POLICY BRIEF

January 2025
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

Advancing water and income security in the unique Maputaland Coastal Plain: A strategic decision support tool to explore land use impacts under a changing climate

Land is a major factor in production, as it provides economic and social benefits. Land use choices can impact ecosystems and water resources, which lead to feedbacks that influence both environmental and economic outcomes. Climate change will also have direct impacts on ecosystem services and land-based production. Land use choices made now, and in the past, will either exacerbate vulnerability due to climate change-related threats to water security or may assist in the reduction of such impacts. Today's choices may influence the adaptive capacity and future trajectory of economic and water security of a region. A decline in the water levels in South Africa's largest natural freshwater lake, Lake Sibaya, serves as a prime illustration of this critical juncture. A recently completed Water Research Commission-funded project evaluated land use dynamics and how climate change will impact current and future socio-economic opportunities in a quest to build resilience and sustainability.

Background

Despite having the least responsibility for causing climate change, vulnerable communities will be the worst affected. In this context, vulnerability refers to the likelihood of being negatively affected. Increased vulnerability arises from factors such as high exposure to risk, limited capacity to cope and adapt, elevated levels of inequality, the status of the environment and, importantly, economic status, which is often linked to the ability to cope and adapt. The most recent Intergovernmental Panel on Climate Change (IPCC) report emphasises that immediate and rapid adaptation is required to reduce negative outcomes.

The impact of anticipated climate change impacts on lives and livelihoods within communities will thus depend on how well prepared they are, the health of the ecosystems which support them and their economic status. Given that South Africa is water scarce, adaptation strategies that promote water security at local and national scales are of paramount importance. Integrated economic valuations are required to inform these which incorporates the ability of the environment/natural resources to sustain productivity. By implication, the impact of climate change on intersections of water security, production systems and economic activity needs to be understood to inform such strategies.

Water security is a fundamental prerequisite to foster economic development and alleviate poverty in South Africa. Threats to water security include economic activities and land use and land cover (LULC) changes that have harmful, often cascading, impacts on the integrity of ecosystems and their associated water resources as well as climate change. More frequent extreme climate events, such as flooding, heat waves and prolonged droughts, will increase due to climate change. Climate models generally agree that Southern Africa will become warmer and drier, but projections for precipitation in the eastern areas within this region are inconsistent. Of concern is that the demand for water already exceeds supply in several regions within the country. Water scarcity limits economic activity and communities' adaptation potential, precisely when action is required to accelerate climate change adaptation. However, fine spatial scale climate projections that inform adaptation to future climate risks at the scale that decision-makers need are fraught with uncertainty.

Integrated resource assessments across land use, economic, and water strategies, in conjunction with the enhancement of knowledge about climate change and associated risks, enable conditions for developing adaptation strategies. Adaptation success is more likely when it ensures context-relevant and appropriate actions that are developed in conjunction with affected communities (Pörtner et al. 2023). Participatory approaches can lead to more positive outcomes, to empower personal agency through the improvement of awareness of climate change risks while exploring ways to improve the net well-being of the area, with the result of a reduction in vulnerability.

Within the uMhlabuyalingana Local Municipality (ULM) (Figure I), situated in the northern Maputaland Coastal Plain (MCP), KwaZulu-Natal (KZN), households experience high levels of unemployment and poverty, while also confronted with ecosystem degradation and a decline in water security. This is particularly evident within the rainfall dependant quaternary catchment W70A, which constitutes a large area within the ULM. Typified by the absence of rivers importing water into the area, since 2001, a decline in the water level of Lake Sibaya, South Africa's largest freshwater lake, reflect the dynamics of the interlinked groundwater aquifer within this catchment.

Climate and particular land uses have been put forward as drivers of water table decline, to the point where there is currently no allocable water within the system to support population growth without the removal of significant areas of commercial plantation forestry. However, commercial plantation forestry, the dominant land use sector within quaternary catchment W70A, is considered an important economic activity for the region, despite their negative impact on the water resource. Sustainable alternatives that provide net benefits, both economically and ecologically, are needed to enhance water security and adaptation potential in the face of an uncertain climate future for the ULM, within quaternary catchment W70A.

