DESIGNING VIABLE STRATEGIES AND FINANCING MECHANISMS FOR SECURING HYDROLOGICAL ECOSYSTEM SERVICES IN SOUTH AFRICA: A REVIEW, INVESTIGATION AND DECISION SUPPORT FRAMEWORK

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

PROJECT BACKGROUND AND RATIONALE

Cities and regions around the world face increasing threats to their water security due to growing water demands in the context of climate change and degradation of their water source areas. In South Africa, there has been considerable effort in meeting infrastructural needs to deliver water to households. However, at the same time, the catchment areas that supply this water have become increasingly degraded. This leads to an increase in the costs of water supply infrastructure required to satisfy water demand and sets the country back in meeting its water security mandate.

In general, it has been recognised that addressing ecosystem degradation at scale requires significant financial investment but that such investment also needs to be smarter in order to yield a higher return on investment. There has been considerable interest in South Africa in finding successful models for financing conservation activities or “nature-based solutions” that improve water security. However, the value and scale of investment into catchment conservation and restoration has been small compared to what is required. Understanding more about implementation and financing options can have important, far-reaching impacts on conserving the health of South Africa’s catchments, addressing land degradation neutrality, and protecting water security in the long-term through cost-effective, sustainable approaches. This project seeks to provide strategic guidance for future initiatives to secure hydrological ecosystem services[1] in South Africa, based on an improved understanding of the potential opportunity and viable approaches for investing in hydrological ecosystem services.

PROJECT OBJECTIVES, SCOPE AND LIMITATIONS

The overall aim of this project was to provide strategic guidance for future initiatives to secure hydrological ecosystem services in South Africa, based on an improved understanding of the potential opportunity and viable approaches for investing in hydrological ecosystem services. The specific objectives were as follows:

1. Review the different types of financing mechanisms for securing hydrological ecosystem services and the institutional, legal, policy and socio-economic factors that have contributed to their success or failure, both internationally and in South Africa;
2. Determine the cost effectiveness of investing in catchment restoration in key water supply areas of South Africa by comparing the costs and benefits associated with invasive alien plant (IAP) clearing to that of planned built infrastructure augmentation projects;
3. Investigate the extent to which further funds could be leveraged from household water users to finance catchment restoration and conservation; and
4. Develop a framework for guiding viable approaches for securing hydrological ecosystem services in different catchments areas.

There were five main tasks attached to this two-year project. The first task focused on a review of options and financing mechanisms for securing hydrological ecosystem services, both internationally and in South Africa. This involved consultation with a number of stakeholders, both individually and in workshops (the second task). The third task involved two research projects: a viability analysis of clearing IAPs from catchment areas, and a contingent valuation study to investigate the extent to which further funds could be leveraged from household water users to finance catchment conservation. The final tasks involved the development of a framework decision support tool and a validation workshop.

Originally, the first research project sought a better understanding of the perspectives of water service providers. However, there was insufficient willingness to participate among the dozen institutions (at the water

[1] Also referred to as watershed services in the literature.

board level) that were contacted, despite following the necessary avenues of communication. This was a major limitation to understanding the lack of participation in EI investments from the institutional side and requires further attention.

A REVIEW OF STRATEGIES TO SECURE HYDROLOGICAL ECOSYSTEM SERVICES AND EXPERIENCE IN SOUTH AFRICA

In addition to a comprehensive review of the literature, this task also included semi-structured interviews with researchers and organisations that have been directly involved in catchment restoration, payments for ecosystem services (PES) or ecological infrastructure (EI) financing projects to obtain further information and insights on their rationale, design, experiences, and lessons learned.

Natural ecosystems have a direct influence on catchment hydrology, contributing towards a clean and reliable supply of water. When catchments become degraded, they lack the functionality and resilience to sustain the supply of ecosystem goods and services. Not only does this affect economies and livelihoods but it also increases the costs of water supply. Highlighted as one of the major causes of loss of ecosystem services in South Africa, ecosystem degradation is mainly in the form of the spread of invasive alien plants (IAPs); loss of vegetation and soil cover in rangelands and cultivated lands, as a result of poor management practices; bush encroachment in grassland and savannas as a result of poor grazing and fire management practices; and pollution from wastewater treatment outputs, agricultural activities, mining and other diffuse sources.

Nature-based solutions are essential to strategies for achieving water security. They are also critical for addressing the dual challenge of biodiversity loss and climate change. Such measures are often more cost-effective than traditional engineering solutions (e.g. augmentation and upgrading of water supply infrastructure) and have the added advantage of a range of co-benefits associated with having healthier ecosystems. Nature-based solutions contribute to biodiversity conservation, can help reduce disaster risk, improve health and livelihoods, and can help countries meet their international climate change mitigation goals. Achieving such outcomes requires thinking about what management actions should take place and then determining which policy and financing measures could best achieve these.

Catchment management interventions to secure water supply focus on reversing IAP invasions and bush encroachment, maintaining vegetative cover, minimising erosion and pollution. These nature-based solutions can be broadly divided into active restoration or conservation measures, with the latter being through sustainable land and resource management or protection. A wide array of environmental policy instruments can be used to bring about restoration and conservation. These are broadly categorised as regulation, incentives (non-monetary and financial) or buyouts. They are highly context specific and are often used in combination. However, when degradation is extensive and severe then there are few, if any, instruments that will work to fix the problem due to the costs involved. In such situations, funding active restoration (i.e. employing labour to undertake restoration) becomes the only viable option. Therefore, most restoration programmes in South Africa have to look at some combination of costly active restoration and incentives to motivate land managers to bring about conservation and sustainable land use practices.

There are a number of existing and potential sources of funding for financing catchment restoration and conservation. In South Africa, catchment restoration has been funded largely through public sector investment. This is generally the case worldwide, where public finance has been, and continues to be, the largest funding source for biodiversity conservation. However, state budgets for restoration and conservation in South Africa are heavily constrained and do not come close to what is required to achieve restoration outcomes. Six times as much funding is needed than what is currently being received if natural resource management and investment in ecological infrastructure in South Africa is to be sufficiently effective.

In South Africa there is some potential to secure funding from other sources through domestic transfers in the form of payments (e.g. from the water sector through water user fees) or offsets, and from international donors, philanthropists and conservation NGOs. Furthermore, to supplement these sources, the government can put in place measures to leverage additional funding from the private sector, for example, through green financial products such as green bonds. However, private sector investment has remained low in South Africa. This has been ascribed to the high risk and uncertainty of returns, and the long timeframes and delayed returns associated with some types of restoration; a lack of secure options in terms of management and disbursement of funds; and a lack of investment vehicles such as bonds. Generally, in South Africa, government and parastatals (such as water boards) are hesitant to invest or issue bonds for nature-based solutions because of the risk and uncertainty, preferring the certainty of investing in built infrastructure. Impact investors want to be sure that they have an impact through well-designed projects and proper use of funds. The high risks associated with nature-based solutions will need to be mitigated by providing more evidence of the cost-effectiveness and benefits of these solutions. Private investors looking for modest, secure returns will best be attracted by bonds, but these are seldom available. Opportunities for venture capitalists looking for high returns remain very limited.

Seen as a win-win situation, being both an incentive and financing mechanism, there has been a very strong interest in payments for ecosystem services (PES) as an approach to financing catchment restoration and conservation. However, in South Africa there are currently no PES schemes in operation, even though initial research has shown that it could be economically viable in some parts of the country.

Payments for ecosystem services schemes involve voluntary transactions where a well-defined ecosystem service is being bought by a minimum of one service buyer from a minimum of one service provider, if and only if, the provider secures ecosystem service provision (i.e. conditionality). Ecosystem services are secured by paying landowners or users to desist from damaging activities or adopt more conservation-friendly practices. The landowners could be people, communities, firms or governments, and the payments could be monetary or non-monetary transfers, from the private sector, government and/or international donors. The system works as long as the payment exceeds the recipients' opportunity cost for their change of behaviour or policy. The most common services paid for are the restoration and/or retention of carbon stocks, biodiversity, hydrological functions and natural landscapes. PES schemes do not always follow the strict definition stated above. They are not always purely voluntary, as they may involve enforced action. The services paid for are not always well defined, and in fact commonly the schemes pay for land management actions that are believed to impact on service delivery (input based rather than output based payments). Conditionality can also be weak, due to poor monitoring design or due to weak institutions, particularly where there is communal or insecure land tenure. While the first two modifications can still achieve the desired outcomes, the absence of conditionality will typically result in failure. The success of PES has also been undermined by its increasingly being set up with development of the service providers as the primary objective. A PES scheme is not a job creation mechanism *per se*, although by definition it should result in service providers being better off than before.

Over 550 PES schemes have been established worldwide, but relatively few of these are in Africa. A large proportion of the initiatives in Africa have failed to progress beyond the pilot stage. The most common schemes in Africa are for carbon, and payments for hydrological ecosystem services schemes are comparatively rare. While schemes in the rest of the world tend to be government funded, those in Africa are mostly privately funded. For example, UN REDD+ schemes are fuelled by international demand for carbon credits to offset carbon emissions, while small scale initiatives to maintain biodiversity are fuelled by international demand for tourism. Water services, on the other hand, are typically driven by local demand for water, and have been slow to develop in Africa because of limited ability or willingness to pay. While in the rest of the world, the service providers tend to be individual landowners, in Africa they are mainly with communities in communal land areas, through a local authority or community organisation. In some countries, where policy and legislation has allowed for the devolution of land, resource and/or wildlife rights to local communities, this forms an excellent basis for PES. Whether land tenure is communal or private, PES will only work if property rights are secure (in other words, there is limited access to land and resources, and there are rules of use that are generally obeyed). It cannot work where there is open access to land and resources.

The set-up costs of PES schemes can be very high and are typically covered with grants. Once set up, a mechanism is needed to channel funds to the service providers. This can be via a revolving fund, or from a trust fund or endowment fund that has been capitalised by the funders. These funds are usually managed by an intermediary, such as an NGO. The independent fund model provides an approach that facilitates long-term, sustainable financing. It also allows the pooling of funds from multiple sources. Although this distances the funders from the service provision, conditionality can be maintained by the intermediary. The independent fund model managed by an external NGO has been tested in Africa in the form of "Water Funds" and "BioFunds". Although these funds are not necessarily confined to brokering PES, they could be key to unlocking some of the barriers that have limited PES development in much of Africa.

There are two main reasons why PES has not taken off in South Africa. Firstly, hydrological ecosystem services are demanded by local water providers and users, rather than international society (as is the case for carbon or biodiversity), and as such, willingness to pay is limited. The unrealised demand from local water service providers is linked to a lack of awareness around the role of natural capital in securing water supplies and the sense that PES is too risky, as well as the low revenues obtained from water limiting ability to pay. Secondly, the nature of the degradation problem in South Africa limits PES as an effective financing option. Invasive alien plants are a major problem in almost all water source areas and are costly to control. In other parts of the world, payments for hydrological ecosystem service schemes focus on forest management, paying landowners to protect forest and desisting from damaging behaviour. Removal of IAPs is complex as well as costly and is unlikely to be achieved through PES. However, there is potential for using PES for incentivising sustainable land management interventions after initial restoration.

Recognising the need for innovative approaches for securing hydrological ecosystem services, initiatives in South Africa have started to move towards a partnership approach where a more concerted effort has been made to encourage stakeholders to support investment in EI through collective action. The emphasis has moved to encouraging investment in natural capital with the aim of producing returns to land managers or investors. These initiatives can employ combinations of the instruments discussed above, including PES. These are chosen based on what is deemed appropriate and achievable, tailored to a specific local context. Partnerships and water funds overcome some of the key challenges that have hampered the success of catchment restoration and conservation in the past, including coordination and financial management, inefficiencies across large groups of stakeholders, and institutional capacity and knowledge constraints.

Seven key findings materialised from the review:

1. Catchment degradation is a major threat to water security, primarily caused by failure to adequately control IAPs and poor land management. Remedying this is extremely costly, and so requires financially efficient solutions.
2. International evidence suggests that implementing nature-based solutions in conjunction with built infrastructure solutions is more efficient than just relying on the latter.
3. The restoration and conservation of catchment areas and river health can be achieved through a range of regulatory and economic policy instruments, which vary in efficiency depending on the context. Selecting the most appropriate policy instrument is an important first step.
4. The success of PES is highly context specific. International success for delivering hydrological ecosystem services is not replicated in communal land contexts and/or where users have limited ability to pay.
5. Protecting the environment is low on the political agenda in South Africa and not prioritised strongly enough in state budgeting.
6. Investment in nature-based solutions is deterred by high risk and uncertainty of returns as well as long time frames and a lack of secure options and opportunities (e.g. green bonds). High returns are unlikely.
7. Independent entities that securely manage funds from multiple sources, such as water partnerships and water funds are most likely to succeed in leveraging the funds needed to restore and conserve important catchment areas.

VIABILITY OF INVESTING IN ECOLOGICAL INFRASTRUCTURE TO SECURE WATER SUPPLY

There is growing awareness of the important role of both ecological[2] and built infrastructure in achieving economic growth and development in terms of water security. However, degradation of ecological infrastructure is resulting in the loss of valuable hydrological ecosystem services that not only affect human well-being but also increase the costs of water supply. Investing in restoration and conservation of catchment areas can effectively support existing built infrastructure and delays the need for more expensive engineered solutions. This not only reduces costs over the long-term, but also generates a range of co-benefits. However, the potential of nature-based solutions to deliver on intended benefits continues to be questioned due to concerns over the lack of scientific evidence.

In this, the first of two case studies undertaken as part of the project, the cost effectiveness of investing in catchment restoration to secure water supply in the key water supply systems of South Africa, was investigated by comparing the water supply gains and costs associated with IAP clearing to those of planned built infrastructure augmentation projects. In each of the 11 water supply systems, the major dam catchments were delineated, and the extent of IAP coverage was estimated for 2022 and 2050 based on the National Invasive Alien Plant Survey (NIAPS) dataset and a simple logistic population growth model. Following this, the cost to clear the modelled extent of IAPs was estimated, as was the associated potential difference in yield as a result of clearing. This information was then used to calculate a unit reference value (URV) for IAP clearing in each dam catchment and water supply system. The URVs for IAP clearing were then compared to the URVs of planned future water infrastructure projects in each area based on information collated from reconciliation strategy reports.

The results provided quantitative evidence of the cost-effectiveness of investing in EI against built infrastructure options to secure water supply. IAP clearing in catchment areas should be considered a formal intervention for securing future water supply alongside built infrastructure options in almost all of South Africa's water supply systems. IAP clearing would lead to a total estimated streamflow gain of 1595 million m^3 and a yield gain of 997 million m^3 by 2050, equivalent to a quarter of the yield gains through implementation of built infrastructure interventions over the same time period. The URVs for built infrastructure ranged from R0.48/m^3 to R44.36/m^3, while the URVs for IAP clearing ranged from R0.79/m^3 to R7.18/m^3. All URVs for IAP clearing were lower than that of built infrastructure interventions, except for just one water supply system, the Orange River System. These findings add to the growing body of literature that advocates for EI investments to secure hydrological ecosystem services by showing that such approaches can be more cost-effective than built infrastructure development options.

COULD CATCHMENT CONSERVATION BE FUNDED THROUGH INCREASED WATER TARIFFS? A CASE STUDY OF THREE SOUTH AFRICAN CITIES

This, the second case study, aimed to address whether household water tariff pricing could be used as a mechanism for securing funds for catchment restoration. The objectives of the study were to (i) determine households' willingness to pay (WTP) for their existing water use (ii) investigate the socio-economic factors influencing household WTP, and (iii) establish whether their aggregate consumer surplus could cover the costs needed to finance catchment restoration. Over 1000 households were surveyed in three coastal metropolitan municipalities in South Africa: the City of Cape Town, Nelson Mandela Bay, and eThekwini. A double-bounded dichotomous choice question was used to elicit WTP, which was analysed in relation to household characteristics and attitudes towards the municipality. The WTP results were then compared with current water payments to estimate consumer surplus.

The results obtained from the double-bounded dichotomous choice model indicated that overall, households had a higher willingness to pay for water and that WTP was positively influenced by household income, age, and satisfaction with municipal water service delivery. Those respondents who were not willing to pay higher

[2] Ecological infrastructure refers to natural ecosystems that supply valuable ecosystem services.

water tariffs mainly had a low confidence in the municipal governments' ability to manage water supply services, or an inability to afford higher water tariffs. WTP differed significantly between the municipalities, largely due to differences in satisfaction and income. There were major differences in satisfaction with municipal water service delivery, with residents in the City of Cape Town being significantly more satisfied than those living in eThekwini and even more so than those in Nelson Mandela Bay. The average WTP for water across all three municipalities was approximately 10% more than what households currently pay for water. Based on the WTP from the higher income categories (>R6401 per month) there was a positive consumer surplus of R756 million for the City of Cape Town and R186 million for eThekwini, which would cover a significant proportion of the estimated costs required to restore the catchment areas supplying water to these municipalities. While the stated WTP is unlikely to be realised in full due to inherent biases in contingent valuation methods, the results do suggest that there is significant potential for increasing revenues through raised tariffs.

However, in Nelson Mandela Bay households were not willing to pay more than they are currently paying for water. Residents in Nelson Mandela Bay had the highest levels of dissatisfaction towards their municipality and the lowest WTP for water. Many stated that paying more for water would not improve the service they were receiving, illustrating a complete lack of confidence and trust in the municipality. The low level of WTP is compounded by the current drought crisis in the region, which has resulted in the municipality raising domestic water tariffs and imposing severe water restrictions on the population.

This study showed that there is significant potential to raise domestic water tariffs. However, the study has also shown that leveraging user fees hinges on functioning institutions. Satisfied residents who have some degree of trust in their municipality are more likely to be willing to pay higher prices for their water.

A DECISION SUPPORT FRAMEWORK TO GUIDE INVESTMENTS IN ECOLOGICAL INFRASTRUCTURE FOR WATER SECURITY

Based on the research outputs of this project, literature and past experience, a decision support framework was designed to guide investments in ecological infrastructure for water security in South Africa. The practical, user-friendly framework aims to provide high-level guidance to decision-makers on the potential opportunity and viable approaches for investing in hydrological ecosystem services, taking into account spatial variation in the nature and scale of the problem in the water supply areas in relation to water demand, the institutional and socio-economic context of the problem areas, suitable options for intervention and potential costs of addressing the problem, the water services institutional context, and the potential user willingness to pay to cover some or all of these costs. The analytical framework lays out in a stepwise approach the "what, where, who and how" of conservation actions for tackling catchment restoration with the aim of supporting decision making backed by scientific and economic data.

It is seen as a starting point for providing useful, context specific information on a wide range of elements for planning and guiding decisions for policy design and informing investment in nature-based solutions to secure hydrological ecosystem services. It operates at the scale of water supply systems, regions delineated by the South African government related to institutional water supply services. The framework is primarily for use by Water Service Authorities and Water Service Providers (municipalities, water boards, DWS) and also for practitioners and policy makers from DFFE, conservation authorities, and NGOs who are involved in the management and conservation of catchment areas in South Africa.

The practical, user-friendly framework includes four main steps, with sub-steps, as follows:

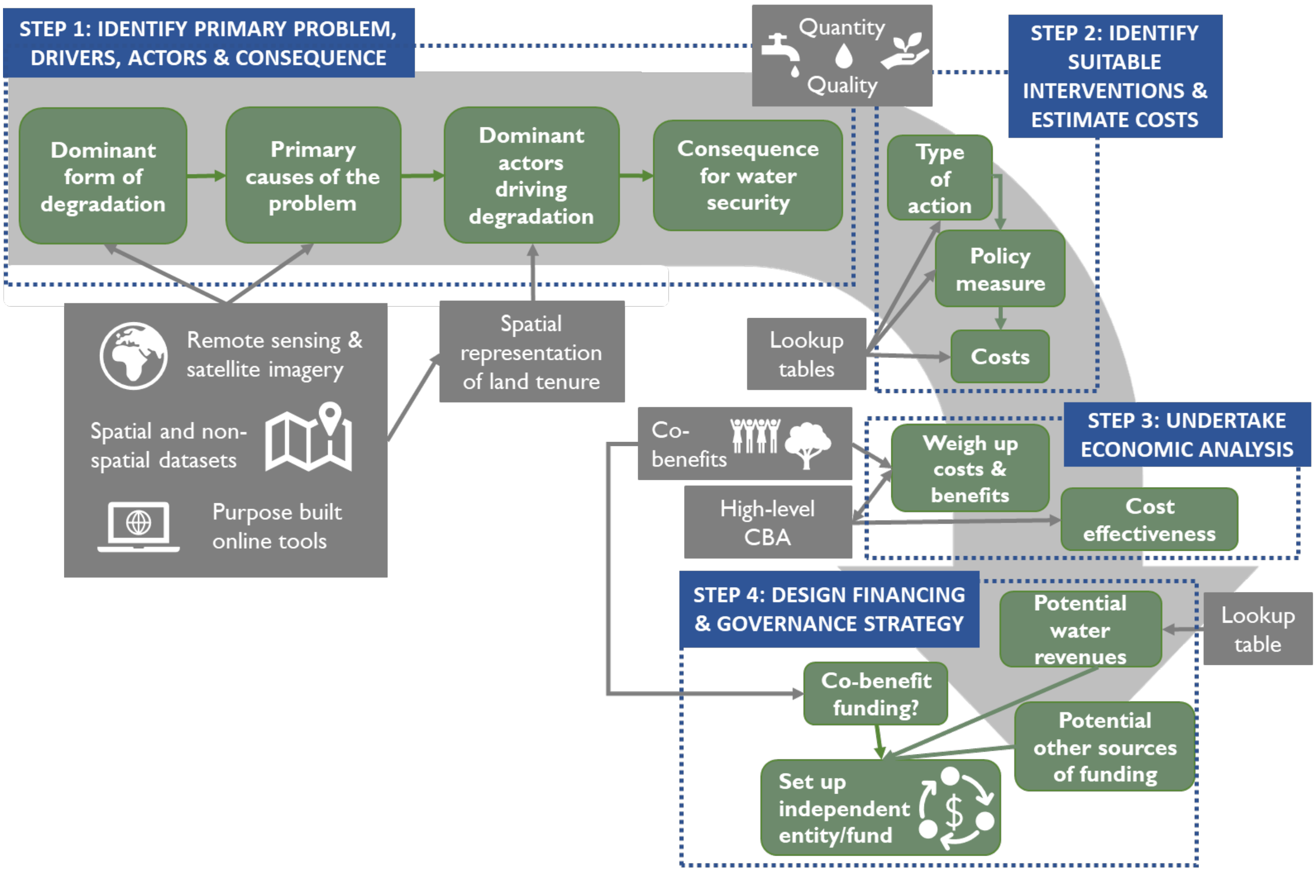

Figure I: The decision support framework follows a stepwise approach in terms of the "what, where, who and how" of conservation actions for tackling catchment restoration.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This study has shown that securing hydrological ecosystem services through catchment restoration and conservation is cost-effective and should be considered as a priority action for achieving water security in South Africa. Furthermore, the study has identified that there is untapped willingness to pay for water which could be captured through tariff increases and channelled through appropriate organisations to pay for catchment restoration. This study suggests that with an appropriate, trusted institutional set-up, there is potential to make a significant contribution towards closing the funding gap in this way.

Given that water service providers, as the main beneficiaries of catchment restoration, stand to gain significantly from such improvements through cost savings, their apparent low willingness to invest in ecological infrastructure requires further investigation. However, this study suggests that this should not impede investment and implementation, as there are other avenues, such as water funds and water source partnerships, that have proven to be successful in securing financing for catchment restoration and conservation.

Finally, context is important. Funding can come from numerous sources and interventions can be financed through a number of mechanisms, all of which are suitable under different contexts, varying spatially depending, for example, on the nature and scale of the problem, the institutional and socio-economic context of the problem, the costs of addressing the problem, the water services institutional context, and the potential user willingness to pay. The decision support framework that has been developed aims to provide high-level guidance to decision-makers and catchment managers on the potential opportunity and viable approaches for investing in hydrological ecosystem services.

The following recommendations are made:

1. Provide training on the use and application of the decision support framework with specific groups of individuals that are involved in water services delivery and catchment management in South Africa so that they are able to learn the necessary skills and improve performance and efficiency with regards to tackling catchment restoration and conservation across key water supply areas.
2. Establish Water Funds in each water supply system, along the lines of those that have already been or are in the process of being established. This will not only help to secure donor and investment funding but will also support the raising of revenues from water tariffs. The private sector, as well as philanthropic donors, are more likely to invest if they know that their money is being ring-fenced for conservation and is well managed. A dedicated financing and governance structure provides this stability and should be explored for all water supply areas in the country.
3. Design and implement a ringfenced domestic water user fee involving increases in line with the inclining block tariff structure. This could be implemented incrementally and in an experimental fashion to test revenue and consumption effects and ensure that there are no regressive effects.
4. Expand the viability analysis to include other forms of ecosystem degradation, namely erosion, bush encroachment and pollution.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS & ABBREVIATIONS

AfDB	African Development Bank
AWARD	Association for Water and Rural Development
BLU	Biodiversity Land-Use Management Project
CBNRM	Community-based natural resources management
CBO	Community-based organisation
CSI	Corporate social investment
DBSA	Development Bank of Southern Africa
DFFE	Department of Forestry, Fisheries and Environment
DWS	Department of Water and Sanitation
EI	Ecological Infrastructure
EICF	Ecological Infrastructure Challenge Fund
EI4WS	Ecological Infrastructure for Water Security Project
EPWP	Expanded Public Works Programme
ESG	Environmental, Social and Governance
GCTWF	Greater Cape Town Water Fund
GEF	Global Environment Facility
IAP	Invasive alien plant
IWRM	Integrated Water Resources Management
LDN	Land degradation neutrality
LUI	Land User Incentive
MEA	Millennium Ecosystem Assessment
NbS	Nature-based solutions
NGO	Non-government organisation
NRM	Natural Resource Management
PES	Payment for ecosystem services
REDD	Reducing emissions from deforestation and forest degradation
SADC	Southern African Development Community
SANBI	The South African National Biodiversity Institute
SANParks	South African National Parks
SLM	Sustainable land management
SRI	Socially responsible investing
TNC	The Nature Conservancy
UCPP	Umzimvubu Catchment Partnership Programme
UEIP	uMngeni Ecological Infrastructure Partnership
UN	United Nations
UNCBD	United Nations Convention for Biodiversity
UNCCC	United Nations Convention on Climate Change
UNCDD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
uWASP	uMhlatuze Water Stewardship Partnership
WfW	Working for Water
WRA	Water Resource Authority
WRC	Water Research Commission
WRUA	Water resource user association
WSA	Water Source Area
WSP	Water Service Provider
WTP	Willingness to pay
WWF	World-Wide Fund for Nature

GLOSSARY

Bush encroachment: Bush encroachment is the process whereby the cover of indigenous woody plants (trees and shrubs) in a grassy ecosystem (savanna or grassland) increases substantially relative to the indigenous woody cover of some (historical) reference state (Turpie *et al.*, 2019a).

Catchment: an area where water is collected by the natural landscape. Precipitation that falls in a catchment runs downhill into streams, rivers, lakes, oceans, or into built infrastructure, such as reservoirs. In this document, the terms catchment, basin and watershed are used interchangeably**.**

Conservation agriculture: improved agricultural activities that are premised on three main principles: minimum mechanical soil disturbance, improved maintenance of ground cover using organic matter, and diversification of crop species to move away from monocultures.

Contingent valuation: a survey-based economic technique frequently used for placing monetary values on environmental goods and services.

Cost-benefit analysis: a conceptual framework and tool used to evaluate the viability of projects or policies based on their costs and benefits over time. It involves the adjustment of future values to their present value equivalent by discounting at a rate which reflects the potential rate of return on alternative investments or the rate of time preference.

Discount rate: the interest rate used in discounted cash flow analysis to determine the present value of future cash flows.

Ecological infrastructure: nature's equivalent of grey or engineered infrastructure. It forms and supports a network of interconnected structural elements such as catchments, rivers, riparian areas and natural corridors supporting habitats and the movement of animals and plants.

Ecosystem services: the benefits people obtain from the Earth's many life-support systems. The Millennium Ecosystem Assessment defines four categories of ecosystem services: provisioning, regulating, cultural, and supporting services.

Invasive alien plants: plant species that are exotic, non-indigenous or non-native to an ecosystem, spread aggressively and threaten biological diversity.

Nature-based solutions: actions taken to protect, sustainably manage, and restore ecosystems to effectively address societal challenges, such disaster risk reduction. Nature-based Solutions simultaneously improve ecosystem health and functioning to the benefit of human and non-human nature.

Net present value: a calculation used to estimate the net benefit over the lifetime of a particular project. NPV allows decision makers to compare various alternatives on a similar time scale by converting all options to current dollar figures. A project is deemed acceptable if the net present value is positive over the expected lifetime of the project.

Payments for ecosystem services: where beneficiaries of ecosystem services compensate ecosystem managers (landowners or resource stewards) to change their practices in order to secure the supply of those ecosystem services. This may involve desisting from damaging activities or adopting more expensive practices that are less damaging to the environment.

Reconciliation strategy: a process of planning the water balance for a specific water supply system, with the objective to 'reconcile' or balance available water sources with water requirements through various strategies in a given time frame, usually one or two decades (DEA, 2013).

Return on investment: a simple ratio of the gain from an investment relative to the amount invested. ROI is calculated by dividing net profit (current value of investment minus cost of investment) by the cost of investment.

Riparian area or zone: the land occurring along watercourses and water bodies.

Sustainable resource management: the use of natural resources in a way and at a rate that maintains and enhances ecosystem resilience and the benefits that they provide.

Unit reference value a common measure in South Africa to assess the economic efficiency of proposed water projects. Simply, the URV is derived by dividing the present value of the costs with the present value of the water supplied to get a R/m^3 estimate.

Water fund: a funding and governance mechanism that engages public, private, and civil society stakeholders to contribute to water security through nature-based solutions and sustainable resource management.

Water security: the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality of water for sustaining livelihoods, human wellbeing, and socio-economic development, for ensuring protection against waterborne pollution and water-related disasters and for the preservation of ecosystems in a climate of peace and political stability.

Water Service Providers: public, private, or mixed entities, or municipal government itself responsible for providing water at the local level.

Water supply system: regions delineated by the South African government related to institutional water supply services.

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CHAPTER 1: INTRODUCTION

1.1 PROJECT BACKGROUND AND RATIONALE

Cities and regions around the world face increasing threats to their water security (Box 1.1) due to growing water demands in the context of climate change and degradation of their water source areas (Abell *et al.*, 2019). Indeed, almost half of the world's population already lives with water scarcity, and it is estimated that by 2050 up to 5.7 billion people will be living in water-scarce areas (WWAP/UN-Water, 2018). Managing ecosystem condition, particularly in the upper catchment areas, can provide a cost-effective means of helping to ensure year-round water availability and improve water quantity for domestic use and for environmental flows. Recognising this, investments in nature-based source water protection are taking root (Abell *et al.*, 2019; Brauman *et al.*, 2019).

In South Africa, there has been considerable effort in meeting infrastructural needs to deliver water to households. However, at the same time, the catchment areas that supply this water have become increasingly degraded. In some areas, this has been through the spread of invasive alien and indigenous woody vegetation, which has reduced streamflow through increased evapotranspiration. In other areas, degradation has taken the form of a loss of vegetation cover and the development of erosion dongas, leading to a reduction in the infiltration of rainfall and a resulting increase in the variation of flows, as well as an increase in sedimentation of reservoirs. Both of these anthropogenic problems – the increase in woody cover and reduction in vegetative cover – lead to an increase in the capital and/or operating costs of water supply infrastructure required to satisfy water demands. This sets the country back in meeting its water security mandate (see Box 1.1).

Box 1.1. Water security

The United Nations defines water security as: "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality of water for sustaining livelihoods, human wellbeing, and socio-economic development, for ensuring protection against water-borne pollution and water related disasters and for the preservation of ecosystems in a climate of peace and political stability" (UN-Water, 2013). There are four core elements within this definition:

- People have access to safe adequate quantities of acceptable quality drinking water for sustaining livelihoods, human well-being, and socio-economic development. Water supply needs to be adequate and reliable, and typically piped to people's homes and places of work;
- Water is available for economic activities and development, energy production, industry and transport as required, and people's livelihoods are not affected by unreliable water supplies;
- Ecosystems are preserved such that they deliver water related ecosystem services. This includes protection of freshwater resources, and the aesthetic and recreational opportunities associated with aquatic ecosystems and human-made reservoirs; and
- Climate related water hazards, such as floods and droughts, and the risks associated with these, are effectively managed.

The spread of invasive alien plants has largely been the legacy of historical introductions of species intended for useful purposes. The other forms of degradation, including indigenous bush encroachment, have come about through poor agricultural and grazing management practices, and have been exacerbated by poverty, poor regulatory frameworks, weak institutions and governance systems (Hoffman & Todd, 2000; Peden, 2005) as well as climate change. Furthermore, a lack of pollution control has led to the eutrophication of many river systems. This degradation has not only disrupted hydrological services such as flow regulation but has led to the loss of biodiversity and a host of other ecosystem services.

Ecosystem degradation[3] problems in South Africa, and their effects on water security, have been recognised for decades, and have been the focus of a variety of policies, laws and interventions (see Turpie *et al.*, 2021). Indeed, as a signatory to the UN conventions for biodiversity (UNCBD), to combat desertification (UNCDD) and climate change (UNCCC), the country is obliged to develop and work towards targets to combat ecosystem degradation. However, efforts have either been insufficient or unsuccessful, partly due to the extent of degradation, and partly due to lack of attention to the social context or a lack of continued funding to ensure sustainability and desired results. Furthermore, UNCCD signatory countries have recently established voluntary targets to achieve land degradation neutrality (LDN) by 2030[4], defined by the UN as "a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems" (UNCCD, 2016). South Africa's LDN targets include clearing and following up on nearly 1.7 million ha of invasive alien plants and addressing land degradation in over 7.2 million ha of grassland, shrubland and sparsely vegetated areas (DEA, 2017; Republic of South Africa, 2018). In addition, the years 2021 to 2030 have also been declared the United Nation (UN) Decade on Ecosystem Restoration.[5]

In general, it has been recognised that addressing ecosystem degradation at this scale requires considerable financial investment (Giordano, Blignaut & Marais, 2012) and furthermore that investments need to be cost-effective. One way of financing the restoration and sustainable management of important water source catchment areas is through "payments for ecosystem services" (PES) schemes, where beneficiaries pay land owners or managers to desist from damaging activities and/or change to more conservation-friendly practices (Wunder, Engel & Pagiola, 2008; Engel *et al.*, 2008)[6]. PES schemes are attractive from a developmental perspective, in that they can deliver on additional objectives, such as poverty alleviation (Brauman *et al.*, 2019). PES has been hailed internationally as an effective means of securing ecosystem services through incentivising landowners (and other resource stewards) to adopt conservation or restoration practices (Wunder *et al.*, 2020). If implemented successfully, PES schemes can be flexible, efficient and effective.

