HARMONISING CLIMATE RESILIENCE IN ISIMANGALISO: A GEOSPATIAL WORKFLOW FOR ADAPTATION, PLANNING AND COMMUNITY OUTCOME

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Key words: Climate resilience, geospatial workflow, adaptation planning, estuarine systems, community outcomes.

Summary

iSimangaliso Wetland Park is a coastal estuarine World Heritage landscape increasingly exposed to climate variability and cumulative human pressures that intersect across environmental, agricultural, settlement, and governance systems. This paper advances the concept of harmonising climate resilience as a multisectoral and multi-scalar process that requires coordinated collaboration across national, provincial, and local spheres of government, supported by shared geospatial evidence. The proposed geospatial workflow integrates hydrological risk, ecosystem condition, land use and land ownership dynamics, settlement exposure, and livelihood dependencies across landscape, catchment, and settlement scales. Through structured spatial analysis, the workflow translates climate risk and opportunity into targeted management actions, spatial planning controls, and community based livelihood interventions, informing an evidence-based intervention plan. By embedding specialist studies, spatial planning instruments, and participatory inputs within a single geospatial framework, the approach strengthens institutional coordination, accountability, and transparency, while actively involving affected stakeholders and communities in adaptation planning. Early implementation lessons further indicate that well-structured geospatial storytelling accelerates decision cycles and strengthens the rationale for investment in nature-based solutions. The study demonstrates how geospatial information can bridge sectoral silos and enable coherent, collaborative responses to climate risk, offering a transferable model for climate-resilient planning in protected and socio-ecologically complex landscapes.

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1. INTRODUCTION

1.1 Background

This paper examines the role of geospatially integrated planning in advancing climate resilience within the iSimangaliso Wetland Park, a UNESCO World Heritage Site characterised by high ecological value and complex socio-spatial dynamics. The study responds to persistent climate driven hydrological disruptions within the Lake St Lucia system and the Mfolozi floodplain, where prolonged back flooding, sedimentation, and altered flow regimes have increasingly compromised agricultural production, settlement stability, and ecosystem functioning (Mather, Stretch and Maro, 2013; iSimangaliso Wetland Park Authority, 2025). Drawing on empirical evidence generated through land use and land ownership analysis, household level spatial surveys, and geospatial mapping, the paper develops and applies a geospatial workflow that links environmental processes with spatial planning and community outcomes, positioning geospatial integration as a governance instrument for managing climate risk in a coupled socio-ecological system (Folke et al., 2016; UNDRR, 2019; iSimangaliso Wetland Park Authority, 2025).

The significance of this research lies in its engagement with the structural disconnect between climate impacts and spatial decision making in environmentally sensitive and institutionally fragmented landscapes. In iSimangaliso, flooding and sedimentation represent spatially differentiated risks that intersect with land tenure patterns, agricultural practices, settlement expansion, and conservation mandates, rather than isolated environmental phenomena (iSimangaliso Wetland Park Authority, 2025). The study demonstrates that extensive areas of both commercial and subsistence agricultural land, including state leased farms, have remained waterlogged for prolonged periods, while adjacent settlements continue to experience recurrent water ingress, undermining recovery and long term livelihood viability (iSimangaliso Wetland Park Authority, 2025). These conditions expose the limitations of sector based responses and underscore the need for an integrated spatial approach capable of synthesising specialist knowledge, planning instruments, and lived experience. By translating climate risk analysis into spatial proposals and planned interventions through a harmonised geospatial workflow, the study contributes to applied scholarship on climate adaptive spatial planning aligned with the FIG 2026 theme : The Future We Want: Beyond the SDGs.