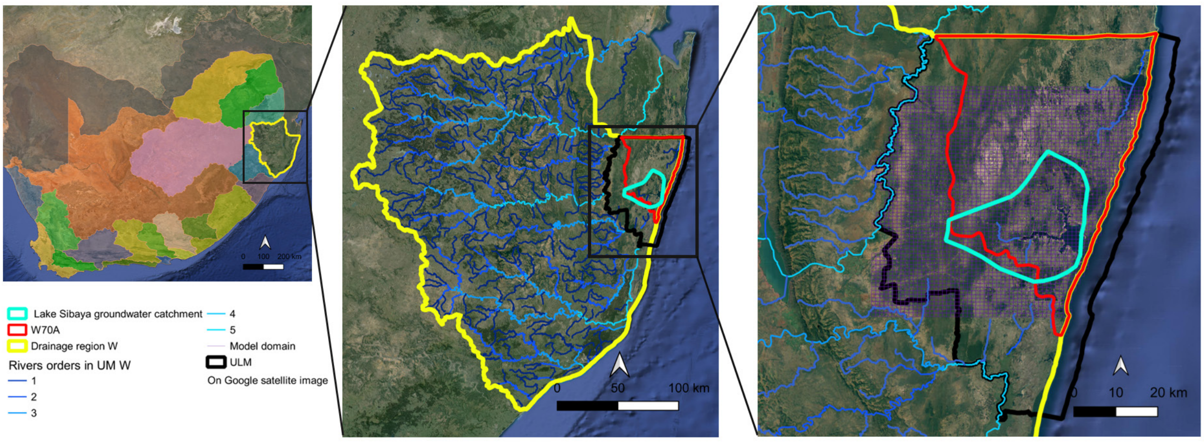

Figure I. Location of the ULM (black boundary) and quaternary catchment W70A within the UM catchment area (yellow boundary), extent of the hydrological modelling domain (grid) incorporating most of quaternary catchment W70A (red boundary) and the estimated (Kelbe 2020) Lake Sibaya groundwater catchment area (light blue). Note the absence of rivers within quaternary catchment W70A.

This project was rooted in the lived challenges identified through participatory engagements with traditional councils (TCs) that represent community areas adjacent to Lake Sibaya. Driven by a societal need to improve water and economic security, a multi-scaled, integrated approach was used to assess the potential impacts of alternative land uses defined by the TCs, under different climate future storylines. It attempted to integrate hydrological, climatological, and economic models to provide decision support to land custodians. Furthermore, it sought to understand the current sources of employment, income, and livelihoods within these areas, along with the future land use preferences of the community. Using this baseline, the study could then use modelling to explore these dynamics under alternative future scenarios and identify current as well as plausible future scenarios of climate and land use through understanding of the regional climate processes for the northern part of KwaZulu-Natal and how these might change under climate change.

Integrated modelling framework

To inform land use choices, this project used an integrated approach to assess the potential impacts of LULC change and climate change on the future well-being within the ULM. To achieve this, it was necessary to integrate hydrological, climatological, and economic aspects. However, the spatial and temporal scales among these elements are generally misaligned, hence a multi-scale approach was adopted.

Decision support tools can be broadly categorised as (i) 'dynamic', in which scenarios can be interactively tested through models, and (ii) 'informational', in which there is a focus on the provision of relevant facts and data without the involvement complex modelling. The aim was to provide a dynamic decisions support tool with the potential to be interactive to facilitate 'least regret' choices.

An 'up-front integration' approach was used to develop a conceptual model that outlined how components would link together to inform the decision support system. This was subsequently fleshed out to explore and clarify scaling issues, data requirements and data flows to understand the current conditions (Figure II). Thereafter a range of future scenarios were simulated (Figure III), incorporating relevant data produced from the Status Quo (SQ) past to present scenario. Iterative learning, data refining and workflow requirements were required throughout the project as needs became more specific and where issues arose. Likewise, assumptions, and perceptions about what was possible had to be regularly adjusted. Limitations also became more apparent as the study delved into details and examined provisional results.

