Municipality, and who are mainly responsible for environmental governance on a local level by taking charge of the enforcement of wetland management. Non-Governmental Organisations (NGOs), such as the Duzi Umgeni Catchment Trust (DUCT), play an important role in educating the local communities and promoting their awareness about wetland sustainability. Lastly, the local community, which includes residents and farmers, is also a stakeholder, as their livelihoods and agricultural practices are directly linked to the uMsunduzi wetland, which emphasises the importance of their involvement and collaboration for effective policy implementation (Raburu et al, 2012). Figure 6.1 shows the various stakeholders involved in the management of the wetland in question.

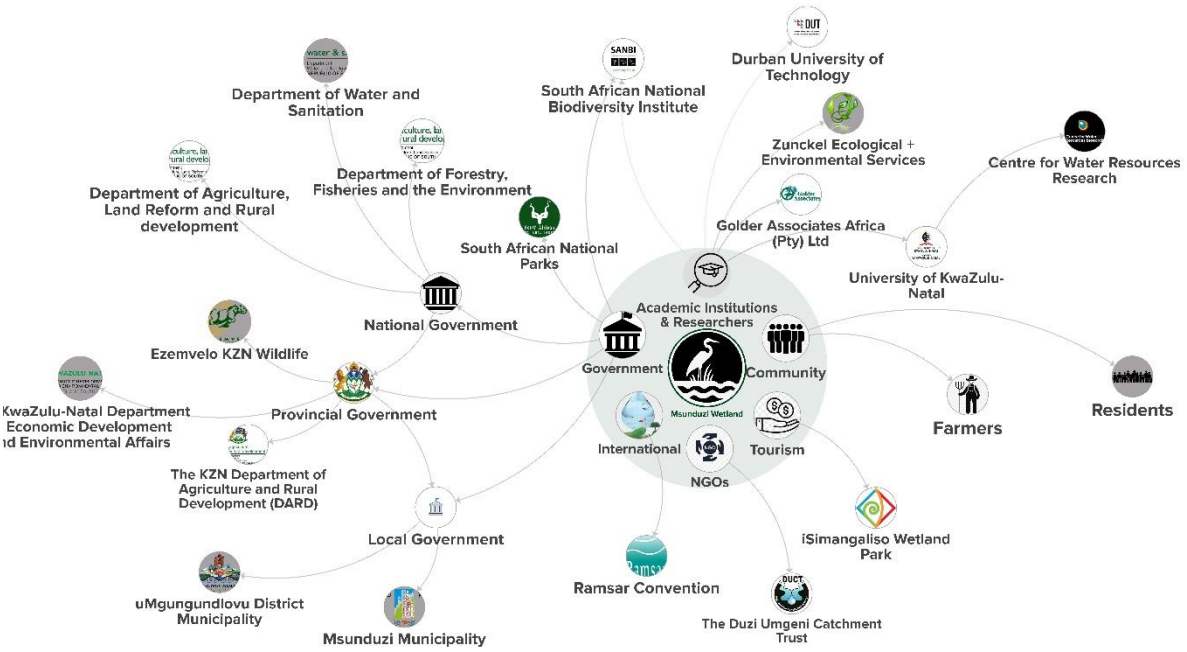


Figure 6-1: Map of stakeholders involved in the management of uMsundizi floodplain wetlands (Source: Authors)

6.2.1 Research design

The ethical approval for this paper was obtained from the Humanities and Social Science Research Ethics Committee of the University of the Western Cape (HS24/3/26), to ensure that this paper constantly complied with its ethical standards and guidelines. This study employed a mixed-methods research design by integrating both the qualitative and quantitative approaches to provide a comprehensive analysis of the institutional structures, policies and implementation frameworks that govern the utilisation of floodplain wetlands in the Msunduzi region. Mixed methods were deemed to be necessary, in order to capture both the subjective experiences of the key stakeholders and the measurable impacts of floodplain policies on the local communities; this approach allows for triangulation and it enhances the validity of findings (Creswell, 2013). Ethical clearance was acquired, before conducting the surveys.

The quantitative phase of this study was designed to evaluate the tangible impacts of floodplain management policies on the local livelihoods within the Msunduzi Municipality. A structured questionnaire survey, characterised by both closed- and open-ended questions, was administered to households situated near the Msunduzi River. The closed-ended questions captured essential data on the demographics, river usage patterns (e.g. fishing, agriculture or recreation), and their perceptions of the wetland management policies, while the open-ended questions provided the respondents with an opportunity to elaborate on their experiences and perspectives. This qualitative nuance was particularly useful for gaining a deeper insight into the subjective responses of the community to the effectiveness of the policy, thereby enriching the dataset with a contextual understanding of the lived experiences of the local population.

The traditional authorities were consulted before the data collection commenced. Chiefs from

the villages of Nkanyezeni, Mdaphuma, Bhobhonono and Emvini were approached to gain permission and access to their respective communities. This culturally sensitive approach ensured that the study was ethically sound and built trust with the local population, thereby facilitating more open and honest responses during the data collection. Stratified random sampling was employed when selecting the respondents, with the stratification being based on their proximity to the river, to ensure a representative sample. This method ensured that various socio-economic and demographic groups were included, thereby enhancing the generalisability of the findings (Bornstein et al., 2013).

The surveys were administered in July 2024 in isiZulu, which is the dominant language spoken in the area. This language fluency was critical in ensuring the accuracy of the responses, as questions could be translated where necessary. The in-person administration of the surveys also allowed for real-time clarification of the questions and maximised response rates. A total of 60 surveys were completed from the villages along the uMsunduzi River confluence. The collected data underwent a rigorous cleaning process to ensure their reliability. Each questionnaire was carefully reviewed to identify and correct any errors, missing values and any illogical responses. The cleaned data were then entered into IBM SPSS (Version 27) for analysis. The data entry process involved creating variables that corresponded to each question, followed by the manual input of responses into a spreadsheet. The SPSS 'data view' function was utilised to review the completeness and accuracy of the data, to ensure that no values were omitted. Descriptive statistics, including frequencies and means, were used to summarise the respondents' characteristics, their river usage patterns and their perceptions of wetland policies. Charts and tables were generated to present the information that addressed the objectives of this study.

The second phase of data collection involved conducting semi-structured interviews with the key stakeholders responsible for the management and use of the Msunduzi River and its floodplain wetlands. These stakeholders included representatives from government agencies, Non-Governmental Organisations (NGOs) and local community leaders. The objective of these interviews was to gain an in-depth insight into the institutional frameworks that govern wetland management, the roles and responsibilities of various institutions, as well as the effectiveness of the policy implementation. Moreover, the interviews explored the extent of collaboration between the stakeholders and assessed the challenges and opportunities within the current management structures. This method allowed for flexibility, which enabled the researcher to probe deeper into the complexities of the stakeholder dynamics, the policy impact and the institutional effectiveness. The interviews were conducted online at times that were convenient for the stakeholders. The semi-structured nature of the interviews allowed for both guided questioning and the open-ended exploration of topics in order to facilitate richer data collection. Interviews typically lasted between 45 minutes to an hour, during which time the participants were encouraged to reflect on the current state of floodplain management and to suggest improvements or collaborative mechanisms that could enhance the policy outcomes.

The qualitative data collected from these interviews were transcribed verbatim and subjected to a rigorous thematic analysis. This method was selected because of its suitability for identifying recurring themes, patterns and relationships within qualitative data (Braun &

Clarke, 2006). Initially, the researcher engaged in open coding, reviewing each transcript line-by-line, to identify the emerging themes related to institutional structures, policy challenges and stakeholder collaboration. The open coding process was followed by axial coding, which organised these initial codes into broader categories and sub-categories, in order to reflect the nuanced roles and interactions of the stakeholders within the floodplain management framework. Themes were refined iteratively by means of a constant comparison, which ensured that both the individual and collective stakeholder perspectives were adequately captured. A thematic analysis facilitated the identification of critical insights into the strengths and weaknesses of the current floodplain management approaches, while it also highlighted areas where the institutional capacity, coordination or resource allocation could be improved. To enhance the validity and robustness of the research, the qualitative findings from the stakeholder interviews were integrated with the quantitative survey results by means of triangulation. This process involved cross-referencing the outcomes of both data strands in order to identify the convergence, divergence or complementarity in the findings. By merging the insights from both the quantitative and qualitative phases, the research was able to offer a holistic view of the floodplain wetland management system, which provided a deeper understanding of how institutional structures and policies impact local livelihoods in the Msunduzi region. The combination of data sources strengthened the conclusions of the study and provided a comprehensive framework for addressing the challenges and opportunities associated with floodplain management.

6.3 Findings

6.3.1 Socio-demographic profile of respondents

The demographic profile of the respondents in this study presents a diverse age distribution. The majority of participants (30%) were aged 56 and above, followed by those in the 36-45 age group, which accounted for 28.3%. Participants aged between 26-35 made up 16.7%, while 13.3% were in the 18-25 age range, and 11.7% were between 46-55 years. In terms of their gender, 68.3% of the respondents were female, while males comprised 31.7%. Regarding their employment status, a significant proportion (63.3%) reported that they were unemployed, while 35% were employed, and only 1.7% indicated that they had ‘other’ occupations. In addition, when asked about their length of residence along the uMsunduzi confluence area, the majority (75%) had lived there for more than 10 years, 11.7% had resided there for 6-10 years, and smaller portions of 6.7% each, had lived in the area for less than a year or between 1-5 years. This demographic overview provides a context for understanding the social characteristics of the community in the uMsunduzi confluence area.

6.3.2 Awareness and perceived effectiveness of the policies governing floodplain wetlands

The findings revealed a limited awareness among respondents regarding the policies or regulations that govern the use of floodplain wetlands in the uMsunduzi confluence area (Table

6.1). A significant proportion of the participants (85%) indicated that they were unaware of any policies, with only 6.7% affirming an awareness of such regulations. Among the few who claimed to have a knowledge of the relevant policies, specific mentions were scarce, with only 1.7% citing the regulations related to floods and another 1.7% referring to the water and sanitation policies. This suggests that even when policies do exist, their visibility and dissemination among the residents is minimal.

Table 6-1 Overview of the participants' awareness of policies governing floodplain wetlands, and perceptions of policy effectiveness

Question	Response	Frequency	Percent
Are you aware of any policies or regulations governing the use of floodplain wetlands in this area?	-	5	8.3
	No	51	85.0
	Yes	4	6.7
Total	-	58	96.7
Do you think these policies effectively protect the floodplain wetlands?	-	5	8.3
	No	28	46.7
	Not sure	23	38.3
	Yes	4	6.7
Total			100

When asked about the effectiveness of the policies in protecting the floodplain wetlands, the respondents displayed uncertainty. A substantial 46.7% of participants believed the policies were ineffective in providing adequate protection. Moreover, 38.3% were unsure about the policies' efficacy, which reflects a notable degree of uncertainty, or a lack of understanding about the role that these policies play. Only 6.7% expressed confidence that the policies that are in place effectively safeguarded the wetlands. These findings highlight a gap in both their policy awareness and their perceptions of policy effectiveness, which indicates that even among those who were aware of the regulations, there was scepticism about their impact. The general lack of awareness and uncertainty regarding the effectiveness of the policy underscores the need for improved communication and the enforcement of regulations, in order to enhance the community's engagement in wetland conservation efforts.

The respondents were asked, *"Do you think floodplain wetland management policies impact community farming practices in this area?"* The open-ended responses were then analysed thematically. The analysis of how floodplain wetland management policies impact community farming practices in the Msunduzi River Basin revealed several key thematic findings. The most dominant theme, expressed by 60% of respondents, was the belief that these policies have no discernible effect on farming practices. Responses such as *"It does not"* or *"They do not*

impact us" reflect a widespread perception that these management policies are either irrelevant or disconnected from the community activities that are conducted in the wetlands. This suggests that the policies are either poorly communicated or not visibly enforced, which creates a disconnect between the regulatory intentions and the community's practical reality. In addition to this, approximately 10% of the respondents indicated a general unawareness of the policies, or an uncertainty about their existence. Statements such as *"unaware"* and *"not sure"* point to a significant communication gap, where community members are uninformed about the objectives of the policies or how they might influence their farming activities. This lack of awareness most likely contributes to the dominant view that the policies have no tangible impact, and it highlights a need for greater community engagement and education with regard to the wetland conservation initiatives.

A smaller subset of respondents (3%) expressed frustration with the perceived ineffectiveness of these policies. Phrases like *"everyone does as they please"* reflect the belief that, even where policies exist, they are not properly enforced, which leads to unsustainable practices in the area. This lack of regulatory enforcement may exacerbate environmental degradation and undermine the goals of floodplain management in the region. Conversely, a minority of respondents (3.4%) reported that these policies negatively impacted their farming practices, although specific details of this impact were not provided. This negative sentiment may stem from the restrictions on their land use or access to natural resources that are critical for farming. In contrast, 6.7% of the respondents reported either a neutral or positive impact of the policies on farming practices. Terms like *"positively"* and *"neutral"* suggest that, while these policies may not have widespread visibility, and they are not universally seen as barriers to farming. This minority view opens up the possibility that, with better communication and policy design, floodplain management efforts could be framed as being supportive of sustainable agriculture.

6.3.3 Suggested improvements for floodplain wetland management policies in the Msunduzi River Basin

Respondents provided a range of suggestions for improving floodplain wetland management policies in the Msunduzi River Basin, with a focus on enhancing communication, awareness and community engagement. One of the most common themes centred around the need for *increased communication* between local authorities and the community. Many respondents expressed that policies should be communicated, with one participant stating that there should be *"better communication with the local community, make an effort to protect the river".* This sentiment was echoed by several others, who suggested that there should be improvements in *"communication from the chief to the community regarding policies and projects"* and *"more communication with the community".*

Another prominent theme involved the need for *community involvement* in policymaking and management efforts. Numerous respondents advocated for actively engaging the local communities in the process, with suggestions such as *"ask input or suggestions from the community"* and *"involve the community".* A recurring recommendation was to ensure that the community is aware of all the activities, with one respondent proposing that authorities should *"let the community know". Awareness and education* also featured heavily in the feedback.

Several participants highlighted the importance of educating the public about the significance of the floodplain, and they proposed *"educational programmes about the river and its potential dangers"* and efforts to *"increase awareness and educate the community".* Furthermore, some respondents called for the stricter *enforcement of policies*, with one suggesting the need to *"enforce rules that protect the floodplain"* and another emphasising the importance of *"managing rules and regulations".* In addition, concerns were raised about *environmental cleanliness* and pollution control, with suggestions such as *"add initiatives to clean water"* and *"companies must clean the river".* Finally, there were calls for addressing their specific local needs, with one respondent suggesting that authorities should *"consider our needs, especially about more bridges,"* which indicated that infrastructure and access also play a role in effective floodplain management.

Community participation in floodplain wetland management decision-making was overwhelmingly rated as ineffective by respondents (Table 6.2). Of the 60 participants, 86.7% indicated that community participation was "*not effective"*, while a mere 8.3% felt it was "*very effective"*, and 5% deemed it to be "*somewhat effective"*. This suggests a critical gap in inclusive decision-making, and it highlights the potential deficiencies in the participatory processes or community engagement efforts by the authorities.

The level of direct involvement by means of their attendance at community meetings or workshops related to wetland management was notably low. An overwhelming 96.7% of respondents reported that they had "*not attended"* any meetings or workshops on the subject. Only 1.7% reported having attended such engagements. The lack of participation in formal meetings may contribute to the perception of ineffective involvement, which underscores the need for more accessible and inclusive avenues for participation.

A vast majority (91.7%) of the respondents indicated that there was "*inadequate communication"* and dissemination of information regarding floodplain wetland management policies. This was compounded by a small proportion (5%) who were "*unsure"*, which suggests their lack of clarity around the communication channels that are employed. Only 3.3% of the respondents felt that there was adequate communication. This highlights a significant communication gap, with most community members feeling uninformed about the critical environmental policies that directly impact their livelihoods.

Table 6-2 Community's perception of participation, attendance at meetings, and the communication of wetland management policies

Question	Response	Frequency	Percent
Effectiveness of community participation in floodplain wetland management decision-making	Not effective	52	86.7
	Somewhat effective	3	5.0
	Very effective	5	8.3
	Total	60	**100.0**
Have you attended any community meetings or workshops related to floodplain wetland management?	No	58	96.7
	Yes	1	1.7
	Total	60	**100.0**
If yes, how would you describe your experience at these meetings/workshops?	Missing (No responses)	60	100.0
Adequacy of communication and dissemination of floodplain wetland management policies	No	55	91.7
	Not sure	3	5.0
	Yes	2	3.3
	Total	60	**100.**

6.3.4 Effective channels for communicating floodplain wetland management policies

The findings suggested a strong preference for community meetings as the primary channel for communicating floodplain wetland management policies. A significant 28.3% of respondents highlighted the importance of meetings alone, while an additional 15% emphasised the role of community meetings specifically. The combination of community meetings with other platforms, such as social networks (including radio, TV and Facebook), was noted by 1.7% of respondents, which indicated a recognition of the value of integrating the traditional with digital media. In contrast, social media and radio stations were less frequently mentioned, with only 3.3% of respondents recommending these channels. This suggests that while there is some support for using social media and radio for communication, face-to-face interactions through meetings are still seen to be the most effective means of engaging the community. The findings underscore the need for consistent and inclusive community engagement strategies that incorporate both the traditional methods, such as community meetings and announcements, and modern communication tools, to ensure the comprehensive and effective dissemination of

policy information.

6.3.5 Awareness and details of community-based initiatives for sustainable floodplain management

The survey results revealed a notable disparity in their awareness of community-based initiatives for promoting sustainable floodplain management practices. A substantial majority (83.3%) of respondents indicated that they were unaware of any such initiatives. In contrast, 15% of respondents reported a knowledge of the existing community-based projects. Among those who were aware, the details that they provided varied and included efforts by the agriculture department to support smallholder farmers, initiatives involving companies cleaning the river, and activities associated with the Expanded Public Works Programme (EPWP) and other environmental projects (EWP). Specific projects mentioned included a river clean-up campaign and the Idisu marathon, which also focused on cleaning the river. These initiatives reflect a range of community-led and governmental efforts that are aimed at improving the environmental conditions. However, the low overall awareness suggests a need for increased visibility and communication regarding these initiatives, in order to enhance the engagement and participation of the community in sustainable floodplain management practices.

6.3.6 Perceptions of the relationship between floodplain wetland management policies and socio-economic development in the Msunduzi River Basin

The survey data showed a predominantly negative perception of the relationship between floodplain wetland management policies and socio-economic development in the Msunduzi River Basin. The majority of respondents (58.3%) viewed the impact of socio-economic development as negative, while 21.7% were neutral, and only 8.3% perceived that there was a positive relationship. This indicates a significant concern among the community members regarding the effectiveness of the current policies in contributing to socio-economic advancement. In addition to these perceptions, the open-ended responses suggest a variety of concerns and recommendations. Respondents highlighted issues, such as excessive soil erosion, inadequate cleaning projects, and the need for enhanced educational and awareness programmes. Suggestions also included the enforcement of rules, with penalties for non-compliance, the improved management of sand mining activities, and increased government involvement. The emphasis on education, community awareness, and stricter regulations reflects a broader call for more robust and effective measures to align floodplain wetland management with the socio-economic development goals.

6.4 Discussion

The main objective of the study was to explore the perceptions of stakeholders on the efficacy of the current policies and legislation that are aimed at conserving the wetlands in the Msunduzi floodplain. To address this over-arching aim, the study (i) identified the institutions, policies

and implementation frameworks that govern the utilisation of floodplain wetlands in the Msunduzi floodplains; (ii) assessed the magnitude of communities' awareness of the policies and legislation governing wetland management; and (iii) evaluated how the existing policies could be made more accessible to the local communities, to implement them effectively.

6.4.1 Awareness and communication

Results of this study highlighted a critical barrier to effective wetland management, more specifically, the widespread lack of policy awareness among community members. A significant majority of respondents (85%; n = 51) reported no knowledge of the existing policies governing the use and management of wetlands. Even among the minority who were aware, their understanding was limited and largely anecdotal. This finding suggests that, regardless of the existence of wetland management policies, their practical implementation is often hindered by the inadequate dissemination of this information to local communities. Poor communication channels or difficulties in accessing the relevant policy documents contribute to this gap, which ultimately undermines the community's participation in sustainable wetland management. This finding aligns with the conclusions drawn by Turyasiyngura et al. (2022) in a similar study, who found that residents living near wetlands are often ill-informed about wetland conservation practices and policies. The lack of awareness not only prevents community members from contributing to the conservation efforts, but it also inadvertently facilitates harmful activities that degrade wetland ecosystems, while it contravenes the enacted instruments and regulations. This gap in communication, as well as the failure to properly disseminate critical policy information, reflects the systemic flaws in the governance of wetland resources, where local actors and key stakeholders in policy enforcement are excluded from the knowledge loop. Such exclusion underscores a fundamental weakness in the policy framework, which fails to account for the social dimensions of environmental governance, particularly the need for inclusive, grassroots-level education and awareness-building. This lack of awareness and engagement from the local population exacerbates the disconnection between the policy formulation and the on-the-ground reality, which ultimately compromises the sustainability of wetland management efforts.

The perception of local communities of the ineffectiveness of existing wetland management policies was a concerning finding. Among the small number of respondents who were aware of these policies, a significant 46.7% expressed the belief that the policies were ineffective and did not provide sufficient protection for wetlands. This scepticism and mistrust reflected deeper issues, including a pronounced disconnect between policy formulation and practical outcomes. The community's perceptions suggest that policies, even when they are present, fail to resonate with, or address the realities of the local stakeholders, thereby undermining the intended purpose of the policies. These findings reflect a top-down governance approach that insufficiently engages with the local communities, particularly when designing the management frameworks. As Sinthumule (2024) and Rabura et al. (2012) have noted, policies and management strategies are often developed with limited consultation or communication with those who are directly impacted by their implementation. This lack of participatory involvement leads to policies that are perceived as distant, irrelevant or impractical by the local

population. As a result, the mistrust of the community grows, which weakens both their compliance with, and the overall effectiveness of, the conservation efforts.