Since their initial introduction in the early 2000s, PES schemes have been implemented in hundreds of projects throughout the world, particularly in developing countries. By 2018 there were an estimated 550 PES programmes in operation, with more than US$36 billion paid each year for environmental services (Salzman *et al.*, 2018). However, while there has been rapid growth in PES programmes in the Americas (particularly South and Central), China and South-East Asia (Börner *et al.*, 2017; Salzman *et al.*, 2018; Wunder *et al.*, 2020), the implementation of PES has been relatively limited in Africa (AfDB, 2015; Bösch, Elsasser & Wunder, 2019).

Indeed, in South Africa, the potential for implementing PES schemes for hydrological services has been investigated in just a few localities (e.g. the upper Thukela and Umzimvubu catchments in the Mnweni/Cathedral Peak and Eastern Cape Drakensberg Areas, and the Baviaanskloof and Tsitsikamma areas; Maloti Drakensberg Transfrontier Project, 2007; Erlank, 2010; Mander *et al.*, 2010, 2017). These two studies succeeded in showing that PES could be feasible on the basis of the costs and benefits involved. However, they have not led to any implementation. Some of the obstacles to the successful implementation of PES in Africa have been identified as insecure land tenure and poorly defined resource rights, absence of willing and able buyers of ecosystem services, weak institutions, high levels of poverty in rural and urban areas

3 Land degradation is often perceived to be the loss of vegetative cover, leading to soil loss, and is particularly concerned with agriculture and food security. In this report we use the term ecosystem degradation to avoid confusion, which includes other forms of degradation such as IAP invasion, pollution and bush encroachment.

4 LDN targets are voluntary targets that parties to the United Nation's Convention to Combat Desertification (UNCCD) have formulated. South Africa went about setting these targets between 2016 and 2018 (Von Maltitz *et al.*, 2019).

5 This unites the world behind a common goal of halting, preventing and reversing the degradation of ecosystems. This includes restoring 350 million ha of degraded landscapes globally by 2030.

6 Also referred to as "payments for environmental services".

limiting understanding and demand for ecosystem services, lack of coordination among public agencies, and legal challenges (Gross-Camp *et al.*, 2012; Lopa *et al.*, 2012; AfDB, 2015).

Meanwhile, research on catchment areas as critical "ecological infrastructure" has further emphasised the need to invest in water source areas throughout the developing world, where these areas are threatened by escalating levels of degradation. There has been considerable interest in finding successful models for financing conservation activities or "**nature-based solutions**" as an efficient solution for improving water security (Box 1.2). However, these also need financing and the scope for private investment based on financial returns is generally found to be extremely limited. Some of the financing options include innovative mechanisms such as corporate social investment (CSI), water bonds, and blended finance models that leverage private investment. While these efforts have gained some ground internationally, they have attracted limited interest in South Africa to date and remain under-utilised.

Box 1.2. Nature-based solutions as defined in this study.

Nature-based solutions are defined here as actions that protect, sustainably manage, or restore natural ecosystems:

- NbS address **societal challenges** such as climate change, human health, food and water security, and disaster risk reduction.
- NbS maintain **ecological integrity**, minimise soil and water loss, and pollution, protecting key hydrological ecosystem services.
- NbS are often more **cost-effective** than engineering solutions, helping to safeguard existing infrastructure investments.
- NbS come with **co-benefits**, such as biodiversity, carbon retention, fisheries and agricultural production, cultural values, etc.

More recently, water funds have emerged in South Africa as a successful model to finance catchment conservation, following their successful implementation in other parts of the world. This funding and governance model uses a business case and strong organisational structure to leverage finance and use it to pay for catchment conservation interventions (TNC, 2018a). Some water funds can be seen as "catchment-orientated PES projects based on a trust fund model" (Goldman-Benner *et al.*, 2012). This model can be seen as an innovative financing initiative that provides an approach for achieving long-term, sustainable financing in contexts where direct cash payments between the beneficiary and service provider might not be possible or where institutional complexities or challenges make strict conditionality impractical or expensive (Goldman-Benner *et al.*, 2012). Water funds have also been termed a "collective action watershed PES", defined by an institution, operating as the intermediary, pools resources from multiple water users (private sector, NGOs, government bodies, international donors) to fund management actions in upstream catchment areas to secure improvements in water quality and supply (Salzman *et al.*, 2018; AECOM, 2020). Their success in Central and South America, and more recently in Africa[7], suggests that this approach (which falls into the broader definition of what a PES scheme represents) could be key to unlocking the barriers that have limited PES development in much of Africa.

Understanding more about these financing options in South Africa can have important, far-reaching impacts on conserving the health of South Africa's catchments, addressing land degradation neutrality, and protecting water security in the long-term through cost-effective, sustainable approaches. Further research is needed to not only fully understand the arrangements, feasibility, institutional challenges and opportunities, and the roles and capacity of relevant institutions within the broader PES/EI context in South Africa, but to understand more about the sustainable mechanisms for financing water catchment restoration, particularly with respect to water pricing for households, and financial incentives that encourage water service providers to invest in ecological infrastructure.

[7] As of 2021, 43 water funds in 13 countries had been created. In Africa, there are two water funds operational; the Upper-Tana Nairobi Water Fund (TNC, 2015) and the Greater Cape Town Water Fund (TNC, 2018a). Business cases for Water Funds in Freetown Sierra Leone, Mombasa Kenya and Tamale Ghana have been undertaken.

1.2 PROJECT OBJECTIVES

The overall aim of this project is to provide strategic guidance for future initiatives to secure hydrological ecosystem services in South Africa, based on an improved understanding of the potential opportunity and viable approaches for investing in hydrological ecosystem services.

The specific objectives are as follows:

1. Review the different types of financing mechanisms for securing hydrological ecosystem services and the institutional, legal, policy and socio-economic factors that have contributed to their success or failure, both internationally and in South Africa;
2. Determine the cost effectiveness of investing in catchment restoration in key water supply areas of South Africa by comparing the costs and benefits associated with invasive alien plant (IAP) clearing to that of planned built infrastructure augmentation projects;
3. Investigate the extent to which further funds could be leveraged from household water users to finance catchment restoration and conservation; and
4. Develop a framework for guiding viable approaches for securing hydrological ecosystem services in different catchments areas.

1.3 SCOPE AND LIMITATIONS

There were five main tasks attached to this two-year project. The first task focused on a review of financing mechanisms for securing catchment hydrological services, both internationally and then investigating the South African experience. This subtask included semi-structured interviews with researchers and organisations that have been directly involved in PES or EI financing projects to obtain further information and insights on their rationale, design, experiences, and lessons learned. Following this a stakeholder workshop was held (Task 2). Both of these tasks fed into Task 3 which focused on investigating the perspectives of the beneficiaries of hydrological ecosystem services. Under this task a viability analysis was undertaken, and contingent valuation methods were used to investigate the extent to which further funds could be leveraged from household water users' willingness to pay in three coastal cities in South Africa to finance catchment conservation. Task 3 was undertaken by two MSc students over an eight-month period. The results from Tasks 1-3 fed into Task 4 which involved the development of a framework decision support tool which was validated at a stakeholder validation workshop (Task 5).

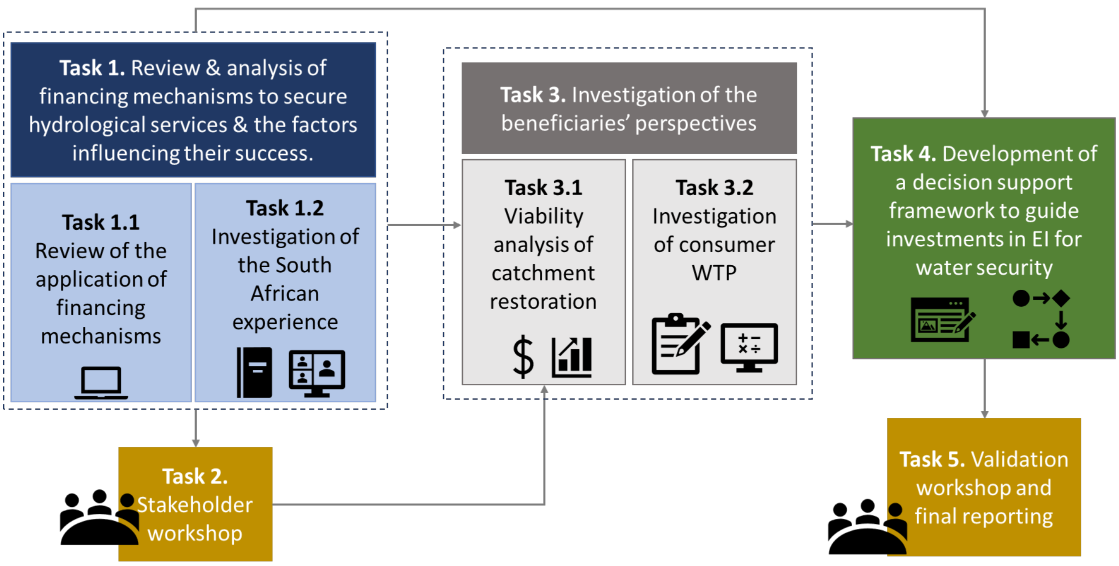


Figure 1.1. An overview of the project tasks.

Originally, the first research project sought a better understanding of the perspectives of water service providers. However, there was insufficient willingness to participate among the dozen institutions (at the water board level) that were contacted, despite following the necessary avenues of communication. This was a major limitation to understanding the lack of participation in EI investments from the institutional side.

1.4 STRUCTURE OF THE REPORT

The remainder of the report is structured as followed:

Chapter 2 provides an overview of strategies to secure hydrological ecosystem services. It includes a detailed review of payments for ecosystem services as a potential win-win solution and reasons as to why it has had limited uptake in Africa. We then review experiences in South Africa and the progress that has been made to date in securing hydrological ecosystem services.

In **Chapter 3**, the cost effectiveness of investing in catchment restoration to secure water supply in the key water supply areas of South Africa over time is determined by comparing the estimated costs and benefits associated with invasive alien plant clearing to that of planned built infrastructure augmentation projects.

Chapter 4 investigates whether there is potential to raise household water tariffs as a sustainable mechanism for financing catchment restoration. The research involved eliciting households' willingness to pay (WTP) for water by undertaking surveys conducted on over 1000 households in three metropolitan municipalities in South Africa. The factors influencing WTP were determined, and it was investigated whether aggregate revenues generated from WTP at the municipal scale could cover the costs needed for catchment conservation.

In **Chapter 5** the research findings presented in Chapters 2-4 were used to develop a decision support framework to guide investments in ecological infrastructure for water security. This is a practical tool to provide high-level guidance on potential opportunity and viable approaches for investing in hydrological ecosystem services in South Africa.

Chapter 6 provides a brief conclusion to the study, with a list of recommendations for future work based on the findings of the research and challenges encountered.

Note that due to the various research components of the project, Chapters 3 and 4 have their own stand-alone literature review, methodology and conclusions that are specific to the objective being addressed in it.

CHAPTER 2: A REVIEW OF STRATEGIES TO SECURE HYDROLOGICAL ECOSYSTEM SERVICES AND EXPERIENCE IN SOUTH AFRICA

Letley, G.K. and Turpie, J.K.

2.1 CATCHMENT DEGRADATION AND ITS DRIVERS

2.1.1 Overview

Natural systems such as forests, grasslands, wetlands and floodplains, have a direct influence on catchment hydrology, contributing towards a clean and reliable supply of water. However, worldwide, the extent and condition of these ecosystems are threatened by increasing levels of degradation. At the extreme, an ecosystem's functioning can be completely lost through irreversible degradation or the intentional conversion to a different land use. When this happens, landscapes lack the functionality and resilience to sustain the delivery of ecosystem services. Not only does this affect livelihoods and quality of life of the people that are reliant on these services but it also increases the costs of water supply (Blignaut *et al.*, 2008). The degradation of ecological infrastructure leads to the need for more traditional grey infrastructure (or the need to fix or maintain existing grey infrastructure more regularly), which comes at a net cost to society (Figure 2.1).

The restoration and protection of these ecosystems is critical to meeting water resources management challenges. Indeed, while investment in built infrastructure is a primary element of achieving water security, even the best-built infrastructure will be unable to supply sufficient water if the integrity of the ecological infrastructure which helps to secure the supply of water of sufficient quantity and quality is compromised. A better adoption of nature-based solutions into conventional infrastructure systems can cost-effectively enhance service delivery while simultaneously ensuring resilience and flexibility (WWAP/UN-Water, 2018; Browder *et al.*, 2019).

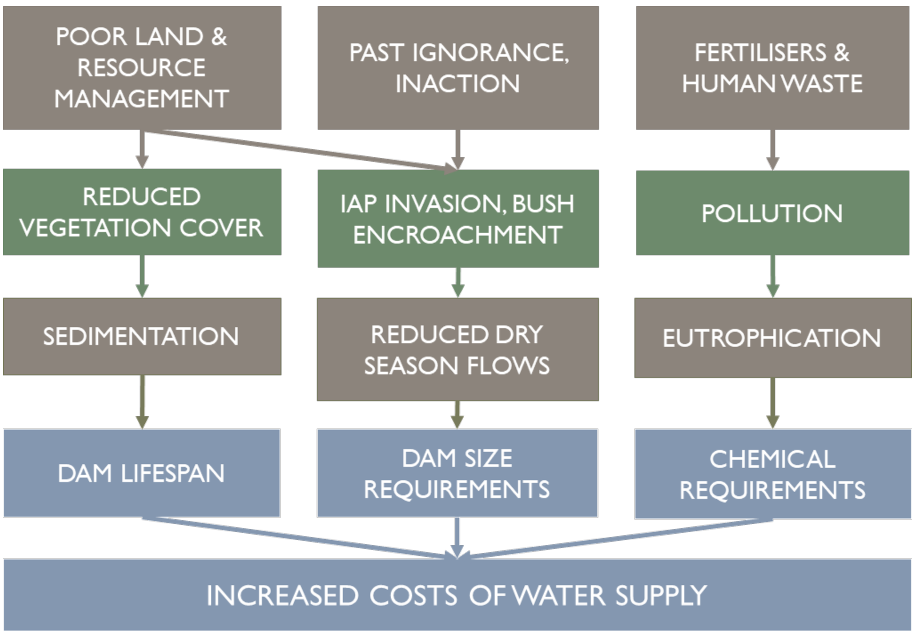


Figure 2.1. The degradation of ecological infrastructure has an impact on grey infrastructure and increases the costs of water supply.

2.1.2 Primary causes of catchment degradation

Ecosystem degradation has been highlighted as one of the major causes of the loss of ecosystem services in South Africa (Turpie *et al.*, 2021b), and is mainly in the form of:

- The spread of invasive alien plants;
- Loss of vegetation and soil cover in agricultural lands (land degradation), as a result of poor management practices;
- Bush encroachment (increases in woody vegetation) in grassland and savannas as a result of poor grazing and fire management practices; and
- Pollution from wastewater treatment outputs and agricultural activities.

2.1.2.1 Invasive alien plants

IAPs are considered to be one of the biggest drivers of land degradation in the country (Von Maltitz *et al.*, 2019). While some IAPs are relatively benign, certain species, once established, can have a significant negative impact on ecosystem functioning. Streamflow reduction is one of the most serious impacts. In South Africa, IAPs include a suite of species such as gums *Eucalyptus spp*., Australian wattles *Acacia spp*. and pines *Pinus spp.* that tend to spread from existing plantations or stands and invade water courses, affecting water flows and reducing ecosystem functioning (Richardson & Van Wilgen, 2004). Other species are known to have impacts on a range of ecosystem services and habitats. In South Africa, IAPs are estimated to reduce water flows by some 1444 million m^3 per year or 2.9% of the naturalised mean annual runoff (Le Maitre *et al.*, 2016). This could rise to 16% if left unmanaged (Van Wilgen & Wilson, 2018). The impacts of IAPs also include diminished agricultural productivity with impacts on both livestock and crops, with total losses in South Africa estimated to be in the billions of Rands (Poona, 2008).

2.1.2.2 Loss of vegetative cover and elevated erosion

The loss of vegetative cover involves the removal of the biological productivity of the topsoil and is caused by human activities, exacerbated by poverty and a changing climate. Agricultural practices are a significant cause of soil loss and erosion in most catchments across the country. Soil erosion is mainly linked to poor grazing management, poor crop management and the abandonment of agricultural fields. The erosion of fertile soil has widescale implications for food security, as well as for water infrastructure (e.g. sedimentation of reservoirs) and the costs of water treatment. Farming in riparian zones and unregulated sand mining along rivers is widespread and particularly problematic for increasing sediment export to watercourses. The combined effects of degraded agricultural lands, overgrazing, riverbank degradation and deforestation are the loss of vegetative cover in the landscape, which exposes soil to erosion.

2.1.2.3 Bush encroachment

Bush encroachment involves the increase and spread in the abundance of a single or few dominant indigenous woody vegetation species, particularly in the grassland and savanna biomes. In South Africa, where these biomes make up 27.9% and 32.5% of the land surface area, respectively, there has been a significant increase in tree cover since national-scale aerial photography was first undertaken in the 1940s. Bush encroachment occurs as a result of poor land management practices, mainly overgrazing and an active reduction in the intensity or frequency of fires, and is also facilitated by increased carbon in the atmosphere (Rohde *et al.*, 2006; Turpie *et al.*, 2019a). It may also be due to historical reductions in megaherbivores which play an important ecological role through browsing and damaging trees (Russell & Ward, 2016; Norris *et al.*, 2020), which are now exclusively restricted to protected areas and game ranches. Bush encroachment is distinct from alien invasions in that it is largely a result of *in situ* management actions, unlike in the case of invasive alien plants which spread onto land as a result of past introductions elsewhere in the landscape. Bush encroachment changes the structure and composition of ecosystems. It impacts on biodiversity and ecosystem functioning, and hence the supply of ecosystem services. It reduces commercial and communal rangeland productivity, since grassy biomass is reduced, and may lead to further damage from overgrazing in a negative feedback as suitable grazing areas shrink. It changes the availability of woody and non-woody resources in the landscape (Russell & Ward, 2016; Turpie *et al.*, 2019a), and aboveground carbon sequestration (Ward, 2005). It can affect soil infiltration rates, groundwater recharge and surface runoff.

2.1.2.4 Pollution

South Africa's freshwater resources are becoming increasingly polluted and turbid, and in many cases are considered to be moderately to highly eutrophic (Oberholster & Ashton, 2008; Van Ginkel, 2011). Increasing anthropogenic activity in water supply catchment areas leads to increasing levels of pathogens and nutrients, which come from wastewater treatment outputs and particularly from under-serviced human settlements, industrial discharge points (e.g. factories) and urban infrastructure; and pesticides and fertilizers from agricultural activities, resulting in increased phytoplankton growth, particularly in slower flowing rivers and in reservoirs. This often leads to eutrophication and toxic algal blooms which leads to higher water treatment costs.

2.1.3 Ultimate causes of catchment degradation

Environmental degradation is often a result of market failure (Box 2.1). Ecosystems deliver considerable benefits in the form of goods and services, but these tend to be undervalued or unvalued in day-to-day decision making, i.e. there are no markets or incomplete markets for environmental goods and services (OECD, 2019), and therefore the supply of these goods and services is not rewarded.

Box 2.1. Examples of environmental market failures. Source: National Treasury, 2006

Externalities: or external effects arise when certain costs and benefits are not included in market prices. Negative externalities can lead to too much of a good or service being supplied whereas positive externalities can lead to under production.

Unpriced assets or missing markets: For many environmental goods and services, markets are often missing or are incomplete. This creates limited incentives for individuals, firms or industries to incur costs to protect and maintain such resources.

Public goods: A public good has two distinguishing qualities: it is non-rival and non-excludible. Non-rival means that one individual's consumption of the good does not reduce another's ability to consume the good. Non-excludible means that it is impossible to prevent individuals from benefiting from the provision of the good or service. Such properties mean that there are no incentives for these goods to be provided by private firms. Therefore, these services are either provided by government directly or on behalf of government. Examples include defence, air quality, biological diversity and public conservation areas.

Undefined or unenforceable property rights: Clearly defined and enforceable property rights are an essential criterion for ensuring that markets exist and are able to function effectively. In their absence, a situation of open access can arise whereby individuals impose incremental costs on other users of a resource that can lead to degradation and over-exploitation. By establishing clear and enforceable property rights for individuals or groups of users, over-exploitation or degradation can be avoided.

Information and uncertainty: A lack of information and uncertainty can prevent a clear and accurate understanding of environmental and natural processes. Incomplete information can lead to economic activities that do not take full account of social costs and benefits. Better information can greatly improve decision-making and may assist in internalising environmental externalities.

Irreversibility: is largely an information problem and concerns uncertainty about possible future development options. It is often difficult to take account of the value future generations may place on certain environmental resources.

Most ecosystem services are not priced in the market because they are public goods (Box 2.1). Therefore, because their markets are incomplete or missing, there is no way to equate the benefits and costs associated with these goods and services either in the present or in the future (Slingenberg *et al.*, 2009; OECD, 2019). The ecosystem goods that are priced, for example, food and timber provision, are usually distorted by price controls and subsidies. Furthermore, the presence of externalities (consequences that no one pays for), or a lack of property rights means that landowners or land managers make decisions that maximise their own profits but do not bear the costs of environmental degradation (Box 2.1). This failure to adequately account for the full economic value of biodiversity and ecosystem services is one of the main factors contributing to their degradation and loss (Slingenberg *et al.*, 2009).

This is a reflection of government/policy failure as ecosystem goods and services are not factored into decision and policy making. This is further hampered by a lack of resources to adequately address the problem. Policy makers are able to correct for these inefficiencies by implementing a number of policy instruments (see section 2.2.2) with the goal of providing incentives or rewards to individuals/landowners/firms to change their behaviour to ensure an efficient level of environmental quality (OECD, 2019).

2.2 AN OVERVIEW OF NBS, POLICY AND FINANCING MECHANISMS TO SECURE HYDROLOGICAL ECOSYSTEM SERVICES

2.2.1 Nature-based solutions

2.2.1.1 Overview

Nature-based solutions[8] are essential to strategies for achieving water security. They are also critical for addressing the dual challenge of biodiversity loss and climate change. Such measures are often more cost-effective than traditional engineering solutions, such as the augmentation and upgrading of water supply infrastructure and have the added advantage of a range of co-benefits associated with having healthier ecosystems. Nature-based solutions contribute to biodiversity conservation, can help reduce disaster risk, improve health and livelihoods, and can help countries meet their international climate change mitigation goals.

Nature-based solutions are used to restore, maintain, and enhance the flow of ecosystem services from water source areas. To achieve such outcomes, requires thinking about what management actions should take place and then determining how the changes could be brought about. In this section of the report, the potential solutions that could be used to address catchment degradation are first described and then the potential policy measures used to achieve these are reviewed.

2.2.1.2 Nature-based solutions to address catchment degradation

Catchment management interventions are needed to rectify market failures for the public good. These aim to restore and maintain ecosystem services to save on engineering costs. Interventions to address water security focus on maintaining land cover and minimising erosion and pollution, as well as water conservation. These nature-based solutions can be broadly divided into active restoration or conservation measures, with the latter being through sustainable land/resource management practices or through outright protection (Figure 2.2). If there is severe damage or if the area is infested with IAPs, then active restoration is required. Otherwise, one can reverse degradation and achieve recovery through better land management and protection. If active restoration is undertaken, then it is usually followed by conservation measures.

[8] Nature-based solutions are defined in this study as actions that protect, sustainably manage, or restore natural ecosystems and in doing so help to address societal challenges such as climate change, human health, food and water security, and disaster risk reduction (based on WWF, World Bank, IUCN).

Active restoration or rehabilitation interventions include IAP clearing, tree planting or reseeding in areas that have been deforested or denuded, de-bushing woody vegetation, undertaking stabilisation work and fixing dongas, and rehabilitating wetlands. Conservation measures can range from sustainable use of land and living resources, to outright protection (Figure 2.2). Sustainable use is focused on maintaining a flow of provisioning services, but without excessive compromise of regulating and cultural services. This can be done at reasonably low cost compared to restoration and outright protection. Outright protection (protected areas) will afford the highest level of regulating and cultural services but tends to be costly.

Sustainable land and resource management interventions aim to reduce soil loss on agricultural land and may include reduced tillage, maintaining soil organic cover by planting cover crops, contour ploughing and terracing to reduce soil loss on slopes, and agroforestry and farmer managed natural regeneration to include and restore trees in and around agricultural fields. Although some of the water towers are securely protected within state land, a large proportion of our catchment areas in South Africa are on private or communal land. Within rural areas, land degradation has been greatest on communal land, whereas pollution tends to be a bigger problem on private land. Invasive alien plants are a problem everywhere. In general, the prevention of degradation through sustainable land management or protection is less costly than active restoration or rehabilitation (i.e. prevention is better than a cure).

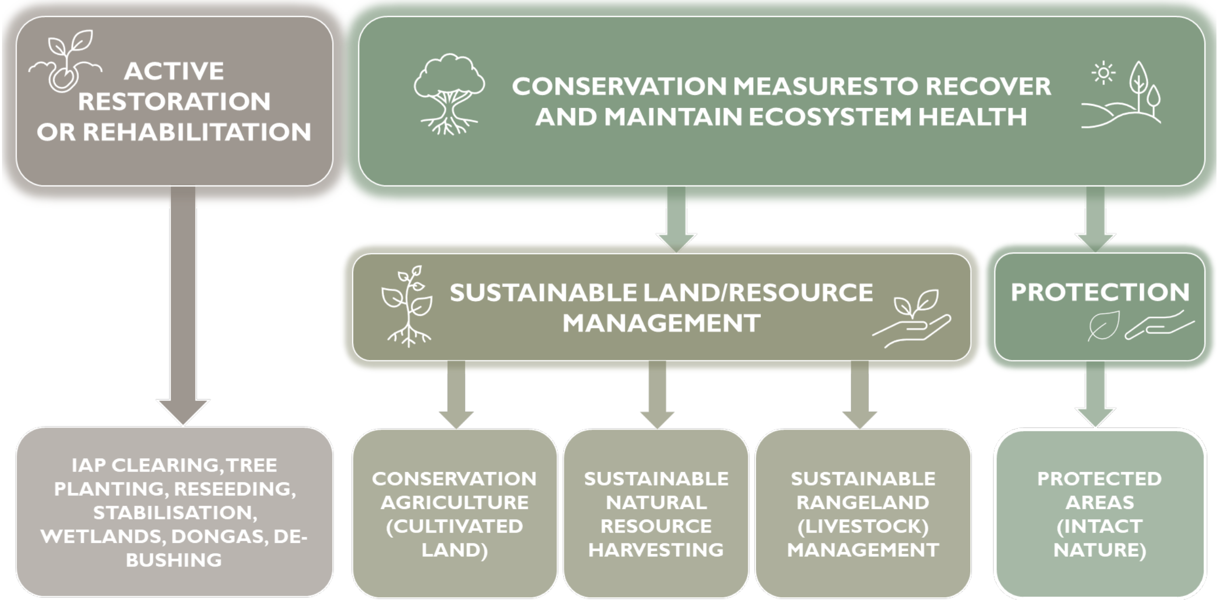


Figure 2.2. Typology of nature-based solutions used to address catchment degradation. Source: based on Turpie *et al.*, 2022.

Protection is appropriate for areas of critical importance for ecosystem services, with riparian areas, steep mountain areas and high rainfall areas being good examples of the latter in the context of water security. If degradation has proceeded to the point where active restoration is required, then typically landowners or managers are not going to be able to afford it as it requires significant upfront capital. Such interventions are usually implemented on a large scale, requiring substantial inputs in the form of equipment and labour. This would need to be paid for by those downstream beneficiaries who value the ecosystem services enough. However, in South Africa active restoration is generally financed through public sector budgets. In the case of sustainable land/resource management measures which aim to prevent degradation, actors can be incentivised to change their behaviour through a number of environmental policy instruments.

2.2.2 Policy instruments to bring about nature-based solutions

2.2.2.1 Overview

The ongoing degradation of catchment areas needs to be addressed through policy instruments aimed at correcting these market failures. Government can play an important role in encouraging more efficient use of land and resources by intervening and influencing the institutions that determine how markets operate (National Treasury, 2006). This can be achieved through a suite of policy measures – broadly categorised as regulation, incentives (non-monetary and financial) or buyouts (Figure 2.3). These are highly context specific and are often used in combination.

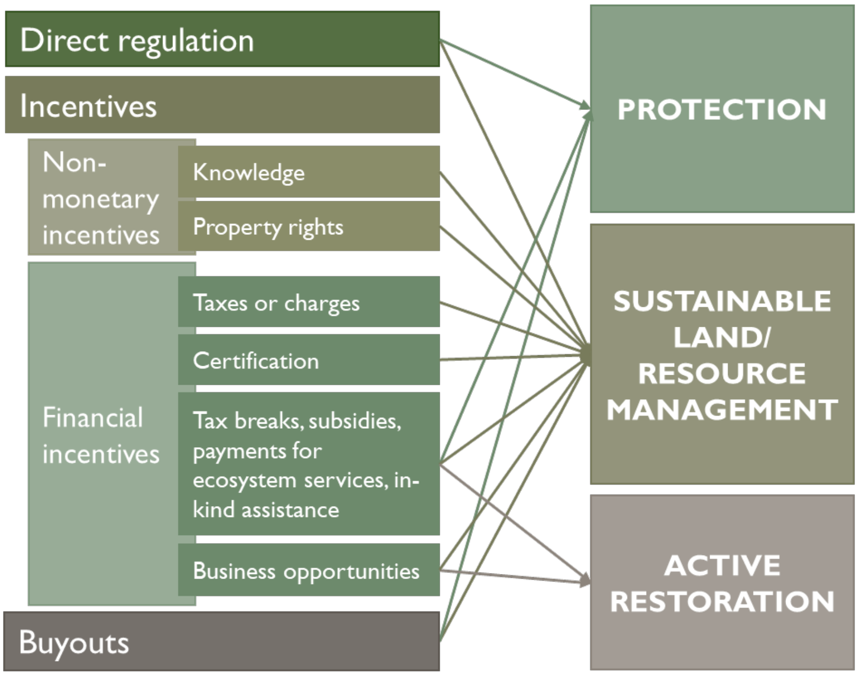


Figure 2.3. A summary of environmental policy instruments used to bring about nature-based solutions.

2.2.2.2 Addressing protection and active restoration

Formal protection and active restoration are typically costly to implement. As a result, there are relatively few policy measures available to achieve such outcomes. Environmental **regulation** is an important deterrent to degradation and can prevent the worst excesses (McManus, 2009). However, it can impose excessive costs on landowners and businesses. Where catchment degradation is severe, it becomes too costly to actively restore, so that even direct regulation will not bring about action as landowners are not able to afford it. This has been the case in South Africa with IAPs where farmers are unable to control the problem on their land as the damage is too far gone and too costly to restore. The National Environmental Management Biodiversity Act (NEMBA) (Act 10 of 2004) – Alien and Invasive Species regulations (2020) lists IAPs which, if present on your property, must be actively combatted and eradicated. Regulation in this regard is also considered unjust as farmers were not responsible for the invasions in the first place (Turpie & Heydenrych, 2000). Similarly, monetary incentives such as **taxes and charges**, are not only unlikely to cover the full cost but are also unpopular. In most cases the only option is to pay specialist teams to undertake the restoration, such as through the government funded Natural Resource Management “Working for” programmes. However, there is the possibility that restoration could be incentivised through the development of business opportunities in the form of bankable projects (Figure 2.3). For example, woody invasive plants could be used to produce charcoal. Such projects can help to defray costs.

Restoration of degraded grasslands through reseeding, fixing of dongas and wetland rehabilitation is also extremely costly and although millions has been spent to date in South Africa, there has not been much success (Turpie *et al.*, 2021b). This is because reseeding and active rehabilitation is pointless without protection thereafter, which is usually difficult to achieve in the communal land areas in which it has been carried out.

Protection can also be costly where the opportunity costs (i.e. forgone benefits from alternative land uses) are high (Schneider *et al.*, 2011). Where they are not so high, protection can be incentivised through tax breaks, subsidies, in kind assistance or payments, or some combination of these (Figure 2.3). Indeed, tax rebates have encouraged private conservation in South Africa, particularly through the Biodiversity Stewardship Programme. With this approach, private (and to a lesser extent, communal) landowners enter into agreements to protect and manage land in biodiversity priority areas in South Africa, led by conservation authorities and supported by NGOs (SANBI, 2015). There are five different levels of biodiversity stewardship agreements, ranging from non-binding to long-term formally declared protected areas called Nature Reserves (SANBI, 2015). The higher the level of commitment by the landowner, the more extensive the support from government. Fiscal incentives apply to those portions of Nature Reserves that are used solely for conservation, which are excluded from being charged property rates, and income tax deductions for management expenses are available for Nature Reserves, Protected Environments and Biodiversity Management Agreements (SANBI, 2015).

Regulation can also bring about protection. For example, where cultivation or forestry setbacks are imposed along rivers and streams. If incentives and regulation are not viable options then buyouts, in the form of land acquisition and compensation could be considered. This, however, is an expensive option. Therefore, paying for active restoration and buying out land for protection needs to be considered in areas where other measures will not be effective in securing ecosystem services, and where this will have a significant cost to society as a whole.

2.2.2.3 Addressing sustainable land/resource management

There is a larger set of policy options available for achieving sustainable land/resource management (Figure 2.3). Although costly, regulation does exist for the management of certain species, and for some farming inputs and methods.

Non-monetary incentives provide reward through non-monetary means, such as **recognition**, or through **extension services** which provide information and management advice. Here knowledge and advice can make a big difference, so extension services are potentially highly valuable when they are implemented effectively. In South Africa, “Herding 4 Health” (H4H) is an example of a programmes that focus on community development activity in rural areas by promoting conservation outcomes through a holistic environmental approach that supports improved rangeland management techniques. The H4H model addresses four key areas: rangelands, animals, people, and policy. Through the use of skilled herders, or eco-rangers, the programme aims to “reduce wildlife-livestock conflict and to manage livestock and rangelands for the rehabilitation of water catchments while at the same time unlocking livelihood opportunities” (Frazee & Myburgh, 2018). Eco-rangers are employed to be custodians at the local level and are trained as communicators, record keepers, trackers, cattle health assessors and vegetation surveyors (Stanway, 2016). Following successful H4H pilot projects across southern Africa, and with a specific focus on Transfrontier Conservation Areas (TFCA), Conservation International (CI) and Peace Parks Foundation are now aligning efforts to transform livestock production for communities and conservation within seven transfrontier conservation landscapes across southern Africa (Frazee & Myburgh, 2018). Their ambitious target is to deploy the successful H4H model to restore and conserve at least one million hectares of rangelands through improved livestock management by more than 15 000 farmers.