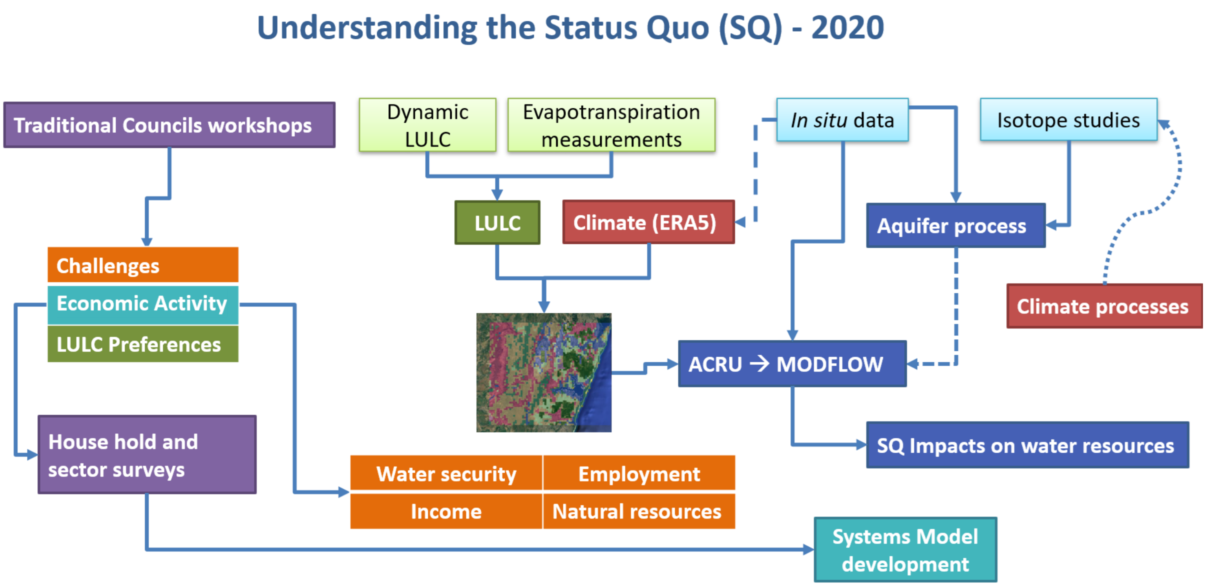

Figure II. Summary of the conceptual integration framework, illustrating linkages and data flows required to understand the past to current dynamics (SQ).

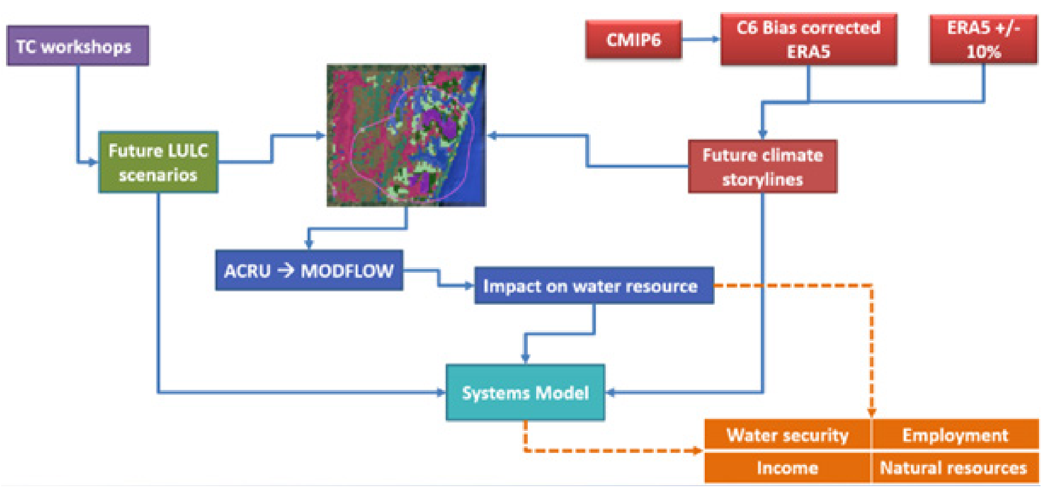

Figure III. Summary of linkages and data flows for future scenarios.

There is a well-recognised gap between climate change science and reliable and usable climate information appropriately packaged for local scale decisions support. Careful messaging is thus imperative in discussions of "possible" future climate scenarios with local communities. Storyline approaches are increasingly being used as a way of exploring climate futures as a way of handling uncertainties. A simple storyline approach, using "what if" scenarios, was thus used within this project, rather than reference to future projections, which could be misconstrued as accurate realities.