The local community's low level of awareness of the policies that are related to floods and water sustainability points to a critical deficiency in the dissemination of information. This finding indicates that, despite the existence of policies, they remain inaccessible or poorly-communicated to those at the grassroots level, which limits their potential impact. This issue is consistent with the broader critiques of policy execution in developing countries, where weak communication systems often obstruct the transmission of national or regional policies to local communities (Rabura et al., 2012). The challenge of policy awareness is not merely a communication problem, but it also reflects deeper governance issues. The inability of local authorities to effectively enforce or promote these policies suggests a lack of institutional capacity, resources, and perhaps the political will to enforce and promote the systematic, sustainable utilisation and management of floodplain wetlands. Local governance structures in many developing contexts are often underfunded, understaffed and disconnected from the communities they serve, which exacerbates the gap between policy formulation and implementation. Consequently, the absence of strong governance mechanisms at a local level undermines the effectiveness of policies that are designed to promote sustainable water management and flood resilience (Driessen et al., 2018).

The issue of a low awareness may have been further exacerbated by the community's perception of the ineffectiveness of such policies. Nearly half of the respondents believed that the existing policies did not offer adequate protection to the wetlands, while an additional 38.3% were unsure of whether the policies were effective or not. This kind of scepticism, if it is not addressed, can be detrimental to any future conservation efforts, if community participation in environmental policy is not incorporated (Sinthumule, 2021). Notably, the uncertainty of the policy's effectiveness can be attributed to the fact that there is no concrete evidence to suggest that these policies are being enforced effectively, or that they have resulted in any restoration benefits to the wetlands. In addition, the findings demonstrate that it is not the lack of regulatory instruments that is detrimental in this context, but rather, their weak enforcement,.

6.4.2 Disconnect between policy and practice

The analysis of how floodplain wetland management policies affected the farming practices in the area highlighted a gap between the purpose of the policies and their implementation. Sixty percent of the participants felt that it was counterproductive to adopt policies that do not present any discernible impact on their activities and livelihoods. Often, such a disconnect implies that either the policies are irrelevant to the communities' activities and practices or that, even if the policies exist, they are not implemented appropriately in the local communities. This finding is critical as it reveals the complexities that exist when attempting to attain an equilibrium between conserving the wetlands and addressing the needs of the people. Wetland resources are key to the rural communities that use agriculture to support their livelihood. A community is not likely to support wetland management policies that are perceived to be irrelevant or that restrict their livelihoods and needs (Saluja, 2023). This failure to establish the relevance of the

policies by the community also highlights the challenges in governance and natural resource management, where policies are designed without considering the needs of the local community (Amadu, 2021).

6.4.3 **Community suggestions for policy improvement**

The suggestions made by the community regarding the management of the floodplain wetland were helpful in bridging the existing gap between planning and implementation. The need for better communication between the ocal government and the communities was the most noticeable recommendation made by the respondents. Many respondents emphasised the necessity for an effective exchange of information relating to the policies and any projects concerned with wetland management or protection. This inclination towards increased communication aligns with the global best practices concerning Community-Based Natural Resource Management (CBNRM), where transparent and inclusive communication is required for trust-building and the sustainability of conservation projects (Dlamini et al., 2021; Turyasingura et al., 2022). The requests of the respondents for regular communication mean that the current channels of communication between the local government and the community are either non-existent or dysfunctional.

The other major theme is the need for greater community involvement in policymaking and management processes. This finding is consistent with a larger body of literature on participatory governance, which emphasises that the incorporation of perspectives and the contribution of the local communities enhances the legitimacy of environmental policies, and therefore, increases the likelihood of their success (Turyasingura et al., 2022; Laltaika, 2022). The call for the community to become involved indicates a desire and a need to be involved in conservation efforts, provided that the community is in the loop on the decision-making.

6.4.4 Education and awareness

Several respondents emphasised the importance of educational programmes in raising awareness of the importance of wetlands and the dangers of environmental degradation. This corresponds with previous studies that emphasised the importance of education in nurturing a positive environmental attitude and behaviour (Langensiepen et al., 2022; Dixon et al., 2021; Kakuba & Kanyamurwa, 2021). Community education programmes could play a vital role in changing the perception of wetlands, from ignored resources to valuable ecosystems that provide critical services, thereby preventing their degradation or misuse. In addition, the need for educational programmes highlights the significance of joining the wetland management efforts with tackling the broader socio-economic development goals in communities. The general objective of framing wetland conservation as part of the strategy for sustainable agriculture, food security and community resilience may, therefore, encourage more community support for wetland conservation.

The findings strongly suggest a general dissatisfaction with the available participatory processes of managing floodplain wetlands, with 86.7% of the respondents being dissatisfied. This lack of meaningful involvement is also evidenced by the poor attendance at public

meetings and workshops by community members, with 96.7% of respondents indicating that they have never participated in any of these events. This could also indicate that there are no meetings or workshops organised in these communities, or it could imply that the community mobilisation strategies that were implemented were not effective.

Poor communication could be a major reason for the low participation, along with their inability to attend meetings, as well as a general feeling among the community members of disempowerment regarding the utilisation and management of their floodplain wetlands. This aligns with the broad criticism of top-down environmental governance structures as being a 'one-size-fits-all' option with regard to meaningful decision-making by local communities. As noted by Sinthumele (2024), the wetland management legal framework in South Africa consists almost entirely of national laws and policies, which indicates a horizontal fragmentation that excludes the local stakeholders from important participation in the management of their wetlands. The local government could therefore benefit from adopting new methods of informing the community that work for most people, such as holding meetings and utilising local news boards or digital platforms.

A unique aspect of this study lies in the presence of the traditional authorities, i.e. the chiefs, in the study area. In an African context, traditional leadership plays a vital role in land management, where traditional figures act as the 'middleman', or intermediary, between the government and the local communities (Schwaiger et al., 2024). This dynamic adds a complexity in wetland management when the empowered chiefs fail to enforce the regulations that are formulated by the government. The chiefs have a strong influence on how land and natural resources are utilised in the Msunduzi region, often without consideration of formal policies. The respondents expressed a desire for more communication from their chiefs, which indicated a sense of trust in their traditional authorities and contrasted greatly with their mistrust of the formal policies. This finding aligns with the work of Amadu (2021), who revealed that rural community members were more willing to comply with the rules and regulations set by traditional leaders, rather than the formal laws. The research of Ubink & Duda (2021) supports this observation, as they noted that traditional authorities have more legitimacy in the eyes of the local community. However, this contributes to the ineffectiveness of the policies, as they need to traverse their way through the traditional leaders first, who may prioritise their personal benefit more than wetland conservation. This echoes the sentiments of Turyasgura et al (2022), who revealed that corruption is a hinderance to the conservation of wetlands. In order to bridge the gap between the local governance and traditional authority, Matsiliza (2024) suggests a collaboration and partnership between the local government and traditional leaders, to best both protect the vital ecosystems whilst meeting the needs of local communities.

6.4.5 Implications and recommendations of the study

The implications of this research extend to both the theoretical frameworks and practical applications. On a theoretical level, the study underscores the necessity of integrating local knowledge into environmental policy formulation. It suggests that a more participatory approach could foster a sense of ownership and responsibility among the community members,

thereby enhancing the effectiveness of wetland management. Practically, the findings call for a reassessment of the existing communication strategies and participatory mechanisms, in order to ensure that local voices are heard and considered in the decision-making process.

Based on the research findings, several practical recommendations have emerged. Firstly, it is imperative to develop robust educational programmes that are aimed at raising community awareness about the significance of wetlands and the policies that govern their management. These programmes should not only disseminate information, but also foster a deeper understanding of the ecological, social and economic benefits that wetlands provide. Secondly, improving communication channels between local governments and communities is essential for bridging the existing gap. This could involve regular public meetings, community forums, and the utilisation of digital platforms to ensure that information flows effectively and reaches all the stakeholders.

Lastly, establishing a collaborative framework that integrates the traditional authorities into the policy-making process can significantly enhance the governance outcomes. By recognising the influential role of chiefs and other traditional leaders, policymakers can harness their legitimacy and local knowledge to support wetland conservation efforts. A collaborative approach that aligns traditional governance with the formal regulatory frameworks could create a more integrated and effective model for managing wetlands, thereby ensuring that the needs of the local communities are met, while promoting sustainable environmental practices.

6.5 Conclusion

This study sought to explore the perceptions of stakeholders on the efficacy of the current policies and legislation that are aimed at conserving wetlands in the uMsunduzi floodplain. To address this over-arching aim, the study: (i) identified the institutions, policies and implementation frameworks governing the utilisation of floodplain wetlands in uMsunduzi floodplains; (ii) assessed the magnitude of the communities' awareness of the policies and legislation governing wetland management; and (iii) evaluated how the existing policies could be made more accessible to the local communities, in order to effectively implement them. By focusing on the perceptions and experiences of the local communities, this research addresses the critical gap in understanding how the knowledge of the community, or the lack thereof, shapes the effectiveness of wetland management strategies in sub-Saharan Africa.

The findings illustrated that the community's limited awareness of wetland policies, coupled with their scepticism about their effectiveness, underscores a profound disconnection between governance and practice. The study further highlights how traditional authorities can either facilitate or hinder policy implementation, depending on their motivation and their relationship with the formal governance structures. By illuminating these dynamics, this research not only contributes to the theoretical understanding of environmental governance in rural Africa, but it also serves as a vital resource for policymakers who are seeking to enhance the participation of the communities in natural resource management. The findings of this study are a pathway towards designing effective strategies and frameworks for improving the sustainable utilisation and management of wetlands as natural capital.

7 ASSESSING THE PERCEPTIONS OF KEY STAKEHOLDERS ON THE CURRENT AND ALTERNATIVE FORMS OF LIVELIHOODS AROUND THE UMSUNDUZI CONFLUENCE

7.1 Introduction

Wetlands are recognised worldwide as highly-productive systems and biodiverse ecosystems that provide essential services to both the environment and to human societies. These ecosystems support a wide variety of plant and animal species, they regulate water supplies, purify water, store carbon and protect people from floods and droughts (Dalu, Mukhuwana, Cuthbert, Marambanyika, Gunter, Murungweni and Dalu 2022). Since 1971, 72 countries globally have collectively identified and designated over 2 000 wetlands, which cover over two million square kilometres, as being important because they help to keep nature and people healthy (Gell et al. 2023). Wetlands are defined as areas with flourishing ecosystems that are abundant in biodiversity and that experience either permanent or seasonal flooding (Osoro et al. 2020).

Despite their ecological and socio-economic importance, wetlands worldwide continue to face significant threats and degradation (Sinthumule 2021). This ongoing deterioration can be attributed to human activities, such as population growth, agricultural expansion, urbanisation, pollution, unsustainable practices, a lack of awareness and inadequate resource management (Kadoma, Perry and Renaud 2023). One of the primary drivers of wetland degradation is population growth and the associated increased demand for land, water and natural resources. As human settlements expand and economic activities intensify, wetlands are often viewed as under-utilised land that can be converted for agriculture and urban development, or for industrial purposes (Okyere et al. 2022). This leads to the loss and fragmentation of wetland habitats, which disrupts their delicate balance and compromises their ability to provide essential services (Masese et al. 2012). These pressures are especially serious in developing countries where human activities contribute to the global degradation of wetlands, as a result of the prioritisation of rapid economic growth and development (Kadoma, Perry and Renaud 2023).

Like many other developing nations, South Africa grapples with a significant water crisis that stems from a combination of factors, including climate change and insufficient wetland management practices (Montmasson-Clair et al. 2022). South Africa's wetlands, which cover

only 2.4% of the land, are being degraded by agricultural practices, urbanisation and industrialisation (Dalu, Mukhuwana, Cuthbert, Marambanyika, Gunter, Murungweni and Dalu 2022), and agriculture is the most significant contributor. Agriculture continues to be a primary driver of the continued loss of wetlands (He et al. 2025). Studies show that the process of developing wetlands for agricultural use can result in pollution from pesticides, fertilisers and wastewater, which disrupt the normal functioning of wetland ecosystems and deplete the water resources in the surroundings (Gu and Jiang 2023). Therefore, the sustainable use of wetland floodplains is critical for maintaining biodiversity, for supporting livelihoods and for ensuring water security, particularly in regions like KwaZulu-Natal, South Africa. The uMsunduzi confluence, where the uMsunduzi River meets the uMngeni River, represents a unique ecological zone that is characterised by a rich biodiversity and significant socio-economic activities that are driven by local communities. These wetland areas serve as essential resources for agriculture, fishing and other activities that are necessary for survival, while they also play a crucial role in flood mitigation and water purification (Sherwill 2024). Near the uMsunduzi confluence in KwaZulu-Natal, South Africa, the sustainable use of floodplain wetlands by smallholder communities is a pressing concern. Rapid land use changes that are driven by human activities complicate the efforts to understand how community members perceive and manage these vital ecosystems.

Therefore, sustainable wetland management requires the active involvement of local communities, who depend on these ecosystems for their livelihoods (Saluja, Prasad, Lwin, Soe, Pottinger-Glass and Piman 2023). In addition, the community's perceptions and traditional knowledge influence how wetlands are used and managed, and their inclusion in the decision-making process is essential for achieving sustainable outcomes. Incorporating a local perspective ensures that the management plans are both effective and socially acceptable. While the global importance of wetlands is well-documented, a notable gap remains in understanding the perceptions and practices of local communities, particularly in under-researched regions such as KwaZulu-Natal, South Africa. The existing literature often overlooks the socio-economic and cultural factors that shape wetland use at a community level. It has been acknowledged that resource management is a complex process that requires the participation of various stakeholders. This study addresses these gaps by focusing on the local communities near the uMsunduzi confluence, an ecologically-rich area that is characterised by significant socio-economic activities. This study seeks to answer the following questions:

- What are the community's perceptions on the sustainable use of wetland within the uMsunduzi floodplain?
- How do local knowledge, cultural norms and economic pressures influence the management and utilisation of the floodplain by community members?
- How can understanding these local viewpoints inform the development of wetland management plans that are both ecologically sustainable and aligned with the community's needs?

Therefore, by explicitly defining these research questions, the study seeks to produce insights that integrate environmental sustainability with the socio-economic conditions of the local farming communities.

7.2 Theoretical Framing

This study is grounded in the Socio-Ecological Systems (SES) framework, which views wetlands not just as natural environments, but as interconnected systems where human activities and ecological processes continuously influence each other (Berkes et al. 2000). This approach emphasises that sustainable wetland management requires the integration of ecological knowledge with social, economic and cultural factors that influence the use of resources. This perspective aligns with the findings of (Marambanyika, Beckedahl and Ngetar 2017), who highlighted the importance of participatory wetland management strategies that are cost-effective and benefit the needs of the local community. Such community-based approaches recognise the value of local knowledge and the active involvement of community members in the decision-making process. The SES framework is not used as a stand-alone theory, but rather as a guiding perspective that contextualises the research within the complex interplay of social, economic, cultural and environmental factors that influence wetland use and management. However, while the SES framework excels at contextualising these interactions, it does not provide a detailed insight into the specific behavioural drivers that influence the individual or collective action amongst community members. In order to address this shortfall, the study incorporated the Theory of Planned Behaviour (TPB) and the Diffusion of Innovation (DoI) as analytical tools for examining the key aspects of the community members' behaviour and the adoption of sustainable practices.

A significant barrier to sustainable wetland management, as identified by (Rebelo, McCartney and Finlayson 2010), is the lack of adequate knowledge among the natural resource planners

and managers regarding the benefits and sustainable practices associated with wetlands. This knowledge gap extends to the local communities. (Dalu, Mukhuwana, Cuthbert, Marambanyika, Gunter, Murungweni and Dalu 2022) found that 80% of respondents in South Africa's Vhembe Biosphere Reserve had not received any formal education relating to wetlands, which underscores the critical need for educational interventions and knowledge sharing. The Ramsar Convention on Wetlands further reinforces the importance of integrating local knowledge into wetland governance, and it advocates for an urgent, collaborative response to wetland degradation, particularly by means of communication between the community members and policymakers. Similarly, (Mdluli 2018) stressed the importance of understanding local perceptions and the socio-cultural dimension of wetland use to inform sustainable management policies.

In order to analyse the behavioural dimensions that influence the adoption of sustainable practices by community members, this study draws on the theory of planned behaviour and the diffusion of innovations to understand how attitudes and social norms shape a community's intention to adopt sustainable practices (Anibaldi et al. 2021, Zeweld et al. 2017) . The theory of planned behaviour was created by Icek Ajzen in 1985, in order to explain human behaviour, especially when people do not have full control of their actions. The theory of planned behaviour states that an individual's intention to engage in behaviour is shaped by their attitudes, subjective norms and perceived behavioural control. The perceived behavioural control reflects the individual's perception of the ease or difficulty of performing a behaviour, which may also be directly influenced, independent of the intention (Ajzen 1991). This theory is influenced by three principal constructs: the attitudes towards behaviour, the subjective norms and the perceived behavioural control. The application of this theory provided a clear explanation of the role of attitudes, the subjective norms and the perceived behavioural control in shaping community decisions and behaviours related to wetland utilisation and conservation. This framework is instrumental in identifying the psychological and social factors that drive sustainable or unsustainable practices. Specifically, the attitude of the community towards wetland utilisation, whether they perceive a wetland as a primary ecological assets requiring conservation, or as agricultural land for immediate use, is critical in shaping their behavioural intention. Subjective norms capture the influence of the community's expectations, cultural values and peer behaviour, which may encourage or discourage their sustainable practices on wetlands. Furthermore, perceived behavioural control addresses the community's confidence and perceived capacity to implement sustainable management strategies, which may be

constrained by factors, such as resource availability, knowledge and institutional support. However, the TPB framework is limited in its ability to account for the broader socio-ecological context, and it does not fully explain how new practices are disseminated or adopted within communities.

Therefore, the Diffusion of Innovation theory complements these frameworks by shedding a light on how new ideas and practices, such as sustainable wetland management, are shared among people, discussed within communities, and gradually embraced or adapted, as part of everyday life (Anibaldi, Rundle-Thiele, David and Roemer 2021, Zeweld, Van Huylenbroeck, Tesfay and Speelman 2017). In this study, this theory helps us to understand how new ideas spread among community members, which is important for creating support programmes and management plans that fit the local community's willingness to adopt them.

In essence, this study uses the SES framework as its overarching approach to capture the complex interactions between the human and ecological factors in floodplain wetland management. Within this broad context, the TPB framework examines the psychological and social drivers of a community's behaviour, while the DoI theory explores how sustainable practices are communicated and adopted within the community. The combination of these frameworks in this study enables a holistic understanding of the factors that shape the local community members' perspectives and behaviours towards floodplain wetland use and sustainability, which supports the development of integrated, socially-acceptable and ecologically-sound management practices. This theoretical integration is important because it ensures that this study not only addresses ecological and social complexes, but it also addresses the behavioural and innovation diffusion aspects that are crucial for sustainable management in the uMsunduzi River Basin.

Therefore, this study integrated socio-ecological theory to explore the community's definition of sustainability, their perceptions and their perceived barriers to adopting sustainable practices, as well as the factors that motivate or hinder their engagement with the wetland. Furthermore, it emphasises the need for an interdisciplinary approach that incorporates the community's knowledge systems, its socio-economic reality and the policy environment, in order to foster sustainable wetland management. This approach enables the integration of cultural, social, ecological and physical factors, and results in the creation of a more comprehensive and effective tool for wetland conservation (Musasa et al. 2023).

7.3 Materials and Methods

7.3.1 Data collection approach

This study employed both quantitative and qualitative approaches to expand the evidence to improve the credibility of findings and to make the most of the strengths of each method. The study used questionnaires, structured interviews, observation, and the Statistical Package for Social Science (SPSS) to analyse the data. According to (Zina 2021) using a mixed-method approach offers a comprehensive understanding of the topic being studied, and the benefits of the other method can effectively offset the shortcomings of that one method. In addition, this study employed methodological triangulation by integrating the questionnaires, interviews, and observation to address the research aims, which highlights its value in enhancing its validity and reducing the bias that is inherent in single-method studies (Bans-Akutey and Tiimub 2021). According to the triangulation methods described by Noble and Heale (2019), this approach refers to the process that uses multiple research methods to study the same phenomenon, thereby enhancing the credibility and validity of the findings by reducing the biases that may arise from relying on a single method.

The use of questionnaires to collect data from the community members enabled a broad sampling approach, which ensured representation across different levels and diverse perspectives within the farming community. Based on the field observation, random sampling was used to select a group of community members from the uMsunduzi confluence area. Random sampling enhances the reliability of the study by minimising bias and ensuring that the findings are representative of the larger population of respondents in the area (Noor et al. 2022). The structured questionnaire featured both open- and closed-ended questions that were designed to gain a thorough understanding of the community's views on the sustainable utilisation of the uMsunduzi confluence. It covered a range of topics, including the socio-economic characteristics and the agricultural practices practised within the wetland, the importance of the wetland perceived challenges, as well as the benefits of using the wetland. Data collection was conducted during daylight hours across various villages within the uMsunduzi Municipality. A total of 60 questionnaires were randomly distributed to households near the floodplain. The questionnaires were distributed to respondents in July 2024, during the day-time hours. The respondents' ages ranged from 18 and above. The questionnaire data were analysed by using SPSS. For the closed-ended questions, descriptive statistics, such as the frequencies, percentages and standard deviations, were computed to summarise and

interpret the quantitative data. For the open-ended questions, the responses were organised and coded thematically, in order to identify the common patterns and categories.