Associated with H4H, as a primary market partner, is the social enterprise Meat Naturally Pty[9] which provides livestock production support and market access via mobile auctions and abattoirs. Meat Naturally Pty was established in 2016 by Conservation South Africa (CSA), and through programmes such as H4H, the business helps community livestock owners to access the grass-fed red meat market auctions as they now have a sustainable and traceable supply of animals (Stanway, 2016; Mbatha, 2021). Since its origination the business has facilitated livestock sales for more than 1500 farmers on more than 320 000 hectares of high biodiversity rangeland in South Africa (Frazee & Myburgh, 2018).

Property rights can be a major incentive for addressing rangeland degradation. Over the last couple of decades, landowners have been granted the rights to the utilization of wildlife on their land which has incentivized a change to wildlife-based land uses in Namibia and South Africa on both communal and private land (Taylor, Lindsey & Davies-Mostert, 2015). Other methods have been implemented in communal rangelands, for example, granting individuals or groups exclusive rights to the use of defined areas of grazing land. This can be successful at the right scale, but compromises adaptability (i.e. transhumance[10], for example in the Maloti-Drakensberg and southern Drakensberg areas), and can go wrong if land is too subdivided, as has happened in Kenya through sub-division of group ranches and land privatization (Løvschal *et al.*, 2017; Løvschal, Håkonsson & Amoke, 2019). Others have opted for a tradable grazing rights system, which is an optimal approach in that it caps the number of livestock in a grazing area, for example in Enonkishu Conservancy in Kenya where the conservancy limited the number of livestock each household could keep on conservancy land (Coldrey & Turpie, 2019).

Financial, or market-based instruments, are instruments that use markets or price mechanisms to create the incentive. These are taxes or user charges to reduce damaging activities, certification, subsidies or tax rebates to encourage conservation, and payments (e.g. payments for ecosystem services) to reduce damaging activities. Taxes or charges are unpopular mechanisms and are usually met with stakeholder resistance, even though they can be particularly effective. Examples of this include charges levied per unit of polluting output or a grazing tax. The difference between taxes and charges is that the former is a state fiscal instrument, whereas the latter could be imposed by local institutions or organisations. In the latter case, these fees are typically paid into a fund that addresses the environmental problem. Taxes and charges are relatively easy to implement, are often effective, and are also a source of revenue (OECD, 2011). Some effort is needed to establish the right level of taxation, since it is difficult to predict the actual response, and taxes must be constantly updated, otherwise they are vulnerable to decreased effectiveness through inflation (OECD, 2011).
Certification is a mechanism which indicates that certain standards have been met in a production system. This is a non-government, market-based approach to incentivise sustainable and ethical production and business practices (Komives & Jackson, 2014). Certification is carried out to provide assurance that the standard(s) in a particular system have been met. This is usually accompanied by the right to mark products with the associated label (or “ecolabel”). The system is voluntary in that producers can choose whether to meet the standards and be certified accordingly. The system as a whole is often referred to as “standards and certification” or simply “certification” (Komives & Jackson, 2014). Common economic benefits of certification schemes include higher prices, improved access to markets and associated business opportunities, reduced vulnerability to environmental change, or other measures of net wellbeing (Barry *et al.*, 2012; Potts *et al.*, 2014). In order to meet certification requirements producers invest in new technologies or change practices to ensure they are environmentally responsible. Expensive certification processes and the absence of price premiums have been found to discourage certification in some areas (Blackman & Naranjo, 2012). Furthermore, a number of certification schemes require environmental management practices that reduce yield but in some cases the cost savings or premium earned might not cover that loss in yield (Barry *et al.*, 2012). However, in many instances certification has provided producers with higher net revenues, better prices for their products and new business opportunities. Indeed, new business opportunities and the associated stable

[9] https://www.meatnaturallyafrica.com/

[10] The action or practice of moving livestock from one grazing area to another in a seasonal cycle, typically to lowlands in winter and highlands in summer.

and secure market access associated with certification is often the primary benefit to producers of joining such a scheme (Barry *et al.*, 2012). In South Africa, such initiatives can be costly as they require assistance with meeting certification conditions and verification. As such, these initiatives are usually NGO-financed.

"Fair Game – Wildlife Friendly Products" is a local South African meat and animal fibre certification with a specific focus on the conservation of biodiversity patterns and processes of predation on productive agricultural landscapes. The Fair Game initiative was developed by Landmark Foundation[11] and includes an ecological management plan, non-lethal predator management, and advocates reduced stocking rates. Products certified potentially include wildlife-friendly veld-raised meats, animal fibre products and other biodiversity resources and harvested products. There is a lack of information about the uptake of this initiate in South Africa and it is unclear how successful certification has been at improving predator and/or rangeland management practices on livestock farms.

Payments for ecosystem services (PES) has been a popular incentive mechanism implemented across the globe for securing hydrological services. It has been hailed globally in that in addition to the environmental gains, it can also promote social development which is important for attracting public sector and donor funding. PES schemes remunerate landowners or ecosystem managers for the provision of ecosystem services (Wunder *et al.*, 2020). Essentially, service users (i.e. beneficiaries) make payments to service providers through voluntary transactions in order to generate offsite benefits (Wunder, 2005). Payments can either be input-based (made on the basis of certain land or resource management practices that are being implemented, as a proxy for ecosystem service provision) or output-based (made on the basis of actual ecosystem service delivery proven by a third-party verifier). Output based payments are more difficult to implement. Payments could be monetary or non-monetary transfers, from the private sector, government and/or international donors. The payments are usually brokered by an intermediary body who is essentially the "institutional home" for the PES scheme. Conditionality[12] of payment is also key. Payments for hydrological ecosystem services are potentially viable as long as the payment that is made exceeds the service providers' opportunity cost for their change of behaviour or policy. PES and its implementation in Africa is reviewed in more detail in section 2.3.

If rangeland management does not improve through regulation or incentive-based measures, then government can consider **formal buyouts** to reduce the number of livestock. This could involve either buying out farmers or moving their operations. However, this can be a complicated and costly intervention.

In conclusion, there are a wide array of environmental policy instruments that can be used to bring about restoration and conservation. However, when degradation is extensive and severe then there are few, if any, instruments that will work to fix the problem. In such situations, funding active restoration (i.e. employing labour to undertake restoration) becomes the only viable option. Therefore, most restoration programmes in South Africa have to look at some **combination** of costly active restoration and incentives to motivate land managers to bring about conservation and sustainable land use practices.

2.2.3 Financing catchment restoration and conservation

2.2.3.1 Sources of funding for securing catchment services

There are a number of existing and potential sources of funding for financing catchment restoration and conservation. In South Africa, the restoration and conservation of catchment areas should ideally be funded through state budgets for the benefit of society. Indeed, funding for catchment restoration in South Africa is

[11] https://www.landmarkfoundation.org.za/fair-game/

[12] The payment to a land owner/service provider is contingent on evidence that their land use has delivered an environmental service, or that the land owner has pursued land use practices believed to provide the environmental service (Wunder, 2005).

largely through the Department of Forestry, Fisheries and the Environment's Natural Resource Management Programmes which spend about R2 billion per year on funding catchment restoration (Coldrey, 2020). This is generally the case across the globe, where international and domestic public finance has been, and continues to be, the largest funding source for biodiversity (Tobin-de la Puente & Mitchell, 2021). However, state budgets for restoration of EI and conservation in South Africa are heavily constrained and largely insufficient and have been declining over recent years. It has been reported that six times as much funding is needed than what is currently being received, if natural resource management and investment in EI in South Africa is to be fully effective (Shackleton *et al.*, 2017). It has been estimated that about R270 million is needed for the uMngeni River catchment (Pringle *et al.*, 2015) and about R370 million is needed for important water source catchments in the greater Cape Town region (TNC, 2018a).

However, there is potential to secure funding from other domestic sources through payments for ecosystem services (e.g. from the water sector through bulk water service providers) or through offsets, and from domestic and international donors, philanthropists and conservation NGOs. Private sector funding can also be leveraged by government by issuing bonds or by supporting the development of viable enterprises relating to restoration and conservation. Many of the partnership initiatives have been exploring these financing options, but they remain in their infancy in South Africa.

Indeed, institutional (or commercial) investors have been recognised as an important potential funding source. These include asset managers, banks, insurance companies, and hedge funds, who pool their capital investing it in a number of different asset classes, such as equities and bonds, with the intention of generating a financial return on investment (Coldrey, 2020). The estimated financial returns that can be generated from EI interventions in South Africa are likely to be lower than the financial returns required by institutional investors (Cartwright, McKenzie & Cartwright, 2015). However, certain investors, such as impact investors, are willing to receive a lower financial rate of return in return for a positive social or environmental impact generated from the investment (Coldrey, 2020). Furthermore, institutional investors are increasingly being compelled to invest responsibly through global initiatives like the Principles for Responsible Investment (PRI) and Environmental, Social and Governance (ESG) investing (O'Connell & Connors, 2019; Trinomics and IUCN., 2019).

2.2.3.2 Barriers to investment

A number of barriers to investment were identified through the interview and literature review process. The most important and most commonly addressed constraints that limit investment in restoration of ecological infrastructure are described below.

1. The public good nature of ecosystem goods and services

Securing finances over the long term for hydrological ecosystem services is challenging because of the public good nature of the benefits that accrue from the interventions (see section 2.1.3). Because most restoration benefits take the form of public goods and services, public funding has been the major source of funds to finance restoration in South Africa. The private sector underinvests in these assets because they cannot control them, or control who benefits from them.

2. Lack of appropriate compensation and financial returns on restoration

Creating new sources of revenue from project developments is one of the requests of many new funders/investors. The projects and their goals are long-term, with many long-term benefits such as improved water quality and quantity and productive land, among others. Many of these benefits do not translate into direct monetary benefits or financial returns in the short term but guarantee a future of economic productivity. However, this is not typically attractive to private investors.

3. Lack of financial coordination and disbursement

A lack of institutional capacity and organisation at the catchment level makes it very difficult to receive, coordinate and disburse funds for investment. Currently, funding is usually directed through a number of state-run projects via government departments, NGOs or other parties (Pringle *et al.*, 2015). This is usually undertaken in a very uncoordinated and inefficient manner. A more focused coordination of government departments and stakeholders at the catchment level would generate better results, as has been the case through catchment partnerships, e.g. UEIP, uWASP, UCPP and GCTWF.

4. Low willingness to pay of beneficiaries

Beneficiaries of catchment restoration for water security in South Africa include large industrial users, municipal water suppliers and irrigation water users. However, investing in catchment management is not an obvious priority for these beneficiaries (Ferraro, 2007), particularly for municipal water suppliers, who are generally plagued with low revenues, financial mismanagement, high levels of unaccounted-for water and unpaid bills, weak capacity, and a lack of knowledge of the importance and benefits of natural capital.

Furthermore, in most cases the catchments are serviced by different municipalities to the downstream receiving municipality which usually lacks the mandate for funding activities outside of their spatial boundaries. However, this is not to say that it is not possible. The City of Cape Town as part of the Greater Cape Town Water Fund provided the first investment (of about R62 million) by a city in South Africa to fund active restoration of mountain catchments outside of its spatial boundary[13] to ensure security of supply for the city.

5. High costs

High costs are often listed as a barrier to investment with some projects or interventions viewed as being too expensive to be worthwhile. Indeed, active restoration and sustainable land management are costly, particularly when degradation is severe. For example, considerable, sustained investment is required to achieve restoration in the Thukela catchment, with clearing IAPs, sustainable land management and active restoration of grasslands estimated to cost in the region of R9 billion (in present value terms, over 25 years; (Turpie *et al.*, 2021b). Average rehabilitation costs in the uMngeni catchment are estimated to be as high as R14 500 per hectare for clearing dense stands of IAPs and R8000 per ha for rehabilitating severely degraded grasslands (Jewitt *et al.*, 2020), with total costs in present value terms for rehabilitation and maintenance of EI amounting to R2.7 billion for priority catchments (Pringle *et al.*, 2015). In the case of payments for ecosystem services, high transaction costs[14] are frequently listed as a barrier to participation, particularly in Africa (Ferraro, 2007; Wunder, 2015; Wunder *et al.*, 2018).

6. Difficulty in obtaining legal or property rights

Land tenure can be a major obstacle to securing funding or ensuring long-term sustainability of a project or investment. Complicated or insecure land tenure can undermine the uptake of sustainable land use practices. For example, in communal agricultural land, soil conservation measures can be time consuming and labour-intensive to build or implement, and other interventions such as agroforestry, for example, may take years for benefits to be realised. The lack of secure individual land tenure could be a serious disincentive to adoption of sustainable land practices. The incentive to invest in such measures is likely to be reduced where long-term ownership of land is not assured or where it is possible to simply move to a new piece of land.

7. Poor information and communication

In many cases, baseline data is either missing, extremely limited or very costly and time consuming to generate. These data are important for creating a convincing business case argument for the investment in

13 Information provided by Louise Stafford, Director of Source Water Protection for South Africa at The Nature Conservancy (TNC) during an interview on 12 August 2021.

14 Transaction costs include administrative costs, bargaining costs, and monitoring and enforcement costs

catchment restoration or SLM, for identifying bankable projects, or for informing ongoing investments. Communication of the importance of ecological infrastructure and the role it plays in water security is generally lacking.

2.2.3.3 *Bridging the investment gap with user fees and charges*

Government can impose mandatory payments to the private sector through legislation. These mandatory payments can come in the form of user fees and charges which are used to capture some of the consumer and producer surplus generated through the distortion in prices that arises out of externalities not being internalised. For example, water prices do not reflect the value of water, and do not even cover all the costs of its supply, which includes catchment management and the active clearing of IAPs. Therefore, water pricing is a powerful mechanism with which to capture consumer surplus to pay for catchment restoration and conservation.

Government authorities are faced with the decision of how much to invest in securing water supply as well as how to price water in order to achieve sustainable levels of use at the household level. This requires some knowledge of societal preferences and potential welfare outcomes. In Cape Town, for example, a tiered pricing system[15] is used which capitalises on wealthier households' higher willingness to pay for water and allows for the supply of free water to the poorest households (Turpie & Letley, *in review*). However, price levels have been relatively low, and have not been effectively used for demand management.

A survey undertaken in Cape Town in 2017 found that residents were willing to pay significantly more for water in order to avoid water shortages in the future (Turpie & Letley, *in review*). The overall willingness to pay for secure water supply under non-drought conditions amounted to some R2.8 billion per year, which was about 90% higher than pre-drought revenues. In addition, residents were willing to pay a further R0.5 billion per annum to fund water supply alternatives that would avoid damages to aquatic ecosystems in the already-stressed dam catchments (Turpie & Letley, *in review*). The results suggest that Cape Town should consider alternative options, such as catchment restoration, in order to augment water supplies. Capturing some of the untapped WTP could raise enough revenues both to ensure the security of water supply and safeguard the aquatic biodiversity of the region's freshwater and estuarine ecosystems.

More surveys assessing household willingness to pay are needed in other parts of the country to get a better understanding of the potential for raising revenues from end users and how water tariff pricing for households can be used as a mechanism for securing funds for catchment restoration. Furthermore, a better understanding of what factors affect the participation or investment by beneficiaries (e.g. bulk water service providers) in funding catchment restoration and management is needed.

2.2.3.4 *Bridging the investment gap by leveraging private capital investment*

The contribution of the private sector to the restoration and conservation of water catchment areas in South Africa has to date been relatively small. Of the many partnerships and projects that have been initiated across the country, relatively few have been able to attract significant private sector investment. Yet there is potential. Private funding is typically leveraged through green financial products, such as green bonds, green lending and green equity, which usually come with tax incentives to enhance their attractiveness to investors. Green insurance involves investment in preventative action, such as restoration of EI or removal of IAPs, to reduce disaster risk, such as flooding or fire risk, in order to avoid future expenditures. These are discussed below.

[15] A tiered pricing system charges low rates for use below some threshold level and rapidly increasing rates above the threshold and is used to raise revenues without placing a heavy burden on poorer residents.

Green financial products, which are debt and equity financial products and services, include green bonds, green equity and green loans. Green bonds are a fixed-income instrument specifically earmarked to raise money for climate and environmental projects (Trinomics and IUCN., 2019). They are intended to encourage sustainability by financing projects that are aimed at energy efficiency, pollution prevention, sustainable agriculture, fishery and forestry, the protection of aquatic and terrestrial ecosystems, clean transportation, clean water, and sustainable water management.

Green bonds may come with tax incentives to enhance their attractiveness to investors. The bond issuer (debtor) borrows a fixed amount of capital from investors (creditors) over a defined period of time (the maturity of the bond), repays the capital when the bond matures, and pays an agreed-upon fixed amount of interest during that period (Trinomics and IUCN., 2019). Green bonds are bonds issued by institutions to achieve double or triple bottom line – they promise positive returns, while also guaranteeing that the supported projects provide social and environmental benefits. Some of these green bonds are guaranteed by large intergovernmental organisations so that even if the project supported by the bond should fail, investors will be fully reimbursed by the guarantor.

According to the Climate Bonds Initiative[16], the total annual issuance of green bonds in 2020 was worth about US$297 million with a cumulative issuance of US$1.05 trillion since 2015. As of December 2020, there were just eight African countries with green bonds, and South Africa had the second highest cumulative value (R2.6 billion) after Kenya (Figure 2.4). As a percentage of world total, in 2020, majority of green bond proceeds were used for energy, buildings and transport, with just 7% being used for water (Figure 2.4).

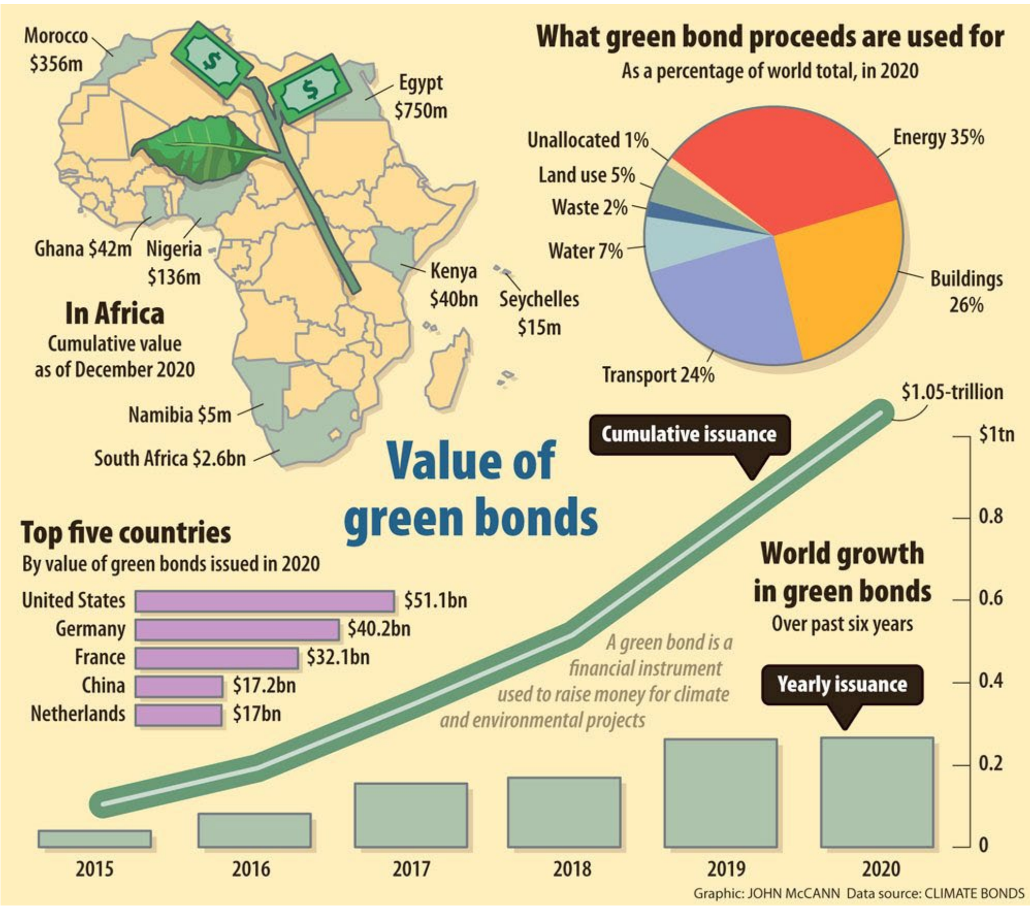


Figure 2.4. The value of green bonds, world growth in green bonds and what green bond proceeds are used for. Source: Climate Bonds, from https://mg.co.za/business/2021-02-20-amid-the-pandemic-green-bonds-are-becoming-trendy/.

[16] https://www.climatebonds.net/

While green bonds have been around for over a decade now, it has only been four years since South Africa launched these types of bonds[17]. However, more than ever before, green bonds are growing as investors look for environmentally friendly projects. In March 2020, the International Finance Corporation (IFC), a member of the World Bank Group, invested US$200 million in the Standard Bank of South Africa Limited's green bond placed on the London Stock Exchange. At the time it was Africa's largest green bond and South Africa's first offshore green bond issuance[18]. The 10-year green bond facility will enable Standard Bank to lend to and finance climate-smart projects in South Africa such as renewable energy, energy efficiency, water efficiency and green buildings. More recently, at the beginning of 2021, the Development Bank of Southern Africa (DBSA) launched its first green bond amounting to R3.59 billion, issued through a private placement with the French development finance institution *Agence Française de Développement* (AFD). By the end of 2020 there were 12 green bonds listed on the Johannesburg Stock Exchange (JSE) with a combined value of R9.3 billion[19].

Funding in the form of green loans can be applied for from public or private financial institutions and operate similarly to conventional lending where a borrower receives a green and repays the finance with interest over an agreed time period. Green loans are used to finance a specific environmental project, or they can be used to finance a specific company programme that has a positive impact on environmental, social and governance (ESG) factors. Green loans differ from green bonds in that they do not access capital markets and usually have a shorter lifetime (Tobin-de la Puente & Mitchell, 2021). While the total number of green bonds have steadily increased over the past decade, less than 10% of the total market has been correctly labelled as "green", and furthermore, only a small percentage have been channelled to biodiversity projects (Tobin-de la Puente & Mitchell, 2021).

Green Equity is a complement to green bonds and loans. It is a public or private investment in a project or an asset that generates a return for investors. Institutional investors invest in environmentally friendly traded stocks and funds that are measured against financial and ESG goals. Therefore, green equity refers not only to the investment products that are available to investors but also the way in which investors invest in them.
An increasing number of investors are wanting to see their money go towards stocks or funds that are not only profitable but that also make a positive impact on society and the environment, i.e. investments that are ethical, responsible, and sustainable. ESG investing, also known as sustainable investing, socially responsible investing (SRI), impact investing, and responsible investing refers to the environmental, social and governance practices of an investment (Daugaard, 2020). This combination implies the integration of ethical values, environmental management and protection, improved social conditions and good governance into traditional financial and investment decision-making (Sciarelli *et al.*, 2021). Therefore, ESG investing assumes that the financial performance of organisations is increasingly affected by environmental and social factors (Boffo & Patalano, 2020).

ESG investing exists in a spectrum of investing that is based on financial and social returns (Table 2.1). On one side of the spectrum, pure social investing or philanthropy seeks to address societal challenges through the provision of grants with an expectation of social returns only, i.e. investors only seek evidence of environmental or social benefits to society (Boffo & Patalano, 2020). On the other side of the spectrum pure financial investment is used to maximise shareholder value through financial returns with limited or no regard for environmental, social or governance practices. In the middle of the spectrum, social impact investing seeks a blend of social and financial return, dependent on the investor's priorities (Boffo & Patalano, 2020). ESG investing focuses on maximising financial returns but at the same time considers factors other than assessment of short-term financial performance and commercial risks. It incorporates the risk assessment of long-term environmental, social and governance challenges and developments, and as a result considers elements of positive behaviour to limit spill overs and ensure environmental protection or improved social issues and good corporate governance (Boffo & Patalano, 2020).

[17] https://mg.co.za/business/2021-02-20-amid-the-pandemic-green-bonds-are-becoming-trendy/
[18] https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=16888
[19] https://mg.co.za/business/2021-02-20-amid-the-pandemic-green-bonds-are-becoming-trendy/

Table 2.1. The spectrum of social and financial investing. Source: Boffo & Patalano, 2020.

	Philanthropy		Social impact investing		Sustainable and responsible investing	Conventional financial investing
Type of investing	Traditional philanthropy	Venture philanthropy	Social investing	Impact investing	ESG investing	Fully commercial investment
Focus	Address societal challenges through the provision of grants	Address societal challenges with venture investment approaches	Investment with a focus on social and/or environmental outcome and some expected financial return	Investment with an intent to have a measurable environmental and/or social return	Enhance the long-term value by using ESG factors to mitigate risks and identify growth opportunities	Limited or no regard for environmental, social or governance practices
			Use of ESG metrics and methodologies			
Return expectation	Social return only	Social return focused	Social return and sub-market financial return	Social return and adequate financial market return	Financial market return focused on long-term value	Financial market return only
	Social impact ↔			Social and financial ↔		Financial returns

An initial criticism against ESG was that returns would be compromised. However, this has not been the case and they have, in fact, proven to be market-beating (Global Sustainable Investment Alliance, 2018). Reports argue that companies can no longer afford to ignore or downplay their ESG ratings (Boffo & Patalano, 2020; Sciarelli *et al.*, 2021). ESG ratings are based on a number of criteria within each of the E, S, and G factors (Table 2.2). ESG ratings are obtained through established ESG rating providers and comprise criteria that may be considered, either by socially responsible investors or by companies aiming to become more ESG focused. Not all criteria are given equal weighting, with issues being prioritised based on local circumstances, geography, specific to an industry, etc. ESG issues that might influence investors include an organisations' effort to mitigate climate change and other environmental issues such as biodiversity loss; or human rights issues with an organisation's supply chain; or workplace diversity and equal opportunities (Boffo & Patalano, 2020).

Table 2.2. ESG criteria. Source: Boffo & Patalano, 2020

Environmental factors	Social factors	Governance factors
Natural resource use	Workforce	Board independence
Energy efficiency	Human rights	Board diversity
Carbon emissions	Diversity	Shareholder rights
Pollution/waste	Supply chain	Management compensation
Environmental opportunities		Corporate ethics

The growth in ESG investing has been driven by individuals and organisations who have recognised the interdependencies between social, environmental and economic issues (Daugaard, 2020), and who want to have an environmental and social impact, together with the economic performance of investing. As such, ESG investing aims to better incorporate long-term financial risks and opportunities into investment decision making to generate improved, sustainable long-term portfolio returns (Boffo & Patalano, 2020). According to Global Sustainable Investment Alliance (see Global Sustainable Investment Alliance, 2018), ESG investing grew to more than US$30 trillion in 2018, a 34% increase in two years, with some estimates suggesting it could reach US$50 trillion by 2050 as investors demand more transparency. In the US in 2019, flows into funds investing in companies with positive ESG practices were more than triple the 2018 total (US$18 billion in 2019 versus US$5.5 billion in 2018).[20]. Investments managed with consideration of environmental, social and governance

[20] https://www.cnbc.com/2019/12/14/your-complete-guide-to-socially-responsible-investing.html

criteria are continuing to grow in Africa too, with US$428 billion in assets as of July 2017 (Global Sustainable Investment Alliance, 2018). With almost US$400 billion, Southern Africa was responsible for the bulk of the assets, an increase of 23% over the past year (Global Sustainable Investment Alliance, 2018). In Africa, South Africa represents the largest amount of sustainable investing assets, followed by Nigeria and Kenya.

Lastly, green insurance is a potential option. Armed with an improved understanding of the link between ecosystem degradation and disaster risk, the private insurance industry has in recent years started to invest in preventative action through the restoration and protection of biodiversity (Tobin-de la Puente & Mitchell, 2021). In many cases, preventative action investments are lower than future insurance pay-outs that would result from damages to insured assets, for example loss or damage to property through flooding or fire. For example, in South Africa, Sanlam has an ongoing partnership with WWF-South Africa and has invested heavily in their freshwater programme to restore and protect the most important water source areas in the country.

2.2.3.5 Bridging the investment gap by facilitating private capital investment

The high and unfamiliar risk profile of green economy-related projects is often unattractive to commercial investors. Blended finance funds can be established to facilitate private capital investment by co-investing with governments or development institutions, often managed as a public-private partnership. There are three main features that characterise blended finance (OECD, 2015; Deloitte, 2017):

- **Leverage**: using public funds to engage and mobilise private capital into deals at scale;
- **Impact**: investments that deliver measurable social, environmental, and economic progress; and
- **Returns**: financial returns are generated in line with market expectations, based on real and perceived risks.

Current levels of private investment in the green economy sectors remain relatively low and evidence shows only a moderate growth in the volume of blended finance that has been deployed since 2015 (Mutambatsere & Schellekens, 2020). One of the largest barriers to private sector investment in these markets is that the returns are not proportional to the level of risk (OECD, 2015; Mutambatsere & Schellekens, 2020). Blended finance allows investors and lenders to manage and alleviate the allocation of risk-and-return expectations (i.e. reduce uncertainty and risks associated with investing in underserved markets), and in doing so enables investors to consider projects that would not usually fall within their typical investment scope (Deloitte, 2017). The objective being to ensure that a project eventually becomes financially viable without concessional finance[21], providing opportunities for self-sustaining approaches that are not only reliant on grant and donor financing (WWF, 2020).

Established in 2011, the Green Fund in South Africa provides catalytic financing for investment in natural resource management, among other things. It is implemented by the Development Bank of Southern Africa (DBSA) and capitalised by National Treasury from the country's national taxes and levies, such as such as motor vehicle taxes, air flight taxes, and fuel levies (Bhandari, 2014). The fund has a portfolio of 20 active and two completed investment projects, representing investment of R680 million since the fund's inception[22]. The Green Fund aims to leverage foreign investment and additional private investment to complement existing financial support provided through the fund. The United Nations Land Degradation Neutrality Fund and the AGRI3 Fund are other examples of blended finance funds.

[21] Concessional finance is below market rate finance that is provided by major financial institutions, such as development banks and multilateral funds to developing countries to accelerate development objectives (The World Bank).

[22] https://www.gov.za/about-government/government-programmes/green-fund

2.2.4 Water funds: a mechanism for channelling investments in hydrological services

Water funds have been established to channel funds from donors to secure hydrological ecosystem services in many parts of the world, including Africa (Salzman *et al.*, 2018). Water funds aim to provide a multi-stakeholder response to addressing environmental degradation in important water source areas. They provide a means by which finance and assistance from downstream hydrologic service beneficiaries (e.g. water service providers and consumers) and donors (motivated by developmental and/or biodiversity conservation benefits) can be channelled to the actors that implement management changes or accommodate conservation actions in important water catchment areas. Water funds thus provide a financing and governance mechanism for linking downstream water consumers with upstream land users, typically taking the form of a public-private partnership (Figure 2.5).

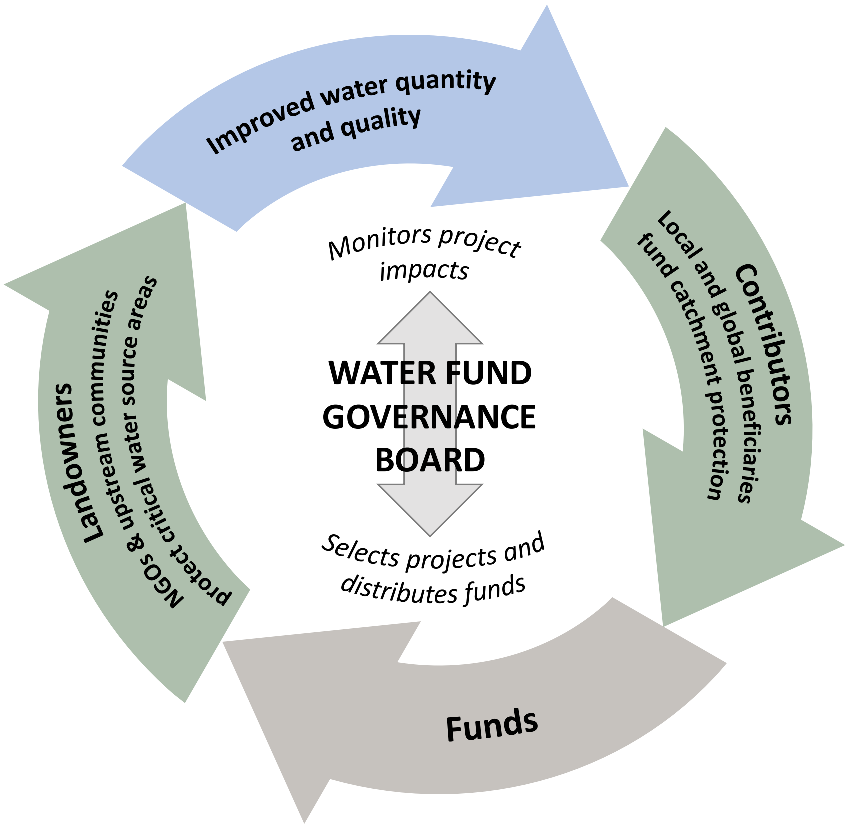


Figure 2.5. Illustration of how a water fund works. Source: adapted from TNC, 2015.

This structure provides the stability and operational capacity to manage numerous stakeholders, while at the same time providing the vehicle for pooling and deploying the collective investments. Therefore, water funds can be considered a PES-like system in that they generate revenues and channel much needed funding to high priority hydrological ecosystem services provided by EI. The concept is based on the principle that it is cheaper to prevent degradation from happening in water source areas than it is to restore already degraded catchment areas in the future. Funding is also used to support economic opportunities that enhance livelihoods for local communities, including agricultural interventions that improve productivity. The catchment conservation measures also build resilience, enhancing communities' ability to adapt to climate change.

Most water funds are established organisations or trusts with an endowment fund structure. An endowment fund is an investment fund established by a foundation, trust or other non-profit organisations that makes consistent withdrawals from invested capital. An endowment is therefore a legal structure and is the portion of money that is raised and invested over the very long term (in perpetuity) in order to earn a relatively steady and predictable stream of income year after year. Usually just the income that is earned by investing the capital of an endowment is spent, but no part of the capital is spent. The initial capital is usually derived from donations. This interest-based, noncapital reducing financing is sustainable and less vulnerable to market fluctuations.