1.2 Problem Statement

Despite its global ecological significance and protected status, the iSimangaliso Wetland Park is increasingly vulnerable to climate driven hydrological disruptions that have altered sediment and flow regimes within the Lake St Lucia system, resulting in persistent back flooding, land degradation, and growing socio economic impacts. Prolonged waterlogging of agricultural land, recurrent water ingress in settlements, and declining ecosystem services have undermined livelihoods, food security, and the conservation economy, particularly within the Mfolozi floodplain. These challenges are compounded by complex land use and land ownership patterns, historical spatial inequities, and fragmented institutional responses, which limit the effectiveness of conventional sector based interventions (Healey, 2006; Davoudi et al., 2012). The absence of an integrated spatial framework that systematically links climate risk evidence, specialist studies, land use planning instruments, and community engagement has constrained adaptive decision making. This study therefore addresses the need for a coherent geospatial workflow capable of harmonising climate resilience, adaptation planning, and community outcomes within the iSimangaliso system.

1.3 Study Area: iSimangaliso Wetland park

iSimangaliso Wetland Park is located on the North-Eastern coast of South Africa in the province of KwaZulu-Natal, stretching along the Indian Ocean coastline. The park extends from the Mozambique border in the north to Maphelane in the south, encompassing Lake St Lucia, Africa's largest estuarine system. It lies predominantly within the uMkhanyakude District Municipality, with key access points near the towns of St Lucia, Mtubatuba, and Hluhluwe.

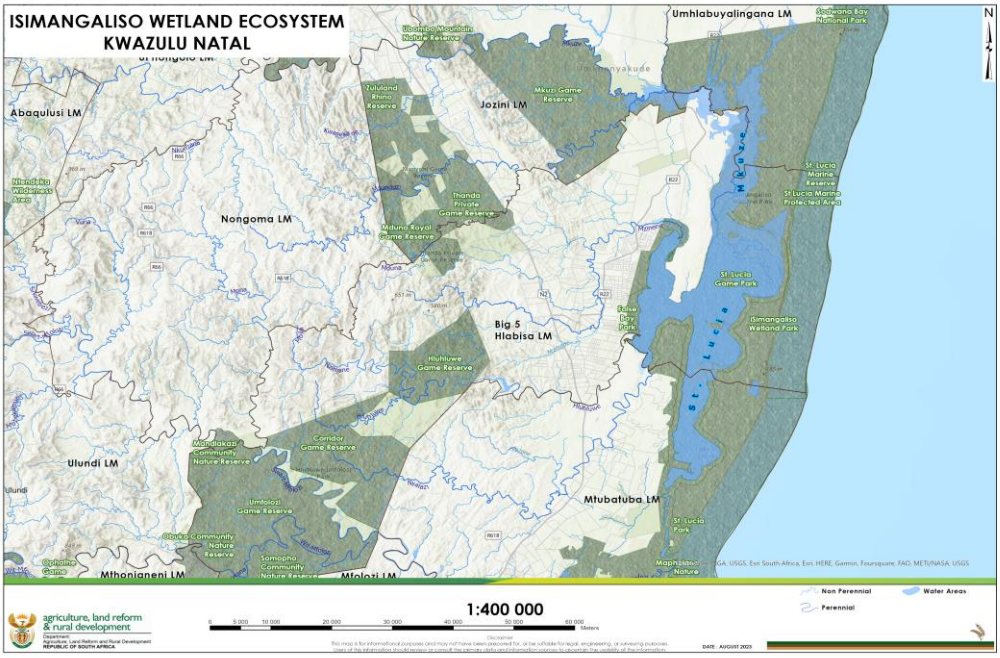


Figure 1.1 Locality Map

2. CONCEPTUAL FRAMEWORK

2.1 Climate variability, cumulative pressures, and estuarine system transformation

The iSimangaliso Wetland Park, inscribed as a UNESCO World Heritage Site in 1999, represents one of the most ecologically complex coastal estuarine systems in Africa, characterised by the interaction of marine, fluvial, wetland, and terrestrial processes (iSimangaliso Wetland Park Authority, 2016; UNESCO, 2022). The Lake St Lucia estuarine system, which constitutes the hydrological core of the park, has historically functioned as a dynamic, temporarily open closed estuary, responding to climatic cycles through shifts in salinity, water levels, and sediment transport (Mather et al., 2013). However, the Basic Assessment Report (BAR) and associated specialist studies indicate that climate variability, particularly the alternation between prolonged droughts and high intensity rainfall events, has intensified system instability in recent decades (iSimangaliso Wetland Park Authority, 2024).