In addition to gathering data from the local community members, this study involved key informants who were associated with the research context, including representatives from Liberty-NPO, the Water and Sanitation Department and the uMsunduzi Municipality authorities. Semi-structured interviews were conducted with these informants virtually, by using the Microsoft Teams platform. The interviews were carried out in July and August of 2024, and each interview lasted between 45 minutes and one hour. The selection of key informants was based on their expertise in water management and restoration, as well as their regulatory function. This approach was essential for obtaining precise insights into the broader environmental and policy contexts that shape smallholder-farming practices along the uMsunduzi confluence. Interviews with the key informants provided an opportunity to explore the regulatory frameworks, their resource management practices, as well as other external factors that influence the smallholder agricultural communities in the region. The interviews were manually transcribed and then analysed by identifying the common trends. By combining data from both community members and key informants, the study provides a comprehensive understanding of the socio-environmental dynamics that impact the agricultural livelihoods in this critical watershed area. Observations were employed to directly witness and document the farming practices of respondents within wetland areas, which allowed for the assessment of respondents' impact on wetland ecosystems. Ethical guidelines were strictly adhered to throughout the interview, with an audio recording being conducted to ensure accurate transcription, in accordance with Ethics Reference Number: HS24/3/23.

7.4 Results

The study involved 60 participants, of whom the majority (68%) were female, while 32% were male. The study field was conducted during daytime hours. Males were frequently away from their households for work, which resulted in females being the majority of the respondents in this study. Overall, the respondents' employment status revealed that 64,4% are unemployed, while 35,6% were employed. Table 7-1 indicates that, while 47.4% of male respondents were employed, compared to 52.6% who were not, a larger percentage of female respondents (70%) were not employed, with only 30% stating that they were employed.

Table 7-1 Socio-demographic characteristics of respondents (N = 60)

Variable	Category	Frequency(n)	Percentage (%)
Gender	Male	19	32.0
	Female	41	68.0
Occupation Status	Employed (Male)	9	15.0
	Unemployed (Male)	10	16.7
	Employed (Female)	12	20.0
	Unemployed (Female)	28	46.7
Age Group (years)	18–25	8	13.3
	26–35	10	16.7
	36–45	17	28.3
	46–55	7	11.7
	56 and above	18	30.0
Length of Residence	Less than 1 year	4	6.7
	1–5 years	4	6.7
	6–10 years	7	11.7
	More than 10 years	45	75.0

Note: Percentages are calculated from the total sample size (N = 60).

A further analysis of the employment distribution shows that females constituted a greater percentage of the unemployment group (73,7%), while males accounted for a larger percentage of the employed group (42,9%), relative to their representation within the sample. The ages of the respondents ranged from 18 to 56 and above. A total of 13.3% of respondents were between 18 and 25 years, 16.7% were between 26 and 35 years of age, 28.3% were between 36 and 45 years, 11.7% were between 46 and 55, and 30% were 56 and above. An analysis of the respondents revealed that the majority (75%) have lived in the area for more than 10 years. A further analysis revealed that 11.7% have lived in the area for 6 to 10 years, and the remaining respondents have lived there for shorter periods, with 6.7% residing there for 1 to 5 years, and 6.7% residing there for less than a year.

The questionnaire assessed whether the respondents used the floodplains, the activities that they practised on the floodplain, their perceptions of sustainable use, as well as the importance of the wetland in their lives. The respondents shared their activities, the benefits and why the floodplain was important to them. The analysis, as shown in Table7-2, indicates that most of the respondents were familiar with wetlands, with 93.3% using the floodplain, 5% not using it, and 1.7% being unsure. Furthermore, 90% revealed that the floodplain was more important, 8% believed it was somewhat important, while 2% revealed that it was not important. Most of the respondents, 73%, shared that the wetland was not used sustainably, 13% believed that it was used sustainably, 12% were not sure, and 2% did not answer.

Table 7-2 The respondents' knowledge, perceived importance, sustainability perceptions, and uses of the floodplain (N:60)

Variable / Question	Category	Frequency of the respondents(n)	Percentage (%)
Have you utilised the floodplain for any purpose?			93.3
	Use	56	
	Do not use	3	5.0
	Unsure	1	1.7
How important is the floodplain in your livelihood?			90.0
	More important	54	
	Somewhat important	5	8.0
	Not important	1	2.0
Do you believe the floodplain wetland is being utilised sustainably in this area?			
	Not sustainable	44	73.0
	Sustainable	8	13.0
	Unsure	7	12.0
	No answer	1	2.0
What activities have you engaged in?	Domestic (drinking, washing, bathing)	37	
	Fishing	35	
	Agriculture	25	
	Grazing	17	

Note: Percentages are based on total respondents (N = 60). Multiple responses were possible for 'Main Uses of Floodplain

The analysis examined the activities that the community members engage in within wetland, which allowed the respondents to select multiple responses. Consequently, the reported percentage exceeded 100%, which reflects the overlapping use of the floodplain for various purposes. The analysis indicated that the majority of the respondents (62%) used the floodplain for domestic use, such as drinking, washing and bathing, 58% used it for fishing, while 42% used it for agriculture, and 28% used it for grazing, as depicted above. Water was frequently sourced from the floodplain, due to the occasional shortage of water in the respondent's household taps, which led them to rely on the floodplain for their domestic and irrigation needs. As one of the respondents explained: "*The community often experiences prolonged periods without tap water, forcing the residents to rely on the uMsunduzi floodplain, which must be boiled first before being consumed. Unfortunately, this is a harsh reality faced by many households in the village; some of them do not have access to taps, and they depend on water tank trucks, and the floodplain" (Respondent 1).*

Figure 7-1 shows that the wetland benefits are perceived as a significant contributor to the respondents' perceptions. Most of the respondents (97%) identified food security as a primary

benefit, which suggests a reliance on the wetland for crop farming and fishing. Furthermore, 67% highlighted the wetland's significant role in income generation through the sale of agricultural products. The additional benefits noted by the respondents included recreational opportunities (30%), its cultural significance (15%), wildlife habitat conservation (8%), flood control (7%) and educational purposes (5%) As one of the respondents explained: *Every year we have the Dusi Canoe Marathon in our floodplain, which puts our village on the map, and we benefit because it attracts a lot of tourists, researchers, and TV people, and we clean the river in preparation for this marathon and make some money for cleaning it (Respondent 2).*

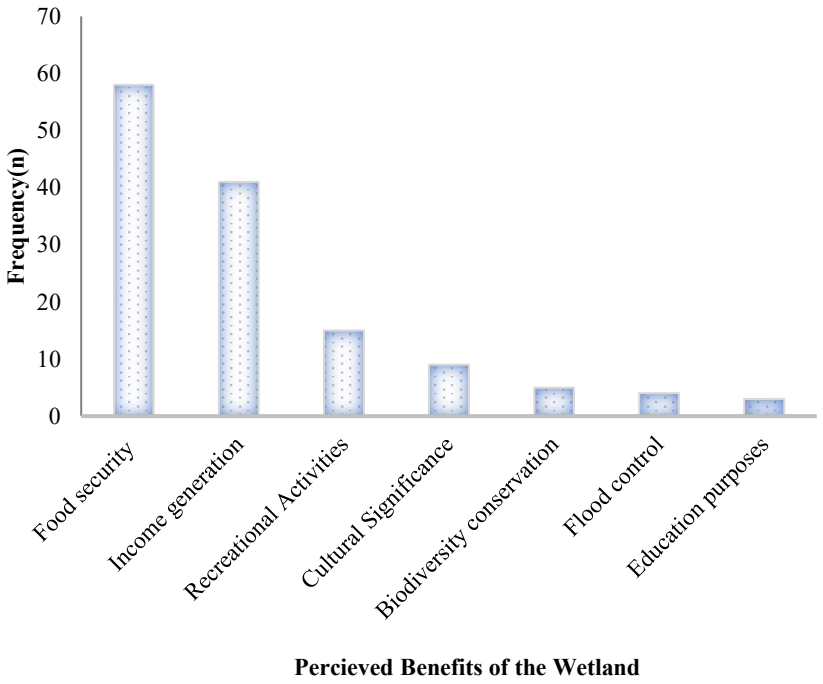


Figure 7-1: Perceived benefits received from the wetland

The questionnaire results also revealed that anthropogenic factors pose significant challenges to their use of the floodplain (Figure 7-2). Water pollution, caused by potential chemical spills and waste contamination, was identified as the primary concern of most respondents (95%). Soil erosion (48%) was also a concern, while illegal sand mining (12%) and habitat destruction (8%) were identified less frequently, although these activities are associated with risks, such as river deepening and biodiversity loss.

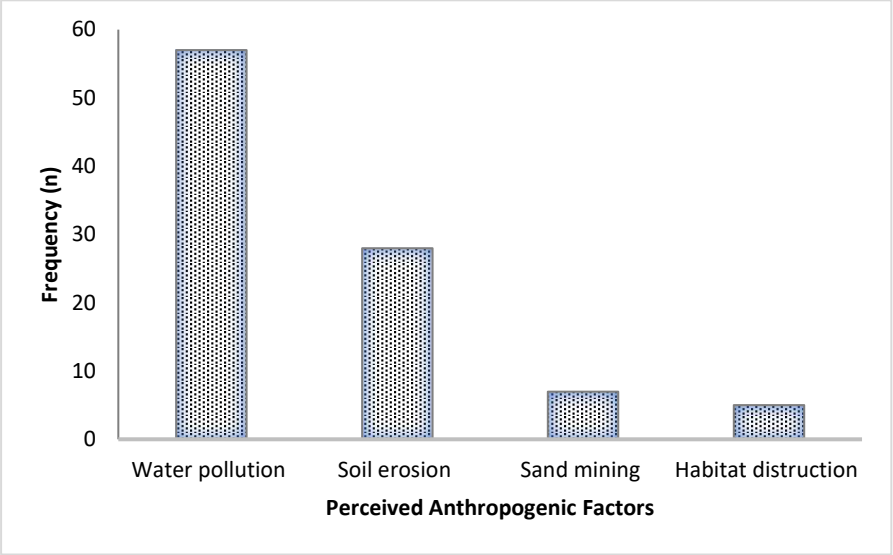


Figure 7-2: Anthropogenic factors that were perceived by respondents to harm the sustainable management of the wetland

The analysis revealed that 93,3% of both genders use the floodplain. Among the male respondents, 31,7% used the wetland, compared to 61,7% of female respondents, and 5,0% indicated that they did not use it, and 1,7% were unsure. Therefore, these results suggest that females use the floodplains more than the male respondents. Furthermore, a cross-tabulation analysis was performed to examine the relationship between their occupational status (employed and not employed) and floodplain use (yes/no). The majority of both the employed respondents (90.5%) and those who were not employed (94,7%) indicated that they use the floodplain.

When analysing the relationship between their occupational status and their perception of wetland importance, a cross-table analysis (Table 7-3) illustrates the perceptions of respondents with different economic statuses. The results indicated that 90.5% of the employed respondents considered the wetland to be very important to them, while 9,5% believed it was somewhat important. Among the unemployed, 89,5% regard the wetland as very important, 7,9% rearded it as somewhat important, and 2,6% regarded it as not important. Furthermore, the results showed that 32,2% of the employed respondents recognised the importance of the wetland, while a higher proportion of 57,6% of the unemployed respondents saw the importance of the wetland. Therefore, this suggests that the unemployed respondents frequently relied more heavily on the wetland, which contributed to their perception of its importance. One of the respondents emphasised the importance of the wetland in this way: "*uMsunduzi is very*

important to me and others who are unemployed because we make a living out of it. Since I am unemployed, I fish and maintain a small garden at the community garden, where I grow spinach and cabbage. I sell the fish I catch and the vegetables to the surrounding communities, which provides income to support my family, so it is important."

Table 7-3 Depiction of the relationship between the occupational status and the perception of its importance

Occupation	Importance	Very important	Somewhat important	Not important	Total
Employed	**Count**	19	2	0	21
	within Occupation	90.5%	9.5%	0.0%	100.0%
	within Importance	35.8%	40.0%	0.0%	35.6%
	Total	32.2%	3.4%	0.0%	35.6%
Not Employed	**Count**	34	3	1	38
	within Occupation	89.5%	7.9%	2.6%	100.0%
	within Importance	64.2%	60.0%	100.0%	64.4%
	Total	57.6%	5.1%	1.7%	64.4%
Total	**Count**	53	5	1	59
	% within Occupation	89.8%	8.5%	1.7%	100.0%
	% within Importance	100.0%	100.0%	100.0%	100.0%
	% of Total	89.8%	8.5%	1.7%	100.0%

In examining the relation between length of residential time and their beliefs about the sustainable use of the wetland (Figure 7-3), the findings indicated that residents who have lived in the area for more than ten years predominantly believed that the wetland was not being used sustainably. This perspective is supported by one of the respondents who reflected on the past and present attitudes toward the floodplain: "*We used to drink uMsunduzi when we were young because people respected and understood the importance of this floodplain as it was our only source of water, but now people do not care because of the development; we have taps that bring water straight into our homes and people throw waste in the uMsunduzi".* This highlights a reduction in community's care for the environment, which appears to be connected to how the reliance of the people on natural resources has shifted over the years.

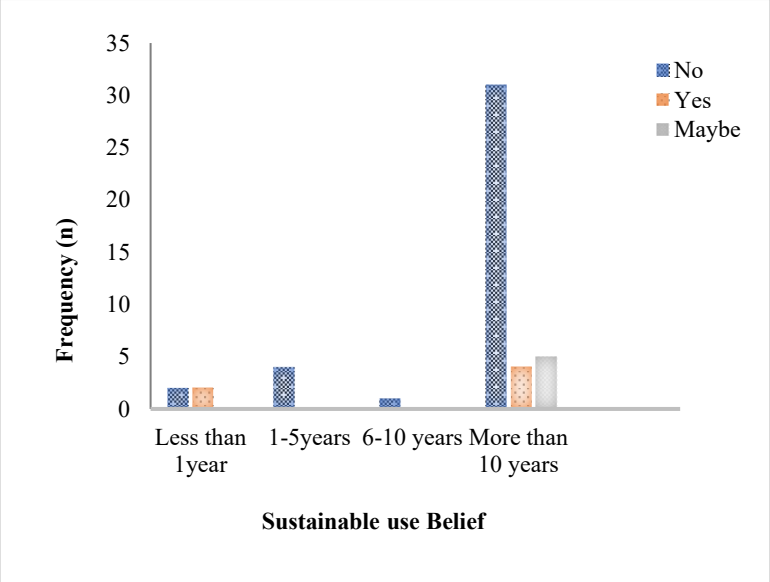


Figure 7-3: Depicts the relationship between the years lived in the area and the perceived sustainable use of the wetland

In assessing the relationship between their awareness of the regulations that protect the wetland and their length of residence, Figure 7-4 shows that the majority of the respondents (88%) were unaware of any regulations or policies aimed at protecting and promoting the sustainable use of the neighbouring wetland. Within this group, 72% have lived in the area for more than ten years, which indicates that many long-term residents lack an awareness of the regulatory frameworks. In contrast, a majority of only 12% of the respondents, which consisted of long-term residents, demonstrated an awareness of the regulations. These findings suggest that although the overall regulatory awareness is low, it is present among a small portion of the population, primarily those who have resided in the area for some time.

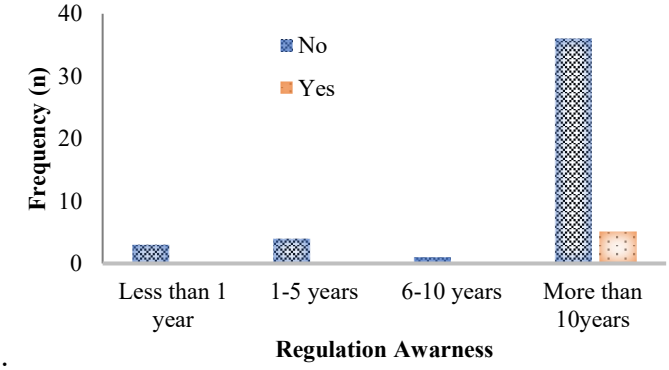


Figure 7-4: The relationship between the years lived around the wetland and their awareness of the regulations that protect the floodplain

One question asked the respondents to assess how well other community members used the floodplain sustainably. As Figure 7-5 depicts, the results show that 57% believed it was not effective, 33% believed it was effective, and 10% felt it was somewhat not effective. This suggests that the majority of community members doubted the overall sustainable practices that are being followed.

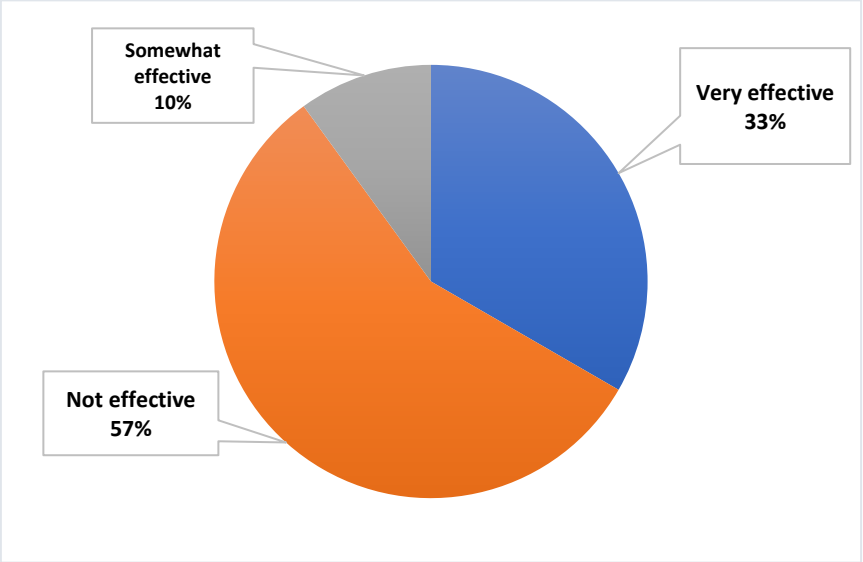


Figure 7-5: The community perception of the effectiveness of sustainable wetland utilisation

As shown in Table 7-4, most of the respondents (90%) reported no awareness of the regulations, while only 10% demonstrated an awareness of the regulations that protect and promote the sustainable use of the wetland. With regards to their perception of the government's efforts, the majority (80%) felt that there was no effort, 10% perceived some efforts, and 10% were unsure. Within a group lacking regulatory awareness, 81.5% believed there was no government effort, 7.4% reported some effort, and 11.1% were unsure. In contrast, among the respondents who reported regulatory awareness, two-thirds (66.7%) perceived that there was no government effort, while one-third (33.3%) acknowledged some level of government efforts. These findings suggest that most of the respondents lack an awareness of the regulations and believe that the government is not making sufficient effort. This perception was stronger among those who were unaware of the regulations, but it was also present among those who were aware.

Table 7-4 Depiction of the relationship between regulatory awareness and perceived government efforts

Regulatory Awareness	Government Effort: No	Government Effort: Yes	Not Sure	Total
No Awareness (n=54) 90%	81.5% (n=44)	7.4% (n=4)	11.1% (n=6)	100% (n=54)
Awareness (n=6) 10%	66.7% (n=4)	33.3% (n=2)	0% (n=0)	100% (n=6)
Total (n=60)	80% (n=48)	10% (n=6)	10% (n=6)	100% (n=60)

Key informant interviews were conducted with three different stakeholders. They revealed that, although policies and regulations exist to protect the wetland, their implementation is hindered by several barriers. One significant barrier lies within the municipality, where the municipality authority shared, "*We have good by-laws, rules and regulations; unfortunately, enforcement of these is a concern due to a lack of staff*". Another major challenge is that many villages surrounding the wetland fall under the jurisdiction of traditional leaders, which limits the formal policy implementation and compliance monitoring. This was further supported by the other key informant who stated: *"It is hard to implement these policies because traditional leaders have their own cultural laws that they enforce in the villages, as government officials, we are limited because we do not own the land rights*". This perspective was echoed by one respondent who stated that, as a community, they live under the authority of the traditional leaders. A key informant from the municipality supported this statement further, by noting that, while the municipality and other government departments have made attempts to enforce policies protecting the floodplain in some villages, community non-compliance has undermined these efforts to preserve the wetland, due to the lack of resources and intimidation. This was further elaborated by a key informant official who stated: *"In the past, we told someone not to build in a sensitive area, but we get threatened or it leads to confrontation with people*". When questioned whether the municipality has communicated its policies to the public, the municipality authority responded: "*As the municipality, we have community outreach programmes in place aimed at educating the communities about the importance of environmental conservation and policies guiding the conservation".* However, most respondents who have lived in the area reported that they were unaware of any such government efforts, despite the claims made by the municipality. Only a small percentage of respondents within the range of more than ten years of residency indicated an awareness of

such measures when they were asked. This was supported by another key informant, "*I think some people are aware of it …but like you said, it is not enough*". This highlights a lack of effective collaboration and communication between the government and the community. The municipal authority further explained that they have a waste management system where a waste truck comes from time to time to collect waste; however, the community is not complying and continues to dispose of their waste in the wetland. However, this contradicts the other respondents' perceptions, as they stated that the municipality provides the waste truck only when the Dusi Canoe marathon is about to take place.