Over 40 Water funds have been established in 13 countries by The Nature Conservancy. This includes the Upper Tana Nairobi Water Fund in Kenya launched in 2015 and the Greater Cape Town Water Fund launched in 2019. The Upper Tana Nairobi Water Fund has already contributed to the improved conservation and management of 40 000 ha of public forest and 78 400 ha of farmland and has increased yields for smallholder farmers by US$3 million per year. It is also estimated to have increased water yields and improved water quality for Nairobi, with benefits to power generation and water treatment facilities worth over US$850 000 per year.

2.3 PAYMENTS FOR ECOSYSTEM SERVICES AS A POTENTIAL WIN-WIN SOLUTION: A CRITICAL ASSESSMENT

2.3.1 Overview

Seen as a win-win situation, being both an incentive and financing mechanism, there has been a very strong interest in payments for ecosystem services as an approach to financing catchment restoration and conservation. However, in South Africa there are currently no PES schemes in operation, even though initial research has shown that it could be economically viable in some parts of the country. Here we undertake a comprehensive review of PES, focusing on why there has been limited implementation in Africa and assessing under what conditions it could potentially be a viable financing option for catchment restoration in South Africa. The assessment is based on discussions with consultants, government and NGOs as well as the literature.

2.3.2 The development and growth of PES

2.3.2.1 PES Fundamentals

PES is a means to secure ecosystem services through incentivising landowners (and other resource stewards) to adopt conservation or restoration practices (Wunder *et al.*, 2020). Many ecosystem services are used, whether purposely or inadvertently, without any payment (Jack, Kousky & Sims, 2008; Bell *et al.*, 2018; Emerton, 2018). Their provision is affected by the land and resource use decisions of individual landholders and communities (the 'ecosystem managers'). When the ecosystem service benefits accrue to the ecosystem managers, e.g. conserving soil fertility to improve onsite crop yields, then landholders are intrinsically motivated to provide these services (Wunder *et al.*, 2020). However, when the benefits flow offsite to others, as is the case with most regulating services, such as water provision to downstream users or climate regulation, the interests of the ecosystem manager will likely differ from off-site beneficiaries. The ecosystem manager will act in her own self-interest, rather than that of society as a whole, which generally results in the ecosystem service being under-supplied. Paying for services creates the incentive for ecosystem managers to change their behaviour to increase service provision (Salzman *et al.*, 2018). The system is potentially viable as long as the payment exceeds the recipients' opportunity cost for their change of behaviour or policy (Figure 2.6).

The most common definition of a PES is a "voluntary transaction where a well-defined ecosystem service is being bought by a minimum of one service buyer from a minimum of one service provider, if and only if, the provider secures ecosystem service provision (conditionality)" (Wunder, 2005).

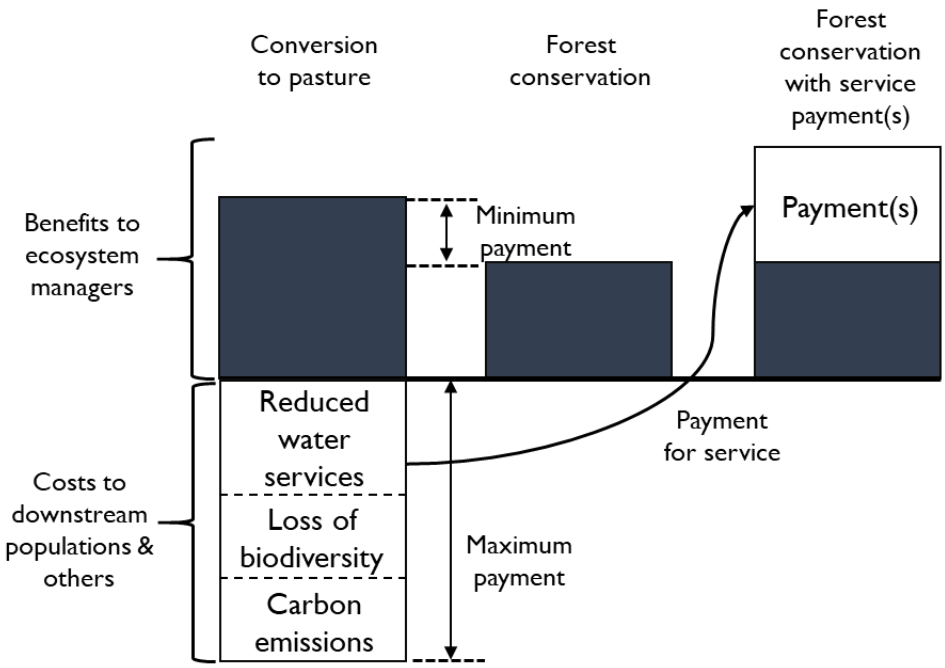


Figure 2.6. The logic of payments for ecosystem services. Source: Engel, Pagiola & Wunder, 2008.

In a typical PES scheme, ecosystem services are secured by paying ecosystem managers or users to desist from damaging activities or adopt more conservation-friendly practices. The service providers could be individuals, communities, firms or governments, and the payments could be monetary or non-monetary transfers, from the private sector, government and/or international donors. The theory of change is summarised in Figure 2.7.

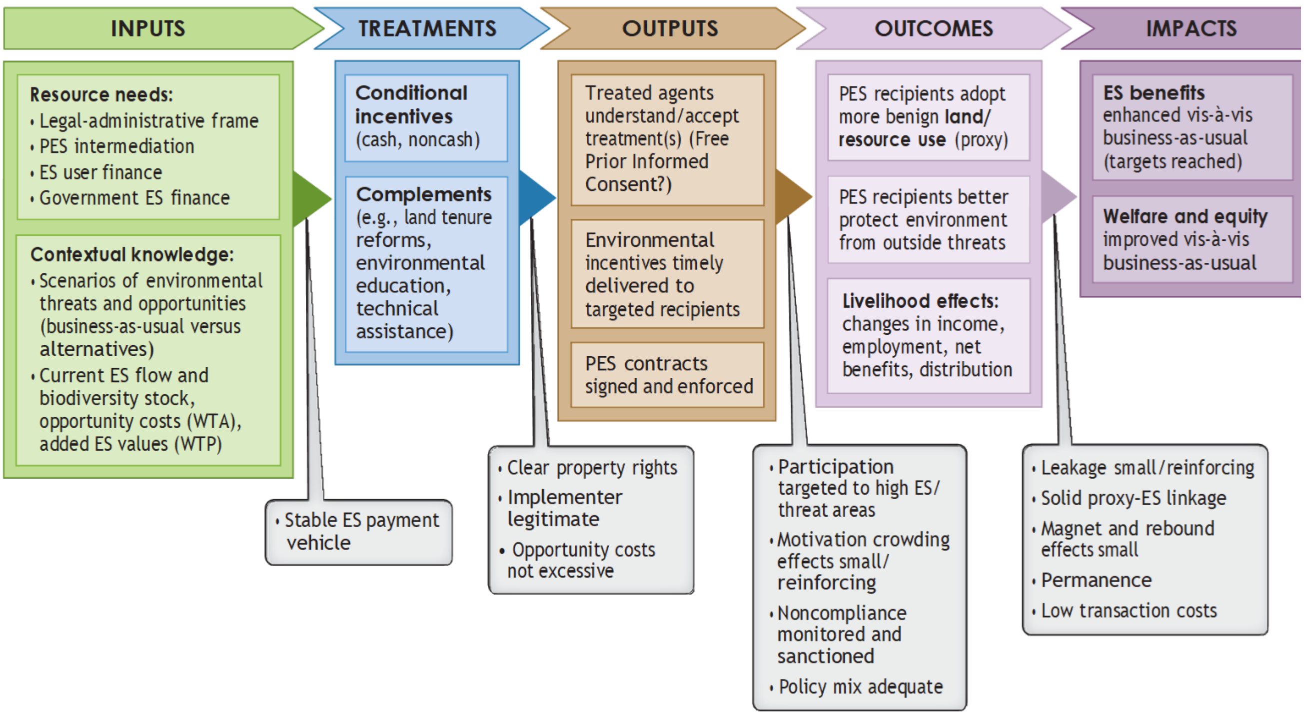


Figure 2.7. A theory of change for payments for ecosystem services. Abbreviations: ES, ecosystem services; PES, payments for ecosystem services; WTA, willingness to accept; WPA, willingness to pay. Source: Wunder et al., 2020.

2.3.2.2 Tendency to deviate from the original concept

Although the definition and conditions of PES schemes as conceptualised by Wunder (2005) are well-known, there has been considerable departure from this concept in practice, including from its strict market-based understanding (Muradian *et al.*, 2010; Goldman-Benner *et al.*, 2012; AfDB, 2015; Papagallo, 2018; Bösch *et al.*, 2019). Because of this issue, the literature has started to distinguish “genuine PES schemes”, which fully meet the abovementioned criteria.

Firstly, PES schemes are not always purely ***voluntary*** arrangements between free market actors, as they may involve enforced action to support high-level agreements. For example, actions can be achieved through specific legislation as well as other government or community action (Muradian *et al.*, 2010; Vatn, 2010; Papagallo, 2018).

Secondly, the services paid for are not always ***well defined***. For example, hydrological flows are naturally variable, so it is difficult to measure the additional output due to the seller’s actions. Thus, PES schemes commonly pay for land management actions that are believed to improve service delivery on average over the long term. Because of this, Wunder revisited his 2005 PES concept and proposed a modified definition as “voluntary transactions between service users and service providers that are conditional on agreed rules of natural resource management for generating offsite services” (Wunder, 2015). Others have also proposed revised definitions along these lines.[23] To achieve success (additionality) with this approach, the causal relationship between land use management practices and ecosystem service provision needs to be well understood (Muñoz-Piña *et al.*, 2008), and the management actions need to be well-defined.

Thirdly, in many cases, the ***conditionality*** of the payment has been found to be weak or absent. While the first two modifications of voluntariness and service definition can still achieve the desired outcomes, the absence of strong conditionality is of particular concern, as it will typically result in failure of the scheme to deliver the targeted services. Some projects are only loosely monitored or not monitored at all (Wunder, 2007), which means that payments are made irrespective of the outcomes. Some are even paid up-front.

The failure to base PES scheme payments on clearly and strictly defined actions or outcomes for which an agreed measurement system has been devised can be because of poor design (difficulty in measurement is often used as an excuse), or because of weak institutions, particularly involving communal or insecure land tenure. PES arrangements may be skilfully negotiated on behalf of a community of service providers by government agents, political or traditional leaders who expect to secure income without reducing their popularity with those community members. In some cases, these problems extend to “elite capture”, where community members that do incur opportunity costs are not fairly compensated. In others, they lead to sabotage, or rent-seeking, where damaging actions are increased to attract higher promises of payment.

There are also widespread concerns that the legitimacy of PES is being undermined by the fact that PES is increasingly being perceived as an opportunity for the generation of *new* income earning opportunities, more than as compensation for the opportunity costs of service provision. PES projects are therefore increasingly being set up with developmental objectives, such as poverty alleviation, regional development and employment creation, as the primary objectives (Wunder *et al.*, 2008), and are being judged on these objectives,

[23] The African Development Bank defines PES as “a contractual agreement between at least an ecosystem service beneficiary and an ecosystem service producer (or an intermediary acting as one of them), by which the former transfers resources to the latter, providing the ES producer adopts specific practices on the land or resource he controls of possesses, in order to enhance the production of specific ecosystem services” (AfDB, 2015). Muradian *et al.* (2010) proposed a broader definition of PES as “a transfer of resources between social actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in the management of natural resources”. Other, broader definitions include those put forward by Porras, Grieg-Gran & Neves, 2008; Sommerville *et al.*, 2009; Tacconi, 2012; Salzman *et al.*, 2018 – see Wunder, 2015.

irrespective of their environmental outcomes. A PES scheme is not a job creation mechanism *per se*, although, by definition, it should result in service providers being better off than before.

2.3.2.3 Global and regional uptake

There are now over 550 PES schemes in operation around the world, with more than US$36 billion paid each year for environmental services (Salzman *et al.*, 2018). While there has been rapid growth in PES programmes in the Americas (particularly South and Central), China and South-East Asia (Börner *et al.*, 2017; Salzman *et al.*, 2018; Wunder *et al.*, 2020), PES remains limited in Africa (AfDB, 2015; Bösch *et al.*, 2019). In 2002, only 7% of PES projects were in Africa (Landell-Mills & Porras, 2002). By 2005, 45 PES schemes were identified in Eastern and Southern Africa, but only nine had reached the point of implementation (Ruhweza & Waage, 2007). The number of initiatives had grown to 70 by 2008 (Bond, Waage & Ruweza, 2008; AfDB, 2015; Emerton, 2018).

PES schemes have developed at a slower rate in Africa compared to other regions, with many having never progressed past the pilot stage. The biggest challenges have weak institutions (particularly insecure land tenure and poorly defined resource rights), heavy reliance on natural resources for meeting subsistence needs in the service provision areas, limited ability to pay for ecosystem services, lack of funding, lack of coordination among public agencies and lack of technical skills (Ferraro, 2007; Gross-Camp *et al.*, 2012; Lopa *et al.*, 2012; AfDB, 2015; Emerton, 2018; Mbopha *et al.*, 2021). PES schemes in Africa have been dominated by REDD+ projects[24] which focus on climate regulating services through the restoration and maintenance of carbon stocks, but there are also a growing number of projects designed to restore and retain important hydrological ecosystem services.

While there have been many interventions that have involved supporting local communities to engage in more sustainable practices (e.g. Community-based natural resource management in Namibia, the Tsitsa Project in South Africa) or to finance restoration in catchment areas (e.g. Working for Water in South Africa, the Greater Cape Town Water Fund), there are no established, genuine PES projects in southern Africa (where land owners/users are being paid conditionally to change their practices). There have been numerous recommendations, and several proposals that have reached fairly advanced stages of research and consultation, but so far there is only one scheme in its pilot phase. These include:

- The proposed Maluti-Drakensberg PES scheme, which focussed on the management of communal grassland areas in KwaZulu-Natal, South Africa (Maloti Drakensberg Transfrontier Project, 2007; Blignaut *et al.*, 2008, 2010; Büscher, 2012);
- The proposed Baviaanskloof-Tsitsikamma PES scheme in the Eastern Cape, South Africa, which would involve the restoration of mainly private land areas invaded by woody plants (Mander *et al.*, 2010);
- The proposed Lesotho Ecological Investment System which involved a PES scheme for improved rangeland management (USAID, 2018); and
- The Wildlife Credits scheme in Namibia, to reward the protection of wildlife habitats and wildlife, which is in the pilot stages (Oberhauser, 2019).

2.3.2.4 Spatial scales

PES schemes can be implemented at various spatial scales, from small catchments or sub-catchments to whole nations (Wunder *et al.*, 2008). Government-financed PES schemes tend to be implemented at larger spatial scales whereas user-financed schemes operate at smaller scales. National or regional schemes have

[24] Reducing emissions from deforestation and forest degradation, with the plus denoting conservation and other co-benefits

been implemented mostly in the Americas and in Asia, whereas smaller regional schemes have been implemented in parts of Europe (Calvet-Mir *et al.*, 2015). In Africa, small-scale schemes tend to be the norm usually implemented through NGOs as intermediaries (Wunder *et al.*, 2008; Calvet-Mir *et al.*, 2015), although there are examples of this type of arrangement at larger spatial scales too. National-level schemes, such as the Payment for Environmental Services Program in Costa Rica and the Payment for Hydrological Environmental Services Program in Mexico, usually have PES as a main feature or component of a country-wide ecosystem/environmental policy (Greiber, 2009).

The advantage of working at larger scales is that the impact can be easier to demonstrate, particularly for catchment PES. This was one of the lessons learned through the pilot Sasumua Pro-poor Rewards for Environmental Services in Africa scheme in Kenya. Buyers' willingness to pay for ecosystem services is greatly enhanced when evidence of impact is more easily provided (e.g. the relationship between catchment protection and improved water quality is more easily evaluated and monitored at the catchment or sub-catchment level (Salzman *et al.*, 2018).

2.3.3 Services, willingness to pay and funding

2.3.3.1 Marketed services

There are four ecosystem services that are most often secured through PES schemes, categorised as follows:

- Carbon sequestration and storage: the capture and long-term storage of atmospheric carbon dioxide. Includes land use practices and interventions that conserve or increase carbon stocks, such as through REDD+. There are five REDD+ activities that contribute to mitigation actions in the forest sector: reducing emissions from deforestation; reducing emissions from forest degradation; conservation of forest-carbon stocks; enhancement of forest-carbon stocks; and sustainable management of forests.
- Biodiversity conservation: land use practices and interventions that promote the protection and sustainable use of biological diversity.
- Water (hydrological services): land use practices and interventions that promote the protection and restoration of water catchment areas. Water-focused PES schemes are usually referred to as payments for watershed services (PWS).
- Scenic (landscape) beauty: the aesthetic value of landscapes, often associated with biodiversity conservation.

PES schemes for biodiversity and carbon have been more common than for hydrological ecosystem services in Africa, whereas the latter have dominated in Central and South America (Wunder *et al.*, 2018). In Kenya, which has a relatively high number of PES schemes, these have been dominated by carbon, followed by water and biodiversity (AECOM, 2020).

Most PES schemes for carbon in Africa (and globally) have been developed under the UN's Reduction of Emissions from Deforestation and Degradation (REDD+) programme. Co-ordinated though national governments, REDD+ projects derive their finances from payment for carbon credits used for offsetting carbon emissions by international companies (Table 2.3).

Carbon PES schemes are usually implemented by a non-government organisation (NGO) or private company with aim of providing financial incentives to local communities through carbon markets. They use a third-party international accreditation system to verify and measure outcomes in terms of tonnes of carbon stored/emissions reductions produced through the PES scheme (AECOM, 2020). One of the challenges that may threaten the financial sustainability of some REDD+ schemes is that the credits are sold on the voluntary market with no certainty of sale. However, in general these schemes tend to be well managed and payments consistent, generating significant positive conservation and livelihood outcomes. Examples of REDD+ schemes in Africa include the Ecotrust Trees for Global Benefit scheme in Uganda which has been in operation since 2002 (Peskett, Schreckenberg & Brown, 2011; Masiga, Mwima & Kiguli, 2012; AfDB, 2015), the Kasigau Corridor REDD+ Project (Bernard *et al.*, 2014), the Chyulu Hills REDD+ Project in south-eastern Kenya (AECOM, 2020), and the Ankeniheny-Zahamena Corridor REDD+ Project in Madagascar (Wendland *et al.*, 2010).

Table 2.3. PES development in Africa. Source: AfDB, 2015.

Ecosystem service	Level of development	Main geographical area	Main beneficiaries (service users/buyers)	Main drivers
Carbon	Med-Low	Central and East Africa	International companies NGOs & private companies as intermediaries	REDD+ & carbon market development
Biodiversity	Low	East Africa, and to a lesser extent Southern and Central Africa	Private tourism operators Protected areas Companies for biodiversity offset	Development of ecotourism & CBNRM Regulation, financial requirements, CSR Policy
Water	Very low	Southern and East Africa	Government Water utilities or hydropower companies	Water stress Lack of solvent demand being a major constraint

PES schemes focusing on biodiversity are found mainly in East and Southern Africa. These are largely driven by international tourism demand. Community-based natural resources management (CBNRM) initiatives have paved the way for agreements between tourism operators and local communities to secure the management and protection of wildlife areas within communal land areas. These involve direct compensation being made to communities (see Nelson, 2008; Nelson *et al.*, 2010; AfDB, 2015). Although these payments are not conditional on a measure of service delivery, they are indirectly conditional on service provision through tourism demand. PES arrangements have also been established between local communities and protected areas, where national parks, for example, directly compensate surrounding communities for their involvement in preventing illegal hunting of wildlife or the destruction of habitat within the park. Most of these schemes are implemented on a relatively small scale and usually always include the involvement of a non-government organisation (NGO) or international institution to oversee the management and distribution of funds.

Payments for hydrological ecosystem services schemes have taken longer to emerge in Africa. This is likely because hydrological ecosystem services tend to be driven by local water demand, rather than international demand as in the above examples, which means the willingness to pay for the service is limited. Examples of water PES schemes in Africa include the Naivasha Basin PES scheme and the Upper Tana Nairobi Water Fund in Kenya (see Chiramba *et al.*, 2011; TNC, 2015; AECOM, 2020). There have been a number of water-related PES schemes that have been piloted at the local scale through private deals between local communities and private companies (e.g. water utilities or hydropower companies). However, many of these have not reached implementation phase, mostly due to a lack of willingness to pay for catchment conservation (AfDB, 2015).

2.3.3.2 Sources of funding

PES schemes can be grouped into three broad categories of funding sources (Engel *et al.*, 2008; Wunder *et al.*, 2008; Ezzine-De-Blas *et al.*, 2016; Salzman *et al.*, 2018): user-financed, government-financed and internationally-financed schemes:

- **User-financed (private) PES** schemes, involve payment of service providers by direct beneficiaries/users of ecosystem services. These may be private individuals, companies, or NGOs. These schemes are fully voluntary, self-organised private deals, usually involving a single buyer and single ecosystem service. Examples of such schemes include the Vittel (Nestlé Waters) watershed protection program in Eastern France (Perrot-Maître, 2006) and the Simanjiro Conservation Easement in Tanzania (Nelson *et al.*, 2010).
- **Government-financed (public) PES** schemes involve payment by government acting in the public interest. Most rely on annual budget allocations, although some do have dedicated funding sources through allocated user fees. Funding is often received from various levels of government. In developing countries, these schemes often receive donor funding. The national PES programs in Costa Rica (Pagiola, 2008) and Mexico (Muñoz-Piña *et al.*, 2008) are well-known examples.
- **Internationally-financed schemes** are usually related to offsets, where actors facing regulatory obligations pay other actors for activities that either maintain, enhance or restore the provision of ecosystem services in exchange for a credit or offset that satisfies their mitigation requirements (Salzman *et al.*, 2018). Examples of such a scheme would include water quality trading (or water pollution capping), wetlands mitigation banking and the European Union's emissions trading system for greenhouse gases[25]. The most common example of this in Africa is the UN's REDD+ model.

Hybrid schemes, involving a mix of government and private funding, are also common (Wunder *et al.*, 2008; Salzman *et al.*, 2018). For example, while government-financed PES, such as Costa Rica's PSA, relies primarily on funding from the state, payments are also received from service users, various international agencies, and NGOs. Similarly, many private schemes are not purely user-financed, in some cases using external funds to co-finance start-up and implementation costs.

In Latin America, Europe, North America and Asia, government-funded schemes are dominant (65-70% of schemes) followed by user-financed commercial schemes, whereas in Africa the opposite is the case with about 85% of schemes being privately funded (Calvet-Mir *et al.*, 2015; Ezzine-De-Blas *et al.,* 2016; Blundo-Canto *et al.*, 2018).

Most PES schemes in Africa have depended heavily on external financial support from international NGOs and development donors (Emerton, 2018). In many cases, the schemes have not reached implementation stage or projects have come to an end as a result of funds drying up. For example, the Western Kenya Integrated Ecosystem Project did not develop into a PES scheme following the World Bank's withdrawal from the project. The more that PES schemes fail, the more difficult it is to attract international finance, which is imperative in most African contexts. The development of a sound business case and sustainable financing model and government and political backing is therefore imperative.

2.3.3.3 The challenge of financing PES

The absence of willing and able buyers of ecosystem services continues to be a major barrier to the development of PES in Africa. This is especially the case for water-related PES schemes (Ferraro, 2007; AfDB, 2015; Emerton, 2018; AECOM, 2020). There are numerous schemes that have encountered great difficulty in establishing companies' willingness to pay for catchment conservation, such as the Sasumua PRESA initiative in Kenya and the Equitable Payments for Watershed Services scheme in Tanzania. In these cases, the beneficiaries felt that the PES payment would be a 'double' payment as they already pay statutory water fees and conservation levies to regulating bodies. In some cases, while the initial willingness to pay is present, securing long-term commitment can be an issue. The voluntary nature of PES allows for beneficiaries to stop payments at any time. This has been the experience in the Naivasha Basin PES scheme in Kenya.

[25] See https://ec.europa.eu/clima/policies/ets_en

Undertaking baseline assessments and delivering a strong business case is critical for providing evidence of causality and convincing beneficiaries to engage in the PES. This information is also critical for convincing future stakeholders of the effectiveness of the scheme and its potential. There are a number of schemes that have been designed without demonstrating this evidence (Emerton, 2018). For example the Equitable Payments for Watershed Services scheme in Tanzania never established a direct link between land-use changes and water quality improvement (Lopa *et al.*, 2012) and the Naivasha Basin PES scheme has been criticised for the same reason (Emerton, 2018). On the other hand, the Upper Tana Nairobi Water Fund conducted a comprehensive assessment that proved critical in securing buy-in from service users.

Securing finances over the long term is difficult. Sourcing funds from multiple funding streams can therefore be very important. There are numerous examples of schemes that have failed due to their reliance on a single external source of funding. The trust fund model approach, as is used by the Upper Tana Nairobi Water Fund, where there is a revolving fund and an endowment fund, ensures long-term sustainable financing (see below). Demonstration projects can be important in instilling the confidence of investors. These are also important for evaluating the effectiveness of the scheme design within the local context.

2.3.4 Stakeholders and governance

2.3.4.1 Types of stakeholders involved in a PES

The planning, negotiation and implementation of a PES scheme requires the involvement of a number of stakeholders (Figure 2.8).

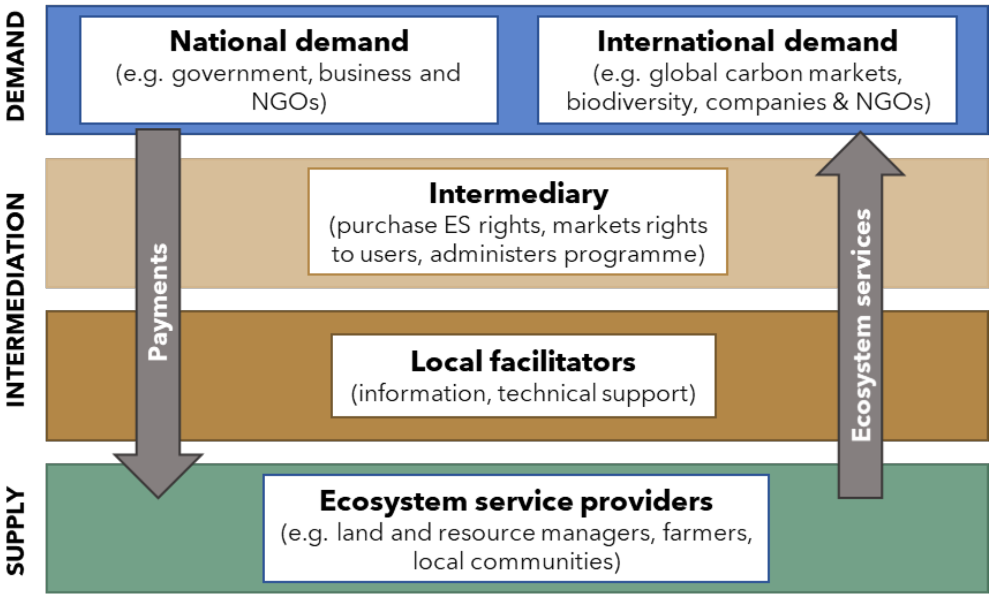


Figure 2.8. A 'typical' governance structure for a PES scheme. Source: Porras *et al.*, 2013; AECOM, 2020.

There are five principal stakeholder groups that can be distinguished (Porras, Grieg-Gran & Neves, 2008; Greiber, 2009; ESC, 2018):

- **Service providers:** landholders or resource managers whose actions can secure the supply of ecosystem services (private landowners, communal landholders, private reserves, government or NGOs managing protected areas).
- **Beneficiaries**: private or public entities that have a demand for the provision of ecosystem services and who are willing to pay to ensure their enhancement, restoration or protection.

- **Funders**: These may be the beneficiaries themselves, or local, national or international donors that provide the funds needed for the provision of ecosystem services on behalf of the beneficiaries.
- **Intermediaries**: These are the agents linking the funders, beneficiaries and service providers, and assist in the administration of the PES scheme. They can also provide scientific advice, assist with stakeholder facilitation and negotiations and capacity building of service providers.
- **Local facilitators or knowledge providers**: provide knowledge and technical support essential to scheme development. Can include resource management experts, valuation specialists, land use planners, regulators, and business and legal advisors that often do not have a permanent role in the scheme but provide important support and knowledge during the design and implementation stages of the process.

2.3.4.2 Engaging service providers in an African context

Most PES schemes globally reward individual farmers who have private land tenure. Having the security of private tenure provides the landowner with a much greater incentive to participate in a programme, as they have far more control over its success. In an African context, PES schemes often deal with farmers on communal land areas, which is a very different matter. A PES established in a communal land area or small-scale farming area can involve large numbers of actors. It is generally necessary to deal with some sort of institution, e.g. the traditional leadership, a committee, community-based organisation or trust, that represents the service providers and negotiates on their behalf. Nevertheless, it is still important that the actual service providers' situation is well understood to ensure that the interventions required are socially and culturally acceptable, or to identify what sensitisation is needed (Nelson *et al.*, 2010; Lopa *et al.*, 2012; Osano *et al.*, 2013; AfDB, 2015; TNC, 2015; Emerton, 2018; AECOM, 2020).

For example, in Tanzania, where community areas and rights are well defined[26], the village authority is a corporate entity capable of entering into legal contracts and which also has the designated legal authority for managing village lands under customary rights of occupancy where traditional authorities played an oversight role (Nelson, 2008; Nelson *et al.*, 2010; Lopa *et al.*, 2012; AECOM, 2020). Thus, for example, the contractual framework for the Equitable Payments for Watershed Services Program in the Uluguru Mountains of Tanzania and the Simanjiro Conservation Easement PES scheme in the semi-arid Simanjiro District of Tanzania involved the village authority. There are also examples of village-based agreements in Kenya. The contractual agreement for the Mikoko Pamojo Mangrove Conservation and Restoration Project in Kenya is between the Mikoko Pamojo community organisation that represents the whole village and the Kenya Forest Service (KFS; AECOM, 2020).

In other countries where community structure is not as well defined, communities are often represented by existing user associations or other community-based organisations. In Uganda, the Trees for Global Benefit PES scheme works with farmers who are organised through district-level farmer associations and local-level community-based organisations (CBOs). This has greatly reduced transaction costs and built capacity and peer support (AfDB, 2015). The Naivasha Basin PES scheme and the Sasumua PRESA in Kenya both operate through the existing Water Resource User Associations (WRUAs) which are charged with management of defined sub-catchment areas under the Water Resource Authority (WRA).

In some countries, where policy and legislation has allowed for the devolution of land, resource and/or wildlife rights to local communities, this forms an excellent basis for PES. In Namibia, for example, under the community-based natural resource management programme, communities can establish conservancies and conservancy trusts, and thereby acquire rights over wildlife. This creates the opportunity for joint venture

[26] This is as a result of the "villagisation programme" in the 1960s, controversial in that it was designed to prevent the reform of the land tenure system (i.e. maintain communal tenure), and led to agricultural decline since the location of villages ignored geographic variation in land (Shao, 1986)

partnerships and also for PES, since it means that there are well-defined communities with well-defined land rights, and a body to negotiate with.

In Kenya, land tenure reform now allows for private tenure in what were large communal pastoral areas, which has led to the establishment of small, individual freehold plots (Osano, De Leeuw & Said, 2012; Osano *et al.*, 2013). While this has been at considerable risk to the environment (Groom & Western, 2013) the security of tenure has facilitated PES arrangements. In some areas, Maasai farmers have formed landowner associations to aggregate their individual plots, creating large viable wildlife conservancy areas which they broker to commercial ecotourism operators in the form of land lease agreements. This has also facilitated the development of PES, such as the Olare Orok Conservancy PES in the Maasai Mara ecosystem (Osano *et al.*, 2013; Osano, De Leeuw & Said, 2017), the Wildlife Conservation Lease Program in Kitengela adjacent to Nairobi National Park (Emerton, 2018), and the African Wildlife Foundation Land Lease Program adjacent to the Amboseli National Park (AfDB, 2015). The latter scheme grew from 50 landowners in one conservancy to over 350 landowners in seven conservancies (AfDB, 2015). In other areas, however, issues such as changing ownership through inheritance and subdivision can also pose a challenge to PES management, as has been the case in the Naivasha Basin PES scheme (Chiramba *et al.*, 2011; AECOM, 2020).

Whether land tenure is communal or private, PES will only work if property rights are secure (in other words, there is limited access to land and resources, and there are rules of use that are generally obeyed). It cannot work where there is *de facto* open access to land and resources. Insecure or weak land tenure is one of the major challenges that have limited the development of PES in Africa (Lopa *et al.*, 2012; AfDB, 2015). For example, there are often few or no limits to grazing or resource harvesting in communal land areas, which are effectively open access. This means that no individual farmer can make a difference.

2.3.4.3 The critical role of intermediaries

The intermediary role has been found to be particularly important in implementing PES schemes in Africa. Having a neutral, independent and capable intermediary to provide support and coordination and to build rapport and trust between service providers and funders has been found to be critical to the success of PES programmes.

Intermediaries (or “facilitation bodies”) can be national or local government agencies, environmental or developmental NGOs, or funding institutions. In Africa, this role is fulfilled by existing national or international NGOs, largely because of high levels of government corruption and a general distrust of government agencies by donors. NGOs are able to provide continuity, which is often a concern with government-financed schemes where turnover in personnel can be high. They also tend to be well connected and provide knowledge and experiences from other countries.

The intermediaries can be well-established NGOs. For example, the Kasigua Corridor REDD+ Project in Kenya is managed by Wildlife Works, which is a private REDD+ program development and management company. In some cases, a new dedicated body has been established to manage the PES scheme. For example, a not-for-profit company called Ol Purkel Ltd was founded to be the intermediary for the Olare Orok Conservancy PES scheme and the Wildlife Foundation was established specifically to manage the Kitengela Wildlife Conservation Lease Program (Osano *et al.*, 2013; Emerton, 2018).

2.3.5 Payment agreements

The payment agreement refers to the agreed contracted payment made to the service providers. The design of the scheme has to include what is being paid for, how much is being paid per unit delivered, and how the delivery will be verified in order to earn the payment. The nature of payments and how they are made needs to be explicit in any PES agreement (Porras *et al.*, 2008; Greiber, 2009). When determining the payment structure for a PES scheme, factors such as economic interests, cultural norms and values, the need for establishing strong incentives, and requirements of upfront investments to achieve scheme outcomes must be taken into account (Greiber, 2009).