iSimangaliso experienced a severe drought conditions between 2001 and 2014 were followed by episodic and intense rainfall events from 2015 onwards, resulting in persistent back flooding, water ingress into settlements, and widespread agricultural land loss within the Mfolozi floodplain (iSimangaliso Wetland Park Authority, 2024). These climatic drivers operate within a landscape already modified by canalisation of feeder rivers, artificial breaching, maintenance of an open mouth, and floodplain land transformation, which together have altered sediment and flow regimes across the estuarine system (Pringle et al., 2023; Pringle et al., 2024).

2.2 Ecological consequences and implications for nature based adaptation

Ecological literature on iSimangaliso consistently emphasises the sensitivity of estuarine functioning to hydrological connectivity and sediment dynamics. Specialist ecological assessments cited in the BAR demonstrate that prolonged inundation and altered salinity conditions have contributed to habitat transformation, loss of estuarine nursery function, reduced biodiversity, and declining ecosystem services (Paul, 2023; iSimangaliso Panel of Experts, 2022).

These findings align with broader literature on ecosystem based adaptation, which positions wetlands, floodplains, and estuarine systems as critical ecological infrastructure for climate resilience when functioning within natural thresholds (IUCN, 2020; IPCC, 2022). Restoring or maintaining ecological processes, including sediment routing, wetland connectivity, and estuarine exchange, is central to reducing flood risk and sustaining livelihoods, particularly where hard engineering interventions alone have proven insufficient or ecologically damaging (iSimangaliso Wetland Park Authority, 2024). However, the literature also cautions that ecological restoration in socially complex landscapes requires careful alignment with land use practices, tenure systems, and economic dependencies to avoid maladaptation or unintended social impacts (Mather et al., 2013). South African environmental and spatial planning legislation mandates the integration of environmental sustainability into development planning. DALRRD is required to align land use, agricultural development, and environmental management. However, institutional fragmentation and sectoral planning silos limit effective climate adaptation.

2.2 Land use, land ownership, and spatial exposure to climate risk

A critical dimension emerging from the iSimanagaliso is the role of spatial configuration in shaping vulnerability. The land use and land ownership report demonstrates that extensive agricultural activity, including commercial and subsistence farming, is concentrated within low lying floodplain areas that are highly exposed to back flooding and prolonged waterlogging (DALRRD, 2024). Government acquired farms under the Proactive Land Acquisition Strategy, as well as communal land in Mpukunyoni Traditional Authority areas, have experienced multi year loss of productivity, undermining lease commitments, food security, and household income (DALRRD, 2024). The study identifies inconsistencies between actual land use practices and municipal spatial planning instruments, noting that farming and settlement activities continue in areas that are environmentally sensitive or hydrologically constrained (iSimangaliso Wetland Park Authority, 2024). While municipal Spatial Development Frameworks and Integrated Development Plans recognise the Mtubatuba St Lucia corridor as a key economic axis, the literature indicates limited spatial integration between conservation planning, agricultural support programmes, and local land use regulation (DALRRD, 2024; iSimangaliso Panel of Experts, 2022). This misalignment reinforces exposure to climate risk and constrains the effectiveness of adaptation interventions.

2.3 Governance fragmentation and the need for multisectoral coordination

The Basic Assessment Report highlights institutional fragmentation as a key barrier to effective climate resilience in iSimangaliso. Responsibilities for water management, conservation, agriculture, spatial planning, and disaster response are distributed across multiple spheres of government, often operating with limited coordination and inconsistent spatial evidence (iSimangaliso Wetland Park Authority, 2024). The Panel of Experts Report further notes that contested decisions regarding mouth management and dredging have eroded trust and delayed action, partly due to the absence of a shared analytical framework that integrates ecological, social, and economic considerations (iSimangaliso Panel of Experts, 2022).

This challenge reflects wider governance debates in climate adaptation literature, which argue that resilience outcomes depend on the ability of institutions to align policies, planning instruments, and investment decisions around common representations of risk and opportunity (UNDRR, 2015; IPCC, 2022).