In addition, the key informants from the NPO said that they were aware of the wetland's deterioration, and they cited the postponement of the annual Canoe marathon due to severe pollution that was caused by both the community and industries, including a chemical spill that made the river unsuitable. The key informant from the NPO stated: *To be quite honest, we acknowledge the ongoing deterioration, we just initiated education programmes, and we employ youth and train them to promote awareness about the critical value of these ecosystems.* The key informant also emphasised that despite their efforts to collaborate with other stakeholders, such as the municipality authorities, they have been unsuccessful because everyone is watching who does what, instead of working together. Despite these challenges, the government authorities, the municipality and local non-profit organisations are actively working together on mitigation processes. They are planning to enhance awareness by means of educational programmes that are aimed at teaching the community about the ecological importance of the wetland. These results show that there are collaborative efforts and they reflect a commitment among the stakeholders to address wetland degradation and to promote sustainable management practices.

7.5 Discussion

This study evaluated the community's perspectives on the utilisation and sustainability of the wetland in the uMsunduzi floodplain. They revealed significant insights into the socio-demographic dynamics, the patterns of wetland use, as well as the perceived benefits, challenges and regulatory awareness. By integrating the Socio-Ecological Systems (SES) framework, the Theory of Planned behaviour (TPB) and the Diffusion of Innovation (DoI) theory, this study provides an understanding of how the social, ecological and institutional dynamics interact to shape the wetland management outcomes. Therefore, this section interpreted the findings of the study in the context of the existing literature and the theoretical

frameworks, in order to critically assess the utilisation and sustainable management of the wetland.

Applying the SES framework highlights the interconnectedness of social factors, ecological processes and governance structures within the uMsunduzi area. The predominance of female respondents (68%) and the high unemployment rate (64,4%) reflect the gender and socio-economic dynamics that frame the utilisationof the wetland. This finding aligns with that of (Sinthumule and Netshisaulu 2022), who noted that women often manage the natural resources in rural areas, but they are often left out when it comes to decision-making. This shows how social factors limit the sharing of different kinds of knowledge and reduce the ability to adapt and manage these ecosystems (Berkes et al. 2003). The higher unemployment rate among females suggests a higher dependence on natural resources, such as wetlands, for their daily needs. The age distribution showed a significant proportion (70%) of respondents aged 36 years and above, with a majority having lived in the area for over 10 years. These long-term residents possess a deep experiential knowledge of the local ecosystem, which enhances their perception of the wetlands' importance (Kadoma et al. 2023). However, the older age groups may be less willing to accept new conservation methods, due to their familiarity and comfort with their traditional practices. This tension between the new and old knowledge of managing these ecosystems shows how social habits and caring for the environment are connected and always changing. This idea fits the socio-ecological systems framework, which states that social and environmental factors are deeply connected over time.

Most respondents (93.3%) actively utilised the floodplain for a range of activities, including domestic use, fishing, agriculture and grazing. These utilisation patterns mirror the global trends reported in other wetland studies, such as those of (Kadoma, Perry and Renaud 2023, Marambanyika, Beckedahl and Ngetar 2017), where wetlands are critical for livelihoods. The significant reliance on wetlands for domestic and agricultural use was motivated by an unreliable tap water supply, which illustrates how central the wetland is to the community's survival. This dependence is consistent with the findings of Saluja, Prasad, Lwin, Soe, Pottinger-Glass and Piman (2023) and Marambanyika, Beckedahl and Ngetar (2017) in Myanmar, where the scarce rural infrastructure reinforces wetland dependence. This can be attributed to one of the respondents: *"I use the uMsunduzi water for cooking and bathing when the water truck is not present. I wish the community could stop throwing baby diapers in the river, because some of us take it as our water source".* Therefore, the theory of planned behaviour (Ajzen 1991) provides a useful framework for understanding these engagements by

explaining how people's perceptions of social pressure and perceived control influence their intention to use and conserve wetlands. Their direct involvement in wetland activities can foster a positive attitude and strengthen behavioural control, which are critical drivers of actual sustainable behaviour. Despite having favourable intentions to conserve these wetlands, structural socio-economic challenges, such as poverty and unemployment, hinder the translation of these intentions into sustainable practices. The respondents recognised the multiple benefits of wetlands, most notably food security, income generation and recreational activities, which underscores the socio-economic and ecological interlinkages that are described by the socio-ecological system framework (Berkes, Folke and Colding 2003). The recognition of these benefits often motivates conservation efforts; however, the underlying economic constraints remain critical for achieving effective wetland management.

Even though the majority of respondents value the wetland, most (73%) perceive the wetland as unsustainable. The respondents expressed that the main threats to sustainable wetland management are pollution and soil erosion, which are problems that are linked to farming and the other activities practiced on wetlands globally (Galatowitsch 2018, Kadoma, Perry and Renaud 2023). Pollution from chemicals and waste is a concern, especially in the uMsunduzi floodplain, where improper waste disposal and failing sewage infrastructure have led to serious water quality issues. One of the respondents illustrated this reality: *"Last year, there was a chemical in our floodplain, but we were not informed promptly; we only found out after our cattle had died from the toxins they acquired from the river".* The DoI theory also explains how institutional and social communication problems hinder effective and sustainable wetland management. The majority of the respondents (90%) reported that they were unaware of any regulations protecting the wetland, and (80%) said there was little to no government effort in conservation. This low regulatory awareness corresponds with the findings of (Saluja, Prasad, Lwin, Soe, Pottinger-Glass and Piman 2023) in Myanmar, where limited community knowledge impedes effective wetland management. From the diffusion of an innovation perspective, this low awareness indicates that the wetland conservation policies have not effectively diffused through to the community, which has limited the adoption of sustainable practices (Turner 2007). According to the diffusion theory, the spread of new ideas or practices requires communication channels, such as social networks and opinion leaders within the community, to promote their adoption. When these elements are weak or absent, innovations such as conservation policies remain localised and fail to influence the broader behaviour change. The respondents indicated that there has been a lack of awareness and communication

regarding wetland conservation, and they emphasised the importance of communicating such information through social media platforms, local meetings and public announcements, as they want to conserve their wetland. Key informant interviews corroborated the institutional challenges, because traditional leaders control the area and there is little power or no resources to enforce rules, which reflects the systematic governance constraints that are highlighted in the SES studies (Berkes, Folke and Colding 2003). The governance challenges, such as the control by traditional leaders and their limited capacity to enforce rules, create major challenges for implementing the policies and spreading conservation practices. Improving policy communication by using social media, public meetings and community involvement could raise awareness and encourage more sustainable behaviour.

The cross-tabulation results reinforced the synthesis of the SES and TPB framework by showing that both the employed and unemployed respondents perceived the wetland as important, although unemployed respondents showed a relatively higher reliance. This is consistent with Marambanyika, Beckedahl and Ngetar (2017), Shrestha (2011), who reported that economically-marginalised groups often depend more heavily on wetlands, which reinforces the positive perception that is grounded in survival needs. Nevertheless, this reliance frequently leads to overexploitation, which illustrates the social-ecological system concept of trade-offs within the social-ecological interactions. It also aligns with the theory of planned behaviour, which suggests that even if people want to use the wetland sustainably, their economic needs might limit their ability to do so responsibly (Ajzen 1991). Therefore, policy measures must tackle these economic factors by encouraging alternative income sources, or offering incentives that reconcile their economic needs with the conservation goals.

The study revealed that culturally-significant activities are linked to the wetland, such as the annual Dusi Canoe Marathon, which plays a vital role in fostering community connection and encouraging river cleaning efforts. These cultural ecosystem services act as motivators for stewardship, which align with the socio-ecological system perspective that recognises that cultural values are essential for socio-ecological resilience (Still et al. 2010). However, the limited participation of women in resource management and decision-making, as highlighted by (Abillah, Mwangi, Otieno and Machogu 2021, Wiafe 2014), restricts the inclusion of diverse local knowledge, thereby reducing the effectiveness of sustainability initiatives. This underscores the need for gender-sensitive governance reforms to enhance the adaptive capacity and equity within wetland management.

7.6 Implications for Sustainable Wetland Management

The findings of this study highlight several important areas that require attention, in order to promote the sustainable management of the floodplain wetland in the uMsunduzi confluence. There is a need to enhance the education programmes and to increase regulatory awareness among the local community. According to the findings of (Saluja, Prasad, Lwin, Soe, Pottinger-Glass and Piman 2023, Shah and Atisa 2021)), targeted education programmes are important for improving the understanding of wetland ecological functions and the relevant laws. The positive correlation observed in this study between higher education levels and supportive conservation attitudes underscores the value of such initiatives. Community-based participatory approaches should be strengthened. According to the SES framework, as well as (Kadoma, Perry and Renaud 2023, Shrestha 2011), inclusive management strategies that are tailored to the local needs encourage community ownership and improve compliance with the conservation measures. Integrating traditional leadership structures with municipal governance could enhance the enforcement of regulations and ensure that indigenous knowledge is respected and incorporated into wetland management. There is a need to address the economic pressures by promoting alternative livelihoods. The strong link between unemployment and the heavy reliance on wetlands that was found in this study points to the urgent need to provide income diversification opportunities. Therefore, creating other income opportunities could reduce the unsustainable use of wetlands. The study highlights the importance of promoting gender inclusion in decision-making, and it shows that women engage more with the wetland; therefore, giving women a greater role in wetland management can bring valuable knowledge and lead to better outcomes. According to the diffusion of innovation model, conservation policies and sustainable practices should be shared effectively with the communities.

7.7 Conclusion

This study revealed that many respondents perceive the use of the wetlands in the uMsunduzi Catchment as being unsustainable. A significant concern is the widespread lack of awareness among community members regarding wetland conservation, coupled with the perceived inadequate government intervention to protect these vital ecosystems. These findings underscore the urgent need for comprehensive measures, to safeguard our wetland resources.

The application of three theoretical frameworks, namely the Theory of Planned Behaviour, the Diffusion of Innovation and the Socio-Ecological System, has been instrumental in

understanding the complex interaction between community behaviour, the dissemination of conservation practices, as well as the dynamic relationships between people and their environment. Insights from these theories have offered valuable guidance for designing holistic and effective wetland management strategies that are socially acceptable, environmentally sound and economically feasible. To ensure effective wetland conservation, it is imperative to implement targeted education programmes that increase the community's ecological knowledge and regulatory awareness. Moreover, fostering active community involvement alongside economic support initiatives will be crucial for reducing unsustainable exploitation. Strengthening regulatory frameworks and ensuring their consistent enforcement will also play a key role in protecting the wetland.

Future research should focus on the long-term tracking of seasonal and annual changes in wetland use, the ecological conditions and the views of the community, which will enhance their understanding of the environmental dynamics. Assessing the level of education, the livelihood initiatives and their enforcement will assist with adaptive management. Lastly, addressing the impacts of climate change and pollution through resilience and adaptation research will be vital for sustaining wetlands and their communities.

8 FROM LIFEBLOOD TO LIABILITY: INTERVIEW INSIGHTS INTO COMMUNITY PERCEPTIONS OF HUMAN-DRIVEN DECLINE IN THE UMSUNDUZI FLOODPLAIN WETLANDS

8.1 Introduction

Wetland ecosystems are globally recognised as indispensable natural assets, and they are celebrated for their productivity and the essential ecosystem services they provide, such as flood regulation, water purification and the direct support of human livelihoods (Dar et al. 2024, Sinthumule 2021). However, despite their immense value, these ecosystems are facing a huge crisis. Historical data reveal a staggering decline in the world's natural wetland areas, with an estimated 64% to 71% that have been lost during the twentieth century alone (Dar, Rashid, Bhat and Dar 2024). This rapid degradation is driven by escalating human activities, and it has been worsened by population pressure, weak governance and poorly-regulated resource use (Abdela et al. 2023, Kadoma et al. 2023).

The uMsunduzi River catchment area in South Africa offers a powerful case study of how these global pressures play out at a local level. Fieldwork conducted in the traditional communities of Manyavu and Ximba revealed a narrative of severe, human-induced decline. Here, the river's identity has been transformed from a respected 'lifeblood' into a 'polluted liability', primarily through the destructive forces of uncontrolled sand mining and the disposal of waste that is not regulated. This shift has created significant threats to the local health, safety and cultural identity. Tackling such a complex environmental and social crisis requires more than just a technical assessment; it demands a deep engagement with the human dimensions of the problem. Understanding the perceptions, lived experiences and attitudes of the communities who are most affected by this ecological destruction is most important (Dar, Rashid, Bhat and Dar 2024, Sinthumule 2021).

To unpack this crisis, this chapter details the community-based qualitative methodology that was used to collect rich, authentic data, while also being upfront about the constraints that were encountered during the fieldwork. It then presents the core findings that were drawn from semi-structured interviews, which are organised around the main themes, including the shifting identity of the river, the drivers of its decline, the devastating consequences for the community and the critical gaps in governance. Finally, the discussion situates these local realities within the broader academic discourse on wetland degradation, arguing that the community's call for

an integrated and locally-empowered governance model is the only viable path towards sustainable management.

8.2 Methodology

8.2.1 Research design

This study utilised a community-based qualitative research design, which emphasises the subjectivity and the positionality of a researcher within the research process. This approach allows for a direct engagement with the community that is being studied, and it ensures that the voices and lived experiences of participants form the foundation of the research outcomes (Mwita 2022, Phoenix et al. 2018). As noted by Steinberg et al. (2023) and Mohanasundari et al. (2023), qualitative research is characterised by a *naturalistic enquiry*, where phenomena are observed and understood in their natural setting, without any attempt to manipulate or control them.

This approach was found to be appropriate for exploring the perceptions and experiences of the Manyavu and Ximba communities regarding the human-induced changes in the uMsunduzi River and its surrounding systems. Similar to the work of Magnus and Rai (2024) on rural community-based action research, this method allowed for a fine and contextuallygrounded understanding of the local ecological and social relationships.

Different from quantitative approaches, which prioritise measurable outcomes, qualitative research accommodates complex social dynamics and emotional contexts. It also recognises the role of the researcher as both a *trusted outsider* and an *effective collaborator* (Magnus and Rai 2024). As a member of the Manyavu community with strong family ties to Ximba, the insider status of one researcher enabled more meaningful and ethical interactions, which helped to ensure that the data that were collected genuinely reflected the participants' 'lived realities'.

8.2.2 Study area and research duration

Fieldwork was carried out across the Manyavu and Ximba communities within the uMgungundlovu District in the KwaZulu-Natal province of South Africa. It was conducted from 6 June and 15 July 2025. The data-collection phase extended over approximately one month.

8.2.3 Sampling strategy

A purposive sampling approach was utilised in this study, by specifically using a combination of stratified purposive sampling and criterion sampling, to ensure the transparent and successful identification of participants who possessed a relevant knowledge and experience concerning the uMsunduzi River and its associated wetlands. This non-probability technique is characteristic of a qualitative research design, as it prioritises the selection of information-rich cases over random selection, which ensures that the sample provides an in-depth understanding of the phenomenon being studied (Campbell et al. 2020). The goal was not statistical generalisation (Steinberg, Bringle and McGuire 2023), but the collection of rich, detailed insights from those who could articulate their perceptions and experiences of the changes in the rivers. The study thus targeted ten participants and it successfully engaged nine (Table 8-1), including four community leaders, two elders and four residents, a number that was deemed to be sufficient for thematic saturation within a qualitative framework that was focused on local ecological and social relationships.

Table 8-1 Different groups of semi-structured interview participants

Participants	Frequency	Rational for Inclusion (Bias mitigation)
Community leaders	4	To ensure a necessary balance between customary ideals (Chiefs) and practical realities (Chief Chancellors) within the TA structure, thus preventing findings from being biased towards a single leadership perspective.
Community elders	2	Elders represent a longitudinal perspective and tradition.
Community residents	3	Residents present their current daily life experience.

8.2.4 Data collection method

8.2.4.1 Semi-structured interviews

The primary data collection method involved semi-structured interviews, which facilitated its flexibility, while maintaining the focus on the research question. Obtaining access to local chiefs required strict adherence to community protocols, including obtaining permission

through an *unobhala* (secretary) and *izinduna* (chief councillors). This stage of the process turned out to be time-consuming, and it resulted in several unsuccessful visits and negotiations, before the interviews could take place successfully.

Interviews were carried out in IsiZulu, after appointments were scheduled to accommodate some of the participants' work commitments. Since IsiZulu is the researcher's first language, it ensured comfort and authenticity during the conversations with traditional communities alongside the uMsundzi River, and it enabled the participants to express their experiences naturally. The fact that interviews were held in the homes of the participants created a relaxed environment that encouraged transparency. Although these discussions were guided by a semi-structured framework, follow-up questions were utilised to delve deeper into the participants' perceptions of human activities and their understanding of how they affect the uMsunduzi River and its associated wetlands.

8.2.5 Data analysis

The data collected through semi-structured interviews were analysed by using a thematic analysis, a method that is suitable for identifying and interpreting patterns within the qualitative data (Mohanasundari, Pratheeba, Preethi, Kasturi, Peter, Guru and Dayal 2023, Phoenix, Nguyen, Gentles, VanderKaay, Cross and Nguyen 2018). The process began with the transcription of all interview recordings in IsiZulu, followed by careful translation into English. This translation process was demanding, as many participants used rich idiomatic expressions that lacked a direct English equivalent during the translation process. Contextual meanings were retained, where necessary, to preserve the cultural nuances, acknowledging that some semantic depth may have been lost in translation.

Afterwards, the transcription data were coded by using the *Notebook ML* application on Google suite. All transcriptions (including the interview questions) were uploaded into PDF format, and the software automatically conducted initial coding and thematic clustering, thereby generating a mind map to visualise these emerging themes for each set of data. This mind map was then reviewed to ensure that its highlighted themes reflected participants' perspectives accurately, and it was later interpreted in relation to the study's research questions and the ,existing literature. This analysis not only revealed the main community perceptions regarding human-induced changes, but it also bridged the gap between scientific understanding and indigenous ecological knowledge. As a result, it contributed to a more inclusive framework for wetland management and environmental policy development.

8.2.6 Ethical considerations

Ethical integrity was a priority throughout all the research stages. Participants were fully informed about the purpose, procedures and the voluntary nature of the research. Their informed consent was obtained before their participation, and individuals were assured that, should they feel uncomfortable, they could withdraw at any stage, without any consequences. All interviews were respectfully carried out in IsiZulu to ensure clear communication and cultural sensitivity. Confidentiality was highly maintained by anonymising the participants' identities by using pseudonyms and safeguarding all the collected data.

Because the researcher held a position as a member of the communities that were studied, particular care was taken to avoid any form of coercion or bias. Respect for the cultural norms, values and traditions remained a priority of the research process, thereby ensuring the ethical authenticity and trustworthiness of the findings.

8.2.7 Limitations of the study

While this study managed to achieve its objective of capturing the everyday realities and perceptions of the uMsunduzi River's degradation, collecting rich, honest data through extensive immersion in the Manyavu and Ximba communities required us to be pragmatic about the practical and methodological concessions that were made. These were not shortcomings, but very genuine trade-offs that were involved in conducting advanced qualitative fieldwork on the ground, in a setting such as KwaZulu-Natal.

8.2.7.1 Constraints of political sensitivity and access

The fieldwork was conducted when the communities were grappling with an intense internal conflict concerning the ongoing sand-mining operations. The research discovered that, while the mining was environmentally destructive, it was simultaneously regarded as a "necessary evil" that provided an income for unemployed young men, and that it was often defended by those in power. This contentious backdrop meant that the researcher, despite being an insider of the community, had to occupy a liminal space, which made it difficult to achieve their full trust. Community members could easily suspect that the researcher was affiliated with one faction in the ongoing fights, which affected the willingness of some individuals to speak openly. This political tension contributed directly to the recruitment shortfall, since the study engaged nine participants, falling just short of the target of ten, because some residents refused to participate, due to the sensitivity of the topic. This means that the findings may have been

influenced by the self-censorship of some key informants, who feared exposure.

8.2.7.2 Constraints of the scope and translation

The findings of this chapter are context-specific and are deliberately not designed for statistical generalisation to the broader uMsunduzi catchment area. The study focused solely on the perceptions and lived experiences of the affected traditional communities (Manyavu and Ximba); therefore, it did not represent the perspectives of the external entities who were identified as themajor polluters, such as upstream industrial businesses in Pietermaritzburg, or the Municipal Authority structures that were blamed for governance failures.

A final constraint was related to the essential translation of the data. All interviews were conducted in IsiZulu to ensure authenticity and comfort. However, the transcription and translation into English proved time-consuming, since many participants used rich idiomatic expressions that lacked a direct English equivalent. Despite a very careful effort to preserve the contextual meanings, it is acknowledged that some semantic depth may have regrettably been lost in the translation process.

8.3 Findings

This section provides report on the major findings that were derived from the fieldwork experience in Manyavu and Ximba villages. These findings provided an insight into the experiences of the people, their lived realities and their proposed solutions regarding the anthropogenic degradation of the uMsunduzi River. An analysis of the data showed four overarching themes: (i) the past importance, and then the decline, of the river; (ii) the primary forces of change from human activities, i.e. the mining of sand and the disposal of waste; (iii) the perilous implications for security and health; and (iv) the perceived ineffectiveness of the existing governance frameworks.

8.3.1 The shifting identity of the uMsunduzi: from lifeblood to liability

The participants in both places revealed their deep historical relationship with the uMsunduzi River; they viewed it not merely as a resource, but as the core of their ecological and spiritual identity. Chief Chancellor Gadla explained that the river *"has been the lifeblood of* [their] *community*", where rituals were performed, and livestock grazed. He emphasised that they traditionally treated the river "*not* [just] *as a resource, but as a spiritual entity, deserving of respect and protection*". Chief Mdlolo recalled a time when, even without municipal services, the water was so clean that when it was dirty, they could simply "*dig holes near the river shore for clean water*." He argued further that there was "*no problem in drinking it because it was*

not harmful to [their] *health*". The river was essential for bathing, washing clothes and supplying the sand and water that were needed for construction, such as making building blocks and mud huts.