2.3.5.1 Defining the service being paid for

Payments can be output-based or input-based (Porras *et al.*, 2008; Wunder *et al.*, 2020):

- **Output-based payments** are made on the basis of actual ecosystem service delivery proven by a third-party verifier. For example, payments would be made for a measured increase in biodiversity, a measured percentage improvement in water quality, or a measured increase in percentage woody cover. Ideally, output-based payments would form the basis for all PES schemes (ESC, 2018).
- **Input-based payments** are made on the basis of certain land or resource management practices that are being implemented, as a proxy for ecosystem service provision. These are more common because they are easier to assess. For example, farmers may be paid to implement conservation agriculture practices or landholders may be paid to desist from harvesting certain natural resources in particular areas. The assumption is that the input activity will result in the desired ecosystem service output (Wunder *et al.*, 2020). In carbon schemes, payments are often made for a particular activity (reforestation) rather than the output of a unit of carbon, and in water schemes the payment is also for activities undertaken in the catchment areas as opposed to the provision of certain water quality targets (Greiber, 2009).

Payments should be proportional to the level of service that is being provided (or the related change in land or habitat condition). This can be achieved by creating a point system where different levels of payment are given to farmers for achieving a specific set of standards or targets relative to a baseline for their farm, and payments are made only after land use changes have been monitored in the field (Papagallo, 2018).

Depending on the type of PES, it may be necessary to assist farmers with the upfront costs and training in order to implement program activities, for example the costs of tree planting or purchasing of specific equipment that is needed to implement conservation agriculture activities. The Trees for Global Benefit scheme in Uganda has a credit system that allows participants to use purchase agreements as assurance for loans. In other cases, the purchasing of equipment for a group of farmers (as part of a CBO or WRUA) with repayment over time is another option.

2.3.5.2 Payment level

Generally, there are three approaches to determining the payment level:

- administratively determined (non-negotiable),
- direct negotiation between beneficiaries and service providers, or
- negotiations through an intermediary.

Administratively determined payment levels have mostly been used in national-level government-financed PES schemes, particularly in Central and South America, where conducting negotiations with service providers at such large spatial scales is not a feasible option. Direct negotiations to determine payment terms and level tend to be used where there are few stakeholders involved and at small spatial scales. There are few examples of direct negotiations in practice. In most local-level PES schemes, negotiations are undertaken through an intermediary, such as an NGO, trust or government entity, that brings together beneficiaries and providers to determine the payment structure. Negotiations will also include whether a flat payment will be made to all participants or whether the price will differ according to levels of outputs achieved or extent of activities implemented by service providers. In theory, the most efficient ways of determining optimal payment levels include ordinary auctions or reverse auctions[27], but this approach is very rarely used in practice.

Most importantly, payments to service providers need to exceed the costs incurred to implement the conservation actions required. The scheme is unlikely to be sustainable if participants feel they are not being paid enough or the payments are not covering their costs or time in achieving the outcomes. This was the case in the Equitable Payments for Watershed Services Program in the Uluguru Mountains of Tanzania which was established as a pilot PES scheme but failed to progress to full implementation (Emerton, 2018). In some cases, the payments are regularly adjusted through negotiation processes to ensure payments increase with inflation, for example (e.g. Olare Orok Conservancy scheme in Kenya and the Kenya Land Lease Program). At the same time, one has to ensure that participants are not paid too much, since those funds could be better directed to scaling up. One way to avoid overpayment is to cap the numbers of farmers that can participate, and then allow individual farmers in the community to bid to be part of the scheme. Farmers' bids will not be below their opportunity costs, and will not be too high for fear of not being selected (Wünscher, Engel & Wunder, 2011; Ajayi, Jack & Leimona, 2012; Lundberg *et al.*, 2018; Kelsey Jack & Jayachandran, 2019).

In setting up a PES there is always some level of heterogeneity among service providers in terms of what they can contribute. It may be necessary to devise a system that is fair in terms of relative service provision and opportunity costs borne by farmers. However, one often sees the opposite situation emerging, as a result of pressure to appease those who cannot provide the same level of service. For example, the Olare Orok Conservancy scheme in Kenya and the Kenya Land Lease Program provide a flat rate payment to all participants irrespective of the location of their land in the conservancy and their performance (Osano *et al.*, 2013, 2017). In this way, weak negotiation can undermine the effectiveness of PES.

2.3.5.3 Cash or in kind

Most PES schemes globally provide direct cash payments to service providers, usually following a simple flat rate for the implementation of different activities (e.g. a per hectare payment if providers are implementing land use management interventions or a per tree payment if landholders are planting trees). This approach is most commonly used in the national-level government-financed schemes in Central and South America and China.

In Africa, schemes often involve non-cash or in-kind rewards. Non-cash payments such as mobile data or agricultural vouchers are often a good solution where there is little in the way of a cash economy, where cash leads to problems of gender equality or other social risks, or where it can be subject to elite capture. The mode of payment should reflect the incentive preferences of service providers and should ideally benefit the whole household. In the Naivasha Basin PES scheme, individual farmers are paid in vouchers which can be used to by farm inputs at local agricultural shops.

In-kind rewards take the form of farm equipment and inputs, and community development projects. Some examples include (AECOM, 2020):

- Providing investments in community development projects such as building schools or clinics, or providing funding for guides and rangers or investing in specific equipment;
- Providing capacity-building to scheme participants to improve land management practices;
- Covering the costs of upfront investments that are needed by farmers to participate in scheme interventions; and
- Working with the community to set-up new livelihood activities, such as sustainable beekeeping or ecotourism initiatives.

[27] A reverse auction is a type of auction in which the role of the beneficiary (or service user) and the service provider are reversed (i.e. service providers compete to obtain business), with the main objective to drive purchase prices down (Greiber, 2009).

While non-cash payments can be linked directly to service provision as for cash payments, this is not the case for the in-kind rewards described above. The latter approach brings developmental benefits and can help to provide enabling conditions but used alone does not adequately fulfil the conditionality requirement of a successful PES.

Nevertheless, complementary activities that build local capacity can help long-term success, especially if the project has to meet developmental as well as environmental objectives. This has been shown by the Trees for Global Benefit scheme in Uganda and the Kasigau Corridor REDD+ Project in Kenya where activities related to tree nurseries, beekeeping and improved access to markets has generated additional household income, and by the Amboseli Land Lease Program and Chyulu Hills REDD+ Project in Kenya where ecotourism lodges, scout programs, and the creation of community forest rangers have generated employment opportunities.

2.3.5.4 Payment to individuals versus communities

Most PES schemes in the rest of the world pay individual landowners. In Africa, where they involve farming practices, they may pay individual farmers. However, in PES schemes involving the management of communal land areas, such as communal rangelands or forests, where it is difficult to assess conservation actions at household scale, rewards are often provided to the community as a whole. In these cases, the community, usually through some representative body, decides the extent to which the income generated should be spent on community projects versus disbursed to households. While the payment to the community might reflect their overall success, there is seldom any differentiation in rewards received at the household level. These systems will work better if there is some form of sanctioning for households that do not comply with the requirements of the scheme. This is difficult to impose externally. Funders are therefore more likely to support schemes in areas where common-pool resource management systems are strong.

2.3.5.5 Duration and timing of payments

To ensure the delivery of ecosystem services over the long-term, a longer contract is usually more preferable from the beneficiary's perspective. However, there are a number of practical challenges that can make long-term fixed payment agreements risky (Greiber, 2009). These include changes in financial and political circumstances, as well as the risk of service providers returning to previous management practices. Furthermore, many schemes in operation, particularly in Africa, were operationalised through donor-funded projects or through funding from an international NGO. When the project comes to an end or the funding dries up, then the PES scheme also breaks down (Emerton, 2018). It is these concerns that make the independent fund approach (e.g. water funds) an appealing (and more realistic) alternative to the strict PES model. This provides a level of flexibility as well as security to donors and beneficiaries.

Payments can be made at regular intervals throughout the contracted period, only upon delivery of the measured ecosystem service, prior to the delivery of the measured service, conditional to meeting specific milestones as laid out in the contract, or a combination of these. In some cases, service providers receive an upfront payment to cover initial capital costs, with annual progress payments to follow (Greiber, 2009).

2.3.5.6 Monitoring of outcomes

Ecosystem services are often difficult and costly to measure. As a result, most PES schemes rely on proxies such as biodiversity indicators, habitat condition or evidence of management measures. Consistent monitoring is critical for ensuring that provision is in fact taking place and that payments are conditional on additionality. A monitoring framework with clear and explicit targets will help to achieve this. This is important for reassuring beneficiaries and donors that the scheme is delivering the expected benefits that they are investing in and can be used by scheme managers to communicate results to existing donors and funders, as well as to attract new potential investors to support the growth of the scheme (De Lima, Krueger & García-Marquez, 2017).

Monitoring systems can involve periodic evaluation or auditing through visual inspections of land use, or through conducting baseline assessments and assessing change on an annual basis through on-site monitoring and field checks, or for larger areas it can involve a combination of satellite surveillance mapping and on the ground spot checks. In practice, the design and implementation of an effective monitoring system usually requires significant time and resources (De Lima *et al.*, 2017; Wunder *et al.*, 2018).

Monitoring on its own is not enough to ensure compliance (Wunder *et al.*, 2008). Therefore, monitoring and evaluation frameworks should include clear, transparent and enforceable sanctions for non-compliance (AfDB, 2015). These can include temporary or permanent PES exclusion, repayments, or loss of future payments. However, in practice, monitoring is costly and sanctions are often practically and politically difficult to enforce (Wunder *et al.*, 2008; Emerton, 2018). As a result, the principle of conditionality is seldom implemented (Wunder *et al.*, 2018). Without conditionality, money spent on PES will not achieve delivery of ecosystem services.

In the Naivasha Basin PES scheme in Kenya, monitoring data are collected using a smart phone tool (provided by WWF), but local monitors who travel between farms on a motorbike to record activities. The International Small Group and Tree Planting Program in Kenya operates through small groups of 6-12 farmers which are audited by an external party. The auditors survey the groups trees and provide information sharing. They also assess the impact of the scheme on health, food supply, etc.

2.3.6 Financial management

In the simplest PES, the buyer negotiates with the seller, and payments are made directly based on agreed conditions. In more complex situations, setting up a scheme involves undertaking baseline assessments, negotiations and program design, and the recurrent costs of implementation such as monitoring and payment administration (Wunder *et al.*, 2018). These transaction costs can be substantial, and are often cited as a major challenge, particularly in Africa (AfDB, 2015; Emerton, 2018; Mbopha *et al.*, 2021). The more complex the scheme, and the higher the number of stakeholders involved, the higher the transaction costs will be (Greiber, 2009). Start-up costs are usually much higher than the operating costs (Wunder *et al.*, 2008; Börner *et al.*, 2017; AECOM, 2020), and are typically funded through a grant. A system then needs to be devised to maintain the conditional payments to the service providers.

Funding for the recurrent payments to the service providers can be channelled directly from the funders on an ongoing basis, e.g. via a revolving fund, or from a trust fund or endowment fund that has been capitalised by the funders. These funds are usually managed by an intermediary, such as an NGO. This model provides an approach that facilitates long-term, sustainable financing. These distance the buyer's payments from the service provided, in that the buyer capitalises the fund in advance of receiving the anticipated service, on the trust that the intermediary will use the funds wisely and see to it that the service is delivered. If this is set up properly, it need not sacrifice the element of conditionality[28]. Most importantly this model also allows the pooling of funds from multiple sources (private sector, NGOs, government bodies, international donors). With most PES schemes, payments are received from a number of sources at different times, e.g. once-off donations, annual lump sum payments or monthly user payments (Porras *et al.*, 2008). Therefore, establishing a fund to pool all of this finance becomes necessary.

[28] Thus some scholars would argue that water funds violate conditionality in that there is no direct connection between the ecosystem service user and the service provider (Goldman-Benner et al., 2012). However, the buyers are typically represented in the governance structure of the Fund.

Separate trust funds, with a defined legal structure, are becoming more popular, especially within the realm of payments for hydrological ecosystem services. For example, water funds have been established to channel funds from donors to secure hydrological ecosystem services in many parts of the world, including Africa (Salzman *et al.*, 2018). Although water funds are not necessarily confined to PES, and can use their funds to pay directly for interventions, e.g. restoration of catchments under the Cape Town Water Fund by trained teams, their success to date suggests that this approach could be key to unlocking the barriers that have limited PES development in much of Africa. Similar types of funds have also been set up for biodiversity conservation.

Where payments are made to communities as a whole, special considerations are needed to ensure that these continue to provide the intended incentives. As mentioned above, this kind of arrangement is more likely to attract funders and to be effective where community management is strong. Where trust in community institutions is low, as is frequently the case, the intrinsic motivation of households to co-operate may be diminished. In a rigorous experimental study carried out to inform the design of PES for Namibia's communal conservancies, Turpie & Letley (2021) found that addressing the risk of financial mismanagement was more important than the payment level. Households with a low level of confidence in the conservancy management were less inclined to participate. However, cooperation increased significantly when external financial oversight by a trustworthy non-governmental organisation was introduced to ensure that funds were invested and disbursed in such a way as to maximise the benefits to the community. People also voiced the desire for such oversight when asked directly.

2.3.7 Legal frameworks

User-financed (or private) PES schemes require very little legislation to get started beyond basic contract law protections (Greiber, 2009; Table 2.4). A specific legal framework is not required, rather user-financed schemes depend on general legal requirements such as the basic legal principles of civil and international law, the absence of legal provisions which would outlaw PES contracts, civil laws that enforce contract rights, and general respect for the rule of law (Greiber, 2009).

Table 2.4. Potential structure of an effective and efficient PES legal framework. Source: Greiber, 2009.

Type of legislation	Objective
Constitution	Recognizing the right to a healthy environment Acknowledging the value of ecosystem services for human well-being
Specific PES law	Introducing a national PES vision Recognizing PES as a legitimate policy instrument Defining the general concept of ecosystem services Defining the concept of PES as well as recognized types of PES Creating specialized institutions Promoting bundling of ecosystem services Establishing ecosystem services inventories
Sectoral legislation	Clarifying/adjusting existing economic instruments to include PES Adding specific provisions for PES fundraising Setting up an institutional framework Regulating monitoring, compliance and enforcement Encouraging decentralized PES management Introducing general requirements for good PES governance
Implementing regulations	Regulating the implementation of specific elements in further detail
Indirectly relevant legislation	Ensuring PES compatibility Avoiding perverse incentives Encouraging land-use planning based on an ecosystem services approach

Many government-financed (or public) PES schemes have been established without any legislation that regulates PES, but there are numerous examples of where PES-related legislation has been advantageous and has shown to stimulate the development of trustworthy markets and ensure good governance. The advantage of a specific PES law is that it promotes PES as a legitimate policy instrument and clarifies and defines its scope. The disadvantages include the risk of further fragmenting environmental legislation, creating complexity and conflicting requirements, and as a result hampering successful implementation. Sectoral environmental legislation and/or policies can be amended to include specific provisions for the development and implementation of PES. This requires less legal drafting and synchronisation with other laws and also provides opportunity to further promote and develop existing economic or financial instruments (Greiber, 2009).

It is also important that any PES framework is compatible with indirectly relevant laws, which are laws that relate generally to natural resources management or financial issues such as land tenure laws, agricultural laws, mining laws, land use planning laws, etc. This ensures, for example, that any perverse incentives are removed.

2.3.8 Conclusions

By design, a PES scheme is only successful if the service has been provided and the costs of providing it have been fully compensated. It is generally accepted that there are at least five necessary conditions for the design of a "genuine" PES scheme (Engel *et al.*, 2008; Emerton, 2018; Wunder *et al.*, 2020):

- PES schemes must involve at least one ecosystem service buyer and one ecosystem service provider where there is some kind of payment or benefit flow;
- Neither the ecosystem service buyer nor the ecosystem service provider can be forced to enter into a PES arrangement (it is a voluntary transaction);
- Potential service providers need to have sufficiently clear property rights to their land and resources[29];
- There must be a clear relationship between the type of land use that is being promoted and the ecosystem service (or bundle of ecosystem services) being provided; and
- Monitoring must form part of the PES design to ensure the provision of the ecosystem service is taking place (additionality and conditionality of payments is being achieved).

Building on the analysis of Huber-Stearns *et al.* (2017), as well as the above review, the key enabling conditions for the success of PES in a tropical/subtropical African context are summarised in
Box 2.2.

Box 2.2. A summary of the key factors that contribute to the success of PES projects or programmes in tropical, developing country, communal tenure contexts.

Biophysical factors critical for achieving outcomes

- The ecosystem to be managed/restored is not degraded beyond repair and has a reasonable prospect of attaining a meaningful level of ecological connectivity and ecosystem service provision;
- Environmental outcomes are measurable;
- Very good baseline data against which outcomes can be monitored;
- Research supports clear links between service provision and land management practices; and
- Scale of the intervention is large enough to have a measurable effect.

Economic factors that encourage buyers/investors:

- Demonstrating clear threat or risk to provision of ecosystem services of high value;
- Low opportunity costs to secure their provision;
- A strong business case showing that benefits exceed costs;
- Meeting the abovementioned biophysical and institutional requirements;
- Equitable distribution of PES benefits and revenues;

[29] Ecosystem service providers should have the right to exclude externals, although this need not entail formal land titles, informally recognised **but secure** rights may suffice (Wunder *et al.*, 2020).

- Improved developmental outcomes for the service providers;
- Clear definitions of the targeted ecosystem services/activities, how they will be measured & valued;
- Evidence of positive impacts of interventions;
- Access to initial capital for implementation of PES (start-up costs of equipment, materials, inputs);
- Realistic evaluation of beneficiaries' willingness to pay; for example water utilities, may already be paying statutory water fees to a regulating body, and may perceive contributing to the scheme as double payment; and
- Proximity to or a close connection with the location of service provision.

Institutional factors critical for achieving outcomes

- Service provider community is well defined and stable;
- Clear and uncomplicated land tenure and property rights;
- The community needs to have a well-respected, fair and transparent institution that can negotiate on their behalf (e.g. CBO or trust);
- Simple, efficient organisational structure
- A strong institutional framework enabling funding flows and distribution, with safeguards (e.g. benefit sharing rules, legal grievance resolutions);
- There is a competent intermediary who facilitates engagement between all actors (civil society, government, private sector) and provides external financial oversight;
- An established rapport and trust between beneficiaries, service providers and intermediaries;
- Effective and comprehensive monitoring and evaluation system executed by an independent body;
- Payment is subject to strong conditionality rules;
- Supportive public institutions, policies and laws;
- Presence of an institutional champion;
- Strong capacity among key actors, including government capacity for relatively swift development of legal frameworks and pilot projects; and
- A design that aims to minimise interannual variability in payments in a compliant system.

Socio-cultural factors that encourage service provision:

- High acceptability of interventions by local communities/farmers;
- Interventions improve human livelihoods and reduce poverty;
- Capacity building of service providers;
- Awareness raising and sensitizing service providers – this is critical for securing involvement;
- Complementary livelihood initiatives;
- Demonstration sites showing positive impacts of interventions on local livelihoods;
- Establishing trustworthy relationships between local communities, the intermediary and other stakeholders;
- Cooperative community-based approach;
- A history of positive outcomes;
- A good balance between outcomes for service providers (e.g. poverty alleviation) and beneficiaries (supply of ecosystem services). Overemphasis of local social outcomes can reduce intended conservation outcomes;
- Fairness arising from equitable access and inclusivity in decision making;
- An absence of social conflicts over land use;
- Benefits accruing to actual service providers exceed their opportunity costs;
- A system designed to avoid free riders or rent seekers.

2.4 EFFORTS AND PROGRESS TOWARDS SECURING HYDROLOGICAL ECOSYSTEM SERVICES IN SOUTH AFRICA

2.4.1 Overview

To address the water challenges in South Africa, the government has acknowledged the importance of investing in water-related ecological infrastructure (Mbopha *et al.*, 2021). In addition to increasing ecosystem services, these interventions have also been identified as a key element in South Africa's transition towards a green economy, providing unskilled employment opportunities and other socio-economic co-benefits (Blignaut *et al.*, 2010; Coldrey, 2020; Mbopha *et al.*, 2021). Outside of government, there are also a number of initiatives and programmes that are working towards the protection and restoration of critical ecological infrastructure. In this section of the report, the efforts and progress that have been made in South Africa to date are highlighted and discussed. Note that the bulk of what is included in the following sub-sections is based on information collated during online interviews with key experts and does not represent all of the programmes/projects that have been undertaken in the country.

2.4.2 National government land restoration programmes

To date, clearing of invasive alien plants accounts for the majority of investments into catchment restoration in South Africa, mostly through the government funded **Natural Resource Management programme**, home to the country's "Working for" programmes (e.g. Working for Water, WfW), and the associated, more recent Land User Incentive (LUI) Programme. The "Working for" programmes which were launched in 1995 (with the Working for Water programme) are managed under the Expanded Public Works Programme (EPWP) and as such have a social protection focus seeking to alleviate poverty through the provision of temporary employment and skills development whereby the contracted labourers are deployed to NRM projects to improve their local environments (Ferraro, 2007; Marais & Mlilo, 2018).

The largest and particularly well-known branch of the NRM programme is the 'Working for Water' (WfW) programme, which is focused on the clearance of IAPs in mountain catchment and riparian areas to restore the integrity and functioning of the natural ecosystem (Turpie, Marais & Blignaut, 2008). Other NRM programmes include Working for Wetlands, Working for Land, and Working on Fire, that address different aspects of environmental degradation (Republic of South Africa, 2018). Running projects in all nine of South Africa's provinces, WfW is the largest natural resource-based poverty relief programme in the country. The bulk of funding for WfW is generated through poverty relief programmes such as the Expanded Public Works Programme and the Reconstruction and Development Programme. However, the government has also made substantial contributions through tax revenues (Turpie *et al.*, 2008).

Since 2010 an average of 200 000 "condensed ha"[30] of IAPs have been cleared per year with around 600 000 ha per year receiving follow-up treatment (clearing usually requires three follow-ups; Van Wilgen *et al.*, 2020). These programmes involve partnerships with local communities and other government departments such as the Department of Agriculture, Land Reform and Rural Development, and Department and Water and Sanitation (DWS) who have a joint responsibility for the implementation of the Working for Wetlands programme and have support functions for the NRM programmes.

Primarily, the NRM programmes attempt to mitigate ecosystem degradation through social upliftment via the creation of jobs and livelihood benefits to marginalised South Africans (Turpie *et al.*, 2008; Giordano *et al.*, 2012). The programmes have managed to attract and redirect substantial funding, mainly owing to its social development aspect. Since their establishment in 1995, as Working for Water, over R15 billion has been

[30] IAPs occur at varying densities, so measures are standardized to the equivalent area at 100% density

invested into the NRM programmes (Turpie *et al.*, 2021b). The annual budget for the NRM programmes has ranged from R2.8 billion to R3.9 billion between 2012/13 and 2016/17, with an average growth rate of 4.5% until 2018/19 (Marais & Mlilo, 2018). This makes the NRM programmes the largest national investment in sustainable environmental management in post-apartheid South Africa (Giordano *et al.*, 2012).

However, despite the benefits of the programme, funding and management constraints have meant that many of the invaded areas have only been partially treated, which is ineffective (Turpie *et al.*, 2021b). Furthermore, a criticism has been the focus of the programmes on employment targets rather than on achieving restoration in the most efficient way. In many cases, a lack of attention to the environmental objectives has resulted in weak implementation and monitoring, failure to follow up, and areas reverting to invasion by IAPs (Turpie *et al.*, 2021b). Thus, IAPs continue to spread and densify, remaining an enormous threat to many ecosystems (Wilson & Henderson, 2017; Van Wilgen & Wilson, 2018; Van Wilgen *et al.*, 2020b). While significant amounts of money have been spent on the problem, the consensus is that while targets have been achieved through focused efforts in protected areas, the clearing efforts outside of protected areas have only slowed down the spread, and degradation is still increasing (Van Wilgen & Wilson, 2018; Van Wilgen *et al.*, 2020b).

The LandCare Programme was initiated in 1997 and is one of DFFE's flagship programmes focusing on sustainable land management, as well as restoration and rehabilitation of degraded areas in rural areas to enhance productivity and food security (Department of Agriculture, 1999; Mulder & Brent, 2006). The key components of LandCare centre around conservation agriculture (farming that encourages minimal soil disturbance, crop rotation and permanent soil surface cover) and funds community-based projects. These projects include support for farmers and landowners (extension services), fencing, and IAP clearing.[31] Among its principle objectives are fostering community-based resource management in a participatory way, empowering sustainable livelihoods, building capacity within communities and between state actors at various levels, private entities, NGOs and communities, and blending together the appropriate upper level policy using bottom-up feedback mechanisms (Turpie *et al.*, 2021b). While there have no doubt been successes countrywide, by 2005 it appeared to have achieved minimal results in communal rangelands (Peden, 2005), with poor uptake and a very low budget relative to the NRM programmes.

2.4.3 Attempts to establish payments for ecosystem services schemes

In South Africa over the last decade or two there has been a strong interest in payment for ecosystem services as mechanism for financing catchment restoration. However, the potential for implementing PES schemes for hydrological services has been investigated thoroughly in just two localities (e.g. the upper Thukela and Umzimvubu catchments in the Mnweni/Cathedral Peak and Eastern Cape Drakensberg Areas, and the Baviaanskloof and Tsitsikamma areas; Maloti Drakensberg Transfrontier Project, 2007; Erlank, 2010; Mander *et al.*, 2010).

The Maloti-Drakensberg Transfrontier PES Project funded by the Development Bank of Southern Africa and the Maloti Drakensberg Transfrontier Project was a component of a much broader conservation project which concerned the conservation and co-management of the escarpment between Lesotho and South Africa. The main aim was to explore the possibilities of paying land users for improved land and resource management. The project was conducted over a 14-month period. A model based on the trade in ecosystem services for investment in water security was developed. However, due to the novelty of the project at the time, it was very research based and lacked a dedicated on the ground focus of socio-cultural factors.

The potential for a PES scheme in the Baviaanskloof and Tsitsikamma catchments was investigated shortly after completion of the Maloti-Drakensberg PES study. Funded through SANBI's C.A.P.E. programme in association with Working for Water (WfW) a feasibility study was undertaken to investigate the establishment

[31] There is no indication that this programme assists commercial landowners.

of a PES system in the Baviaanskloof and Tsitsikamma catchments focused on water and carbon sequestration services. Three possible buyers of water-related ecosystem services were identified: the Nelson Mandela Bay Municipality (NMBM), the then Department of Water Affairs, and the Gamtoos Irrigation Board (Mander *et al.*, 2010). Using hydrological and economic modelling approaches, both studies succeeded in showing that PES could be economically viable on the basis of the costs and benefits involved. However, they have not led to any implementation. A number of constraints were listed as reasons for why the two PES schemes did not reach implementation, as follows (based on literature and J. Blignaut, M. Mander; pers. comm.):

- Funding challenges due to low willingness to pay (or reluctance to pay) by water service providers.
- Communal land tenure systems (open access) in the project areas.
- Weak institutions and the lack of an institutional home. The institutional home would have provided the stability and operational capacity to continue with the PES scheme.
- The projects lacked a practical or action-based focus, with the practicalities of implementing a PES scheme not fully investigated or tested.
- A lack of coordination among and across public agencies and with other stakeholders at the catchment level, as well as at the national level.
- High transaction costs, implementation costs of active restoration (e.g. clearing IAPs) and ongoing operating costs.
- Uncertainty around the payment model in terms of it being input-based or output-based.

While these are valid challenges, most of them can be overcome. However, even if the values for hydrological ecosystem services were clearer, and the relationship with land use more apparent, stakeholders more coordinated, and the costs more manageable, securing financing for payments requires two key things: (1) water service consumers (beneficiaries) who are willing and able to pay, and (2) strong institutions that are capable of excluding nonpayers (free-riders, Ferraro, 2007; AfDB, 2015; Emerton, 2018; AECOM, 2020). Hydrological services are driven by local water demand, rather than international demand as in carbon or biodiversity PES schemes and as such willingness to pay is limited. Another important reason for the lack of PES schemes in South Africa relates to the nature of the degradation problem that we have in the country. Invasive alien plants are a massive problem in all water source areas, and they require costly ongoing active restoration measures to clear them. In other parts of the world, payments for hydrological ecosystem service schemes focus on forest management, paying landowners to protect forest and desisting from damaging behaviour. The problem of IAPs is complex and costly and as such cannot be fixed with PES alone.

Although there have been a number of barriers to PES development in South Africa, this does not mean that there are no opportunities for implementing PES. Indeed, there is still potential for the application of PES in certain settings. It could be a useful tool for incentivising sustainable land management interventions after initial restoration has been undertaken, for example.

The main reason for the failure of PES in South Africa has been around the low willingness to pay by water service providers. The unrealised demand from local water service consumers is linked to a lack of awareness around the role of natural capital in securing water supplies and the sense that PES is too risky (Ferraro, 2007). Further issues may include unknowns around the raising of revenues from the end users (i.e. capturing their willingness to pay), risks and uncertainty regarding return on investment, legal and institutional barriers, and potentially cheaper traditional grey infrastructure alternatives.

This requires further investigation in South Africa to understand more about financial incentives that encourage bulk water service providers (as the buyers of ecosystem services) to invest. Indeed, in most PES schemes that are in operation elsewhere in the world, existing revenue streams are used to make payments, and only in a few cases have rates paid by end-users (through water tariff pricing) been raised and ringfenced for conservation and restoration (Ferraro, 2007). This requires that the water services authorities have adequate revenues for investing. However, in South Africa most water services authorities are financially constrained and using existing revenues is not possible. Increasing water tariffs could generate the revenue needed to finance catchment restoration and conservation. This provides the opportunity for PES schemes that connect water users directly to bulk water suppliers. This requires assessing the potential to do so by determining household willingness to pay.

2.4.4 Projects addressing land management

There are numerous projects that have been undertaken in South Africa over the last two decades that have aimed to improve catchment conservation and restoration. The projects included here are by no means the only ones or the most important ones, but represent a broad coverage based on interviews undertaken with experts managing these projects. A project is considered an individual or collaborative enterprise that is carefully planned to achieve a particular aim but usually has a defined timespan. In South Africa most restoration projects have relied heavily on government and donor funding to carry out their research and implement restoration interventions, with very little funding from the private sector. In some cases, these projects have failed to raise enough financial commitment to ensure sustained, long-term action.

The Tsitsa Project is one such project that has relied almost entirely on government funding. The project undertakes landscape restoration upstream of two dams on the uMzimvubu River in the Eastern Cape, initially as part of the Mzimvubu Water Project. The project, which was instigated and has been funded by DFFE since 2014, involves efforts to encourage sustainable land management in a very degraded part of the catchment. The project has a strong research focus, which through the research programme, will work towards understanding the drivers of land degradation within the study area as well as the social context of the work. The project is a multi-stakeholder initiative between DFFE, Rhodes University, LIMA Rural Development Foundation, University of Fort Hare and the University of the Free State. Through the project, citizen scientists have been employed as well as community monitors and eco-rangers who monitor and track sedimentation levels in the water, weather and landscape changes, community income-generating projects and sustainable rangeland and farming practices. Local community members have been employed in IAP clearing activities through the national NRM Working for Water programme and other income generating activities such as growing grass plugs for restoration work. Through education, employment opportunities (e.g. active restoration through WfW), access to new red meat markets, and alternative livelihood programmes, sustainable land management is encouraged. The project has been slow to demonstrate ecological impacts, however, because of the long time it has taken to develop trusted relationships and build capacity in a very complex system (M. Wolff, *pers. comm.*)[32]. Despite these challenges, the extensive networks and relationships that have been formed between different institutions means that this initiative is poised to make an impact. With the very necessary but intangible benefits that this project has yielded, mindsets seem to be beginning to change. Furthermore, some areas of improved grazing are beginning to demonstrate benefits (M. Wolff, *pers. comm.*).

There are long-standing projects in the Baviaanskloof and Langkloof catchment areas as well as in some catchments surrounding Cape Town operated by Living Lands. Living Lands is a non-profit organisation that undertake projects and programmes to build social and ecological resilience, with a particular focus on restoring catchments and securing water resources, i.e. they are concerned with creating sustainable socio-ecological systems. The projects use bottom-up approaches to facilitate social learning and collective action, with the majority of work aiming to mobilise civil society and to foster collaboration amongst land users. It prides itself on collaborating with diverse stakeholders on the ground including commercial farmers, small scale farmers and irrigation boards. These stakeholders are engaged in knowledge sharing and skills development and in some cases are actively involved in catchment restoration activities which is incentivised through alternative livelihoods gains and improved agricultural production. Funding and support through the national NRM programme, Global Environment Facility (GEF) and Common Land has resulted in rehabilitation

[32] Margaret Wolff from the Rhodes University Restoration Research Group is the coordinator of the Tsitsa Project.

across more than 1400 hectares of land in the Baviaanskloof, including revegetation, IAP control, gabion work, building of close to 1200 silt traps, and regenerative agriculture. There has also been rehabilitation on about 100 hectares of communal lands, and rehabilitating 1850 hectares of degraded thicket by planting Spekboom. Other projects include piloting new composting practices and honey bush farming in the Langkloof, and exploring alternative livelihood initiatives by planting lavender and rosemary for the essential oils industry (Living Lands, 2021). Living Lands has been working with TNC and the Nelson Mandela Bay Municipality (as well as other stakeholders, including the private sector through the '4 Returns Partnership') to set up a water fund to support upstream management of supply catchments. However, to date this has not materialised. Living Lands attract funding for their projects from both local and international funding organisations, such as the South African Government, the private sector, landowners and international bodies. In 2020, project costs amounted to just over R7 million (Living Lands, 2021).

Over the past seven years, funded by USAID and managed by The Association for Water and Rural Development (AWARD), a project looking at building improved transboundary governance and management of the Olifants Catchment of the Limpopo Basin through systemic and participatory approaches (known as "RESILIM-O": Resilience in the Limpopo Basin Program – Olifants, Pollard *et al.*, 2020) has been undertaken. Project partners have included DWS, DFFE, SANParks, SANBI, various local municipalities, the Government of Mozambique and a number of NGOs and academic institutions. The project focused on water resources protection and water security, land and biodiversity management, climate change adaptation, and institutional capacity for resilience (Pollard *et al.*, 2020). Over the seven-year timeline, through a number of sub-grant funded projects, RESILIM-O achieved the following:

- Developed the tool FlowTracker which ensures real-time monitoring of flows and compliance with gazetted standards, and is freely available and used by stakeholders to monitor flow compliance and dam levels;
- Developed an integrated decision support system INWARDs to assist DWS officials with compliance monitoring and enforcement and the authorization of water use;
- Developed the River Health Monitoring Network of private protected areas, and the middle and lower Olifants operations networks;
- Integrated biodiversity and climate change adaptation into spatial planning in the lower Olifants region through the application of the Critical Biodiversity Area (CBA) maps and land-use guidelines;
- Facilitated the provincial inclusion of biodiversity in Spatial Development Frameworks;
- Developed a proof of concept for an electronic version (mobile phone app) of the Critical Biodiversity Areas (CBA) map;
- Undertook invasive alien plant control and restoration of the biodiverse, strategic water source area of the Blyde Catchment;
- Integrated climate change into local government's Integrated Development Plans (IDPs) and into the IDP situational analysis in two municipalities; and
- Support to institutions of Higher Learning with curriculum revitalization and capacity building of young professionals through internship/mentorship.