2.5 Synthesis and gap addressed by the study

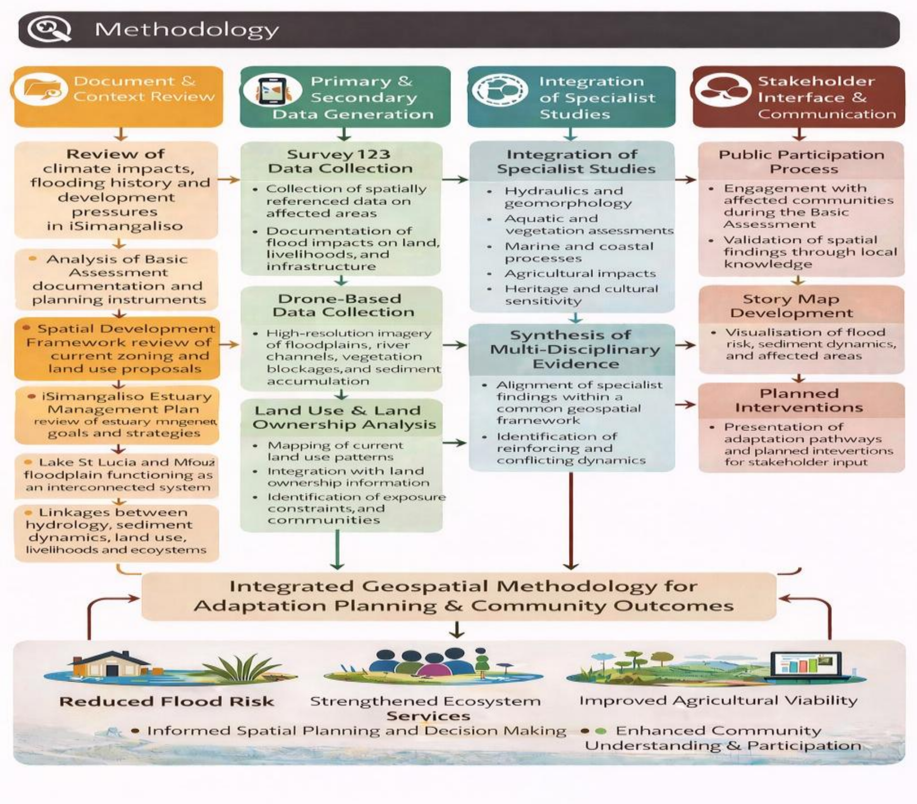
Collectively, the reviewed literature evidence converge on the need for an integrated, geospatially enabled approach to climate resilience in iSimangaliso. Climate variability and cumulative interventions have altered hydrological and ecological processes, while land use patterns, tenure arrangements, and governance fragmentation have amplified exposure and constrained adaptive responses (iSimangaliso Wetland Park Authority, 2024; DALRRD, 2024). Although extensive specialist knowledge exists, the literature identifies a persistent gap in the translation of this knowledge into coherent spatial planning and community centred adaptation outcomes.

This study addresses that gap by advancing a geospatial workflow that harmonises climate resilience as a multisectoral process, integrating specialist studies, land use and land ownership analysis, planning instruments, and stakeholder engagement within a single spatial framework. By doing so, it responds directly to the challenges identified in the BAR and contributes to broader scholarship on climate resilient spatial planning in protected and socio ecologically complex landscapes.

3. METHODOLOGY

The study employed a geospatially integrated methodology to operationalise harmonised climate resilience within the iSimangaliso system by linking environmental processes, spatial planning, and community outcomes as illustrated in Figure 3.1. Primary spatial data were collected using Survey123 to document flood impacts on agricultural land, infrastructure, and livelihoods, complemented by drone-based imagery capturing floodplain dynamics, channel blockages, vegetation, and sedimentation. These methods enabled fine-scale spatial representation of climate impacts that are often overlooked in conventional datasets, strengthening the empirical basis for adaptation planning. Land use analysis was integrated with land ownership data to assess exposure, constraints, and planning opportunities across flood-affected areas, allowing climate risks to be directly linked to specific land parcels and planning zones in support of Spatial Development Framework alignment (Figure 3.1). The methodology further incorporated public participation and specialist studies from the Basic Assessment process within a unified geospatial framework to integrate local knowledge and interdisciplinary evidence. A story map was developed to visualise risks, scenarios, and spatial responses, supporting transparent decision-making and reinforcing the alignment between climate resilience, spatial planning, and community outcomes.