However, this traditional reliance has been violently severed due to the increasing pollution, which has changed the river into a public hazard. MaMlambo, an old lady who has lived near the river for 69 years, lamented that the river is "*a thing of sadness now, not life*". Mr Qwabe encapsulated this change from a civic perspective, stating: "*I can't proudly show my two children the resource that built our home and sustained my father, because it's now a polluted liability*".

8.3.2 The principal drivers of environmental decline

The degradation of the uMsunduzi is driven by a combination of internal community practices and uncontrolled external exploitation that is primarily centred on waste disposal and resource extraction.

Community members frequently highlight the issue of unregulated waste. Chief Mdlolo pointed to the widespread disposal of *"used pampers"* being thrown into ravines and valleys, which are then *"washed into the river during drought, which results in severe pollution"* after storms. Sean, a high school student, noted simply that if *"the rubbish truck is full, people just dump their bags near the water, and then it washes in"*.

More disturbingly, the leaders mentioned the significant external pollution sources. Chief Councillor Gadla reported illegal activities, observing *"mobile toilet waste being illegally disposed of by outside church events, which is an abomination"*. He added that the Traditional Authority (TA) also faces a continuous fight *"with illegal dumping from people who do not belong to* [their] *area"*. Chief Magaba expanded on the severe contamination coming from upstream: *"Many businesses not only around this community, but from upstream in Pietermaritzburg, they dispose of the chemicals into this river"*. He noted that the waste created during construction, along with *"old baby diapers floating in the river"*, means that no one can safely drink the water.

Apart from the pollution, resource extraction, particularly sand mining, was identified as the most destructive physical activity. Chief Councillor Xaba confirmed that while sand extraction allows people to "*collect water to use for making blocks*", the miners "*no longer backfill the holes, leaving deep waters*". Mr Qwabe condemned this activity, arguing that it is "*an*

unsustainable extraction of a resource that took centuries to form", and it amounts to "*a short-term economic gain for a few, exchanged for long-term environmental disaster for the community*". Chief Chancellor Gadla acknowledged the immense contradiction that is inherent in this practice, calling it a "*necessary evil*" because "t*he financial benefit for the young men is too important to stop"* as it provides *"livelihoods and supports many families here*".

8.3.3 Observed consequences: health, dafety and ecological loss

The relentless degradation has resulted in tangible, negative consequences that affect the safety, health and traditional economy of the community. The water quality is now uniformly described as severely compromised. Mr Gwabe observed that the water is *"permanently opaque and carries a persistent chemical odour"*. Chief Mdlolo noted that the river *"no longer has the opportunity to be clean"* (rejuvenate itself) because of persistent human activities. The Chief Councillor Xaba explained that the water is so polluted that community members *"sometimes experience itching bodies after washing* [their] *bodies with this water"*. This toxic environment forces parents to keep their children away, and as Chief Magaba noted, children who go into the river often "*come out with rash*".

Furthermore, the physical structure of the river has been compromised, which has introduced severe dangers. Sand mining and erosion have made the river *"erode to deepen, making it far from reach"*. The unrehabilitated excavations create *"deep, unpredictable pools, increasing the risk of drowning, which is a constant tragedy here"*. Chief Councillor Xaba gravely stated that the unfilled holes *"result in the death of children during summertime, when they go into these places for swimming"*. The destabilised floodplains also contribute to infrastructure damage; Chief Magaba noted that heavy rains destroyed a community bridge in 2021, due to the changing depth of the river that was caused by upstream mining. Livestock are also affected; Chief Mdlolo mentioned that cows often *"get stuck in the holes alongside the river or in the wetlands, resulting in their death"*.

Ecologically, the river is described as 'dying'. Mr Qwabe stated categorically that the *"fishery is destroyed"* and *"nothing edible can survive"*. Chief Mdlolo observed that water birds, such as *amahlokohloko* and *omakoti*, have largely disappeared from the river area. Mayaka noted that the pollution impacts the economic activities of traditional residents, i.e. his wife's income from making and selling mats has been affected because *"the reeds in the wetland are of poor quality and the area is too polluted to access"*.

8.3.4 Governance gaps and traditional authority frustration

A critical finding was the vast disparity between the existing laws, the traditional governance structures and functional on-the-ground enforcement.

The Traditional Authority (TA) leaders affirmed that they possess clear, effective internal rules that are based on traditional laws and protocols. Chief Chancellor Gadla touched on the enforcement power of the traditional court, citing an incident where a man was *"brought to the traditional court and charged a fine"* of R5 000 for disposing of the mobile toilet waste into the uMsunduzi River. Chief Mdlolo also believed their rules are effective within the community, citing a *"reduction in the degradation of the river"* since mandatory cessation periods were introduced for sand miners to allow restoration. He also mentioned the control of fire-burning to prevent soil erosion, which severely polluted the river and generated flash floods during the rainy season.

However, this local effectiveness is severely undermined by external threats and a profound lack of government support. Chief Mdlolo was explicit about this lack of unity, saying, *"I can't lie, there is no support at all"* from the Municipal Authority. Chief Chancellor Gadla argued that the TAs are the *"true custodians of this land and the environment, yet [they] are given zero financial support by the government, compared to the Municipal Authority"*. He noted that their traditional laws are *"ineffective"* against external threats like *"the municipal sewerage overflows or the illegal dumping trucks from outside the area, because the Traditional Authority has no power over those external entities"*.

From the perspective of the community members, the rules are non-existent or *"ineffective"*. Mr Qwabe commented that even though legal frameworks may exist, *"locally, there is zero enforcement. There are no signs, no publicised fines and no official body actively patrolling. Therefore, the rules exist in law, but not in reality, here in Manyavu"*. Sean, the student, echoed this frustration, asking rhetorically: *"If there were [rules], no-one seems to follow them, so what's the point?"* He concluded that if the rules *"were working, the river would be clean, right? Since it's not clean... it means the people who are meant to be in charge are not doing their job"*.

8.3.5 Pathways to restoration: community demands for collaboration

The community suggested strong ideas that focused on empowering the local custodians, reforming the funding models and improving communication.

Traditional leaders consistently demanded financial parity and direct support. Chief Chancellor Gadla insisted that the government *"must provide direct financial grants to the Traditional Authority, specifically for environmental protection, without filtering it through the distant Municipal Council"*. He argued that this funding is required to *"officially employ the river monitors, to purchase equipment to clean the banks, and to build better waste collection points"*. Chief Mdlolo also proposed structural reform by suggesting that, since disasters occur primarily in their areas, a *"Department of Disaster could be initiated within the traditional authority of every Chief's village"*.

Community members emphasised the need for collaboration and active participation, by stating that they currently have *"no formal platform or regular meeting specifically dedicated to the management of the uMsunduzi River"*. Mayaka recommended that the authorities should *"establish a local River Management Committee",* which formally includes community members, local farmers and businesses, and he insisted that this must be a *"genuine partnership, not just a rubber-stamping exercise"*. Chief Magaba emphasised that solutions must involve a *"community consultative process where communities are made part of the solution and not a solution thought of by someone, somewhere"*.

Finally, there is a severe lack of accessible information. Mr Qwabe stated that the average resident *"relies only on visual observation and community gossip"*. Mayaka added that the community is *"kept in the dark about water quality, management plans, and who is actually responsible for fixing the ongoing problems"*. The community seeks educational programmes and formal engagement, in order to restore the dignity of the river and ensure its future sustainability.

8.4 Discussion

The results of the Manyavu and Ximba fieldwork revealed the extreme, human-caused degradation of the uMsunduzi River and related wetlands, largely through sand mining and the disposal of waste, as well as an observed failure in effective governance. The degradation poses a threat to the historical significance of the ecosystem and has apocalyptic implications for the health and safety of the locals. These individual experiences resonate so deeply with the international debate on the modern crisis of wetland ecosystems, mostly in the third world, where population pressure is acute and where there is intensifying competition for resources (Kadoma, Perry and Renaud 2023, Narayanan and Venot 2009).

8.4.1 The context of wetland degradation and human-induced drivers

The uMsunduzi River environment suffers from degradation due to sand-mining operations and waste disposal activities, which mirror the widespread dangers that exist throughout Africa and Asia (Abdela, Oumer and Ukule 2023, Sinthumule 2021). The research conducted in the Manyavu and Ximba communities by using qualitative experiential validation demonstrated that the local crisis represents a broader worldwide wetland decline, which has destroyed between 64% and 71% of the natural wetland areas during the 20th century (Dar, Rashid, Bhat and Dar 2024). The local research shows that these delicate ecosystems receive poor management, while people treat them as useless wastelands (Sinthumule 2021).

8.4.1.1 Similarities: pollution as a critical mechanism of decline

The qualitative results of how the community relates to pollution validate other global and regional research outcomes, which indicate a global failure to control effluent in peri-urban areas (Hale et al. 2023, Singh et al. 2023).

Waste Disposal and Sewage: The wide-scale disposal of uncontrolled waste, including "used pampers" and domestic rubbish, as well as excessive external contamination in the form of "municipal sewerage overflows" and the unauthorised dumping of "mobile toilet waste" were mentioned by the Manyavu and Ximba communities. This resonates strongly with research citing that pollution and solid waste mismanagement are the significant drivers of wetland degradation (Allahyari et al. 2024, Kadoma, Perry and Renaud 2023). These results replicate the drivers in the Khushalsar wetland (domestic and industrial sewage and solid waste without treatment) and the Anzali Wetland in Iran (domestic and industrial wastewater effluent discharge) (Allahyari, Marzban, Gonzalez-Ollauri, Nazari, Ben Hassen and Surujlal 2024, Dar, Rashid, Bhat and Dar 2024).

Industrial Influence: The explicit involvement of Pietermaritzburg-based upstream companies that are discharging chemicals into the uMsunduzi River aligns with the finding of the systematic review that industrial pollution plays a significant role in putting such an environment under stress (Mandishona and Knight 2019, Nyumah and Brambilla 2025). This is because such problems originate in structural deficits shared by the Third World, where increases in the population and poor infrastructure cause waste crises (Allahyari, Marzban, Gonzalez-Ollauri, Nazari, Ben Hassen and Surujlal 2024, Kadoma, Perry and Renaud 2023). The deterioration of the uMsunduzi, from its historical status as a sacred "lifeblood" to a toxic "polluted liability", is therefore an immediate, lived result of these structural forces that can be

enabled anywhere.

8.4.1.2 Similarities and differences: resource extraction and socio-economic drivers

The resource extraction pressures that were identified, like unregulated sand mining, have very similar characteristics to human-induced degradation under other socio-economic drivers.

Economic Need: Sand mining was welcomed as a *"necessary evil"* by leaders in the communities, since the short-term economic gain brings *"livelihoods and supports many families."* The conclusion agrees with the wider literature that determines the economic need to be the most frequent cause of human activities in floodplain wetlands, with wetlands being used by people for construction material, such as sand and clay, to accommodate the increasing populations (Kadoma, Perry and Renaud 2023, Msaki and Kessy 2014).

Difference: Acute Safety Risks: However, when drawing into focus a significant qualitative distinction in the identification of the acute and immediate physical safety risks involved with this particular unsustainable practice, this uMsunduzi study makes the following point that bears them out. Sand miners *"no longer backfill the holes, living in deep waters"*. This absence of rehabilitation has resulted in *"deep, unpredictable pools, increasing the risk of drowning",* as noted by a community member of more than 60 years, maMlambo. Although studies elsewhere acknowledge economic justification for the extraction (Kadoma, Perry and Renaud 2023, Msaki and Kessy 2014), the uMsunduzi findings indicate that government inaction in enforcing the basic environmental requirements (e.g. backfilling) effectively converts economic constraints into a fatal community risk. The resultant damage to the ecology, i.e. the impaired water quality and ruined local fisheries, directly compares the short-term benefit for a minority with a *"long-term environmental disaster for the community."*

In summary, the home-grown realities of the uMsunduzi River, namely the poisoning by off-site upstream polluters and the reorientation of sand-mining areas into drowning hazards, are a testament to the fact that, while drivers (pollution and resource extraction) are indeed universal in their alignment within the worldwide degradation context, the unprecedented depth of governance deficits aggravate the ecological and social consequences within Manyavu and Ximba. This qualitative evidence is a key testimony to how uncontrolled development pressure and weak regulatory enforcement translate into the often-cited statistics of environmental degradation and tangible human tragedy. It supports the argument that the failures of local-level governance constitute a key enabling mechanism for globally-identified drivers (Abdela et al. 2023, Yasin et al. 2025).

8.4.2 Community perception and the valuation of ecosystem services

The present study employed a qualitative method, thus allowing the researcher to enjoy being in an insider position and able to access oral histories, in order to acknowledge the lived experiences of the respondents and find the space between scientific judgment and local ecological understanding (Magnus and Rai 2024). Local views matter, since they reflect the concerns and reliance of the residents, which should be the basis on which future planning and policy are developed (Dar, Rashid, Bhat and Dar 2024, Sinthumule 2021).

The decline of wetlands in Manyavu and Ximba communities is the direct result of the loss of vital Ecosystem Services (ESS), which affects the health and well-being of the community, as noted in Ondiek et al. (2020). In other socio-ecological environments, wetlands are widely depended upon by people for provisioning services like food, fodder and fuel (Dar, Rashid, Bhat and Dar 2024, Yilma 2019). For instance, a study in the Boyo wetland in Ethiopia confirmed that provisioning services, namely, fuel wood, fodder and grazing, were given the highest priority by the people, which often led to trade-offs, so that regulatory and supporting services then decreased (Yasin, Tekalign, Takele, Mcmahon and Desalegn 2025). Such a utilitarian valuation, in which wetlands are viewed mainly as a matter of use, normally puts them under pressure (Mokuku and Taylor 2015).

However, there are strangely optimistic attitudes within communities towards conservation, even when there is all-round degradation. Studies in South Africa have shown that the local communities have a much more positive mindset toward wetlands and conservation, which suggests that they are willing to regulate harmful activities and even offer money, or vote, for conservation (Sinthumule 2021). Equally, local surveys in the area surrounding the Khushalsar wetland, indicated conservation support by, among others, advocating for prohibiting harmful practices and a willingness to provide financial input (Dube et al. 2024). This indicates the grassroots people's participation that can be leveraged to help in future management interventions (Nyumah and Brambilla 2025).

8.4.3 Governance challenges and the necessity of integrated management

One of the key findings in the study was the perception of the ineffectiveness of the existing governance systems. Note that this discovery could have been exacerbated by the recruitment issues in this research; the political sensitivity of sand mining would have inclined those who had a stake in the activity to respond less, thus putting the majority of the most outspoken

critics of the scenario in the spotlight. This challenge is common among many developing nations, where the drive for economic development and rapid urbanisation often conflict with the conservation requirements, particularly when government agencies fail to enforce environmental laws effectively (Kadoma, Perry and Renaud 2023, Mandishona and Knight 2019). In the uMsunduzi River communities, citizens called for pragmatic solutions like more policing, the effective delivery of services (the removal of refuse and sewage), the hi-tech surveillance of criminality, and most importantly, the formalisation of local authorities like a "permanent uMsunduzi Catchment Forum" or "River Management Committee". However, since this research only focused on what occurred to the impacted communities, it did not contain the voices of municipal officials and the upstream corporations that are listed as polluters. Subsequent research would therefore be needed that brings these external stakeholders into the picture, in order to get a clear view of the governance freeze.

These indigenous recommendations conform to the global recommendations that are founded upon participatory and integrated management practices. The studies all point towards the fact that conservation efforts are boosted by means of stakeholder involvement and collaboration (Kadoma, Perry and Renaud 2023). Community-Based Wetland Management (CBWM) practices are supportive of sustaining highly over-exploited wetlands, provided that such practices incorporate local indigenous practices and knowledge (Nyumah and Brambilla 2025).

To ensure the successful application of the wetland policy, it is essential today to move beyond consultation with the local people, and to engage them as cooperative stakeholders. A bottom-up strategy, which is founded on the social deliberation of common meaning and values, creates more democratic environmental policies (Langensiepen et al. 2023). Degradation mitigation options generally involve diversifying the livelihood opportunities away from high-impact uses, establishing buffer zones, upgrading infrastructure for resource user groups, and putting in place continuous public awareness and education campaigns (Abdela, Oumer and Ukule 2023, Mukasa et al. 2024, Tecklie et al. 2022). Institutional support for wetland conservation and an improvement in the peaceful coexistence between the wetland and the communities are critical for the long-term sustainability of our resources (Dar, Rashid, Bhat and Dar 2024).

8.5 Conclusion

This chapter documented the sobering reality of environmental degradation and social disillusionment, as seen in the Manyavu and Ximba communities. This qualitative, in-depth field study revealed a riveting, poignant narrative: the uMsunduzi River, which was once

regarded as a spiritual and ecological "*lifeblood"*, is now regretfully regarded as a hazardous *"polluted liability"*.

This disastrous change has been driven by the relentless impact of uncontrolled waste disposal, including external pollution from *"municipal sewerage overflows"*, and industrial chemicals from upstream Pietermaritzburg industries, and they have been compounded by the highly-destructive practice of sand mining, which is locally-regarded as a *"necessary evil"*. The destruction has produced concrete and calamitous consequences; for example, the unrehabilitated sites that present immediate physical hazards, including the very real *"drowning risks of children in the summer"*. Moreover, contamination poses health risks, such as skin diseases, and it has permanently undermined the traditional fishing industry, as well as the harvesting of high-quality reeds.

At the root of this environmental crisis lies the profound policy failure. The traditional Authorities (TAs), who have long maintained effective local governance, have been rendered *"functionally useless"* in the face of large external polluters. This outcome stems from a simple institutional shortfall and the absence of direct material incentives from the State, which leaves the communities, who perceive themselves to be the *"true custodians"*, as powerless.

The people of Manyavu and Ximba are not mere bystanders; their clearly articulated proposal for restoration demonstrates adeep ecological knowledge and a strong conservation ethos, which is consistent with trends elsewhere in South Africa. Their vision emphasises official recognition, equality and harmonious co-management through *"genuine collaborative partnerships"*, full participation in the local River Management Committee, direct budgetary allocation to TAs for their operational costs, and the exclusion of the far-off Municipal Council.

Although the politico-sensitivities and context-specific nature of the study limit its statistical generalisability, the findings offer a valuable model of effective rehabilitation. The over-arching message is clear: the future of the uMsunduzi River depends on moving beyond the policy framework. Sustainable restoration must be firmly grounded in local empowerment, which actively involves the custodians who live along its banks as the central participants in the solution.

9 INTEGRATING GEOSPATIAL AND SOCIO-ECONOMIC DATA TO ASSESS THE RELATIONSHIP BETWEEN SPATIOTEMPORAL CHANGES BETWEEN 2000 AND 2024 IN WETLAND SPATIAL EXTENT AND COMMUNITY PERCEPTIONS ALONG THE MSUNDUZI RIVER FLOODPLAINS

9.1 Introduction

Wetlands are among the most productive and valuable ecosystems globally. These vital ecosystems encompass various types of water bodies, including marshes, fens and peatlands (Kundu et al. 2024). Wetlands cover approximately 5 to 10% of the earth's land surface globally. Despite this relatively small extent, their high productivity and diverse biology support about 40% of the world's species (Chen et al. 2019, Kundu, Kundu, Rana and Mahato 2024). Some of their critical functions include climate regulation, water supply, water purification and biodiversity maintenance (Zhu et al. 2022). Regardless of their important contribution to the environment and the people, wetland ecosystems are disappearing at an alarming rate, due to accelerating anthropogenic pressures. The Rasmar Global Outlook (2025) reports that over 400 million hectares of wetlands have been lost since 1970, with their annual loss rate ranging from 0.2% to 3.14%, and it is reported to be three times faster than that of forests (Kundu, Kundu, Rana and Mahato 2024). The factors that lead to wetland loss have been identified as population growth and economic development, which are characterised by agricultural expansion, urbanisation, aquaculture and pollution (Ballut-Dajud et al. 2022). In developing regions, such as Africa and Asia, wetland conversion is accelerated by socio-economic pressures and weak environmental governance, which have led to the erosion of both ecological and livelihood resilience (Imdad et al. 2023, Song et al. 2012).

The Water Research Commission (2024) noted that wetlands make up 2.2% of South Africa's land surface. This is a decline from the 2.4% that was identified by Adeeyo, Ndlovu, Ngwagwe, Mudau, Alabi and Edokpayi (2022). This is a clear indication that South Africa's wetland ecosystems are critically endangered and therefore, intervention is needed. However, understanding wetland degradation requires more than just mapping the biophysical changes; it requires an acknowledgement of how the local communities experience and manage such resources (Géant et al. 2025). Researchers argue that approaches that rely only on geospatial data fail to capture the diverse socio-ecological relationships that shape wetland use and conservation (Imdad, Sahana, Ravetz, Areendran, Gautam, Dwivedi, Chaudhary and Sajjad 2023, Matsa et al. 2020). Thus, an integrative methodology that considers remote sensing and a GIS-based spatial analysis with socio-economic field data is essential for gaining an insight into the magnitude of wetlands transformation.

Traditional methods of monitoring wetlands have been used for a long time. Despite their accuracy, they are costly and laborious, due to their field-based nature, and they have limited spatial coverage (Zhao et al. 2023). Advances in remote sensing technologies have introduced timely and non-destructive ways of monitoring wetlands. Satellite-based remote sensing has been proven to be quite effective in mapping wetlands and for detecting changes over time, and it has been widely accepted as providing spatially-explicit data that effectively quantifies the spatial extent and distribution of wetlands (Saha and Gayen 2025, Zhang et al. 2025). Satellite imagery from the Landsat series offers data on land cover, which are suitable for assessing the temporal variation of wetlands. The recent Landsat series has a maximum temporal resolution of 16 16-day cycles and can capture variations in the visible, near-infrared, shortwave infrared and thermal infrared parts of the electromagnetic spectrum (Li et al. 2021). They also embody spectral indices, such as the Normalised Difference Vegetation Index (NDVI), the Normalised Difference Water Index (NDWI) and the Modified Normalised Difference Water Index (MNDWI), which are suitable for vegetation and water body extraction (Singha and Pal 2023). Therefore, this makes Landsat imagery ideal for detecting spatiotemporal changes in the wetland extent and distribution.