Challenges included weakening governance systems, failing maintenance of monitoring systems, the lack of adequate and updated planning and water resource availability assessments, the perceived notion that biodiversity is only the responsibility of (underfunded) conservation entities, weak capacity of local governments to take on the mandate for climate change planning and adaptation, and putting on hold the catchment management agency (CMA) process in 2017 (Pollard *et al.*, 2020).

2.4.5 Projects to encourage local government and WSP investment in ecological infrastructure

SANBI's Biodiversity Land-Use (BLU) Project was initiated in 2015, funded by GEF through the UNDP. The main objective of the project is to increase capabilities of authorities to support improved regulation and land use management at the municipal scale. The five-year project had two components. The first component of the BLU Project focused specifically on land and NRM regulation and compliance by working directly with relevant government departments. The second component of the project focused on improving land management and resource use through biodiversity stewardship, in particular, by strengthening the implementation of stewardship and environmental tax incentives (S. Manyike, *pers. comm.*[33]). Part of component one included illustrating the potential financial gains from ecosystems and to promote increasing budget allocations for investments in ecological infrastructure. The Ecological Infrastructure Challenge Fund (EICF) was an outcome of this BLU Project objective. Since its development, the EICF has funded seven restoration related projects in three different municipalities. The projects focus on clearing IAPs, rehabilitation degraded rangelands, and rehabilitating wetlands on municipal-owned land. The projects also aim to raise awareness and build capacity at the local level and to mainstream EI into municipal IDPs.

SANBI's Ecological infrastructure for water security "EI4WS" project was launched in 2018 and aims to integrate biodiversity and ecosystem services into development and finance planning. The Project received a five-year investment of ~R90 million from the Global Environment Facility (GEF) and has DFFE as the national focal point and the DBSA as the project implementing agent for the GEF in South Africa. SANBI is the designated project executing agency. Project implementation involves partnerships with various private and civil society organisations, including DWS, WRC and WWF-SA, and is focused on strengthening on the ground implementation of EI restoration projects in two catchment areas; the greater uMngeni catchments and the Berg-Breede catchments. This project is linked to the uMngeni Ecological Infrastructure Partnership (UEIP).

There has also been numerous WRC funded projects that have focused on strengthening investment in EI and investigating the benefits of such. One such project was the "Demonstration of how healthy ecological infrastructure can be utilised to secure water for the benefit of society and the green economy through pragmatic research approach based on selected landscapes" (Jewitt *et al.*, 2020). The project focused its efforts on supporting the service provider partners of the uMngeni Ecological Infrastructure Partnership (UEIP) through research in pilot study sites. Components of the project included an economic evaluation of investing in EI as well as an analysis quantifying the impact of setting a water resource management tariff at Umgeni Water.

The Development of a Comprehensive Manual for River Rehabilitation in South Africa (Day, Rowntree & King, 2016) is another WRC funded project that focused on providing best practice guidelines for identifying and contextualising river degradation, and then providing a range of potential solutions for addressing the problem and preventing further degradation of EI.

2.4.6 Partnerships and water funds

Following the failure of PES and recognising the need for collective action and innovative financing approaches for securing hydrological ecosystem services, initiatives in South Africa started to move towards a partnership approach where a more concerted effort has been made to persuade and convince stakeholders to support investment in EI through collective action. The premise being that a group of stakeholders all with a vested interest in water supply catchments being better managed, come together to raise funding and cover restoration costs and/or persuade or incentivise land managers to change land use practices using a wide array of mechanisms. Indeed, partnerships and water funds are able to employ any of the types of policy

[33] Sagwata Manyike is the manager of the Biodiversity and Land-Use (BLU) Management Project and was interviewed in August 2021.

instruments discussed above, including PES. These are chosen based on what is deemed appropriate and achievable, tailored to a specific local context.

Essentially, a partnership is an arrangement between two or more parties formalised through a Memorandum of Understanding (MoU) or a letter of intent. The partnerships included here consist of a mix of government, business, civil society, traditional leaders and communities, and academia. A formal partnership agreement works to align stakeholders and offers stability and operational capacity in an otherwise uncoordinated and busy space.

2.4.6.1 Catchment scale partnerships

The uMzimvubu catchment partnership programme (UCPP), the uMhlathuze Water Stewardship Partnership (uWASP) and the uMngeni Ecological Infrastructure Partnership (UEIP) are examples of formal partnerships that operate at the catchment scale across all land tenure types (state, communal and private land). However, the UCPP, which is situated in the rural Eastern Cape, does have a stronger focus on restoring, rehabilitating, and maintaining ecological infrastructure on communal land through communal custodianship and through community based natural resource management. The uWASP and UEIP have a strong water stewardship focus, working with businesses and industry that operate in a more urbanised setting, as well as with traditional leaders and communities on communally owned land where rangeland management is an important component of the work being undertaken. These three partnerships rely on a mixed funding stream, but the majority of their funds still come from government or donor funding. Each of these are described in more detail below.

The uMzimvubu catchment partnership programme (UCPP) aims to address severe land degradation and IAP infestation in the Mzimvubu River catchment through sustainable restoration measures that support “economic development and job creation for local people, and enhance flows of benefits from ecosystem goods and services” (SANBI and Wildlands Conservation Trust, 2015). Essentially, this is a partnership of stakeholders to support implementation of sustainable rangeland management through cash and in-kind assistance, with the supporting stakeholders all having a vested interest in grassland conservation. In 2011, Conservation South Africa, in partnership with Environmental and Rural Solutions, led a process to develop a 20-year strategy for the Mzimvubu River catchment which resulted in the formation of the UCPP. The UCPP is a partnership between 34 organisations[34] and is an example of a Biodiversity Partnership Area[35] in which the partners all agree to act together and share resources at the landscape scale (SANBI and Wildlands Conservation Trust, 2015).

The UCPP has over the years had success in clearing IAPs and restoring important grazing land through their rangelands management project which focuses on communal herding practices to assist with grassland restoration through rotational grazing (SANBI and Wildlands Conservation Trust, 2015). The rangeland management project employs ecorangers from eight local villages to manage the movement of cattle and to ensure stock is kept in agreed areas for certain periods of time. Therefore, farmer cooperation is incentivised by subsidising the management cost of sustainable rangeland management, and the costs of better herd and business management, which then translates into increased cash income for farmers through access to meat markets (Mbatha, 2021). The Meat Naturally Pty model provides access for stock farmers, through a negotiated stewardship agreement for improved rangeland management and specified livestock supply, to mobile auctions and husbandry-linked benefits (ERS, 2016). The model works on the annual or bi-annual sale of healthy cattle off improved grassland at village-based auctions, thereby providing small-scale farmers with

[34] The 34 members include two traditional authorities, two municipalities, four state departments, two parastatal organisations, seven national NGOs, three regional NGOs, ten local NGOs, two small consultancies, and two universities

[35] BPAs are a type of biodiversity stewardship achieved through informal agreements that do not legally bind parties to any obligations. However, as with the UCPP, BPAs can be formalised with the signing of a MoU.

the opportunity to reach new markets (Mbatha, 2021). The sales are both an incentive and reward for compliance by stock owners and grazing management structures with agreed conditions, including management to improve grassland quality and cover (ERS, 2016). Since its inception, numerous auctions have been held in the Matatiele area involving over 150 households realising an average of R16 000 per household per auction (ERS, 2016). Sanctions are implemented if the eco-rangers have not been compliant through adjusting commission rates at auction, depending on the number of times they have defaulted (i.e. not followed the rangeland management regime, grazed in resting areas, etc.; S. Zukulu[36] *pers. comm.*). Other sanctions include paying of a fine to the grazing association (S. Zukulu *pers. comm.*). This approach has shown impressive results (see ERS, 2016; Stanway, 2016; Mbatha, 2021 for more information). Other activities include a small biochar business which has been created through the UCPP where local community members are employed to make charcoal from wattle plants which is then sold on to companies and smelters (S. Zukulu, *pers. comm.*)[37].

The formation of the uMhlathuze Water Stewardship Partnership (uWASP) was catalysed by a major drought in 2016, and the need for a collective response. This saw the Department of Water and Sanitation (DWS), the Proto-CMA Pongolo-uMzimkulu, the National Business Initiative (NBI), WWF-South Africa, the Strategic Water Partners Network, and the International Water Stewardship Programme (IWaSP) enter into a formal partnership constituted through a letter of intent (uWASP, 2016). Since its formation in 2016, two people have been employed full time by the NBI and WWF-South Africa, with further support and funding received from the German development agency, GIZ, International Water Stewardship Programme (IWaSP), Mondi and Tongaat Hulett. The uWASP aims to serve as a coordination hub for collective action on water security; collaborate with stakeholders and water users across the region; implement measures to improve water security for industry, agriculture and communities; use water as a focal point for transformation and economic development; and work with public sector institutions to support improved service delivery and natural resource management (uWASP, 2020). A detailed partnership work plan and governance structure has been approved and five priority projects were initiated at the end of 2017. These projects aim to address downstream water use efficiency opportunities; agricultural water stewardship practices; ecological infrastructure requirements (IAP clearing and wetland restoration); the development of local community environmental champions for pollution control; and improved management of the coastal lakes and surface water dam in the uMhlathuze catchment (uWASP, 2020).

The uMngeni Ecological Infrastructure Partnership (UEIP) is committed to finding ways of better integrating nature-based solutions into water resource management in the greater uMngeni River catchment (Gola, 2016). The catchment-wide partnership was formed and launched in 2013, led by the eThekwini Metropolitan Municipality and SANBI, together with Umgeni Water and the KwaZulu-Natal regional office of the Department of Water and Sanitation (DWS). There are over 20 stakeholders that have signed the MoU, however, most of these are government or NGOs with only one private sector partner (SAPPI). Since its inception, SANBI has acted as the centre of coordination for the UEIP and is responsible for appointing a UEIP coordinator. The UEIP has a very strong research component, which is driven by its academic partners, e.g. University of KwaZulu-Natal. A number of comprehensive research projects have been undertaken in recent years to identify where and how investment into the restoration and protection of EI can be made to ensure long-term water security (see for example, Pringle *et al.*, 2015; Mander *et al.*, 2017; Hughes *et al.*, 2018; Gokool & Jewitt, 2019; Jewitt *et al.*, 2020). Furthermore, the UEIP has demonstrated the benefits of investing in ecological infrastructure in the catchment through a number of pilot projects, in collaboration with local and district municipalities, such as the Baynespruit Rehabilitation Project in the uMsunduzi Municipality, the Save Midmar Project in the uMgungundlovu Municipality coordinated through KZN Department of Economic Development, Tourism & Environmental Affairs, and the Palmiet Rehabilitation Project in eThekwini Municipality driven and funded through research at UKZN (Gola, 2016). Through the UEIP 100 water monitoring stations have been

[36] Sinegugu Zukulu is the chairperson of the UCPP and was interviewed in August 2021.

[37] Sinegugu Zukulu is the chairperson of the Umzimvubu Catchment Partnership Programme (UCPP) and was interviewed in August 2021

implemented, over 300 jobs created for the youth through their "Enviro Champs" programme and over 300 hectares of important riparian zone has been cleaned, cleared and maintained. In 2020 the UEIP mobilised funding from P4G – Partnering for Green Growth, an international grant investment, and from the Department of Science and Innovation (DSI). Previously the partnership has also received funding from the Green Fund (through the Development Bank of South Africa).

2.4.6.2 Water source partnerships

Similar to the catchment scale partnerships, and usually working with them, water source partnerships are a mechanism for support which WWF seeks to facilitate, performing different roles in different water source areas, as appropriate (C. Gelderblom, *pers. comm.*). The underlying principle is to strengthen catchment governance and support mandated institutions including catchment management agencies (CMAs) and water user associations (WUAs). At a national level the organisation is collaborating with DFFE to create and document mechanisms to secure water source areas, including reviewing the current baseline and supporting the development of policies, interventions and mechanisms to help secure them. At a catchment level WWF supports the placement of catchment coordinators within mandated organisations providing additional capacity to work across sectors and institutions to facilitate the implementation of local projects often through the establishment of green SMMEs (C. Gelderblom, *pers. comm.*).

The key principle behind water source partnerships is the gradual process of facilitating collaborative governance, at a water source area scale, bringing together community, public and private role-players from different sectors. This involves assembling a wide array of stakeholders to identify agreed priorities and align resources behind implementation whilst recognising that each partner has a unique role and must also achieve their own mandate. In supporting this approach WWF assigns capacity to engage with and support processes in each water source area acknowledging that the most appropriate platform will be driven by local circumstances and stakeholders. In some areas this has involved supporting existing platforms providing additional coordinating capacity and resources and encouraging significant expansion of implementation. In other areas, where there are already local platforms and programmes, the water source partnership may primarily serve to facilitate alignment of existing plans to ensure complementarity and to identify any gaps. Lastly, where there are no suitable platforms for collaborative governance it may be necessary to support the establishment of new structures.

In summary, the main objectives are to:

- Strengthen catchment governance by building capacity of key mandated institutions and local platforms; facilitating coordinated action; and identifying and securing innovative and sustainable financing mechanisms;
- Implement integrated catchment management through for example, rehabilitating EI and addressing the context specific threats to the integrity of the water source area; and
- Create opportunities and capacity in local communities through promoting sustainable land and water stewardship; and supporting job creation through the establishment of green small-medium or micro enterprises and promoting the green economy.

WWF is currently supporting collaborative catchment governance in seven of the DFFE nationally prioritised strategic water source areas (SWSAs: Boland, Eastern Cape, Southern, Mpumalanga, Northern Drakensberg, Ekangala, and Outeniqua)[38]. For example, in the Zululand Coastal Plains Aquifer WSA, WWF is supporting the uMhlatuze Water Stewardship Partnership (uWASP) as the best vehicle for collaborative governance in this water source area. WWF were one of the founding members and have supported the development of information sharing tools. In the Eastern Cape Drakensberg WSA, WWF are supporting the uMzimvubu

[38] These areas were chosen to align with WWF's existing involvement with implementation and their contribution to water security; C. Gelderblom, *pers. comm.*

Catchment Partnership (UCPP) as the best vehicle for the collaborative governance and have also been involved with securing direct support for implementation of priority projects. In the Southern Drakensberg WSA, WWF is a member of the uMngeni Ecological Infrastructure Partnership (UEIP) which is strengthening local collaboration. This is complemented by work undertaken in the uMkhomazi catchment where a programme is being undertaken to strengthen governance of water resources, and a process is underway to explore the development of a water fund together with partners such as The Nature Conservancy (TNC) and Duzi Umngeni Conservation Trust (DUCT). In the Table Mountain WSA there were no existing structures addressing groundwater, resulting in the establishment of the Table Mountain Water Source Partnership with WWF as the secretariat. Through this partnership, groundwater policies have been revised, an open access groundwater dashboard has been developed, groundwater monitoring has been extended, and there has been important awareness raising on groundwater (K. Schachtschneider, *pers. comm.*). In other WSAs such as the Boland Groot Winterhoek, Outeniqua-Tsitsikamma and Northern Drakensberg, WWF is exploring how best to support collaborative governance while also supporting the implementation of priority projects.

2.4.6.3 Water funds

Water funds are a funding and governance mechanism that engages public, private, and civil society stakeholders to contribute to water security through nature-based solutions and sustainable resource management. Around the world, water funds have been shown to be a useful vehicle for sourcing and pooling funding from various sources and allocating these resources to strategically designed conservation measures in key water source areas (TNC, 2018b).

The Greater Cape Town Water Fund (GCTWF) is one such water fund that is working towards bringing together beneficiaries and linking stakeholders in pursuit of a common goal of securing water. The GCTWF operates at a large scale, focusing restoration efforts, particularly IAP clearing, in the catchments that feed the Western Cape Water Supply System (WCWSS). The users of the WCWSS include the Cape Town metropolitan area, the agricultural sector, and small municipalities (TNC, 2018a). A quarter of the required budget for the first six-year restoration phase for the GCTWF came from private investors. This seed funding was used for the initial clearing of IAPs which was undertaken over the first two years (L. Stafford, *pers. comm.*). Since then, funding has been received from government and other private businesses and philanthropists, such as Coca-Cola and JP Morgan. Some water funds are set up to become institutions, while others operate with a steering committee or an oversight committee. The GCTWF is working towards becoming an institution. In addition to the GCTWF, there are four other potential water funds currently in the feasibility or scoping phase of development in South Africa – Kruger to Canyons, Overstrand, eThekwini and the Garden Route (L. Stafford, *pers. comm.*).

The Greater Cape Town Water Fund has over the last two years focused on clearing IAPs from seven priority catchments that supply water to the WCWSS. Significant progress has been made in coordinating catchment restoration with all catchment institutions following the same annual plan of operation (L. Stafford, *pers. comm.*). Furthermore, the City of Cape Town contributed R62 million to the Fund, the first investment by a municipality in South Africa to address restoration outside the boundary of the city itself.

2.4.7 Key challenges

In the interviews with key experts, several insights were gained as to what the main challenges have been affecting success in catchment restoration and how partnerships are aiming to address these through a more coordinated, collection action approach (Figure 2.9).

Over the years there has been a lack of coordination and clashing mandates between decision-makers in different fields and administrative departments. There can be a number of different government departments and local authorities involved as stakeholders in catchment management, each of with their own mandates and agendas which often do not align, or which overlap but remain uncoordinated (P. Gola, *pers. comm.*). As such there can be a lack of harmonisation which leads to inefficiency. Furthermore, aligning stakeholder perceptions and priorities to work towards a common future goal is challenging and results in inefficiencies. For example, stakeholders can find it difficult to agree on shifting their individual priorities and changing their perceptions (L. Stafford, *pers. comm.*). As a result, stakeholder buy-in can be difficult to achieve and project plans are derailed or slowed down. The partnership and water fund approach provides the much-needed stakeholder management and facilitates coordination.

Initiatives that rely on the participation of multiple stakeholders can be particularly challenging to implement. All of the initiatives discussed in this review involve a wide range of stakeholders, from different government departments (most commonly DWS and DFFE), other spheres of government, NGOs, private companies, associations of water users, civil society, local communities, and traditional leaders. Apart from the organisational aspect, challenges can arise when certain key stakeholders have conflicting interests and are not interested in or are opposed to the initiative or play hardball in the negotiation process. Building trust through this process is what seems to underpin successful, long-term partnerships and projects. Stakeholder equity is therefore critical. While it can be painstaking work keeping these partnerships alive, it is essential for creating constructive learning spaces and the ability to adapt to changing circumstances (P. Gola, *pers. comm.*).

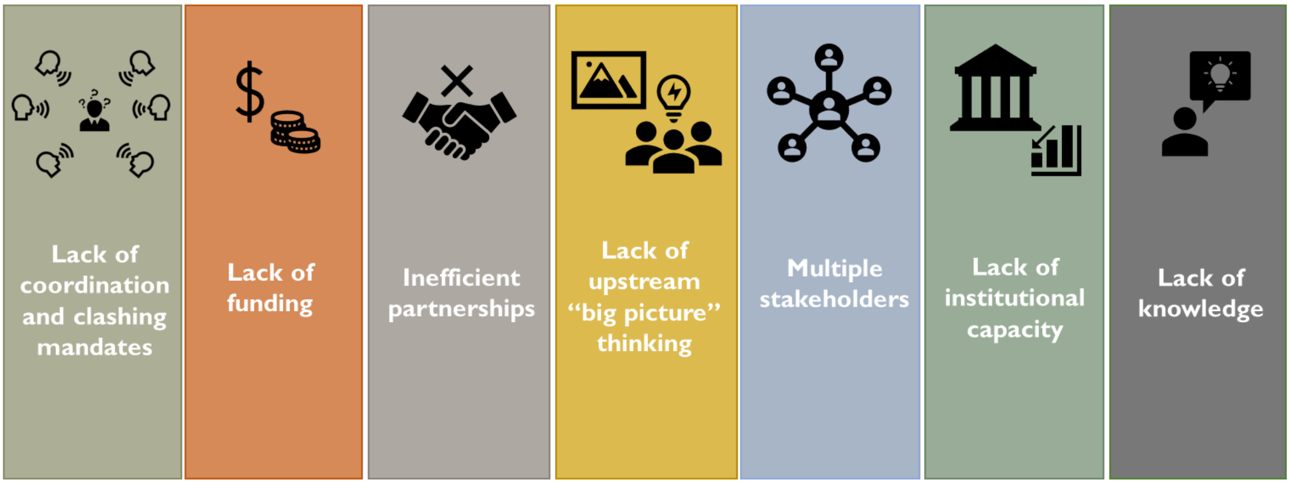


Figure 2.9. The seven key challenges affecting success of catchment restoration and conservation partnership initiatives in South Africa.

The key to achieving responsive, capable government institutions, robust partnerships and empowered communities is through the development of skills, coupled with accountable decision-making (S. Zukulu, *pers. comm.*). However, many institutions are weak, and many donors and NGOs are not willing to invest in building or fixing institutional arrangements, especially within government structures. This makes it very difficult to coordinate and manage projects and funds effectively. The water source partnership approach aims to address these issues effectively and efficiently.

Catchment management and restoration has to happen at the landscape scale, and this requires municipalities, water utilities and government departments to think about the larger picture in terms of upstream impacts affecting downstream infrastructure, for example. It can be difficult to change their interests and bring them on-board to assist with upstream activities if these are outside of their usual mandate or spatial boundary (L. Metcalfe, *pers. comm*). This has implications for the way in which a project is designed and the types of interventions and incentives it uses as the basis for ensuring change. Getting to know the physical and social characteristics of a landscape in-depth and over a sustained period of time is essential for being able to develop the relationships necessary to sustain action as well as to design appropriate interventions (M. Wolff, *pers. comm.*).

A large number of stakeholders interviewed claimed that, in general, there is a lack of sustainable funding to advance projects long-term. Usually there is a high chance of failure during the initial setup stages when an initiative is dependent on seed capital. Access to finance during this stage is often crucial to the success of any restoration project, where the upfront capital costs can be very high. Furthermore, pre-feasibility studies are undertaken but often funds are not available for the next phase and the project is stalled. Those interviewed felt that the lack of funding and support from local government, in particular, was a barrier for establishing catchment restoration initiatives. Poorly managed funds and corruption are a major concern. Through the partnership and water fund approach, alternative financing options are being investigated and funding is better coordinated.

Finally, there is a lack of awareness of what natural capital is, and the importance of protecting and restoring natural capital to ensure the delivery of ecosystem goods and services (S. Manyike; P. Gola, *pers. comm.*). While it can be difficult initially to convince stakeholders that they should put money, time or labour into restoring catchment areas, they become more willing to contribute once it is explained to them how sustainable land use and active restoration (i.e. clearing of IAPs) is linked both to improved productivity of the land and improved water security. Recent water crises in different parts of the country have made this more evident to people. This is particularly true for getting private investors on board. The drought in Cape Town had a big impact on investor perception as the impact on the economy was made very clear. Even financiers are beginning to build the risks associated with landscape degradation (such as fire hazard and catchment deterioration due to alien invasives) into their risk assessments.

2.5 KEY FINDINGS

In summary, there are seven key findings that materialised from the review:

1. **Catchment degradation is a major threat** to water security, primarily caused by failure to adequately control IAPs and poor land management. Remedying this is expensive, and so requires **financially efficient solutions**.
2. International evidence suggests that **implementing nature-based solutions** in conjunction with built infrastructure solutions is **more efficient** than just relying on the latter.
3. The restoration and conservation of catchment areas and river health can be achieved through a **range of regulatory and economic policy instruments**, which vary in efficiency depending on the context. Selecting the **most appropriate** policy instrument is an important first step.
4. The **success of PES is highly context specific**. International success for delivering hydrological ecosystem services is not replicated in communal land contexts and/or where users have limited ability to pay.
5. **Protecting the environment is low on the political agenda in South Africa** and not prioritised strongly enough in state budgeting.
6. **Investment in nature-based solutions is deterred by high risk and uncertainty** of returns as well as long time frames and a lack of secure options and opportunities (e.g. green bonds). High returns are unlikely.
7. **Independent entities** that securely manage funds from multiple sources, such as water partnerships and water funds are **most likely to succeed** in leveraging the funds needed to restore and conserve important catchment areas.

CHAPTER 3: VIABILITY OF INVESTING IN ECOLOGICAL INFRASTRUCTURE TO SECURE WATER SUPPLY

Webster, K., Letley, G.K. & Turpie, J.K.

3.1 INTRODUCTION

The Anthropocene has presented humanity with many challenges, the most pressing of which can be categorised into three major themes: adapting to climate change, protecting biodiversity, and ensuring human well-being (Seddon *et al.*, 2020). Degradation of ecological infrastructure (EI) is a global issue that negatively affects all three of these major challenges by diminishing the capacity of naturally functioning ecosystems to provide valuable ecosystem services. Indeed, a global study found that the cost of ecosystem degradation due to land cover change and associated loss in essential ecosystem services is approximately US$300 billion annually, with Sub-Saharan Africa accounting for the largest share of this global cost (Nkonya *et al.*, 2016). Intensive and extensive agricultural practices, invasive alien plants (IAPs), land transformation, fire suppression, hydrological alteration and urban sprawl are the main threats facing natural ecosystems and their biodiversity (Turpie *et al.*, 2017b; IPBES, 2018).

In an age of drastic environmental change and human population growth, opportunities for pursuing economic development in more sustainable ways are becoming better understood and more widely sought after. Investing in the resilience of natural systems through restoration and conservation are crucial aspects of achieving a more sustainable trajectory. This requires a holistic approach where economic growth, ecosystem health, as well as human well-being are considered. Investment in EI to secure hydrological ecosystem services presents an opportunity to reverse the effects of degradation, while restoring ecosystem functionality to produce essential ecosystem services, such as water provision.

There is increasing understanding of the role that both ecological and built infrastructure can have in economic growth and development in terms of water supply. Muller *et al.* (2015) argue that EI will not have the capacity to meet the demand of future water requirements such that built infrastructure will. This argument considers water supply investment as being directed exclusively to either EI or built infrastructure; however, water supply services are not solely derived from ecological or built infrastructure, but both. Therefore, investing in the protection and restoration of EI to complement existing built infrastructure can improve upstream water yields, while at the same time ensuring the longevity and most efficient use of existing built infrastructure. Essentially, investing in the restoration and maintenance of EI simultaneously protects existing built infrastructure investments. A combination of investments in EI and built infrastructure should be considered crucial in securing resilient, reliable water supply.

There is currently a lack of quantitative information that shows the positive relationship between naturally functioning EI and built infrastructure to produce reliable water supply. The value of EI investments to secure water supply is nested within this information and would help to advance the pursuit of more sustainable approaches to water supply globally. Therefore, this study had a specific focus on understanding the role that EI investments through IAP clearing could have in supplementing already existing bulk water supply infrastructure (i.e. built infrastructure).

The overall aim was to determine the cost effectiveness of investing in catchment restoration to secure water supply in the key water supply systems of South Africa over time by comparing estimated costs and benefits associated with IAP clearing to that of planned built infrastructure augmentation projects.

The following objectives were set to achieve the overall aim:

1. Describe the current (2022) and future (2050) types and extent of IAP invasion in catchment areas of existing infrastructure owned and managed by Water Service Providers (WSPs) by simulating a spread model of the latest available South African IAP data, produced by Kotzé *et al.* (2010).
2. Determine the cost of clearing IAPs from relevant catchment areas based on their estimated extent and the amount of water that could be gained in their absence between 2022 and 2050.
3. Examine the planned sequence of water supply infrastructure developments and associated costs to meet projected demands between 2022 and 2050 across South Africa's water supply systems.
4. Evaluate the cost-effectiveness of IAP clearing compared to built infrastructure developments for each water supply system.

Considering the overall aim, it was hypothesized that, within regional context, investing in EI in the form of IAP clearing could be a cost-efficient intervention for enhancing and securing future water supply when compared to built infrastructure interventions and should be planned for ahead of these interventions when this is the case. Although the benefits of catchment restoration are widely recognised, the lack of quantitative information and real-world examples regarding the cost-efficiency of catchment restoration for enhancing water supply is limited. South Africa was used as a case study to provide a national-scale indication of the viability of catchment restoration as a cost-effective EI investment mechanism to secure water supply in the long term.

3.2 LITERATURE REVIEW

3.2.1 Catchment areas as critical "ecological infrastructure"

Nature provides humans with a broad range of goods and services that are important for human well-being and for which we do not bear the cost (Costanza & Daly, 1992). However, as natural systems are degraded over time through increased human pressures, these benefits are lost (Sutton *et al.*, 2016; IPBES, 2018). The valuation of ecosystem services has become increasingly recognised since the term's emergence in the early 1980s and has since been used to effectively communicate society's dependence on the benefits of naturally functioning ecosystems (Ehrlich & Ehrlich, 1981; Kumar & Kumar, 2008; Gómez-Baggethun *et al.*, 2010). Valuation techniques had been used since the 1960s, however studies of this kind exploded in the 1990s as natural scientists began to recognise the appeal in presenting ecological issues in economic terms for decision-makers (Gómez-Baggethun *et al.*, 2010). Understanding the value of ecosystem services started to reveal the costs associated with degradation of functioning ecosystems and has helped policy-makers prioritise actions that promote ecosystem service delivery and avoid the loss thereof (Akhtar-Schuster *et al.*, 2011). However, despite the abundance of literature that aims to inform policy, formulation of policy that protects and conserves the systems that produce valuable ecosystem services is still limited. To gain traction with policy-makers, the scale at which the valuation of ecosystem services occurs needs to be refined. Turpie *et al.* (2017) highlight that much of the work on ecosystem service valuation is based on studies from around the world and collated in global databases. While international values can be important for formulating conservation and biodiversity financing strategies, they often lack the reliability and policy relevance for local contexts (Turpie *et al.*, 2017b). There is therefore recognition of the need to refine the scale at which valuation of ecosystem services is assessed to better understand the distribution of their value and to optimize allocation of finance from a national context.

Another way of gaining the attention and interest of policy-makers is by referring to the complexity of ecosystem services by way of more familiar terms, for example 'infrastructure'. 'Ecological infrastructure' (EI) can be defined as naturally functioning ecosystems that provide important services to humans (Hughes *et al.*, 2018; Mbopha *et al.*, 2021). The concept of EI has the same objectives as engineered infrastructure and can be considered the "nature-based equivalent" of engineered structures that provide the same services (Cumming *et al.*, 2017). It is considered a subset of the more widely used 'natural capital' which is defined by the (Natural Capital Forum (2017) as "the world's stocks of natural assets which include geology, soil, air, water and all living things". From an economic perspective, EI can be considered the source, raw material, or *asset* from which ecosystem services are derived (SANBI, 2014). To maintain this asset base, measures are needed to conserve and protect natural systems. Such measures are recognised at 'Nature-based solutions' (NbS).

NbS serve as an integrated approach to solving environmental and economic challenges holistically. There has been growing awareness of the potential for NbS to be included in national and global strategies to maximise the benefits received from nature and to achieve economic growth sustainably. However, the lack of investment in these initiatives is widely recognised as one of the main barriers to implementation and monitoring of NbS (Seddon *et al.*, 2020). Building upon the concept of EI, 'investing in ecological infrastructure' (or "EI investments") is an emerging area of interest that falls under the NbS umbrella and serves as a relatively new approach to understanding and communicating the true purpose of restoring and maintaining natural ecosystems (SANBI, 2014). Just as built infrastructure requires an initial capital investment followed by on-going operation and maintenance investments to produce desired services, so does EI. Essentially, 'EI investments' refers to the long-term directing of money into schemes or initiatives that actively focus on the conservation or restoration of ecosystems that provide valuable services for human well-being. Vogl *et al.* (2017) highlights the need for a modification in widely accepted accounting standards to include natural capital (or EI) values. To achieve this, there should be a movement towards bettering frameworks that assess the costs, benefits, and cost-effectiveness of restoring natural systems that have been degraded over time, including (but not limited to) catchment areas (or 'watersheds') that are important for downstream water supply (Sutton *et al.*, 2016). The lack of cost-benefit and cost-effectiveness analyses for the adoption of EI investment approaches in catchment areas and the role it plays in increasing the risk of such investments is also noted by Palmer *et al.* (2015). Without this information, investors are unlikely to participate due to the risk and uncertainty associated with this lack of evidence.

One of the main values of naturally functioning catchment areas lies in the hydrological services they provide. These systems are vital to human well-being and biodiversity as they regulate the quantity and quality of the water resource (Brauman *et al.*, 2007; Hunter, MacDonald & Carter, 2010). Yet already limited resources are greatly threatened by catchment degradation (Le Maitre *et al.*, 2020). Conservation and restoration of catchment areas is a common example of how EI investments can be harnessed to secure hydrological ecosystem services into the future and is attracting the interest of economists, conservationists and policymakers alike (Sun, Jiang & Zheng, 2020). However, in the pursuit of economic development, the conventional method for resource provision and management in the water supply sector has been through built infrastructure (Palmer *et al.*, 2015). Many developing countries still address water security solely through engineered solutions, for example through dams, pumping schemes, and major inter-basin transfer schemes (Smakhtin *et al.*, 2001). However, there is a growing body of literature that recognises the potential of investing in catchment restoration to restore and maintain the yield of existing built water supply infrastructure. In fact, evidence for its success in sustaining, supplementing, and even substituting investments for built water supply infrastructure is increasing (SANBI, 2014; UNEP, 2014; Palmer *et al.*, 2015).

3.2.2 Impacts of catchment degradation on water security

Water catchment areas are a source of provisional, supportive, and regulating ecosystem services, for example, the provision of water includes extraction for municipal, agricultural, industrial, commercial and thermoelectric power use, while supporting services provide water for plant growth and habitat for aquatic species (Brauman *et al.*, 2007). However, catchment areas are also subject to varying degrees of degradation which diminishes their capacity to provide these services to downstream users (Brauman *et al.*, 2007). Degradation of EI and the loss of ecosystem services are intimately related, where the ability and capacity of a system to provide essential services is diminished as degradation worsens (Favretto *et al.*, 2016). This is explicitly evident in the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Assessment Report on Land Degradation and Restoration, one of the most comprehensive global reviews on the connection between ecosystem degradation and ecosystem services to date (IPBES, 2018). It is estimated that up to 10% of annual global GDP is lost to the effects of ecosystem degradation, and when the value of economic benefits is taken into account, this translates to approximately USD 1.4 trillion each year (IPBES, 2018).