Net outcomes of future land use-climate storylines

The effects of climate and LULC change in the MCP have been acknowledged in the past, but their socioeconomic impact has not been analysed before. The objective was to quantify the impact of varying LULC scenarios under three future climate storylines, namely the C6Dry and C6Wet and the ERA5Wet for the ULM within the MCP. A system dynamics model (ULMCatchMOD) was custom-built to simulate the economy and dynamics of the ULM under these scenarios for the period 2024 to 2050. The hypothetical scenarios included converting 50% of the commercial forestry plantations to either Dryland Crop; Marula or macadamia orchards; an increase in the number of tourists visiting the area (non LULC based); and a loss of grasslands to bush encroachment. The data used was obtained from diverse sources, including surveys (primary data collection), literature, expert opinion, and the climate and hydrological outcomes from within this project.

The ULM economy comprises a diverse range of household economic activities, but they are mostly subsistence in nature and are highly vulnerable to changes in climate and land use. Survey data revealed that tourism, as well as income from crafts, generated significantly more income and employment then commercial eucalyptus forestry plantations at the household level. While the primary food sources for all households was shops, 68.6% of households supplement their food source through subsistence cultivation. Of all households surveyed (217), 38.3% consider themselves water insecure. Climate change awareness is low (49.6%).

Using three economic indicators, namely actual cumulative value (primarily for household economic activities), employment potential, and the net present value (NPV) of net cashflow projections, it was ascertained that by switching 50% of the commercial eucalyptus plantation forestry with, for example, cassava, is likely to result in more favourable outcomes for households. It has been estimated that the relative increase in the NPV of the sectoral cashflows could be between 9% and 33% higher compared to the SQ for the C6Dry and ERA5Wet scenarios respectively, depending on the LULC scenario. However, some scenarios resulted in worse economic outcomes (mixed Dryland Crop) under C6 climate futures. Among the crops, cassava has higher cumulative benefits per hectare compared to maize, groundnuts and vegetables and is more resilient under drier future climate storylines. Similarly, employment is likely to be higher by between 18.47% and 205.12% relative to the SQ scenario. In a much wetter future the model demonstrates several options that would result in net gains relative to the SQ. A 50% loss in grasslands to bush encroachment is likely to reduce livestock productivity in the area, by reducing the cattle population by 13%.

It is evident that the existing LULC distribution was designed to promote economic development, however, the economic status at the household level has remained stagnant. The commercial eucalyptus plantations, which cover vast areas in the coastal regions within the ULM, including the Lake Sibaya groundwater catchment area, offer fewer employment prospects per hectare in comparison to other activities. The information from more than 200 respondents of the HH survey provides evidence of this.

To diversify their economies, households cultivate in wetlands to take advantage of the high-water table. However, the model did not consider the negative effects of a decline in the water table on wetland farming due to time constraints, the complexity of agronomic processes, and the lack of a fine scale Digital Elevation Model (DEM) which, it was discovered, would be needed to assess the water levels using the groundwater model in target points within wetlands to work out area available under varying groundwater conditions. It is recommended that future studies focus on the assessment of the value of wetlands in the area, including the impact of changes in the water table on wetland-related benefits and risks.

Ecosystem degradation, driven by the declining water table, has negatively impacted on households. Comments from household (HH) surveys shed light on the negative impact that the decline in the water table has had on natural resources, such as reeds used for craft, an important source of income.

The ULMCatchMOD revealed that bush encroachment also has negative impacts on cattle production. Given the relatively constant nature of bush encroachment in the model, future research can construct models or extend the current model to simulate the impact of bush encroachment in the area through the analysis of historical trends. These models can also explore possible strategies to alleviate the issue. The model can also cater for non-land-based scenarios such as the commercialisation of cattle, improved market access and different tourism occupancy rates.

Summary matrix

The outcomes of various hypothetical land use choices were assessed under different climate future storylines. To achieve this, economic, climate and hydrological components were integrated in different ways throughout the project. This culminated in developing a very simple matrix for each climate future storyline to summaries and compare consequences of LULC choices in relation to water security, employment, economic wellbeing, and natural resource (ecosystem) integrity (for an example see Table 1).