Although modern classification methods and techniques, such as Object-Oriented Classification (O-OC) and Maximum-likelihood (MLC) have gained momentum in spatial assessment studies, the traditional machine learning algorithm Random Forest (RF) remains a highly effective and robust method for classification (Yan et al. 2023). It uses different decision trees to train samples and integrate predictions, which makes it the best-performing and most effective tool for land cover mapping, due to its low manual intervention (Wang et al. 2023, Yan, Zhu, Zhao and Su 2023). Therefore, combining Landsat imagery and RF is an effective method for achieving detailed land cover results in wetland mapping studies.

While remotely-sensed data provide an objective and quantitative means of monitoring the changes in wetlands and their spatial extent, it cannot capture the human perceptions and social dimensions that influence the use of wetlands (Dibaba et al. 2025). A study that integrates geospatial data and socio-economic aspects can capture and provide a full understanding of the spatial changes in a wetland and their implications for the communities.

Given that few integrative studies have been conducted on floodplain wetlands, this study aimed to comparatively detect and characterise the spatial extent of wetlands in 2000 and 2024. It also aimed to assess the relationship between variations in wetland's spatial extent and the community's perceptions of the significance of wetlands along the floodplains of the uMsunduzi River.

9.2 Methods and Materials

9.2.1 Image acquisition and processing

Satellite images were acquired to assess the temporal changes in the spatial extent within the wetlands of the uMsunduzi River floodplains. Two datasets were collected, namely, a Landsat 5 Level-2 Collection 2 image (1 January to 31 December 2000) and a Landsat 9 Level-2 Collection 2 image (1 January to 31 December 2024). Both Landsat images were obtained from the United States Geological Survey (USGS) records, and were selected based on their low cloud cover and surface reflectance corrections for radiometric, as well asatmospheric influences (USGS, 2025). Both the image analysis and processing were performed in the Google Earth Engine (GEE) platform, which is a platform that provides a low-cost and wide range evaluation method for ecological assessments, and this carries out a cloud-based geospatial computation and analysis efficiently (Gorelick et al. 2017, Zhao et al. 2024).

9.2.2 Socio-economic data collection

The socio-economic aspect of the study sought to complement the geospatial analysis by providing community-based perspectives regarding the utilisation and management regulations of the wetlands located along the uMsunduzi River floodplains. The study used structured household questionnaires to collect socio-economic data in Manyavu and Ximba, which are both villages located along the river floodplains. These villages were purposefully selected due to their proximity to the focus area of the study, as well as the villagers' dependence on the wetland-related resources for their livelihoods. The houses were chosen randomly to provide a representative coverage within the villages (Matsa, Mupepi, Musasa and Defe 2020). The study was able to complete a total of 60 questionnaires, 30 for each village, between the 10th and 25th of July 2025. The questionnaires were administered by means of face-to-face interviews, in order to ensure the clarity of responses and to accommodate the varying literacy levels among participants.

The questionnaire design combined closed-ended questions, which provided quantifiable data on the demographic characteristics and livelihood activities, with open-ended questions that allowed the respondents to express their views and knowledge, in detail, of the environmental changes and drivers of wetland degradation. The collected data were then entered and coded in IBM SPSS Statistics (Version 29), in order to perform a descriptive and inferential statistical analysis. This socio-economic aspect complemented the geospatial analysis by giving first-hand information on how human-environment interactions affect the condition of wetlands over time.

9.2.3 Image classification

The classification of Landsat satellite imagery was carried out to identify and map the spatial

distribution of different land cover classes along the uMsunduzi River floodplains for both 2000 and 2024. This was the core process that involved determining the class to which each specific pixel belongs (Saha and Gayen 2025). The classification process was performed in the Google Earth Engine (GEE) cloud computing platform, which offers effective tools for large geospatial data processing and analysis (Gorelick, Hancher, Dixon, Ilyushchenko, Thau and Moore 2017). Supervised classification was used, due to its ability to allow the researcher to control the class definitions and apply the knowledge of the region of interest, in order to train the algorithm effectively (Matsa, Mupepi, Musasa and Defe 2020).

Two images, Landsat 5 TM of 2000 and Landsat 9 OLI/TIRS of 2024, both with Level 2 Surface Reflectance, were analysed. Upon retrieving the imagery from the United States Geological Survey (USGS), the satellite imagery description had stated that the imagery had already been pre-processed by USGS, in order to correct the atmospheric effects, thus providing ready-to-use reflectance values that were suitable for classification. The study had made sure to only select images with minimal or no cloud cover, for reliable results. The spectral bands used included Band 1 (Blue), Band 2 (Green), Band 3 (Red), Band 4 (NIR), Band 5 (SWIR1) and Band 7 (SWIR2). The specific bands were chosen based on their spectral response characteristics that were relevant for distinguishing the water, vegetation, soil and built-up features within the landscape (Dibaba, Dibaba and Hirpa 2025, Saha and Gayen 2025).

To enhance the separability of the classes, certain spectral indices were derived and utilised as auxiliary input layers for the classification. The indices increased the separability of the vegetation, water and other land cover classes by utilising the spectral response of the surface feature within the visible, near-infrared (NIR), and shortwave infrared (SWIR) bands. Indices utilised are presented in Table 9.1 below.

Table 9-1 Indices and equations

Name of Index	Abbreviation	Equation	Reference
Normalized Difference Vegetation Index	NDVI	(NIR − Red) / (NIR + Red)	(Saha and Gayen 2025)
Normalized Difference Water Index	NDWI	(Green − NIR) / (Green + NIR)	(Jahanbakhsh and Hasanlou 2025)
Modified Normalized Difference Water Index	MNDWI	(Green − SWIR1) / (Green + SWIR1)	(Xu 2006)
Land Surface Water Index	LSWI	(NIR − SWIR1) / (NIR + SWIR1)	(Christian et al. 2022)

The indices that were employed were significantly useful for this wetland assessment study. They were all important for differentiating the wetland features from the surrounding land cover. The NDVI

enhances the vegetation greenness, while NDWI and MNDWI identifies the open water bodies, and the LSWI captures both the soil and vegetation moisture (Christian, Basara, Lowman, Xiao, Mesheske and Zhou 2022, Saha and Gayen 2025).

Ground reference data were obtained from the field in 2024, as well as from Google Earth Pro for the 2000 image, by means of the Visual Interpretation (VI) of high-resolution imagery. These reference points were used to define the training samples for each land cover class. Eight (8) major land cover classes were identified and delineated, based on prior field knowledge and visual interpretation. Each class was represented by multiple training polygons, in order to capture its spectral variability within the category.

Random Forest was employed to enhance the classification quality. RF is a machine learning algorithm that uses bootstrap aggregating and binary recursive partitioning to create numerous decision trees on randomly sampled subsets of data and features (Ding et al. 2025). Groups of decision trees vote for the most common class for each sample (Breiman, 2001). The model was optimised with its hyperparameters, that is, the number of features that were randomly chosen at every node (*mtry*) and the number of trees (*ntree*). In particular, the *ntree* was set at 300, while the maximum depth of each tree (*max Nodes*), the number of minimum samples to split for the nodes (*minSamples*), and the randomisation seed were left to be the default in GEE. The bag fraction was set to be 0.5, which allowed for the addition of randomness into the process of constructing the trees. Zhao, Feng, Xie, Zhu and Zhang (2023) and Yan, Zhu, Zhao and Su (2023) listed several advantages of RF, i.e. it possesses very adjustable hyperparameters, has an efficient learning mechanism and that results in quick model training, and it is robust against outliers, overfitting and high-dimensional data, which makes it suitable for use on different datasets. All these factors make RF an ideal algorithm for mapping the distribution of wetland vegetation for the study area.

9.2.4 Accuracy assessment

An accuracy assessment was conducted in the Google Earth Engine by means of the independent derivation of validation points from the training dataset. Validation generated notable accuracy metrics, such as the Overall Accuracy (OA), the User's Accuracy (UA), the Producer's Accuracy (PA) and Cohen’s Kappa Coefficient. These accuracy metrics evaluate the agreement between the classified map and the reference data, and hence, they estimate the reliability of the classification (Zekarias et al. 2021, Zhao, Feng, Xie, Zhu and Zhang 2023). The Overall Accuracy offers the percentage of pixels that are correctly classified, whereas the User's Accuracy and the Producer's Accuracy offer the omission and commission errors, which measure the in-class accuracies, respectively. The Kappa Coefficient accounts for the probability of chance agreement and it therefore offers a more reliable accuracy measure. Achievement in the classification was estimated by following the threshold stated by Dettori and Norvell (2020), where kappa values of > 0.80 indicate good agreement.

The study area shapefile boundary was acquired from the ArcGIS Online Municipal Demarcation Board (2025). It was then extracted and clipped to ArcGIS Pro 3.0. The shapefile was used to delineate the spatial extent of the classified images for change detection. Furthermore, the fully-classified images were imported to ArcGIS Pro and clipped to the uMsunduzi River floodplains by using the "Buffering spatial analysis tool" in ArcGIS Pro to calculate the spatial extent of the wetland vegetation in both villages. The buffer zone was set to be 100 square meters away from the conclusion of following the NEMA regulations, which state that it is not permitted to build structures or infrastructure with a footprint of 100 m square meters or more within a watercourse, or within 32 meters from its edge, without environmental authorisation (NEMA, 2020). The area occupied by wetland vegetation over the two years was compared to derive the magnitude of change. The wetlands map of South Africa, which was updated and supplied by SANBI in 2023, was utilised for identifying the wetlands in this study.

9.3 Geospatial Data Results

9.3.1 Spatial distribution of land use land cover types in uMsunduzi Catchment in 2000 and in 2024

The 2000 and 2024 classified Landsat images in Figure 9.1 illustrate the spatial distribution of the major Land Use and Land Cover (LULC) classes over the Msunduzi Municipality. The agricultural areas, built-up areas and natural vegetation have expanded significantly from the year 2000 to 2024, while wetlands, forests, bare land and homesteads have declined in their areal extent. As shown by the classification maps, wetlands have decreased by approximately 15.5%, at a rate of 1.52 per cent per year (Figure 9.1), which indicates substantial wetland losses due to land use change.

The increase in agricultural land from 258.53 km² in 2000 to 672.82 km² in 2024 represents a 160% expansion, largely at the expense of the wetland and forest areas. Built-up areas, on the other hand, increased by 27.93 km², which reflects urban expansion and population growth in the peri-urban catchment (Saha and Gayen 2025). However, forest cover decreased from 456.92 km² to 224.01 km². This suggests the continued deforestation and conversion to cropland and settlement areas. The spatial map of 2000 shows wetlands as the dominant land cover type along the floodplain and in the region, while the 2024 map indicates the fragmentation and reduction of wetland zones, especially near settlement and agricultural borders. This pattern aligns with human-driven land cover changes that have been observed elsewhere in South African catchments.

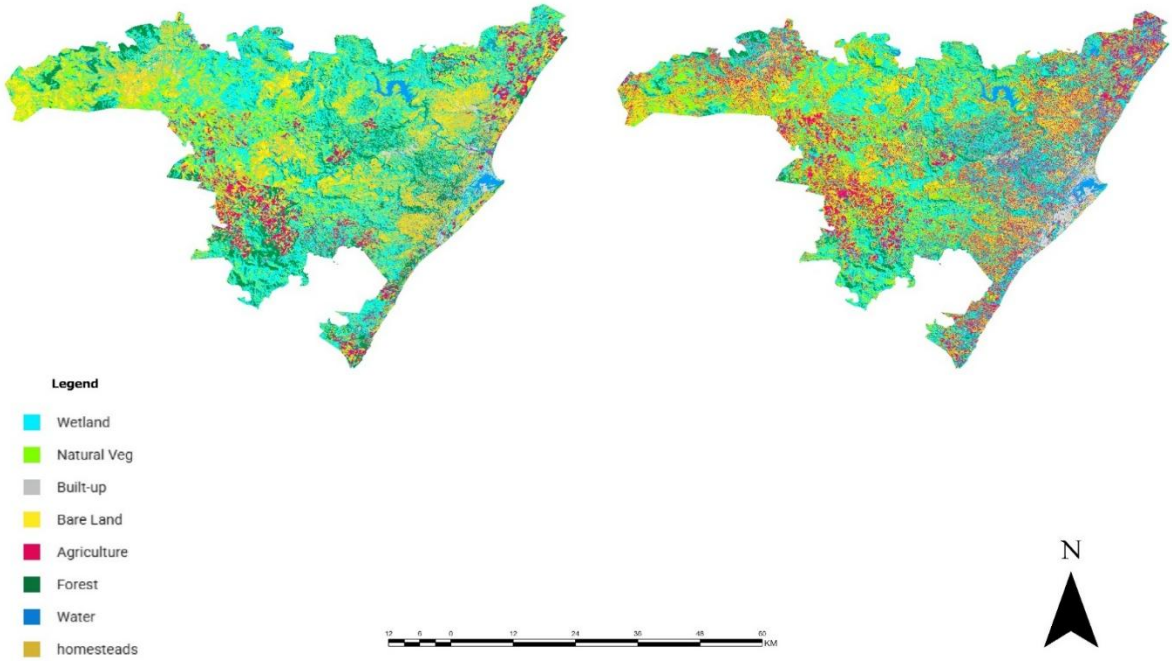


Figure 9-1: Maps of Landsat 5 TM (2000) and Landsat 9 OLI (2024) classification

9.3.2 Classification accuracy assessment

An accuracy assessment was conducted in the Google Earth Engine for both years, by using independent validation points. The User Accuracy (UA), Producer Accuracy (PA), Overall Accuracy (OA) and Kappa Coefficient for the years 2000 and 2024 are illustrated in Figure 9-2. The OA for the year 2000 was 64%, with a Kappa coefficient of 0.59, while the 2024 classification achieved an OA of 85% and a Kappa of 0.82%. These values are an indication of the agreement between the classified and reference data; the 2024 classification indicates a strong agreement, which confirms the reliability of the classification, while the 2000 classification has a weak agreement, due to the confusion that occurred between bare land, agricultural areas and homesteads, while a minor overlap was observed between built-up areas and homesteads in 2024. The improved accuracy in 2024 can be attributed to the enhanced spectral resolution in Landsat 9 OLI imagery and the inclusion of additional indices, such as NDVI, NDWI, LSWI and MNDWI, which improved the class separability. The wetland map, also provided by SANBI, was used in this classification, and it was updated in 2023, which improved the classifications.

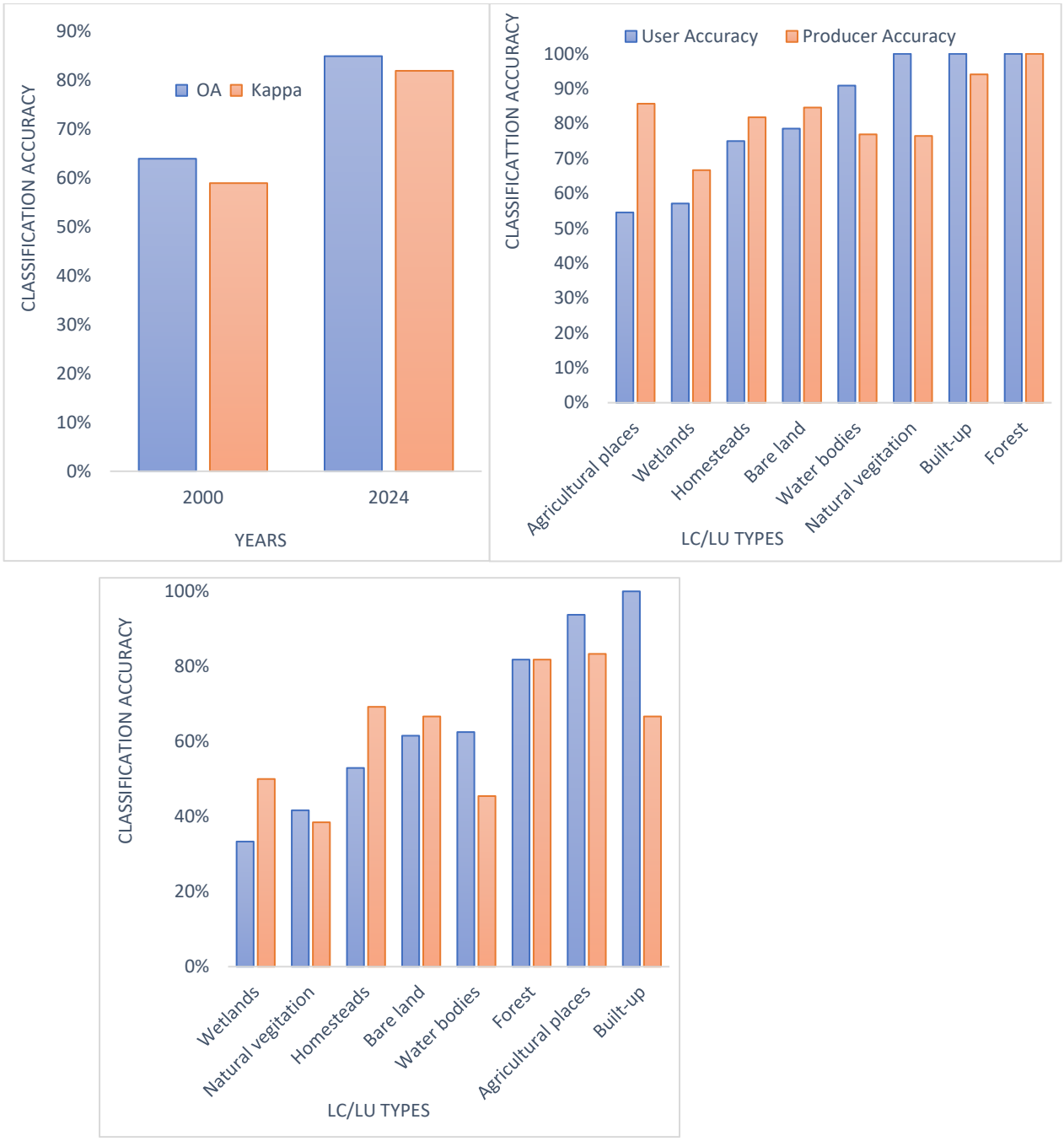


Figure 9-2: (a) presents the overall accuracy (OA) and Kappa for the year 2000 and 2024, respectively, UA & PA for the year (b) 2000 and (c) 2024

9.3.3 UMsundizi floodplain land cover changes

The change detection analysis (Figure 9.3) showed substantial land transformation across the uMsunduzi floodplain between 2000 and 2024. The most evident transitions included the conversion of wetlands and forested areas into agricultural and built-up areas, particularly in the upper reaches of Manyavu (West of the map) and Ximba (East of the map) in 2024. The overall classified region shows that the natural vegetation increased, by expanding from 594.25 km² to 898.35 km², as shown in Figure

9.4(a). This expansion is attributed to vegetation regrowth in previously-degraded or fallow areas. Homesteads, however, decreased from 732.73 km² to 418.55 km², possibly due to rural-urban migration and the consolidation of housing within built-up settlements. These spatial dynamics demonstrate the ongoing trade-off between ecological preservation and socio-economic development within the floodplain, with the wetlands emerging as the most affected ecosystem type.

Figure 9.4(b) shows the changes in the spatial extent of the wetland vegetation. It can be observed that the floodplains in Ximba in 2000 had 2.72 km² of wetland vegetation, which decreased to 1.80 km² by 2024. The floodplains in Manyavu were covered by 5.63 km² of wetland vegetation that also decreased to 3.73 km² in 2024. This decrease in wetland vegetation spatial extent suggests a degradation of the floodplain wetlands of the UMsunduzi River.