Surface water resource systems in South Africa are particularly threatened by ecosystem degradation in the form of IAP invasion, bush encroachment, and erosion (Lötter & Le Maitre, 2021). IAPs are particularly well-known as a driver of degradation worldwide and can have significant biological, financial, and economic impacts (Van Wilgen *et al.*, 2020a). The effect of IAP infestations on streamflow reduction is well demonstrated in the literature (Prinsloo & Scott, 1999; Görgens & Van Wilgen, 2004; Le Maitre *et al.*, 2016). Therefore, from a financial standpoint, the presence of IAPs has two opportunity costs. The first is related to a loss in the value of production due to reduced water resources, while the second is related to the increased cost associated with new water supply augmentation schemes needed to compensate for water lost to IAPs (Le Maitre *et al.*, 2020). From an economic standpoint, the impacts of IAP invasions are much broader as they negatively affect biodiversity and disrupt the optimal functioning of ecosystems that humans depend on for service provision (Le Maitre *et al.*, 2020).

Agricultural expansion, encroachment into natural wetlands and the removal of natural vegetation result in elevated levels of erosion and subsequent increases in sediment loads to rivers and streams. The extent to which sediments end up in river systems is determined by several factors including soils, rainfall, slope and the type and amount of vegetative cover. Vegetative cover prevents erosion by stabilising soil and by intercepting rainfall, thereby reducing its erosivity (De Groot, Wilson & Boumans, 2002). This is particularly valuable where soils are highly erodible. Vegetated areas, in particular wetlands, may also capture the sediments that are eroded from agricultural and degraded lands, preventing them from entering streams and rivers (Blumenfeld *et al.*, 2009; Conte *et al.*, 2011). This protects downstream areas from the impacts of sedimentation, which include impacts on water storage capacity, hydropower generation, water treatment and navigability of rivers (Pimentel *et al.*, 1995). While some level of sedimentation of reservoirs is expected under natural conditions and planned for, elevated catchment erosion either incurs dredging costs, elevated water treatment costs (through increased backwashing of filters) or shortens the projected lifespan of reservoirs and related infrastructure. Globally, anthropogenic sedimentation has been estimated to account for about 37% of the annual costs of reservoirs (i.e. $21 billion) in terms of replacement costs (Basson, 2009). In urban contexts, elevated sediment loads also have to be removed from sewerage systems, storm water drainage systems and harbours.

South Africa's ecosystem degradation has been compounded not only by climatic (water-scarce, low rainfall, semi-arid) and geological (high erodibility in many parts) factors, but also political and social factors, placing enormous strain on select parts of the country where overgrazing and erosion are prevalent (Hoffman & Ashwell, 2001; Clover & Eriksen, 2009). Roughly 720 000 ha of sheet and gully erosion covers South Africa (Department of Environmental Affairs, 2017). Soil erosion is a particularly serious problem in many of the steeply sloping escarpment areas of KwaZulu-Natal (Thukela), the Eastern Cape (uMzimvubu), and Limpopo, mainly linked to poor grazing management and abandoned agricultural fields (Hoffman & Todd, 2000; Peden, 2005; Sonneveld, Everson & Veldkamp, 2005).

3.2.3 South Africa's water supply sector

Institutional governance is recognised as a major barrier to the successful implementation of EI investments for securing hydrological ecosystem services and can be referred to as 'institutional failure' (Vogl *et al.*, 2017b; Mbopha *et al.*, 2021). It is critical to consider which level of institutional government would be most suitable for the effective management of incentive arrangements related to EI investments (Mbopha *et al.*, 2021). From a hydrological EI investments context, a number of key actions must take place at the relevant level of institutional governance. Generally, the largest scales, i.e. national and global, are responsible for influencing and designing water development policy and frameworks, directing resources into different types of EI investment strategies – particularly those with the highest return on investment (ROI), and allocating infrastructure funds to investments in EI specific to hydrological ecosystem services (Vogl *et al.*, 2017b). The regional and local levels are responsible for ensuring the effective implementation of EI investments to meet their respective water security goals (Vogl *et al.*, 2017b). This includes assessing different EI investment options, designing context-specific program, assessing ROI for the context-specific region, building and engaging in partnerships, and creating a plan to monitor the impacts of the program (Vogl *et al.*, 2017b). Context specificity refers to the ecological, economic and societal setting of the region in question.

South Africa's Constitution states that everyone has the right to access sufficient water. The legislative framework outlined in the Water Services Act 108 of 1997 aims to ensure this right by regulating institutions that provide water services. However, demand for water is expected to further increase with population growth, urbanisation, economic growth, and higher standards of living (Sun *et al.*, 2008; Wang *et al.*, 2018; Oiro *et al.*, 2020). This has put governing water service institutions under significant pressure to deliver water requirements under often constraining conditions in relation to funding, water resources and bulk water supply infrastructure.

South Africa has a complex water management and supply system. Beck *et al.* (2016) highlighted the three major levels of institutional water governance in South Africa. Among other key institutions such as national NGOs, donor agencies, research institutions and international agencies and partnerships, South Africa's water sector can be viewed at the national, regional and local levels (Beck *et al.*, 2016). The national level consists of governmental departments, which includes the Department of Water and Sanitation (DWS). The regional level consists of three main entities, including Catchment Management Agencies (CMAs); water boards, which are considered "organs of state"; and Water and Sanitation Forums (DWA, 2013; Beck *et al.*, 2016). Lastly, the local level of the water sector's institutional governance consists of municipalities, which are also referred to as Water Service Authorities (WSAs); Water Service Providers (WSPs), which can be public, private, or mixed entities, or municipal government; and Water User Associations (WUAs). The roles and responsibilities of each of these entities are described in Table 3.1.

Population growth is a key driver of water use in South Africa and can influence the levels of water use in different sectors, such as the agricultural, industrial and domestic sectors (DEA, 2013). Water resource system planning requires detailed consideration and reliable coordination of institutions from all scales, however, in the scope of this study, water boards and the DWS are most relevant. The DWS produces reconciliation strategy studies which are used by water boards to determine future water requirements for a specific water supply system (WSS) and to guide planning for future water supply infrastructure (DEA, 2013):

Water supply systems (WSSs)

WSSs are regions delineated by the South African government related to institutional water supply services. Each region is dependent on existing and functioning water supply infrastructure that collects and/or delivers water from source areas (i.e. catchment areas). Government-owned entities called water boards (or water service providers (WSPs)) as well as the Department of Water and Sanitation (DWS) are responsible for the management of water services in these areas.

Reconciliation strategy studies

Reconciliation strategies involve a process of planning the water balance for a specific WSS, with the objective to 'reconcile' or balance available water sources with water requirements through various strategies in a given time frame, usually one or two decades (DEA, 2013). This can be achieved by increasing water supply through the construction of built infrastructure, restoring and rehabilitating catchment areas, and/or implementing water conservation and demand management (WC/WDM) strategies to reduce consumption. Each of South Africa's major WSSs are associated with a context-specific reconciliation strategy study that outlines a portfolio of augmentation options and their relevant costs and energy requirements (DEA, 2013). The studies are conducted and published by DWS and serve as a strategic input for development planning in South Africa's water sector.

Table 3.1. The roles and responsibilities of South Africa's governing water sector institutions at the national, regional and local levels. Adapted from DWS, 2015a.

Institutional level	Institution	Roles and responsibilities
National	Department of Water and Sanitation (DWS)	Formulate policy in the water sector; regulate, monitor and provide support in ensuring suitable, equitable and safe water and sanitation services; and coordinate between lower-level institutions.
Regional	Catchment Management Agencies (CMAs)	Manage water resources at the regional or individual catchment level while involving local communities in their agenda. This is all planned and implemented within the scope of the National Resource Strategy Framework.
	Water boards (can also be referred to as 'water service providers', WSPs)	Provision of water services in the form of bulk potable and bulk wastewater to other water services institutions (such as municipalities) within their areas of supply (also referred to as Water Management Areas (WMAs)).
	Regional Water Utilities (RWUs)	Build, operate, maintain, and support regional bulk infrastructure; and assist local and district municipalities, on an agency basis, to deliver services where they lack capacity to do so effectively.
Local	Municipalities (or Water Service Authorities, WSAs)	Ensure the provision of water services within their area of jurisdiction. These actions are regulated by the Department of Cooperative Government and Traditional Affairs (CoGTA).
	Water Service Providers (WSPs)	Provide water and/or sanitation services to end users within a specific geographical area through a contractual agreement with a WSA or other water services provider.
	Water User Associations (WUAs)	Co-operative associations made up of individual water users who wish to contribute to the undertaking of water-related activities for their mutual benefit.

3.3 METHODS

3.3.1 Context and study design overview

South Africa is an arid country, with a mean annual rainfall of approximately 490 mm (Bailey & Pitman, 2015). There are 22 strategic water source areas (SWSAs) (Figure 3.1). SWSAs cover 10% of land that disproportionately supplies 50% of the country's water runoff (Lötter & Le Maitre, 2021). SWSAs roughly correlate with South Africa's water supply systems (WSSs).

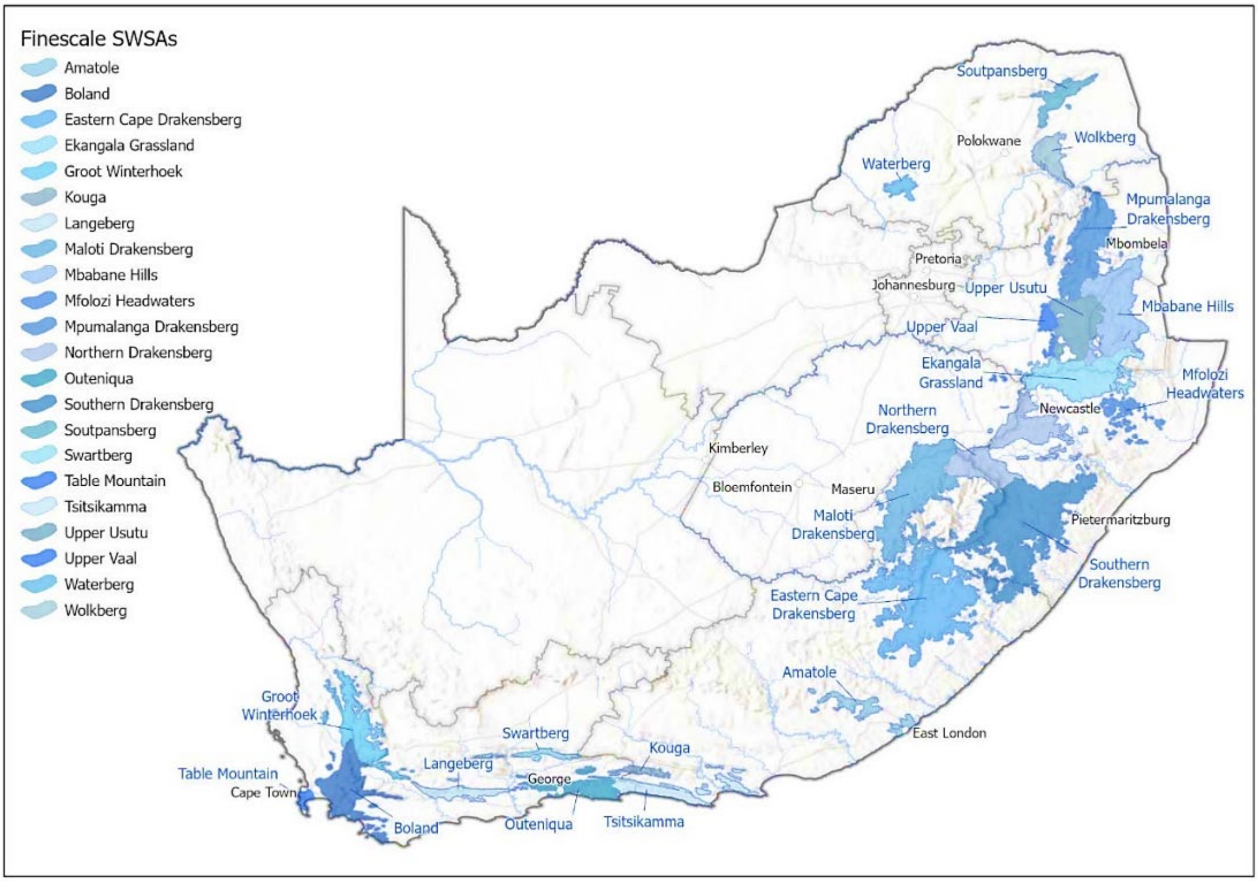


Figure 3.1. The Fine-scale Strategic Water Source Areas (SWSAs) for surface water in South Africa. Source: Lötter & Le Maitre, 2021.

To assess the viability of investing in EI as a means to secure hydrological ecosystem services into the future, the costs and benefits of associated interventions were compared to the alternative built infrastructure interventions. The primary approach to securing hydrological ecosystem services is addressing catchment degradation. Presence of invasive alien plants (IAPs), erosion, siltation, and bush encroachment are all common indicators of catchment degradation (Al Sayah *et al.*, 2021; Turpie *et al.*, 2021b). The key type of ecosystem degradation assessed in this study was IAP invasion. Therefore, the costs of clearing IAPs in catchment areas of major surface water infrastructure was weighed against the benefit of additional water supply through these interventions. Similarly, the costs of engineered interventions were weighed against the benefit of their additional water supply.

This study focused on water catchment areas of existing large dams owned by WSP's at the regional level of South Africa's institutional water supply system, i.e. water boards. Water boards are responsible for the management of South Africa's bulk surface water and are therefore considered key stakeholders in the water supply sector. There are currently nine official water boards in the country, however, the City of Cape Town and Nelson Mandela Bay Metro were also included as water boards as they manage their local infrastructure and supply as independent WSPs. Therefore, a total of 11 WSPs were considered. WSSs were considered the most relevant level of analysis as South Africa's Department of Water and Sanitation (DWS) analyses water demand, requirements and the relevant interventions needed to meet demands at this level. These analyses are referred to as 'reconciliation strategy studies' which contain the most detail for planned built infrastructure interventions at the relevant scale. The WSSs considered in this study and associated details are listed in Table 3.2.

Table 3.2. List of the South African water supply systems (WSSs) considered in this study and their relevant water management areas (WMAs)/catchment areas, reconciliation strategy studies (RSS), and the responsible water service providers (WSPs) for each area.

WSS	WMA/catchment	RSS	Responsible WSP(s)
Algoa Water Supply System	Kouga River System, Sundays River System	Algoa	Nelson Mandela Bay Metro
Amatole Water Supply System	Buffalo, Nahoon and Upper Kubusi rivers	Amatole	Amatola Water
Crocodile West Water Supply System	Crocodile River Catchment	Crocodile (West)	Magalies Water, Rand Water
Integrated Mgeni Water Supply System	Thukela, uMngeni, Mvoti, Mooi, and Umkomaas river catchments	KZN Coastal Metropolitan	Umgeni Water
Integrated Vaal River System	Upper, Middle and Lower Vaal River	Vaal	Rand Water, Sedibeng Water
Limpopo WMA North	Mogalakwena Catchment	Limpopo	Lepelle Northern Water, Magalies Water
Luvuvhu-Letaba Water Supply System	Luvuvhu-Letaba WMA	Luvuvhu-Letaba	Lepelle Northern Water
Olifants Water Supply System	Olifants River Catchment	Olifants	Lepelle Northern Water
Orange River System	Upper and Lower Orange River WMAs	Orange River	Bloem Water, Sedibeng Water
Richard's Bay Water Supply System	Mhlatuze River Catchment	Richard's Bay	Mhlatuze Water
Western Cape Water Supply System	Riviersonderend – Berg River System	Western Cape	City of Cape Town, Overberg Water

3.3.2 Delineating dam catchment areas

A sub-dataset of South Africa's large dams was created using the South African National Committee on Large Dams (SANCOLD) 'South African Register of Large Dams' dataset (SANCOLD, 2018) to include only large dams either owned and managed by the relevant WSPs or owned by DWS but managed by the relevant WSPs. To be considered a 'large dam' the following criteria had to be met: 1) dams with a wall height of ≥15 m from the lowest point of the foundation; and 2) dams with a wall height between 5 m and 15 m and a capacity of >3 million m^3 (SANCOLD, 2018). The coordinates of each dam in the subset were retrieved from Google Earth.

All spatial analysis was conducted using the ArcGIS software (ArcMap version 10.4.1). A STRM derived 30 m DEM retrieved from Consultative Group for International Agricultural Research's (CGIAR) Consortium for Spatial Information (CSI) (CGIAR CSI, 2022) was used to create a flow accumulation raster for South Africa. The flow accumulation raster was then used as a reference for pour point placement. The raster was categorised into two classes: one that represented 'feeder cells' which had a flow accumulation value between 0 and 4000; and another that represented 'flow cells' which had a flow accumulation between 4000 and the maximum. Pour points were then placed within flow cells where branching rivers/streams converged into a single inlet for each dam (see example in Figure 3.2). The 'Watershed' tool was then used to delineate catchment areas for each pour point, i.e. sub-catchment areas, which were later consolidated into single catchment areas per dam.

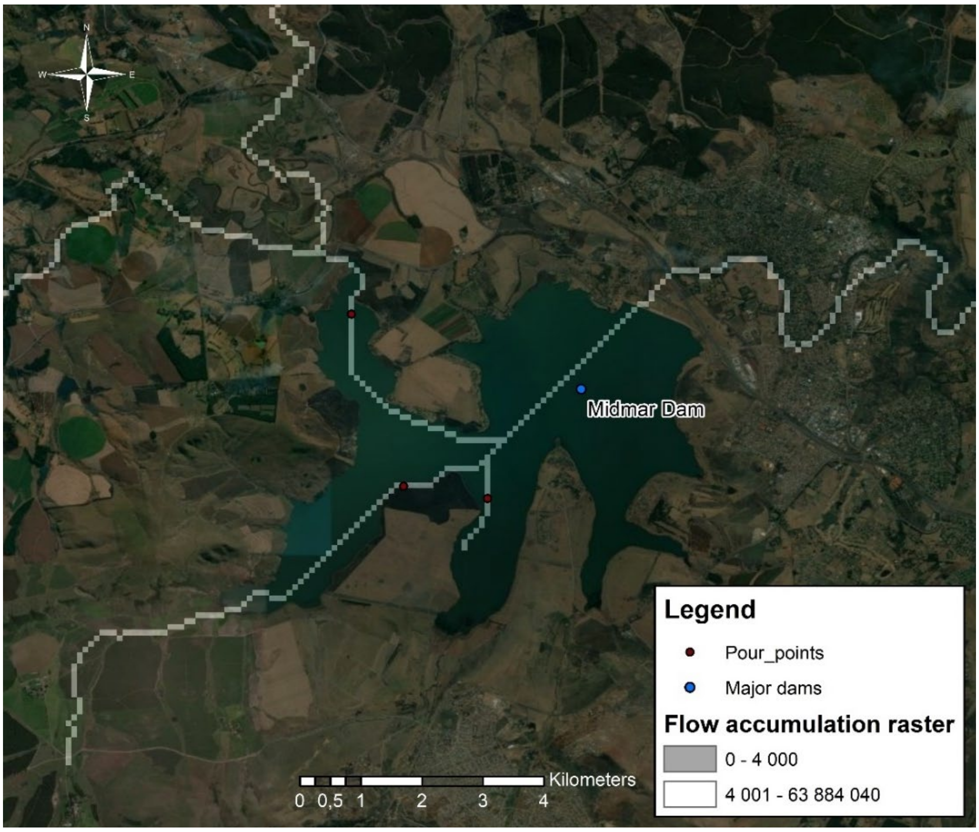


Figure 3.2. Example image showing the placement of pour points for the Midmar Dam owned and managed by Umgeni Water and situated in the Integrated Mgeni Water Supply System. 'Flow cells' are displayed in transparent white and 'feeder cells' in transparent black.

To accommodate more efficient and accurate analysis, particularly for modelling IAP spread, South African quaternary catchment data (DWS, 2011) were spatially joined to the dam catchment data, providing a new dataset (hereafter referred to as the "dam-quat" dataset) that provided information on quaternary catchments relevant to each dam. To achieve this, it was assumed that 1) dam catchment areas aligned with the boundaries of one or many quaternary catchment areas, and 2) if a dam catchment area was too small to be assigned a quaternary catchment by the GIS tool, the quaternary catchment that contained the dam catchment area was manually selected and included in the dam-quat dataset. This process resulted in each dam catchment area being represented by one or more quaternary catchment areas.

3.3.3 Extent of IAP coverage in catchment areas

To estimate IAP clearing costs, it was necessary to estimate the extent of current and projected IAP coverage in the relevant catchment areas. The extent of IAP coverage was based on the National Invasive Alien Plant Survey (NIAPS) dataset which was attained through low level aerial surveys and statistical interpolation (Kotzé *et al.*, 2010). This dataset is currently the most recent and comprehensive spatial dataset available for IAP coverage across South Africa and provided information on the average density of IAPs at a 250 m^2 spatial resolution as in 2010. Although the NIAPS data includes information for a number of IAP species, this study focused on gums (Eucalyptus spp.), pines (Pinus spp.) and wattles (Acacia spp.) due to their impacts and prominence in South African water resource systems.

Since the NIAPS dataset was published in 2010, IAP coverage firstly needed to be updated to current (2022) and modelled to future (2050) estimates of infestation to enable the calculation of potential clearing costs at both time steps. To achieve this, a simple logistic population growth model (Equation 1) was applied to the 2010 data. The equation applies the effect of an environment's finite resource availability which limits the growth of a population (Tisdell & Seidl, 1999). This is otherwise known as the 'carrying capacity' (Tisdell & Seidl, 1999). The equation is defined by the product of the growth of an existing population and the carrying capacity, where k is the growth rate, P is the population size, t is the relevant time step, and K is the carrying capacity, which in this case was considered to be area available for infestation, or 'invadable' land.

$$\frac{dp}{dt} = kP_{t-1}(1 - \frac{P_t}{K}) \quad [1]$$

To determine a measure of the potentially 'invadable' land, i.e. the carrying capacity, the South African National Land-Cover dataset (SANLC) 2020 (DFFE, 2021) was used to determine the number of 'invadable hectares' per quaternary catchment area. The SANLC 2020 dataset is the latest available version of South Africa's national landcover consisting of 73 landcover classes with an overall map accuracy of 85.47% (DFFE, 2021). It was assumed that invadable area included all land that was not classed as "built-up", "cultivated", "mines and quarries", or "waterbodies".

The spread of IAPs is largely determined by the rate at which the species under consideration can reproduce. The literature presents a wide range of spread rates for gums, pines and wattles, ranging from 2.6% per annum for wattle (Rebelo *et al.*, 2013) to 15.6% per annum for pine (Van Wilgen & Le Maitre, 2013). Therefore, a more general spread rate of 7.5% per annum was applied to all three types of IAP species to account for the broad range of spread rates seen in the literature. This spread rate was also used by (Turpie *et al.*, 2021b) for the same collection of high water-using species. Equation 1 was applied to the NIAPS 2010 data to calculate condensed ha estimates for gums, pines and wattles in each quaternary catchment area from 2022 to 2050.

3.3.4 Cost-effectiveness analysis

3.3.4.1 Overview

To derive the costs of interventions for catchment restoration and rehabilitation, information was gathered from the primary literature that addressed the spread of IAPs (Le Maitre *et al.*, 2016; Turpie *et al.*, 2019b, 2021b) and methods of calculating estimates of the cost to clear IAPs per hectare. Similarly, all information pertaining to built infrastructure interventions was retrieved from reports published by DWS, who provide access to reconciliation strategy studies for bulk water supply augmentation options for each water supply system in South Africa. These reports included the relevant cost and yield information needed to undertake the assessment.

Unit reference values (URVs) can be used as a direct measure of the benefits derived from water resource interventions and are commonly used to assess the feasibility of projects in the water supply sector (Van Niekerk & Du Plessis, 2013). This is done by calculating the cost per cubic meter of water over the lifetime of the project (Van Niekerk & Du Plessis, 2013). Hence, URVs were used as a measure to compare the financial costs and benefits (additional water gain) derived from EI and built infrastructure interventions in this study. The economic lifespan of a particular water development scheme is usually between 30 to 45 years (Van Niekerk & Du Plessis, 2013). However, given the timing of the study, all analyses assumed that interventions would begin in 2022 and were evaluated up to 2050, assuming a 28-year project lifespan for IAP clearing and management.

3.3.4.2 Assessment of planned infrastructure development

Each of the study focus regions are depicted in Figure 3.3. To determine the planned sequence of infrastructure development to meet future demand per WSS, each of the relevant reconciliation strategies (listed in Table 3.2) were analysed. Only the interventions planned to take place between the base year of 2022 and the end year of 2050 were considered.

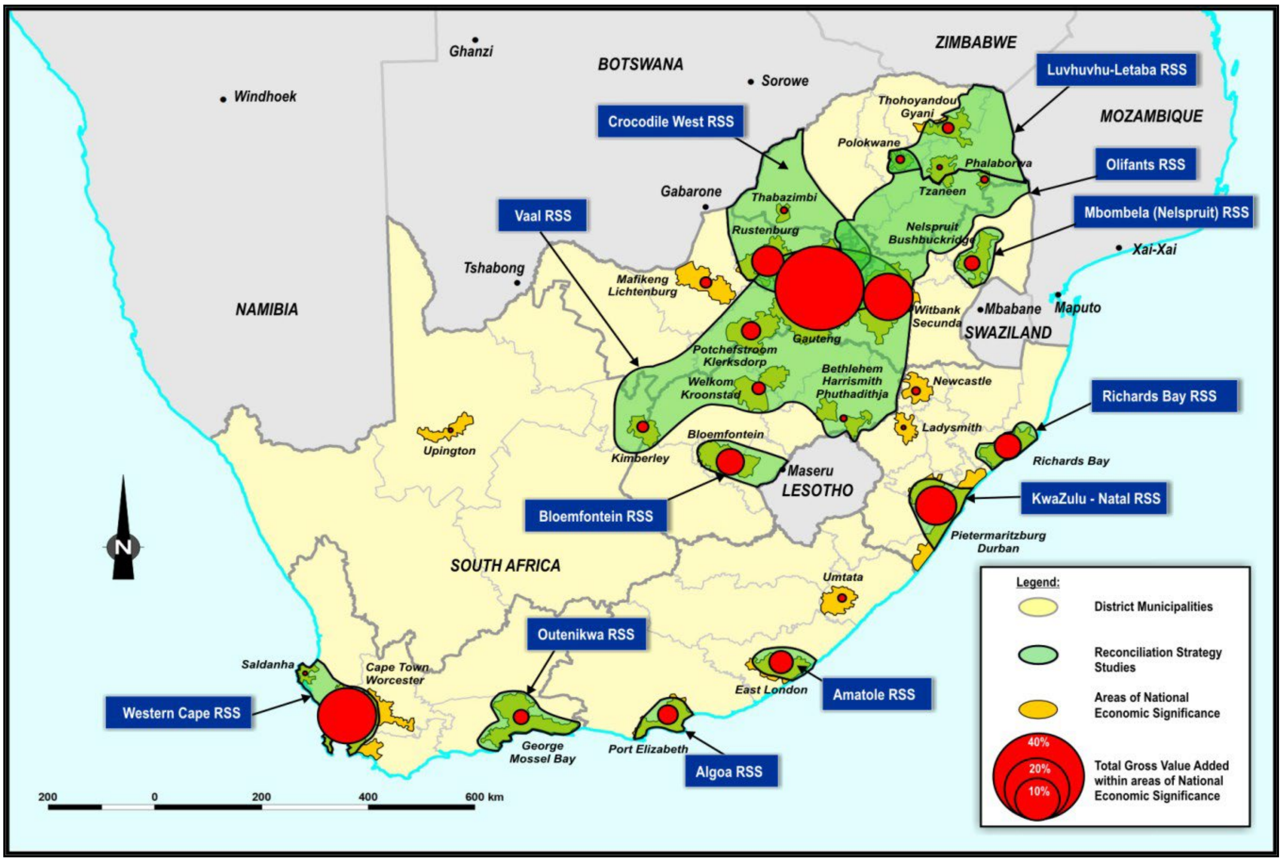


Figure 3.3. The regions and scales of the twelve reconciliation strategy studies conducted and published by South Africa's Department of Water and Sanitation. Source: DWS, 2022.

To determine the benefit associated with built infrastructure interventions, yield gains and URVs for each water supply option were extracted directly from the relevant WSS reconciliation strategy reports. Where cost and URV information was not available for a given intervention, a representative URV based on the average of similar interventions planned for in other WSSs was calculated and assigned to it. Taking inflation into account, the URVs of each intervention were reported in 2022 Rands.

3.3.4.3 Costs of clearing IAPs

Cost estimates for clearing IAPs in South Africa were based on person-day estimates provided by the Working for Water (WfW) programme. Person-day estimates are derived from data collected over the lifespan of the WfW programme and are based on the costs to clear different groups and age classes of IAPs in riparian and landscape settings using different treatment methods (Turpie *et al.*, 2021b). Further, Turpie *et al.* (2019b) developed a set of regression models that estimated the number of person days required to clear one hectare of gum pine and wattle trees under certain conditions. The regression models used to calculate person-day estimates for each of these species are shown in Table 3.3. In the same study, the cost to clear one condensed hectare of IAPs through the WfW programme was estimated to be R450 in 2018, which covered management, equipment and training Turpie *et al.* (2019b). Taking inflation into account, the cost to clear IAPs in 2022 was estimated to be R500 per person day. Based on the person-day estimates and the cost to clear one condensed hectare of infested land, the cost of initial and follow up clearing events for gums, pines and wattles was calculated for each quaternary catchment. If a quaternary catchment area had an IAP density of less than 5%, it was assumed that investment in clearing would be inefficient (Turpie *et al.*, 2021b). Therefore, a 5% density threshold was applied to the base year (2022) whereby all quaternary catchments that had an IAP infestation of less than 5% were excluded from the cost model. It was assumed that the first two follow up clearing events would take place in three-year intervals after the initial clear in 2022 (i.e. in 2025 and 2028) and every six years thereafter (i.e. in 2034, 2040 and 2046) until 2050. A discount rate of 8% was used to determine the present value of costs over the time period (based on Van Niekerk & Du Plessis, 2013). All cost calculations were conducted at the quaternary catchment level and later consolidated to the WSS level.

Table 3.3. Regression models used to calculate the number of person-days required to clear one hectare of gum, pine, and wattle species, where I_{ha} is the invadable hectares in the relevant quaternary, and x is the average percentage density per pixel. Source: Turpie *et al.*, 2019b.

Species	Initial clearing	Follow ups
Gums (*Eucalyptus spp.*)	$I_{ha}(2.4254e^{0.028x})$	$I_{ha}(1.7074e^{0.1(0.028x)})$
Pines (*Pinus spp.*)	$I_{ha}\ (2.0647e^{0.027x})$	$I_{ha}(1.6161e^{0.1(0.027x)})$
Wattles (*Acacia spp.*)	$I_{ha}\ (2.0057e^{0.028x})$	$I_{ha}(0.2006e^{0.1(0.028x)})$

3.3.4.4 Calculating URVs for IAP clearing

The URV for securing water supply through clearing IAPs is derived by dividing the total present value of costs (PVc) by the PV of water supplied (PVw), as shown in Equation 2 (Van Niekerk & Du Plessis, 2013). The total PVc to clear IAPs from a given area is the sum of initial and follow up PVc costs. The initial PVc is the product of the number of person-days required to clear IAPs in the first year and the cost to clear one condensed hectare of infested land, while the PVc of one follow up event is the product of the number of person-days required to clear IAPs in a follow up event and the cost to clear one condensed hectare of infested land. The total PVc is the sum of these for all three IAP species.

$$URV\ \left(\frac{R}{m^3}\right) = \frac{PV_C}{PV_W} \qquad [2]$$

The PVw is based on the quantity of water gained if IAPs are removed from catchment areas. To determine the quantity of water that would be gained through IAP clearing by 2050, estimates of the impacts of IAPs on water flows was used. Le Maitre *et al.* (2016) provide estimates of flow reduction as a result of IAPs for each of the primary catchments in South Africa, but not for quaternary catchments. Therefore, a factor to represent the amount of water used by IAPs per unit area was calculated for all primary catchments and then applied to each relevant quaternary catchment (see Appendix A). The gain in streamflow was then converted into a gain in yield by applying a ratio between water flow and yield based on Cullis *et al.*, 2007, who estimated changes in yield due to alien plants in all of South Africa's major water management areas to be between 35% and 82% of the reduction in mean annual runoff (mean across all WMAs was 54%). The relevant streamflow to yield ratio was applied to each quaternary catchment according to the WMA within which it is located. An estimate of the yield of water that could be gained if IAPs were cleared was then calculated for the period between 2022 and 2050 using Equation 3, where W_t is the quantity of water at year t, and r is the discount rate.

$$PV_w = \sum\left(\frac{W_t}{(1+r)^t}\right) \qquad [3]$$

3.4 RESULTS

3.4.1 Catchment areas

The sub-dataset of dams consisted of 64 large dams that were owned and/or managed by one of the 11 South African WSPs (see Appendix A). The catchment areas were made up of a total of 64 quaternary catchment areas with a combined catchment area of approximately 230 500 km^2 (Figure 3.4). The Integrated Vaal River System contributed the greatest of this area (46.9%), and the Western Cape Water Supply System the least (0.7%).