Figure 3.1



Methodology for the Study

4. GEOSPATIAL WORKFLOW FOR ADAPTATION PLANNING AND COMMUNITY OUTCOMES

The geospatial workflow provides a structured pathway for translating climate risk intelligence into coordinated adaptation actions within the iSimangaliso Wetland Park. The workflow begins with system pressure and problem definition, where climate driven hydrological disruptions, altered sediment and flow regimes, and persistent back flooding in the Mfolozi and Msunduzi floodplains are spatially identified Figure 4.1. In practice, this stage was informed by GIS mapping and field verification that revealed extensive waterlogging of commercial sugarcane farms, PLAS farms, and subsistence agriculture, as well as recurrent water ingress into settlements. These pressures directly affect livelihoods, food security, and lease commitments, particularly for more than one thousand farm workers dependent on floodplain agriculture.

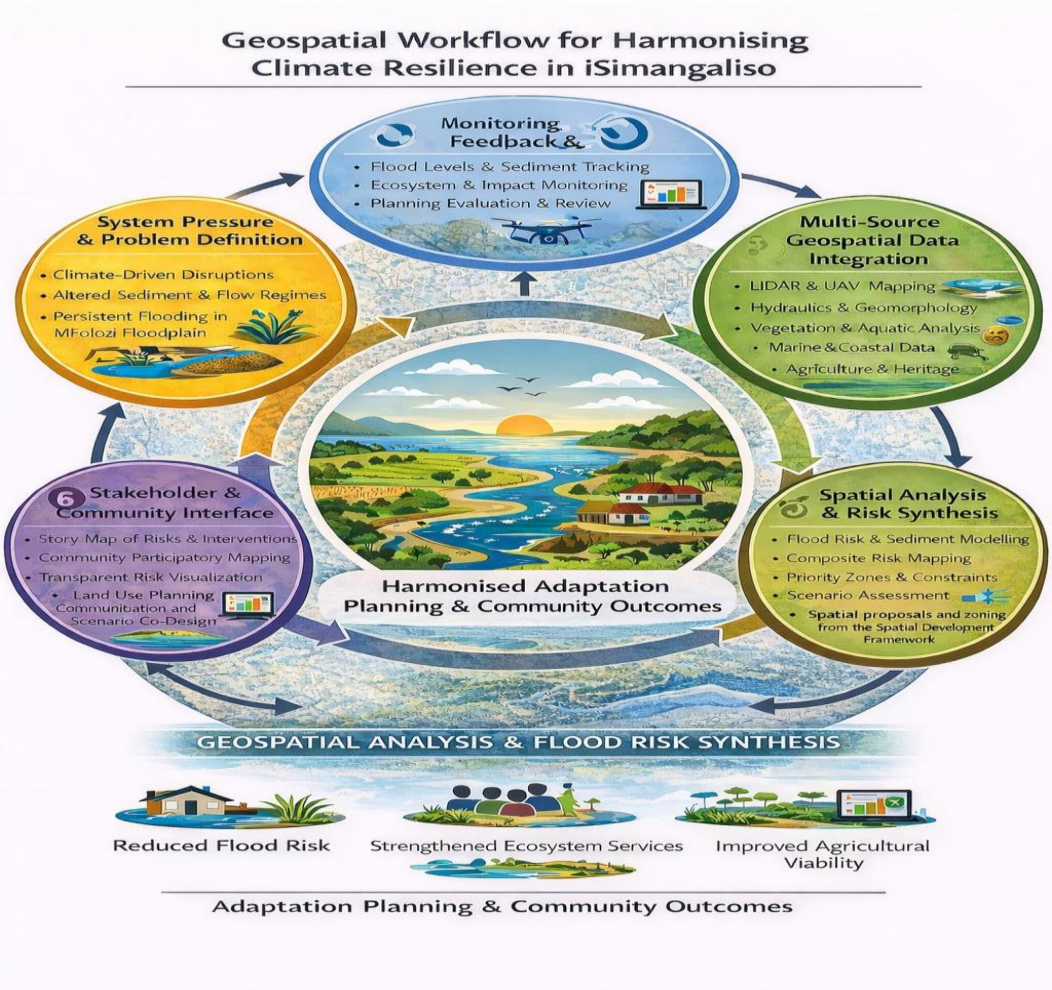
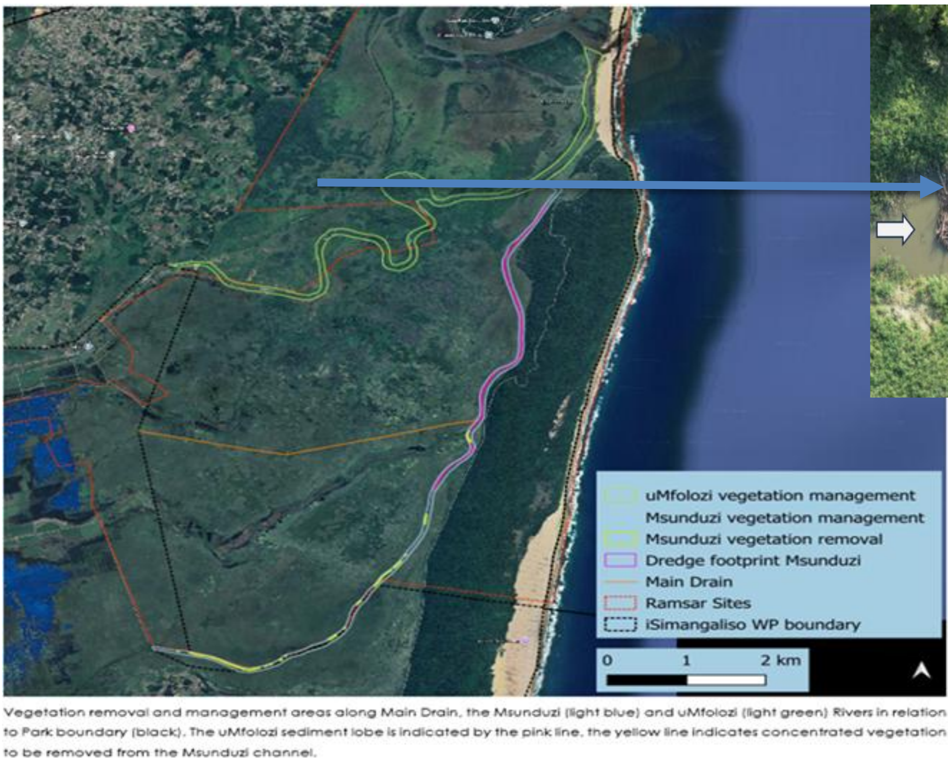


Figure 4.1:Geospatial Workflow for harmonising climate Resilience in iSimangaliso Wetland Park

The multi source geospatial data integration component operationalised this understanding by consolidating land use and land ownership data, household survey results collected through Survey123, UAV imagery, and specialist study outputs from the Basic Assessment process. This integration enabled the identification of reed and vegetation proliferation hotspots along the Msunduzi and lower uMfolozi River channels, where excessive growth had partially or fully obstructed natural streamflow. These spatial insights directly informed the BAR application, which proposed phased vegetation clearance and sediment removal to restore conveyance and reduce flood risk to adjacent farmland and settlements. The integration of land ownership and land use layers further clarified where state land, conservation areas, and subsistence farming overlap, highlighting planning and management complexities that require coordinated institutional responses.