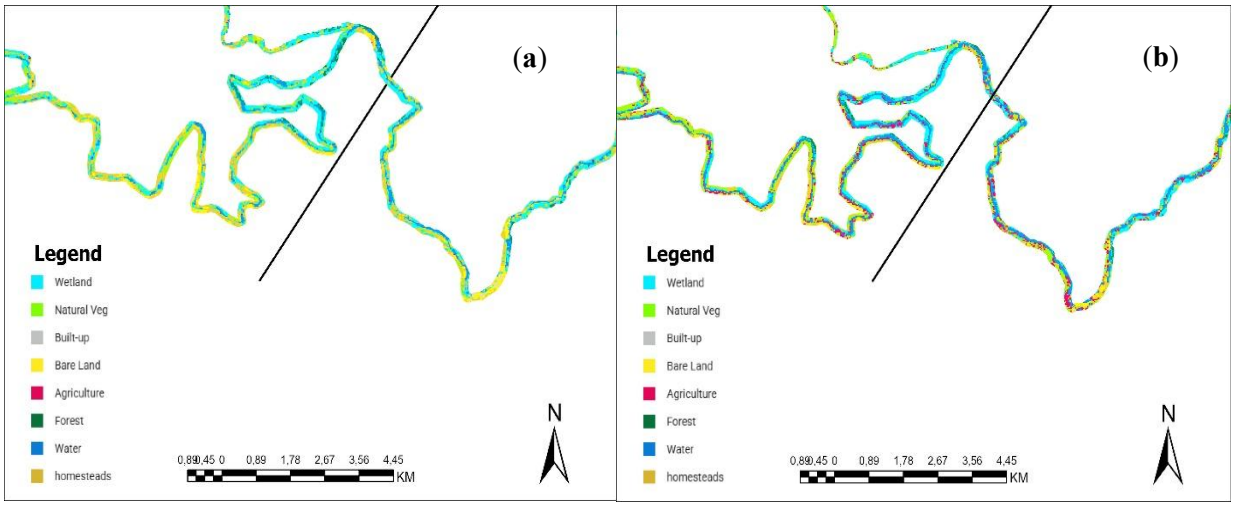


Figure 9-3: uMsunduzi River floodplain in (a) 2000 and (b) 2024

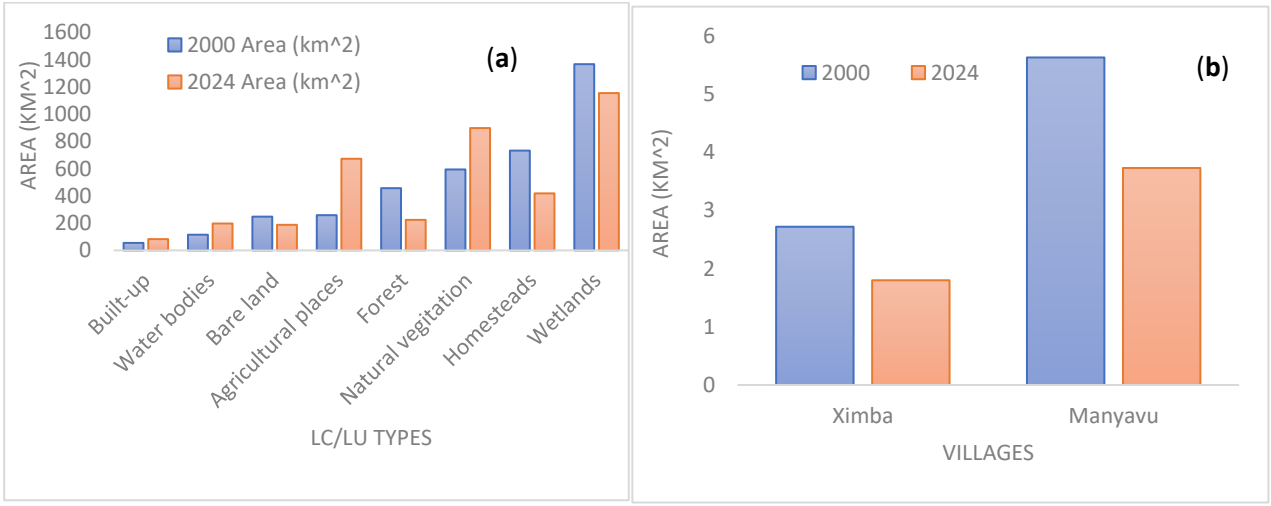


Figure 9-4: (a) Spatial extent of classified LC/LU types of 2000 &2024 and (b) spatial extent of wetland vegetation in the villages

9.4 Socio-economic Data Results

9.4.1 Wetland utilisation patterns

The field results indicated that wetlands are heavily utilised in both villages. In Manyavu, 28 households (93%) and in Ximba, 29 households (97%) reported the active use of wetland areas for activities, such as crop farming, livestock farming, water collection and fishing, which correlated with the change detection results (Figure 9.5). This high percentage of dependence underscores the economic and subsistence value of wetlands in supporting rural livelihoods. However, it also highlights the potential pressure exerted on these ecosystems through their over-utilisation.

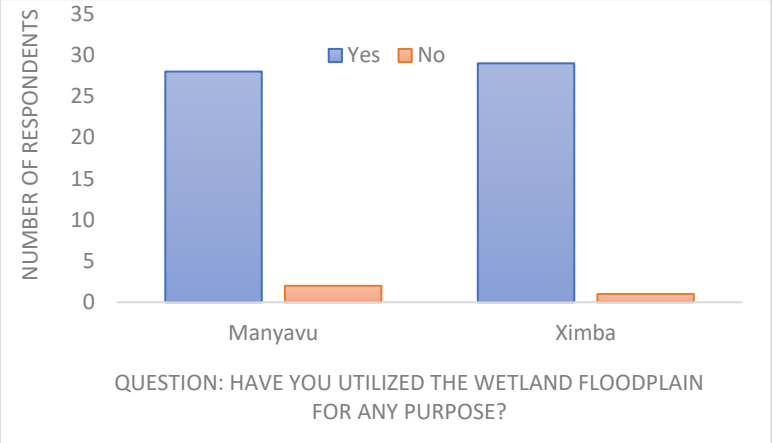


Figure 9-5: Manyavu and Ximba floodplain utilisation frequency

9.4.2 Awareness of wetland degradation

Most of the respondents indicated the realisation of floodplain wetland degradation in their local environments. In Manyavu, 28 out of 30 respondents indicated that there was ongoing noticeable degradation (Figure 9.6). In Ximba, 25 out of the total respondents indicated a similar level of awareness. The remaining few respondents indicated their lack of knowledge or their perceived minimal environmental change. These results suggest a generally high level of awareness of the floodplain wetland degradation among the local communities, which was most likely influenced by their dependence on the wetland resources for their daily livelihoods.

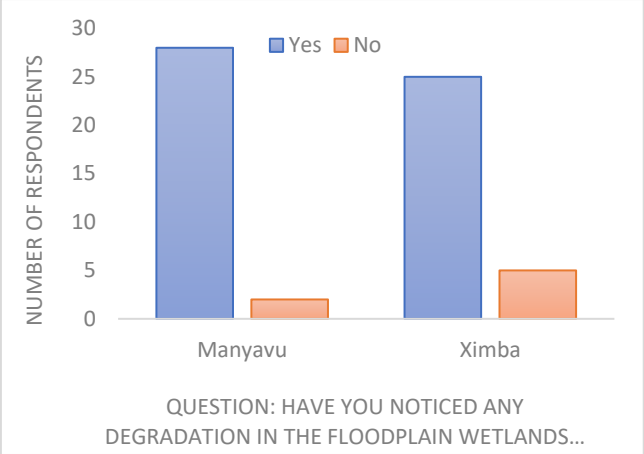
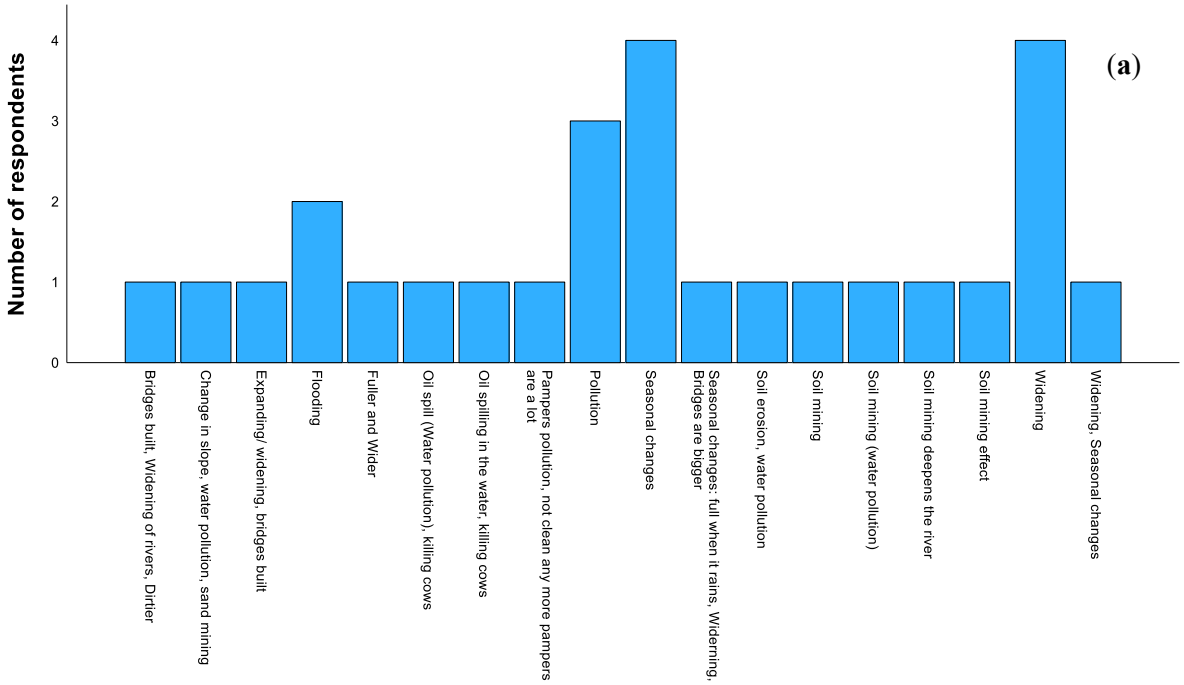


Figure 9-6: Manyavu and Ximba's awareness of wetland degradation

9.4.3 Perceived causes of wetland degradation

Respondents in both villages identified multiple drivers that contributed to the wetland degradation. The most frequently reported causes included the expansion of agricultural practices, seasonal changes and pollution. Manyavu villagers emphasised that the farming activities (n =7) and seasonal changes (n =6), followed by soil mining (n =5), were the dominant stressors (Figure 9.7). In Ximba, respondents pointed to the seasonal changes (n =10) and pollution (n =9) along the river channels as being a major threat. These findings align with the spatial results, which show a notable decrease in wetland and forest cover in the areas that are adjacent to agricultural and built-up zones.



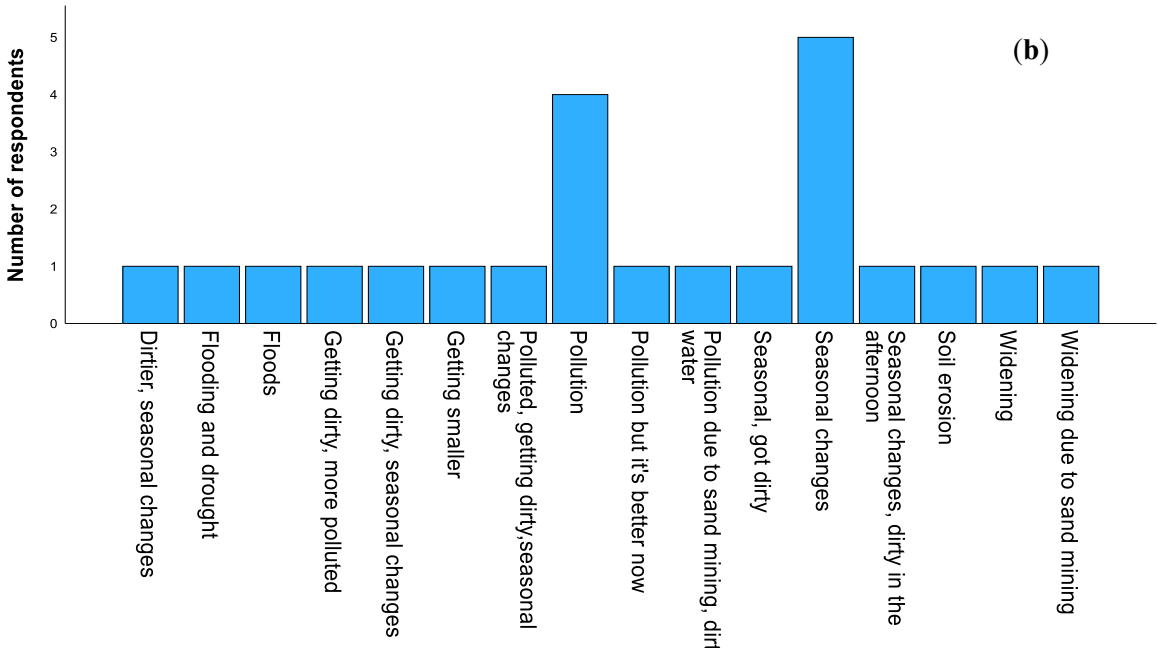


Figure 9-7: Manyavu (a) and Ximba (b) perceived causes of wetland degradation

9.4.4 Knowledge of wetland regulations

Although a general knowledge of the value of wetlands and degradation was present among villagers, their knowledge of the formal policies and regulations of management was low. Nearly the entire sample did not know about the current environmental policy or the by-laws regarding wetland use in either village (Figure 9-8). The local involvement in conservation and the pressures that lead to the further degradation of the uMsunduzi floodplain may be restricted by a lack of such knowledge. Improving human-focused awareness programmes and incorporating local knowledge systems into wetland management can boost the advantages of sustainable management.

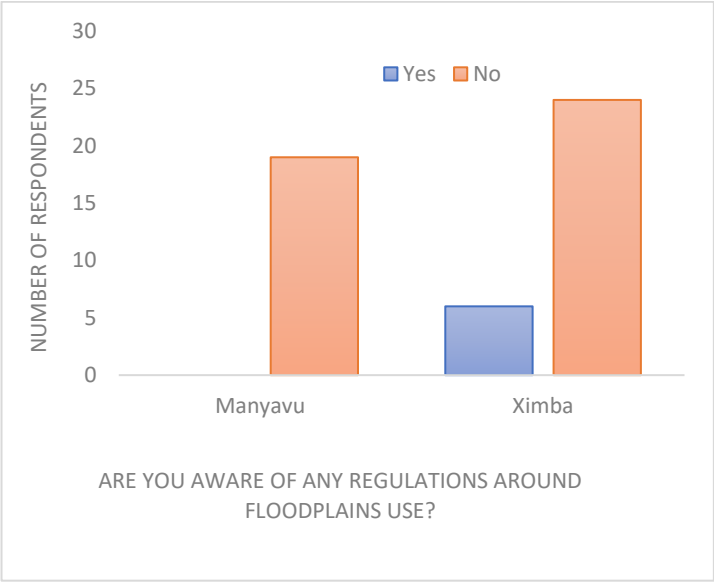


Figure 9-8: Manyavu and Ximba's knowledge of wetland regulations

9.5 Discussion

The objective of this study was to detect, characterise and compare the spatial extent of the wetlands in 2000 and 2024. It also aimed to assess the relationship between the variations in the spatial extent of the wetland and community's perceptions of the significance of wetlands along the floodplains of the UMsunduzi River.

9.5.1 Land use and land cover changes

The classification results of this study showed significant changes in the wetland vegetation within the 24 year period (2000-2024). Both villages highlighted a decline in spatial extent of the vegetation in the wetland, with it decreasing in Manyavu from 5.63 km ² in 2000 to 3.73 km ² in 2024, while it decreased in Ximba from 2.78 km ² in 2000 to 1.80 km ² in 2024. The degrading of wetland vegetation between these years represents a decrease of about 50.98% of the total floodplain wetlands within the area of the villages. This therefore supports Kundu, Kundu, Rana and Mahato (2024) argument that wetlands are degrading at an alarming rate in developing regions. The 2000 classification map showed a high and continuous wetland vegetation zone distributed along the uMsunduzi River floodplains. However, on the 2024 classification map, the same region was more fragmented. This significant change in the wetlands was corroborated by the community members who unanimously confirmed that there were significant ongoing changes in the floodplains across both villages.

Indices, such as the NDVI and LWSI, were among the most influential spectral classification features identified by Random Forest, which suggests that they provided substantial evidence of this transformation. Saha and Gayen (2025) mentioned that NDVI values approaching +1 represent dense and healthy vegetation. The 2000 Landsat 5 TM image had higher NDVI values across the floodplain, compared to the 2024 Landsat 9 OLI image. This could indicate that the floodplain had dense and healthy vegetation in 2000, and a typical healthy wetland ecosystem with high productivity (Imdad, Sahana, Ravetz, Areendran, Gautam, Dwivedi, Chaudhary and Sajjad 2023). The average values of NDVI had dropped by 2024, which indicated vegetation loss and stress. The LWSI is a spectral feature that is used for assessing wetlands and it is sensitive to vegetation and soil moisture. Wang, Zhou, Wu, Wang, Zhang, Xiong and Xu (2023) also demonstrated a decline in number of wetland zones detected, based on the LWSI, which confirmed its sensitivity in detecting the vegetation health of the floodplain. Therefore, this trend is in agreement with Shi et al. (2024) observations that over 50% of the wetlands have been lost globally since the 20th century.

The increase in agricultural areas (from 258.53 km² to 672.82 km²), in contrast to the wetland vegetation, indicated increased farming practices that were driven by subsistence and small-scale commercial farming. The household surveys from both Manyavu and Ximba highlighted that the

communities relied heavily on wetlands for their crop farming, livestock farming, water supply and fishing. Thus, land cover change is not only a spatial phenomenon, but it is also a reflection of the socio-economic dependency and livelihood pressures (Aslam et al. 2024, Dar et al. 2024). Likewise, the expansion of built-up area is contingent upon the expanding peri-urban development in and around Pietermaritzburg, in that marginal wetland and vegetated land are being converted into residential and infrastructural land. These conversions represents a common rural-urban land conversion gradient, with ecosystems becoming more transformed to serve human needs.

9.5.2 Ecological implications of wetland transformation

The decrease in the forest and wetland LULC has drastic ecological consequences. Wetlands in the uMsunduzi River floodplain provide essential ecosystem functions in the forms of flood regulation, groundwater recharge, biodiversity maintenance and water purification (Zhao, Feng, Xie, Zhu and Zhang 2023). The destruction of these wetlands reduces the hydrological and ecological function-regulating capacity of the landscape (Song, Wang, Li, Tedesco, Li, Jin and Du 2012, Sterzel et al. 2020), which will, in turn, directly affect the community and their environment. In some instances, this explains the devastating destruction of homesteads during the flooding periods in KZN.

Furthermore, the reduced values of NDVI, LSWI and NDWI in 2024 suggest a decrease in the standing water and soil moisture, which can negatively affect the natural flood buffer capacity and lead to more surface runoff and erosion that could possibly lead to floods and water sources pollution during the rainy season. The degradation of the uMsunduzi floodplains affects the community members, but it expands to the species that are located within the wetlands and dams downstream. As Lu and Chang (2023) argued, wetland fragmentation can also displace the habitat of species, it can shift the vegetation cover and heighten the vulnerability to invasive species.

The observed deforestation reflected by the forest cover reduction from 456.92 km² to 224.01 km² is of particular concern, considering that riparian forests play an important role in preserving undisturbed wetland systems (Zhu et al. 2023). Their clearance for agricultural development or settlements also increases sedimentation and nutrient loading into the river system, which leads to the deteriorating quality of water.

9.5.3 Linking community knowledge to spatial change

The socio-economic implications provide a necessary background to the understanding of spatial change. In the villages, 93% of the Manyavu respondents and 83% of Ximba respondents showed an awareness of wetland degradation, as would be expected with their direct dependence on the ecosystems for their livelihood. However, being aware does not always make way for sustainable practices.

The villagers identified the expansion of agricultural land, pollution, sand mining and seasonal changes

as being the main causes of wetland loss. These observations best correlate with the classified spatial trends, as the classified maps showed a decrease in the spatial extent of the wetland vegetation. Despite these observations and their awareness, their knowledge of the wetland management regulations was low. Being uninformed on management policies mirrors the findings of Gubamwoyo et al. (2025), who argued that weak community engagement and poor policy dissemination hinder effective wetland management in South Africa. Therefore, the continuance of unsustainable land-use systems constitutes a practice-awareness gap, which is triggered by economic reliance, and it diminishes access to alternative livelihood opportunities.

The consistency between the local observations and the remotely-sensed outcomes further upholds the imperative of integrating local knowledge with geospatial data. Not only does this confirm the spatial changes that were observed, but it also emphasises the social drivers of these changes, such as the demographic pressure, livelihood demands and the weak enforcement of environmental policies.

9.5.4 Integration of geospatial and socio-economic data

Integrating socio-economic and geospatial data was significant for assessing the complexity of the wetland spatial changes in the uMsunduzi floodplain. Employing Landsat 5 and Landsat 9 data, together with indices like NDVI, NDWI, MNDWI and LSWI, improved the classification accuracy and enabled an in-depth evaluation of surface moisture, vegetation and the spatiotemporal distribution of water bodies. The use of a Random Forest classifier demonstrated a strong reliability, with an overall accuracy of over 85% and a Kappa value of over 0.80 for the recent Landsat image, which confirmed the consistency of the classification. This proof thus supports previous research in explaining the effectiveness of Random Forest in varying landscapes (Yan, Zhu, Zhao and Su 2023)

Adding the household questionnaire data added an in-depth understanding to the spatial analysis by adding the social context. Questionnaire and interview data are essential for identifying the underlying anthropogenic and socio-economic factors that drive LULC change (Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020)(Matsa, Mupepi, Musasa and Defe 2020). The ability to directly connect local observations with the remote sensing results illustrates the value of a mixed-methods approach, or rather, an integrative method, where human-environment relations are studied in terms of their larger context and not solely in biophysical terms.

9.6 Implications of the Study

The number of published integrative studies on assessing and mapping environmental changes is relatively low in developing regions, particularly inAfrica. This integrative study provides a deeper understanding of wetlands' spatial changes through human perceptions, as well as a geospatial assessment. The results highlight that the uMsunduzi River floodplain wetlands are undergoing an intensive vegetation loss and spatial reduction. The results are supported by both a remote sensing analysis and community perceptions. Therefore, it can guide policymakers and conservation practitioners in the development of sustainable wetland management interventions that balance ecological protection with livelihood needs.