Table 1. Summary matrix of impacts of different LULC scenarios under the warmer drier (C6Dry) climate future storyline relation to 4 key challenges. Green indicates a positive impact relative to the SQ, orange indicates a negative impact relative to the SQ, clear is no change. Red text indicates that, there is no allocable water for that scenario based on the water level in relation to the RQO's.

Very dry few extreme rainfall events (C6Dry) Climate future storyline	Water	Employment	Economic status	Natural resource/ Ecosystem integrity	Net outcome
Bush Encroachment	Worse (-1)	No change (0)	Worse (-1)	Worse (-1)	-3
Dryland Crop	Better (+1)	Better (+1)	Worse (-1)	Worse (-1)	0
Irrigated Crop	Worse (-1)	Better (+1)	Worse (-1)	Worse (-1)	-1
Dryland Cassava	Better (+1)	Better (+1)	Better (+1)	Worse (-1)	2
Dryland Macadamia	Better (+1)	Better (+1)	Better (+1)	Worse (-1)	2
Dryland Marula	Better (+1)	Better (+1)	Better (+1)	Worse (-1)	2
Irrigated Macadamia	Worse (-1)	Better (+1)	Better (+1)	Worse (-1)	0
Irrigated Marula	Worse (-1)	Better (+1)		Worse (-1)	
Status quo +60% Tourism	No Change	Better (+1)	Better (+1)	Worse (-1)	1

Using the matrix in Table 1, it is easy to see that, under the C6Dry future, Dryland Macadamia, Cassava and Marula appear to be water wise economically viable choices, that provide better benefits then the SQ, whereas the SQ coupled with bush encroachment results in the worst outcomes for all challenges relative to the other choices tested. The scale used in the summary matrix provides a proof of concept for a simple story board approach for engagement. It is currently too crude to pick up nuanced differences between choices, particularly in the extent of economic and employment returns. A broader scale range is recommended, but this should be based on more accurate parameterisation of the economic input data.

Policy implications and recommendations

Anticipated impacts of climate change, which include an increase in the severity and frequency of extreme events, will exacerbate poverty and vulnerability if no proactive action is taken to empower communities to adapt. While temperature increases are inevitable, the trends in precipitation at local scales are less clear. Unpredictability in rainfall patterns and higher temperatures will impact food security and incomes derived from natural resource-based livelihoods.

To achieve sustainable development, as prescribed by South Africa's National Development Plan (NDP), the challenge is to strike a balance between economic development, environmental sustainability, and resilience to anticipated climate change impacts. To date, this has been an elusive outcome in the ULM. Demand for water from various users has surpassed the available yield potential. As a result, the adaptive capacity of vulnerable households within the region has declined, at a time when every effort should be made to enhance adaptation strategies in the face of climate change. Given the impact of land use on water security within ULM, considering land use options should be an important component in adaptation strategies. This project aspired to develop a means of empowering vulnerable local communities to make informed and 'least regret' land use choices for the optimisation of beneficial outcomes in the context of an uncertain future climate.

Immediate and rapid adaptation is imperative to reduce climate change impacts. While climate change science and adaptation strategies receive considerable attention globally and nationally, the lived realities of climate impacts and the implementation of adaptation actions are often experienced at individual and household levels. Top-down interventions that disregard local context frequently exacerbate already vulnerable situations. Furthermore, while there is progress within South Africa, significant barriers to the effective implementation of climate adaptation strategies within Government structures exist, particularly at the district and local municipal levels.

Given the impact of land use on water security within ULM, considering land use options should be an important component in adaptation strategies. Participatory and engagement methodologies that incorporate local roleplayers are increasingly being advocated to catalyse contextually appropriate and acceptable adaptation strategies at local levels. The manner in which this is done should aim to empower and promote local agency but are not without their own risks and complexities. For scientists, the challenge is to suspend scientific thinking enough to listen as well as learn to value multiple forms of knowledge, including local experience and indigenous knowledge systems. The reward is a co-learning process which enriches emergent science outcomes that are more likely to translate into societal impact.

For more information,
contact WRC Research Manager, Dr Brilliant Petja, at email: brilliantm@wrc.org.za