Through spatial analysis and risk synthesis, the workflow translated integrated datasets into decision relevant outputs. Flood and sediment modelling, combined with composite risk mapping, supported the prioritisation of intervention areas and sequencing of actions.This analysis underpinned the phased approach adopted in the application, beginning with vegetation removal and maintenance, followed by targeted dredging of accumulated sediments in the Msunduzi River Channel, the lower uMfolozi River Channel, and the Beach Channel where required (Figure 4.2). Importantly, the workflow enabled risk and opportunity to be assessed across landscape, catchment, and settlement scales, linking immediate channel management needs to longer term spatial proposals and zoning considerations derived from the Spatial Development Framework.



Woody debris blockages along the lower uMfolozi (arrow indicates flow direction)

Figure 4.2 Proposed areas for Dredging and vegetation removal and pictures of flooded farms

The Spatial Analysis led to the following three main intervention to reduce flloding in the area: 1)Removal and control of vegetation from the Msunduzi River Channel and the lower uMfolozi River Channel (In an environmentally friendly manner). 2)Dredging of sediment from the Msunduzi River Channel, including Msunduzi sediment , the lower uMfolozi River Channel and Beach Channel (if required), Vegetation management/maintenance. 3) Clearing of new vegetation growth and woody debris along the Msunduzi and uMfolozi River Channels, Main Drain and Beach Channel. All of the three will need the Basic Assessment report for the Environmental Authorisation to be issued before they commenced (Figure 4.2).