9.7 Conclusion

The objective of this study was to assess the relationship between variations in the spatial extent of wetlands and the community perceptions of the significance of wetlands along the floodplains of the Umsunduzi River within 24 years, by using the supervised classification of Landsat imagery in Google Earth Engine, based on Random Forest, and associating the detected wetland spatial extent changes with the community perspectives. Based on the findings of this study, it can be concluded that:

- the extent and health of the uMsunduzi River floodplain wetland vegetation area have significantly declined between the years 2000 and 2024. This is shown by the decrease in the spatial extent the wetlands in the classified map of 2024, based on NDVI, NDWI, MNDWI and LSWI, which reflected lower values than those in 2000, which were detected by using the Random Forest classification;
- agricultural expansion and settlement expansion were the overall causes of the loss of wetland vegetation, as had been expected in community reports that cited pollution, crop and livestock farming as some of the major causes of the degradation;
- the community perceptions corroborated the changes that were detected by using remotely sensed data, with community members in Ximba and Manyavu recognising the decline in vegetation and wetland degradation, although they were not aware of any associated regulations. This indicates a gap in information between their environmental awareness and sustainable action.

The study findings imply that integrating remote sensing techniques with community-based assessments provides a more holistic understanding of wetland vegetation change and its social drivers. This integrated approach can inform data-driven and participatory management strategies that are aimed at restoring wetland vegetation and ensuring the sustainable use of the floodplain. In the long term, applying continuous geospatial monitoring through platforms such as Google Earth Engine, and strengthening the local environmental awareness, could improve the resilience of the wetlands.

10 GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

10.1 General Discussion

Wetlands are one of the most valuable and productive, yet fragile, global ecosystems that occupy about 65% of the terrestrial surface (Jia, Mao, Wang, Ren, Zhu, Li and Zhang 2020). Floodplain wetlands are wetland areas on mostly flat, or gently-sloping, land that is adjacent to, and formed by, an alluvial river channel, under its present climate and sediment load, which is subject to periodic inundation by the overtopping of the channel bank. Floodplain wetlands have been used for agriculture in many regions of the world, due to their high moisture content and fertility, which are maintained by the natural nutrient deposition caused by floods (Dlamini, Adam, Chirima and Hamandawana 2021). Due to the wide range of resource extraction activities that are attracted to this natural endowment, wetland ecosystems are vulnerable to degradation (Barbier and Thompson 1998). Due to their appropriateness for agriculture and the myriad ecosystem goods and services that they offer, the majority of wetlands in Africa face serious risks (Barbier 2000, Davidson 2014). These scenarios are also present in other African nations, with Nigeria, Rwanda and Ethiopia, for instance, encouraging farmers to create wetlands as a buffer against the food shortages brought on by droughts (Barbier 2000). Although numerous studies in these countries have noted the value of wetlands in supporting the production of rice, maize and different vegetable crops for both subsistence and commercial usage (Dlamini, Adam, Chirima and Hamandawana 2021), their sustainability is being jeopardised by the use of unsuitable human resource practices. This is perpetuated by a lack of effective routine monitoring methods and limited mechanisms to guide the formulation of environmentally-friendly interventions.

In South Africa, approximately 15% of the floodplain wetlands have been left intact after the encroachment of anthropogenic activities (Skowno, Poole, Raimondo, Sink, Van Deventer, Van Niekerk, Harris, Smith-Adao, Tolley and Zengeya 2019). The uMsunduzi and Umfolozi floodplain systems, which are located on the northern outskirts of South Africa's KwaZulu-Natal province, are increasingly showing signs of the same threats. The functional capacity of the floodplain system has been severely strained by exploitative and extractive uses, such as agriculture and development by the expansion of urban areas. The farmers and community members who use these lands have the most responsibility for most of the problems. The conservation regulations continue to be alienating people in the nearby communities who depend on these resources for their livelihoods. However, the extent of consciousness regarding the consequences of their actions, as well as the potential long-term advantages or long-term benefits, still need to be understood.

In the current scenario, it is imperative to strike a balance between wetland preservation and sustaining

the agricultural resource base in the region. Achieving this requires policymakers in agriculture and conservation to have access to reliable data regarding the farmers' environmental awareness and, if necessary, to take steps to enhance it. In addition, when implementing future initiatives for wetland conservation, it is essential to prioritise the involvement of farmers in the district. In this regard, agroecological practices and the implementation of conservation regulations have been widely adopted worldwide to ensure the sustainable utilisation of wetland resources. However, the key question remains: Are these practices and regulations effectively implemented, and do they enhance the capacity of the communities in developing countries to manage their natural resources sustainably? To address these long-standing questions, comprehensive literature reviews were needed, along with the integration of geospatial techniques with qualitative insights from questionnaires and interviews to profile the health, spatial extent, sustainable utilisation and conservation of floodplain wetlands. However, very few studies focused on integrating the geospatial techniques with the qualitative insights, in order to facilitate the effective profiling of the health, spatial extent, sustainable utilisation and conservation of floodplain wetlands in developing countries, including South Africa. With this in mind, this Water Research Commission (WRC)-funded project (2023/2023-01462) focuses on evaluating how geospatial, human and socio-economic approaches can be integrated to profile the agroecosystem nexus within the uMsunduzi River floodplains, in order to inform efforts to transform the community practices in the area. To achieve this overarching goal, the project was guided by the following specific objectives: (i) to conduct a systematic literature review on the successes and failures of agroecological practices in wetland areas across the Global South, (ii) to map the spatial extent of wetlands around the uMsunduzi confluence, and (iii) to assess the perceptions of key stakeholders, such as smallholder farmers and wetland park authorities, regarding the current and alternative livelihood practices in the uMsunduzi confluence area. The following specific objectives were drawn up, to address these objectives:

1) to systematically review the literature on the successes and failures of agroecologically sound practices in wetland areas in the Global South;
2) to systematically review the literature on community perceptions regarding the utilisation and management of wetlands;
3) to systematically review the literature on Governance Challenges and Policy Effectiveness in Wetland Management;
4) to delineate the spatial distribution and extent of wetlands (vegetation) along the uMsunduzi river floodplain and within the uMngeni catchment (DWS U20), KwaZulu-Natal, South Africa, using Landsat ETM+ and Landsat OLI satellite data and Random Forest;
5) to examine the community perspectives and policy effectiveness: floodplain wetland management and its socio-economic impacts in the Msunduzi River Basin;
6) to assess the perceptions of the key stakeholders on current and alternative forms of livelihoods around the uMsunduzi confluence;

7) to explore and analyse the community perceptions of the human activities that are contributing to the decline of the Umsunduzi floodplain wetlands, using interview insights; and
8) to integrate geospatial and socio-economic data in order to assess the relationship between the spatiotemporal changes in wetland spatial extent between 2000 and 2024 and the community perceptions along the uMsunduzi River floodplains.

In systematically reviewing literature on the successes and failures of agroecologically-sound practices in wetland areas in the Global South, it was concluded that the successful application of sound agricultural practices was mostly in pans and marshes, whereas the least successful application was mostly in flood plains and constructed wetlands. The management of tillage, fisheries, water and soil management practices was associated with negative outcomes. An inadequate understanding of wetland ecology among the farmers, insufficient training in wetland management, ineffective management policies, traditional beliefs, policy constraints, as well as adverse climate conditions like droughts, were among the most significant factors that contributed to the failures associated with these agroecological practices in the wetlands of developing countries.

In systematically reviewing the literature on community perceptions regarding the utilisation and management of wetlands. It was also oncluded that, while many communities show a positive perception toward conservation efforts, inherent neutral and negative attitudes highlight the need for focused initiatives that promote engagement and education. Meanwhile, in systematically reviewing the literature on wetland governance-related challenges and policy effectiveness, it was concluded that although strong laws to protect wetlands exist, their impact is weakened by limited resources, by fragmented governance across multiple sectors, as well as poor coordination. This often results in policies that look effective on paper, but fail in practice. The evidence shows that a top-down approaches do not work, mainly because they overlook the realities of the local communities. However, where community-based by-laws are implemented, wetlands experience less degradation, and people are more willing to comply. This highlights the importance of a grounded, locally-informed approach to wetland management.

Geospatial applications are aimed at assessing the magnitude of land use and land cover changes within the wetlands. It was concluded that Landsat spectral variables, particularly the NIR and SWIR bands, together with indices such as NDVI and NDWI, greatly improve the accuracy of wetland and land-cover classification when used within a Random Forest model. The model's high overall accuracy (84%-91%) and strong Kappa values (0.78-0.84) demonstrate its reliability for mapping wetlands. Specifically, vegetation in the wetlands in the uMngeni catchment declined by 33.5% between 2000 and 2024, which was largely due to expanding agricultural and urban land uses. The urban areas grew by 22.52% and agricultural land grew by 6.42%, as they replaced wetland ecosystems and contributed

to habitat fragmentation. The floodplain buffer showed a similar pattern, with built-up areas expanding from 2 248.9 ha in 2000 to 2 412.3 ha in 2024.

In evaluating the perceptions of key stakeholders on current and alternative forms of livelihoods around the uMsunduzi confluence, it was concluded that community members relied on the wetland for a range of activities, including fishing, crop farming, grazing and domestic use. However, several human-related pressures, such as sand mining, water pollution, soil erosion, limited awareness, exclusion from decision-making and poor waste management, were making it difficult to use the wetland sustainably. Community members were aware that the wetlands have been drastically changing over the years; however, they perceived wetland use in the uMsunduzi catchment to be unsustainable, largely due to the limited community awareness and insufficient government action.

In assessing the perceptions of Traditional Authorities and community leaders on current and alternative forms of livelihoods around the uMsunduzi confluence, it was concluded that the uMsunduzi River, which was once regarded as a spiritual and ecological "*lifeblood*", is now regretfully regarded as a hazardous "*polluted liability*". It was also concluded that Traditional Authorities, who have historically upheld effective local governance, became “functionally useless” when confronted with large external polluters. This situation has arisen from institutional shortcomings and the lack of direct material support from the State, ultimately leaving communities, who see themselves as the “*true custodians*”, powerless.

In assessing the perceptions of community members regarding the efficacy of current policies and legislation that are aimed at conserving wetlands in the Msunduzi floodplain, it was concluded that they have a limited awareness of the wetland policies, coupled with a scepticism about their effectiveness. This underscores a profound disconnection between governance and practice. The findings highlighted how traditional authorities can either facilitate or hinder policy implementation, depending on their motivation and their relationship with the formal governance structures.

Finally, in integrating the geospatial and socio-economic data to assess the relationship between the spatiotemporal changes in wetland spatial extent and community perceptions along the uMsunduzi River floodplains between 2000 and 2024, it was concluded that there was a strong agreement between the geospatial and socio-economic data analysis in profiling the changes of floodplain wetlands along the uMsunduzi River. Combining remote-sensing data with socio-economic information provided a more complete and nuanced understanding of the changes taking place, which underscores the importance of integrating both types of data in spatial assessment studies.

10.2 Limitations of the Study

While this research provides significant insights, its findings are shaped by several methodological and contextual constraints.

Data Resolution and Remote Sensing Constraints: The analysis of land use and wetland change relied primarily on Landsat satellite imagery. The moderate resolution of this data (30-meter pixels) limited our ability to map small or complex wetland edges with high precision. This may have resulted in an underestimation of fine-scale degradation or fragmentation.

Socio-Economic Data Collection and Integration Challenges: Collecting detailed community data presented specific hurdles. To comply with South Africa's Protection of Personal Information Act (POPIA), we could not collect the precise GPS coordinates for individual households. This legal and ethical necessity created a significant methodological gap: while we have rich data on the community perceptions and precise data on wetland changes from satellites, we cannot spatially link them at a household, or precise plot, level. This limits our ability to perform a fine-scale, parcel-by-parcel analysis of how specific livelihoods or perceptions correlate directly with on-the-ground ecological changes.

Sampling Bias and Temporal Scope: The community survey sample carries a potential gender bias, as questionnaires that were distributed during weekdays resulted in a majority-female respondent pool, with many men being unavailable, due to work commitments. In addition, the study provides a critical, but static, snapshot. Without the longitudinal monitoring of wetland use, our understanding of how practices and dependencies shift over time, in response to ecological or economic changes, is limited.

Constraints in Multi-Stakeholder Collaboration: A key limitation was the lack of sufficient engagement and collaboration with major stakeholders, including projects like the UEIP and key government departments. While these entities were crucial for addressing catchment issues, they were often unable to fully commit to the project. Furthermore, their institutional roles appeared to overlap, particularly during catchment forum meetings. This, coupled with their diverse departmental mandates, created significant challenges in fostering the integrative, coordinated action needed to solve the complex catchment problems.

Limitations of Predictive Modelling: The land use change model (ANN-CA) was effective at projecting trends that were based on historical biophysical drivers, like the slope and proximity to roads. However, its realism was constrained. It did not incorporate key socio-political variables, such as land tenure, policy enforcement, or direct economic data, which heavily influence land decisions. This means the model may not accurately simulate future changes driven by new policies, market shifts or unplanned urban expansion.

Geographic and Contextual Specificity: The in-depth focus on the uMngeni and uMsunduzi catchments provided rich, locally-relevant findings. However, this specificity also means that the results are not directly generalisable to all wetland systems. The governance challenges, community perspectives and even wetland types that were studied are particular to this socio-ecological context in KwaZulu-Natal.

Partial Integration of Data Streams: A core conceptual aim was to bridge the geospatial and socio-economic data. In practice, this integration was partially achieved. For example, community perceptions

and satellite-derived change maps are discussed in relation to each other, but they were not fused into a single, interactive analytical model, due to the spatial privacy constraints mentioned above, as well as the complexity of dynamically linking the qualitative and quantitative datasets. This means some analyses of the drivers and impacts remain parallel narratives, rather than a fully unified causal explanation.

10.3 Conclusion

The main objective of this project was to assess the integration of geospatial data and the qualitative insights gathered through questionnaires and interviews, for providing baseline information that could be used to guide the magnitude and transformation of community farming practices and livelihoods that are dependent on the floodplain wetlands to facilitate their restoration. It can be concluded that combining remote-sensing data with socio-economic information provides a more complete and nuanced understanding of the changes that are taking place, which underscores the importance of integrating both types of data in spatial assessment studies. Both at the uMgeni Catchment and uMsunduzi River floodplain scale, wetlands were drastically decreasing. The uMsunduzi River, which was once celebrated as a spiritual and ecological "*lifeblood*," is now, regrettably, viewed as a hazardous "*polluted liability"*. Human-related pressures, such as sand mining, water pollution, soil erosion, limited awareness, the exclusion of community members and traditional leaders from the decision-making, as well as poor waste management, make it difficult to use the uMsunduzi River's floodplain wetlands sustainably. This is compounded by a profound disconnection between governance and practice. Well-framed regulations have been extensively enacted, but these are not adequately communicated to the traditional authorities, who enforce their implementation. Financial support at the grassroots levels limits their effective implementation by the traditional authorities at a grassroots level. It can be concluded that traditional authorities can either facilitate or hinder policy implementation, depending on their motivation and their relationship with the formal governance structures. This implies that wetland policies can only succeed if the traditional authorities are partners, and not obstacles. Their motivation, cooperation and relationship with the government directly shapes whether wetlands are protected or degraded. Above all, wetlands fall under multiple sectors (water, forestry, biodiversity and agriculture), which results in fragmented governance that leads to conflicting or overlapping responsibilities. Consequently, well-designed policies will be poorly enforced or insufficiently resourced, therefore weakening their effectiveness. These findings highlight the need for stronger conservation efforts, including better education on wetland ecology, greater community participation, as well as greater economic support, in order to reduce unsustainable practices. Reinforcing regulatory frameworks and ensuring their consistent enforcement will also be essential for protecting these wetlands in the future.

10.4 Recommendations

Several institutional and research gaps remain, with regard to the integration of geospatial data and qualitative insights gathered through questionnaires and interviews. These can be integrated to profile the nexus between human activities and wetland ecosystems as follows:

- Although this project demonstrated that the geospatial data and qualitative insights gathered through questionnaires and interviews can be integrated to profile the nexus between human activities and wetland ecosystems, it is important to recognise that this relationship is highly complex. Therefore, a follow-up project is needed to develop a 'complexity-type model' that is capable of integrating all the relevant variables. Such a model would enable the simulation of different scenarios, by providing a deeper understanding of how various activities collectively influence the broader agroecosystem.
- There is a need to strengthen integrated wetland monitoring, especially in peri-urban and rural areas, where there are many lateral and overlapping regulatory instruments. The use of combined geospatial and socio-economic data should be routinely utilised to track the wetland conditions, human pressures and livelihood dependence. This will generate regular updates on the spatial data and reports on the changes for all stakeholders.
- Community awareness and capacity can be enhanced through the introduction of education and awareness programmes that focus on wetland ecology, sustainable practices and pollution prevention. This could be coupled with the training of community members on climate-smart and wetland-friendly farming techniques. If these are associated with support for livelihood diversification, they may reduce the pressure on wetland resources.
- Traditional authorities can be empowered as key partners and essential co-managers of wetland resources, to ensure that they are fully informed of the regulations. This could be coupled with the provision of financial and logistical support to enable them to enforce the by-laws effectively. They also need to be included, and actively involved in, existing collaborative platforms with the municipal structures and environmental agencies.
- Governance coordination across sectors can be improved by developing an integrated wetland framework that aligns the water, forestry, biodiversity and agricultural mandates. There is also a need to create a single coordination body, or task team, to reduce duplication, to manage conflicts and to streamline the responsibilities. This task team could ensure effective communication between the government departments and local institutions.
- Policy enforcement and accountability can be strengthened by translating national regulations into clear local implementation guidelines that are accessible to communities and traditional authorities. This could also include increasing the funding for on-the-ground enforcement, monitoring, and community-based custodianship. In addition, participatory monitoring can be introduced, where communities help to report degradation, illegal sand mining, pollution or

encroachment into the floodplains.

- Human-induced pressures can be reduced by introducing entrepreneurial activities that are centred on waste recycling. There is also a need to invest in solid waste management, sewage infrastructure and erosion control in high-pressure zones. Furthermore, alternative resource-use practices that minimise disturbance to wetlands need to be identified and established.
- Future work should expand on these findings by incorporating higher-resolution datasets, socio-economic drivers and participatory governance approaches, in order to capture the complexity of wetland use and management. In addition, future studies that integrate geospatial data with qualitative insights to profile the health, spatial extent, sustainable use and conservation of floodplain wetlands should consider using a gradient approach for measuring the coordinates of specific homesteads and linking household-level qualitative information to their location, relative to the river.

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APPENDICES

APPENDIX 1: CAPACITY DEVELOPMENT REPORT

Introduction

Provision was made in the project's contractual budget to fund three full-time master's students over the project's four-year period. To date, three students have been recruited, and one post-doctoral fellow has been engaged. The project team is also going to leverage other funding streams, such as the NRF SA Chair of Land Water Governance at Cape Peninsula University of Technology (CPUT) and the NRF SA Chair in Landuse Planning and Management within the College of Agriculture, Engineering and Science (AES) at the University of KwaZulu-Natal, to increase the number of students involved in the project. This document is a detailed capacity-building report from the initiation of this project up until today.

Postgraduate student recruitment

To date, the project engaged one postdoctoral fellow, who, part of their time, was dedicated to the project as follows:

- Dr Tinashe Kanosvamhira– Human Geographer – Agroecological, food systems and Policy analysis

The postdoc formed part of capacity development targeted at Early Career Researchers at the University of the Western Cape– the next generation of researchers. The post-doc's specific roles and responsibilities are to organise field trips, acquire data, co-supervising postgraduates and contribute to writing the deliverables as part of their capacity development.

A total of three postgraduate students were identified and engaged to take up some of the work packages and specific objectives of this project. These students are;

- Abusiswe Rigala (UWC MA 1) (completed Wetland LULC assessment)
- Palesa Jessica Mokgala (UWC MA 2) (completed Wetland Policies assessment)
- Nokwanda Nkabinde (UWC MA 3) completed Community perspectives assessment.
- Thabiso Mavundla (UWC Hons 1) (completed GIS and community perspective assessment)
- Mihla Ndlovu (UWC Hons 1) (completed community perspective assessment)

Specifically, the three students are registered at the Department of Geography, Environmental Studies and Tourism. University of the Western Cape under the supervision of the research team members. All three students were awarded the bursaries during the financial year 2023/2025. The capacity-building table above shows their details. Each student's progress report is detailed in Appendix 3.

APPENDIX 2: INFORMATION DISSEMINATION

Conference presentations

- Students' Presentations at the departmental Conference
- Nokwanda Nkabinde: *An Examination of Smallholder Community Perceptions on the Sustainable Utilisation of Flood-Plain Wetlands along the UMsunduzi Confluence in KwaZulu-Natal*, Western Cape Wetlands Forum (WCWF) Student Day, 12 September 2024, SANParks CRC Tokai, Cape Town, South Africa
- Nokwanda Nkabinde: *An Examination of Smallholder Community Perceptions on the Sustainable Utilisation of Flood-Plain Wetlands along the UMsunduzi Confluence in KwaZulu-Natal*, Institute of Water Studies Open Day, 21 May 2025 at the University of the Western Cape (Life Science Auditorium), Cape Town, South Africa

Workshops

- Mbulisi Sibanda: *Land use dynamics and ecosystem services preservation*, Lowlands landscape restoration for agricultural development and biodiversity and ecosystem services preservation in Africa Workshop, 19-Aug 24, Africa Rice, Mbe, Cote d'Ivoire
- Mbulisi Sibanda: *Ecosystem services and co-benefits for sustainable agricultural landscapes and resilient food systems*, Lowlands landscape restoration for agricultural development and biodiversity and ecosystem services preservation in Africa Workshop, 19-Aug 24, Africa Rice, Mbe, Cote d'Ivoire

Draft manuscripts

- Seven draft papers - two submitted, four in preparation for submission

Published Papers

- MOKGALA PJ, KANOSVAMHIRA TP, CHIMONYO VGP, DLAMINI M, MABHAUDHI T AND SIBANDA M 2026 Community perspectives and policy effectiveness: a study on floodplain wetland management and its socio-economic implications in the Msunduzi River Basin. *Wetlands Ecology and Management* 34 (1) 13. https://doi.org/10.1007/s11273-026-10114-2