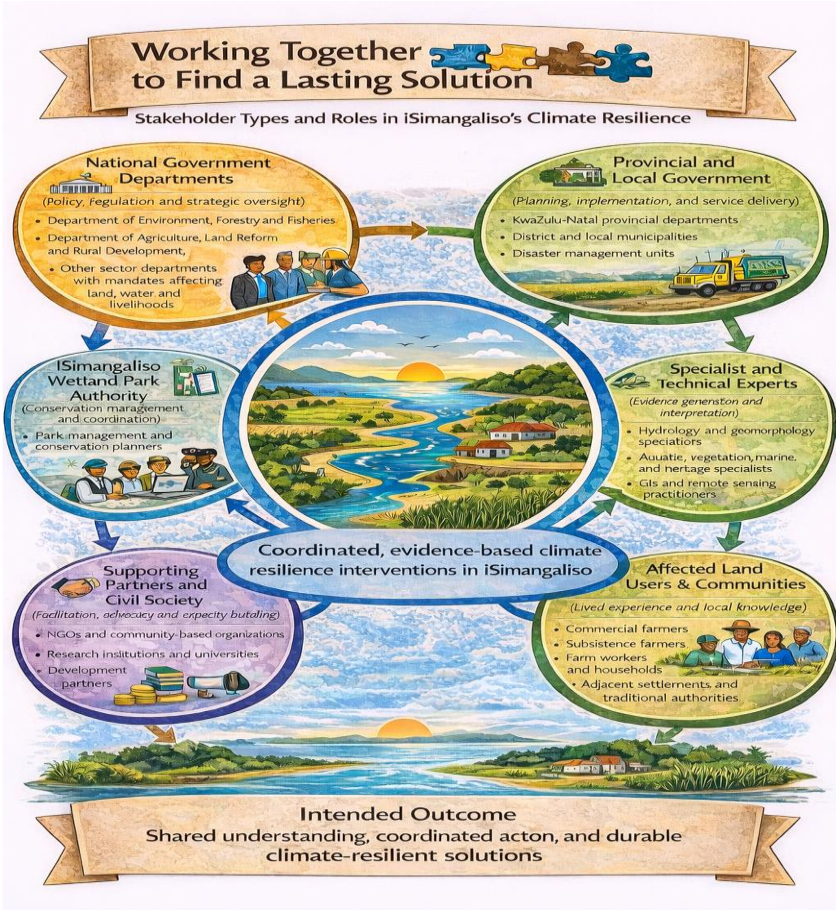


Figure 4.3 Affected Stakeholders in iSimangaliso Climate resilience

The stakeholder and community interface component ensured that technical analysis was grounded in lived experience and supported collaborative decision making. Community surveys revealed uneven access to support programmes, with farmers in severely waterlogged areas unable to meet application requirements due to limited access to their fields, in contrast to farmers in less constrained areas. These findings strengthened the rationale for revising assistance mechanisms and informed broader intervention planning, including land acquisition considerations, improved access roads, and drainage system upgrades. The use of geospatial storytelling and participatory mapping supported transparent communication of risks, interventions, and trade offs, while the monitoring and feedback element of the workflow enables ongoing tracking of flood levels, vegetation regrowth, and ecosystem response following implementation. Collectively, the workflow demonstrates how geospatial integration can harmonise climate resilience actions across sectors, support evidence based intervention planning, and strengthen community outcomes within a complex World Heritage landscape.

5. FINDINGS AND SYNTHESIS

- Geospatial analysis confirmed that persistent back flooding in the Mfolozi and Msunduzi floodplains is driven by blocked channels, sediment accumulation, and dense vegetation proliferation, rather than isolated rainfall events.

- Land use and land ownership mapping revealed that commercial sugarcane farms, PLAS farms, and subsistence agriculture are concentrated in low-lying flood-prone areas, increasing exposure to prolonged waterlogging and productivity losses.
- GIS-derived vegetation hotspot mapping, Specialist studies and Estuary Management Plan identified priority sections of the Msunduzi and uMfolozi river channels where reed encroachment directly constrains natural flow and drainage capacity.
- Community survey data collected through Survey123 demonstrated uneven access to support programmes, with farmers in highly waterlogged areas unable to meet assistance requirements due to limited physical access to fields.
- Spatial overlays showed direct overlap between subsistence farming, conservation areas, and flood-prone zones, highlighting land use conflicts and planning enforcement challenges.
- The geospatial workflow integrated specialist studies, land use analysis, household surveys, and remote sensing to create a shared spatial evidence base for multisectoral decision-making.
- Risk and opportunity were structured across landscape, catchment, and settlement scales, enabling prioritisation of vegetation clearance, dredging, and maintenance interventions in the most constrained channels
- Spatial analysis informed the sequencing of intervention phases, linking short-term flow restoration actions with longer-term planning and land acquisition considerations
- Integration of community survey results into spatial outputs strengthened the legitimacy of the intervention plan by grounding it in lived experience and livelihood impacts
- The workflow translated complex geospatial evidence into a coordinated intervention plan that aligns climate resilience actions with spatial planning, agricultural support, and ecosystem restoration objectives

5. CONCLUSION

This study demonstrates that climate resilience in complex estuarine landscapes such as iSimangaliso depends on a harmonised, geospatially enabled approach that integrates environmental processes, spatial planning instruments, and community realities within a single governance framework. By translating fragmented specialist knowledge and climate risk evidence into coherent, decision-ready spatial intelligence, the proposed geospatial workflow strengthens coordination across spheres of government, enhances accountability, and grounds adaptation responses in both scientific evidence and lived experience. The iSimangaliso case shows how geospatial integration can shift climate adaptation from reactive interventions toward proactive spatial planning and transformation, linking immediate flood risk management with longer-term land use and development decisions. In doing so, the study contributes to post-SDG resilience debates by illustrating how shared spatial evidence can support collaborative, future-oriented planning in protected and socio-ecologically complex landscapes.

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Annexure A: List of Figures

Biographical Notes:

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Ms Nontuthuzelo Ntshabele

Ms Ntshabele has 26 years of experience in environmental planning, environmental planning services, and spatial information management. She is a registered professional in Spatial Information and a registered Professional Planner. She has presented the following papers in the in the international geospatial and planning discourse through the presentation of conference papers, including:

1)FIG Congress 2023 (FIG Working Week, Orlando, USA), 24–29 May 2023, Orlando: Towards Identifying Fundamental Datasets and Associated Data Custodians for Marine.
2)ESRI User Conference, San Diego, California, USA, July 2024: Mapping for Spatial Justice: Leveraging GISc for Transformative Change in South Africa.

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