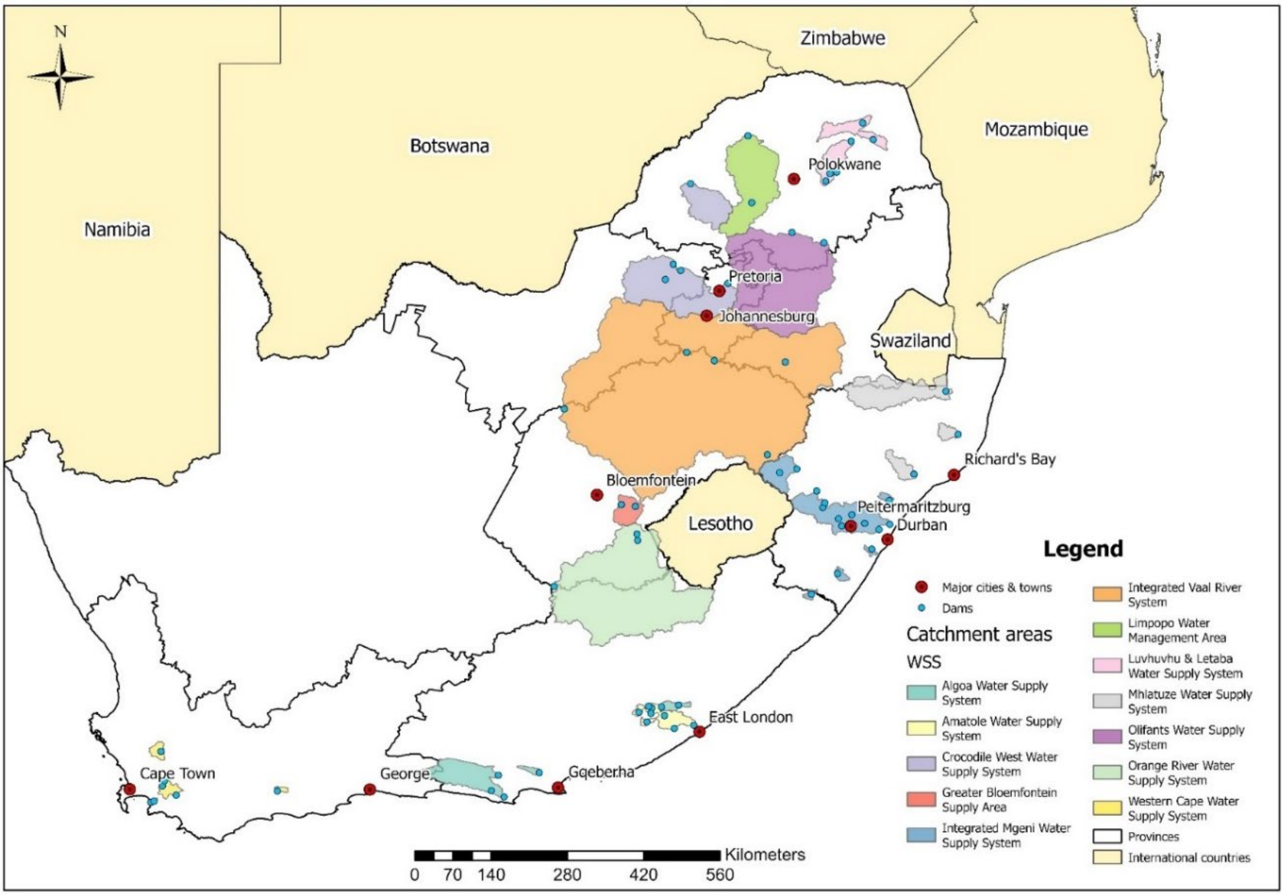


Figure 3.4. Spatial distribution of dams and catchment areas (coloured by WSS) included in the IAP spread and cost-effectiveness analyses.

3.4.2 Extent and spread of IAPs

Using the IAP spread model, based on the NIAPS 2010 data (Kotzé *et al.*, 2010), IAP coverage in 2022 was estimated to be close to 623 000 condensed ha, which covered 2.7% of all catchment areas combined. At a spread rate of 7.5%, it was estimated to quadruple to 2.5 million condensed ha, or 10.9%, by 2050 without implementation of clearing interventions. The Amatole WSS had the highest percentage area of IAP coverage in both 2022 (22%) and in 2050 (58.22%) (Figure 3.5). Conversely, the Orange River System was estimated to have the lowest percentage area of infestation in both 2022 (0.27%) and 2050 (1.61%). No invasions were reported in the original NIAPS 2010 data for the Greater Bloemfontein Supply Area. Therefore, this WSS was excluded from any further analysis.

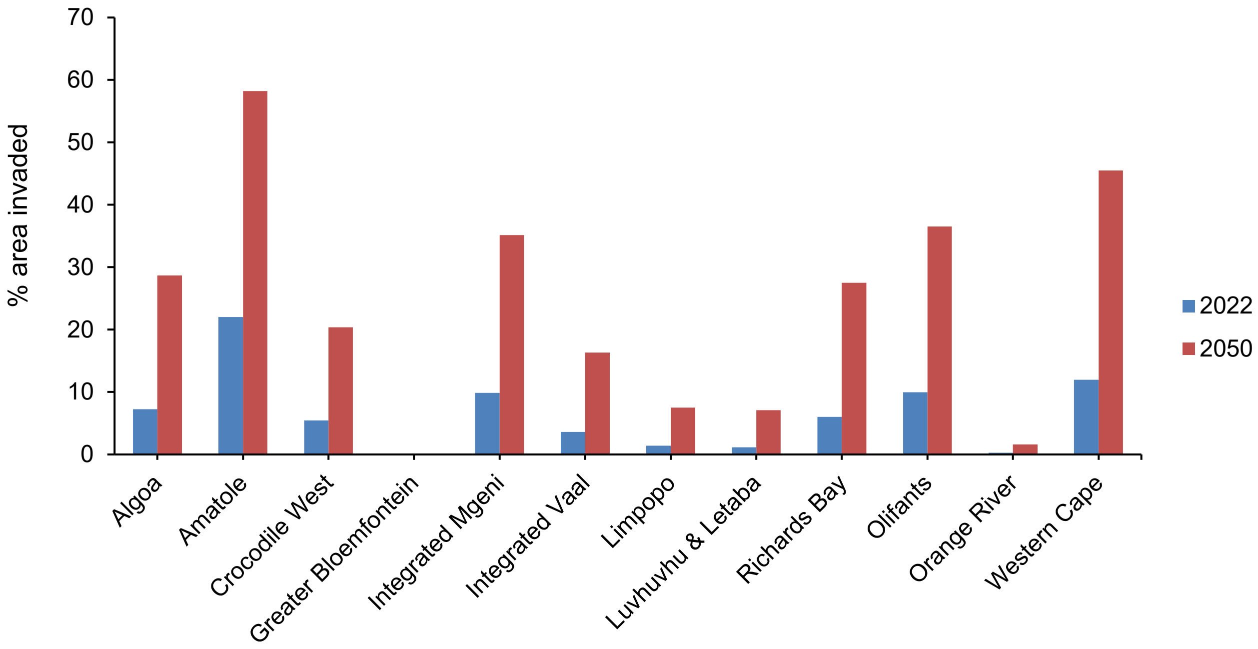


Figure 3.5. Present (2022) and future (2050) percentage area of IAPs in each water supply system (WSS).

Overall, gum and wattle species were more prolific than pine species in most water catchment areas in 2022 and in 2050 (Table 3.4). Wattle species were shown to spread the most drastically by 2050, having the highest average coverage (9.53%) between all three species. The Amatole WSS's high percentage of invaded area was dominated by wattle infestation which covered 21.92% of the WSS's total catchment area by 2050.

Table 3.4. The percentage cover of each IAP species in catchment areas of each water supply system (WSS) in 2022 and 2050.

WSS	% Cover in 2022			% Cover in 2050		
	Gum	Pine	Wattle	Gum	Pine	Wattle
Algoa WSS	0.49	0.87	5.23	1.27	2.87	21.92
Amatole WSS	1.10	3.80	11.10	2.44	10.57	29.32
Crocodile West WSS	1.89	0.09	1.65	7.66	0.31	5.61
Integrated Mgeni WSS	2.95	1.16	2.50	10.28	3.57	9.71
Integrated Vaal River System	1.25	0.15	0.49	5.74	0.69	2.11
Limpopo WMA North	0.88	0.00	0.15	4.74	0.00	0.75
Luvuvhu-Letaba WSS	0.52	0.19	0.11	3.19	1.20	0.71
Richard's Bay WSS	0.21	0.10	4.24	0.92	0.52	19.33
Olifants WSS	2.28	0.04	3.08	7.99	0.17	11.67
Orange River System	0.09	0.04	0.10	0.56	0.33	0.52
Western Cape WSS	1.50	5.49	0.84	7.06	19.55	3.15
Average	**1.20**	**1.08**	**2.68**	**4.71**	**3.62**	**9.53**

3.4.3 Cost-effectiveness analysis

It was estimated that the Integrated Vaal River System would have the greatest area infested with IAPs by 2050 (approximately 922 000 condensed ha), resulting in the highest present value (PV) clearing cost to remove them (R4.7 billion; Table 3.5), while the Luvuvhu-Letaba WSS was estimated to have the smallest area of invasion (approximately 25 000 condensed ha) and would therefore require the lowest allocation of EI investment for IAP removal (R71.8 million).

The amount of water that could be gained by removing IAPs from catchment areas increased exponentially between 2022 and 2050, resulting in a streamflow increase of about 1 595 million m^3 and an increased yield of some 997 million m^3 (Figure 3.6). This was approximately 24% of the amount of water that could be gained through implementation of built infrastructure interventions in the same time frame.

Across all 11 WSSs considered in this study, a total of 52 planned water supply projects were specified in the relevant reconciliation strategy studies between 2022 and 2050. Combined, planned built infrastructure interventions would result in an additional water yield of approximately 4 173 million m^3 per year (Table 3.6).

Built infrastructure for bulk water supply schemes are presented at a very high assurance level of supply, generally between 99% to 99.9% (Blignaut, Marais & Turpie, 2007) which is accounted for in the yield gains stipulated in the reconciliation strategy studies, and hence those included in Table 3.6. However, clearing IAPs for gain in water yield has a considerably lower assurance level of approximately 90% (Blignaut *et al.*, 2007). The current IAP clearing water yield gains stipulated in Table 3.5 and Figure 3.6 are presented at a 100% assurance level and is therefore a slight overstatement. However, this reveals the full potential of the water gains associated with well implemented and maintained IAP clearing interventions.

Table 3.5. The total condensed hectares (c.ha) that would be infested in 2050 if no clearing was pursued, the water gained by 2050 with intervention and the present value (PV) in 2022 Rands of the investment required to clear IAPs in existing bulk water supply infrastructure catchment areas of each relevant water supply system (WSS) between 2022 and 2050 at a discount rate of 8%.

WSS	Area infested by 2050 without intervention (c.ha)	Increase in streamflow by 2050 with intervention (million m^3)	Increase in yield by 2050 with intervention (million m^3)	PV of clearing costs (R millions)
Algoa WSS	145 657	103.9	43.9	740.80
Amatole WSS	92 804	87.7	42.7	578.89
Crocodile West WSS	235 377	66.5	35.8	1 414.64
Integrated Mgeni WSS	227 610	303.9	148.9	1 231.66
Integrated Vaal River System	922 233	423.4	338.7	4 696.02
Limpopo WMA North	61 764	22.8	12.3	136.84
Luvuvhu-Letaba WSS	24 929	11.8	6.8	71.80
Olifants WSS	524 977	263.0	193.6	3 078.45
Orange River System	45 818	26.6	14.3	145.45
Richard’s Bay WSS	188 057	180.4	89.2	889.88
Western Cape WSS	46 326	105.4	71.0	325.93
Total	**2 515 554**	**1 595.4**	**997.1**	**13 310**

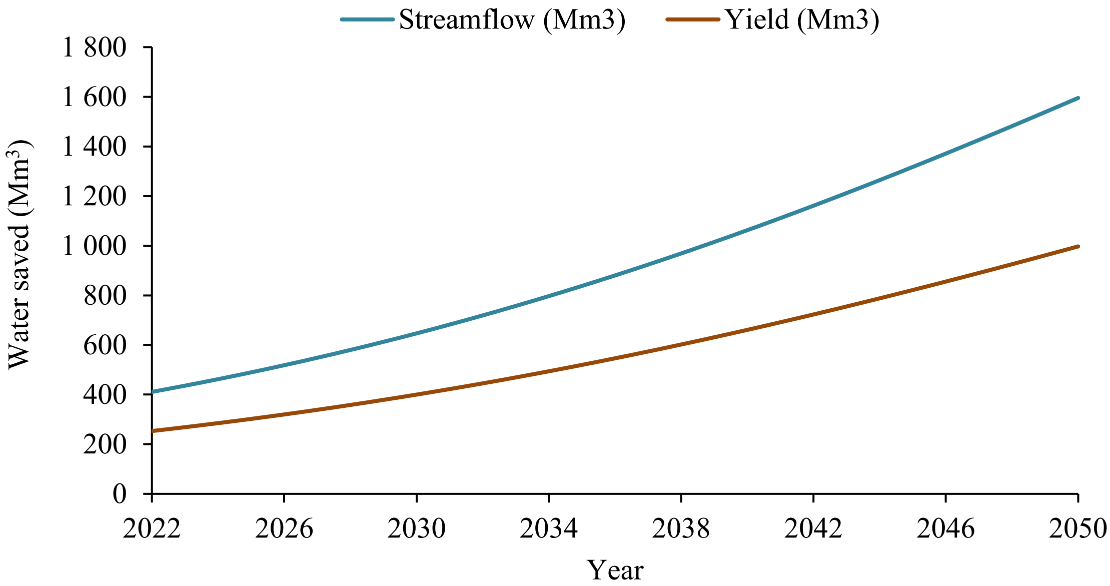
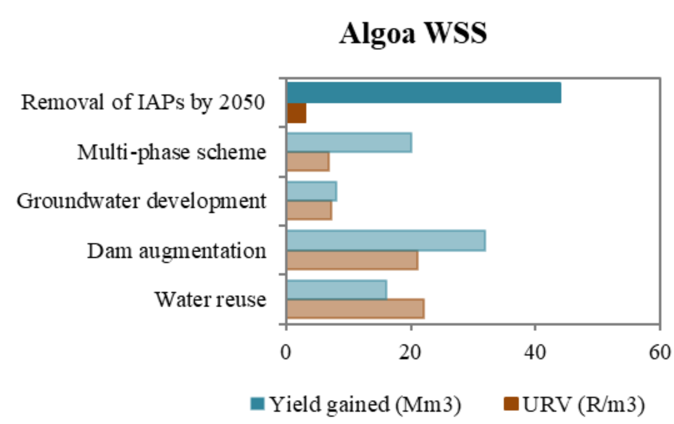


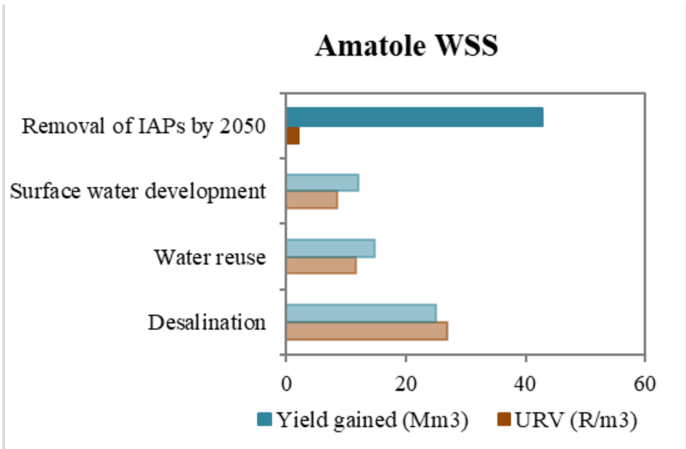
Figure 3.6. The amount of water (million m³) that could be gained in terms of overall streamflow and yield if IAPs were cleared from all WSS catchment areas from 2022 to 2050.

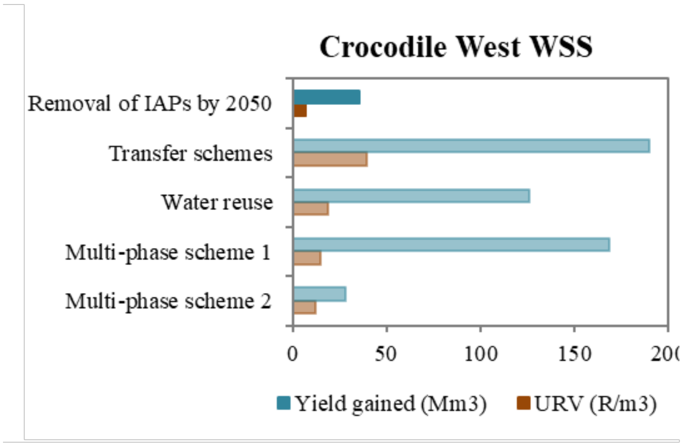
Table 3.6. The number of water supply projects planned for construction/implementation between 2022 and 2050 and the additional water yield that would be gained from for each WSS.

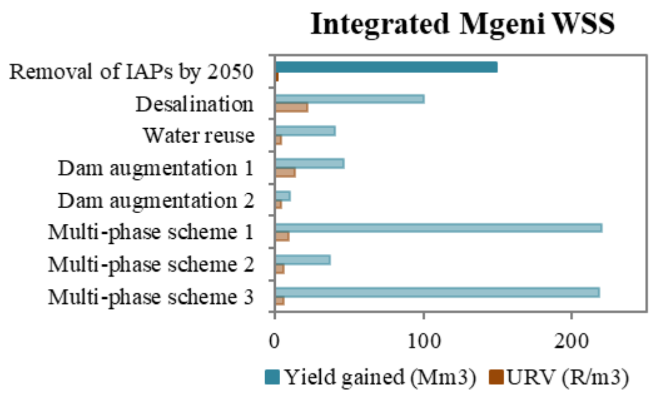
WSS	Number of augmentation projects	Yield gained (million m³/a)
Algoa WSS	5	126
Amatole WSS	3	52
Crocodile West WSS	5	513
Integrated Mgeni WSS	7	671
Integrated Vaal River System	3	1 144
Limpopo WMA North	1	50
Luvuvhu-Letaba WSS	4	33
Olifants WSS	5	361
Orange River System	3	862
Richard’s Bay WSS	8	148
Western Cape WSS	8	213
Total	**52**	**4 173**

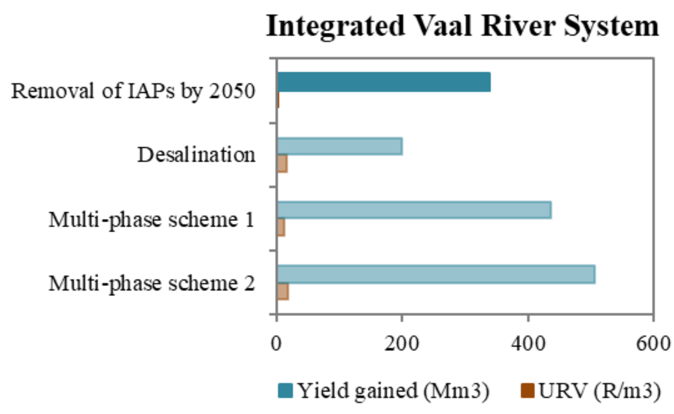
When the URVs and yield gains of IAP clearing are compared with that of planned built infrastructure developments, it becomes clear that IAP clearing is a cost-effective intervention for securing water supply. IAP clearing was the most cost-effective water supply option for all WSSs except for the Orange River System, which showed relatively low water gains for the associated URV (Figure 3.7). Overall, IAP clearing averaged as the most cost-effective augmentation option.

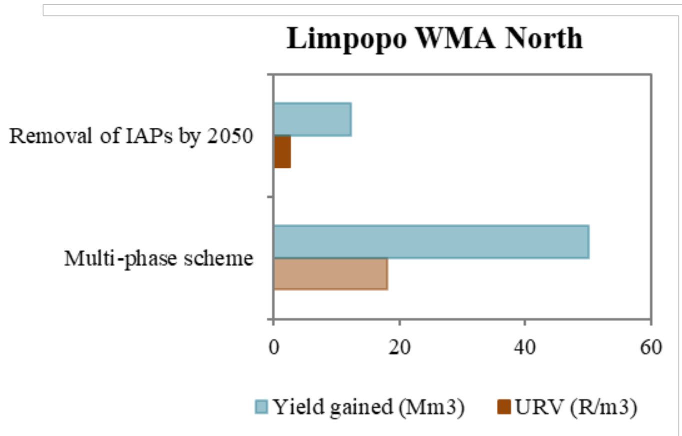

Algoa WSS
Removal of IAPs by 2050
Multi-phase scheme
Groundwater development
Dam augmentation
Water reuse
0
20
40
60
Yield gained (Mm3)
URV (R/m3)

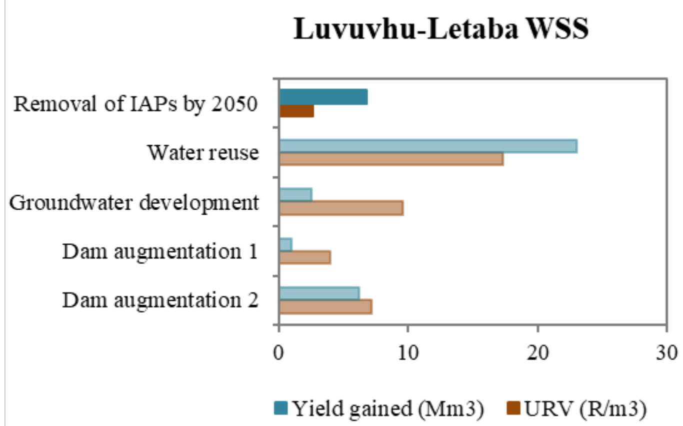

Amatole WSS
Removal of IAPs by 2050
Surface water development
Water reuse
Desalination
0
20
40
60
Yield gained (Mm3)
URV (R/m3)

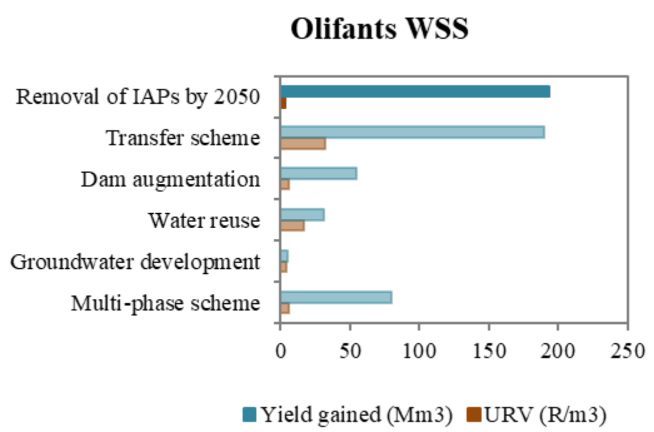

Crocodile West WSS
Removal of IAPs by 2050
Transfer schemes
Water reuse
Multi-phase scheme 1
Multi-phase scheme 2
0
50
100
150
Yield gained (Mm3)
URV (R/m3)


Integrated Mgeni WSS
Removal of IAPs by 2050
Desalination
Water reuse
Dam augmentation 1
Dam augmentation 2
Multi-phase scheme 1
Multi-phase scheme 2
Multi-phase scheme 3
0
100
200
Yield gained (Mm3)
URV (R/m3)


Integrated Vaal River System
Removal of IAPs by 2050
Desalination
Multi-phase scheme 1
Multi-phase scheme 2
0
200
400
600
Yield gained (Mm3)
URV (R/m3)


Limpopo WMA North
Removal of IAPs by 2050
Multi-phase scheme
0
20
40
60
Yield gained (Mm3)
URV (R/m3)


Luvuvhu-Letaba WSS
Removal of IAPs by 2050
Water reuse
Groundwater development
Dam augmentation 1
Dam augmentation 2
0
10
20
30
Yield gained (Mm3)
URV (R/m3)


Olifants WSS
Removal of IAPs by 2050
Transfer scheme
Dam augmentation
Water reuse
Groundwater development
Multi-phase scheme
0
50
100
150
200
250
Yield gained (Mm3)
URV (R/m3)

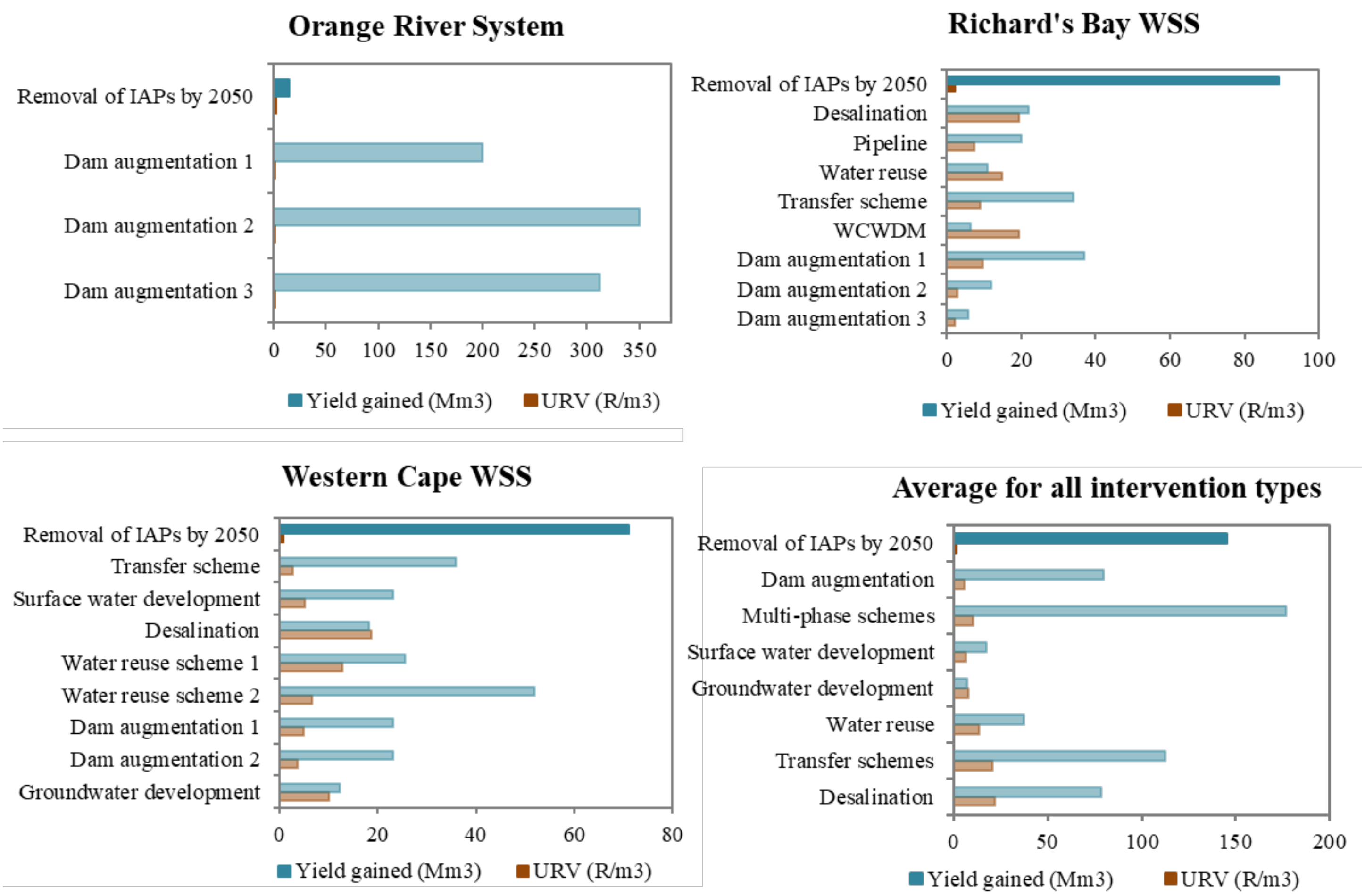


Figure 3.7. Unit reference value (URV) and yield gained through implementation of various interventions for each water supply system (WSS), and finally, the average URV and yield gained per intervention type.

The URVs for built infrastructure ranged from R0.48/m³ for the new Vioolsdrift Dam augmentation project in the Orange River System (DWA, 2015), to R44.36/m³ for the Zambezi River transfer scheme in the Crocodile West WSS (DWS, 2015b), while the URVs for IAP clearing ranged from R0.79/m³ for the Western Cape WSS to R7.18/m³ for the Crocodile West WSS (Table 3.7). All URVs for IAP clearing were lower than that of built infrastructure interventions, except for the Orange River System which had low levels of IAP invasion and planned built infrastructure interventions that would produce a significant amount of water.

Table 3.7. A summary of the overall extent of IAPs (% IAP coverage) within each water supply system (WSS) as well as the unit reference values (URVs) associated with built infrastructure and IAP clearing. URVs are reported in 2022 Rands.

WSS	% IAPs		Range of Built Infrastructure URVs (R/m^3)	URV IAP clearing (R/m^3)
	2022	2050		
Algoa WSS	7.26	28.68	6.77-25.62	2.99
Amatole WSS	22.00	58.22	8.46-28.66	1.97
Crocodile West WSS	5.43	20.35	12.38-44.36	7.18
Integrated Mgeni WSS	9.84	35.12	4.54-21.91	1.43
Integrated Vaal River System	3.61	16.30	11.80-17.61	2.78
Limpopo WMA North	1.40	7.50	*17.95	2.53
Luvuvhu-Letaba WSS	1.14	7.10	**3.98-17.32	2.60
Olifants WSS	9.96	36.51	4.50-31.92	2.82
Orange River System	0.27	1.61	0.48-0.84	2.45
Richard's Bay WSS	6.03	27.50	2.22-19.36	2.01
Western Cape WSS	11.97	45.49	2.57-18.77	0.79

*Only one planned built infrastructure intervention.

**Values based on the average URVs of similar projects due to deficient data.

3.5 DISCUSSION

Using South Africa as a case study to investigate the financial viability of investing in EI compared to built infrastructure revealed that IAP clearing in catchment areas of large dams is a cost-effective approach to secure water supply. Broadly, the yield gained from clearing IAPs equates to approximately 19% of the capacity of the Gariep Dam, the largest dam in South Africa (Appendix A). Of all the 11 WSSs analysed, only the Orange River System produced a URV for IAP clearing that was less cost-effective than for planned built infrastructure options for the region. This can be explained by the low levels of estimated invasion in its catchment areas, so removal of IAPs would not result in a significant gain in additional water when compared to the built alternatives which also presented a significantly higher yield than most other WSSs.

IAP clearing is a cost-effective intervention that can delay construction of more expensive built infrastructure options. This should be regarded as an attractive opportunity as built augmentation options become progressively more expensive due to the cheaper interventions being implemented first (Rodriguez, Van Den Berg & McMahon, 2012). Additionally, water management costs are likely to become more costly over time as storage space in existing impoundments decreases due to sedimentation (Mander *et al.*, 2017). WSPs should therefore plan for IAP clearing ahead of other augmentation interventions as the suite of benefits associated with postponing construction of bulk water supply infrastructure can be significant. It must be noted that there are a number of co-benefits that are not accounted for in the URVs presented in this study, for which their contribution can be very significant (Mander *et al.*, 2017). For example, removal of IAP species not only leads to additional water gains but allows for indigenous regrowth, which significantly reduces sediment mobilisation (Acreman *et al.*, 2021). On the other hand, built infrastructure such as dams can worsen the effects of sediment mobilisation, leading to sediment accumulation and reduced water quality in downstream impoundments and rivers which carries further management costs down the line (Mander *et al.*, 2017).

Other economic and environmental benefits of investing in EI can include improved water quality, restoration and protection of biodiversity, increased health of downstream aquatic ecosystems, wildfire and flood risk reduction, job creation, and potential for value added products (Turpie *et al.*, 2008; Hughes *et al.*, 2018; Seddon *et al.*, 2020; Acreman *et al.*, 2021; Turpie *et al.*, 2021b). Furthermore, climate change is a recognised as a serious threat to water security where declines in rainfall and increases in temperatures and evaporation have been predicted (Engelbrecht, 2005). Infrastructure that is fixed in position and capacity may lack the resilience necessary to cope with such changes, particularly in the face of rising water demand (Wertz-Kanounnikoff *et al.*, 2011; Vogl *et al.*, 2017b). Ecosystem-based adaptation is nested within NbS approaches, hence, EI investment through the adaptive management of catchment areas offers a potential solution for the need to increase the resilience of current water supply. Although investing in EI does not stand as a full substitute for built infrastructure approaches, it must be emphasized for its complementary potential, particularly in the context of climate change (Marais & Wannenburgh, 2008; Palmer *et al.*, 2015).

Despite the recognition of ecological infrastructure as being complementary of built infrastructure by the DWS (DWA, 2013), there is still a general lack of initiative for the EI investment movement in South Africa. Only two of the eleven WSSs have formally acknowledged and actively incorporated catchment restoration as a key intervention for securing water supply in the long-term. These include the Integrated Mgeni WSS, managed by Umgeni Water, and the Western Cape WSS, managed by the City of Cape Town and Overberg Water. Umgeni Water in the Integrated Mgeni WSS is involved in the 'uMngeni Ecological Infrastructure Partnership' (UEIP) which is an initiative dedicated to exploring the role and potential of EI investments in supplementing and/or substituting built infrastructure to improve water security in the uMngeni River catchment (Pieterse, Schroder & De Jager, 2017). Since the UEIPs inception in 2013, the initiative has gained over 20 signatories from government, academia, civil society and business, and has led to the development of an Ecological Infrastructure Investment Plan which will feed into future reconciliation strategy study updates (Pieterse *et al.*, 2017).

Similarly for the City of Cape Town in the Western Cape WSS, the Greater Cape Town Water Fund (GCTWF) was initiated in 2018 with a core purpose of pooling financial support from public and private water users to restore the integrity of EI in catchment areas that supply water to the Western Cape WSS (Turpie *et al.*, 2019b). IAP clearing is formerly included as a prioritised augmentation option in the latest reconciliation strategy study for the Western Cape WSS (Tlou, Fisher-Jeffes & Singh, 2021). The net URV of R1.20/m^3 outlined in the reconciliation strategy is higher than the URV of R0.79/m^3 estimated in this study. However, the reconciliation strategy value is still significantly lower than the range of URVs determined for built infrastructure augmentation options in the WSS (R2.57/m^3-R18.77/m^3) and was also the most financially viable augmentation option explored in the strategy (Tlou *et al.*, 2021). Another study completed for the GCTWF set out to determine priority areas for catchment restoration in the Greater Cape Town area and estimated a URV range of R0.30/m^3-R0.80/m^3 to clear IAPs in the top seven priority sub-catchments (Turpie *et al.*, 2019b). The Western Cape WSS URV determined in this study falls at the upper end of this range.

Other South African studies have also evaluated IAP clearing as an EI investments approach to securing water supply. These studies were also done at finer, catchment-level scales including the Olifants River catchment in Limpopo (Morokong *et al.*, 2016), Baviaanskloof-Tsitsikamma catchment area in the Eastern Cape (Mander *et al.*, 2017), and the uMngeni catchment area in KwaZulu-Natal (Mander *et al.*, 2017). The findings of this study agree with the outcomes of these case studies, where the EI investment approach was found to be a considerably cheaper option for securing water supply than the built infrastructure alternatives. However, the results of Mander *et al.* (2017) highlight that the severity of degradation can play a large role in increasing EI investment costs as more expensive approaches may be necessary to address the specific conditions of the area. In a comparison between the uMngeni and Baviaanskloof-Tsitsikamma catchment areas, uMngeni had more severe levels of degradation which consequently resulted in a higher EI URV (R2.50/m^3) than the Baviaanskloof-Tsitsikamma (R1.17/m^3) due to expensive measures needed to re-vegetate the area at a large-scale (Mander *et al.*, 2017). Nonetheless, the R2.50/m^3 URV still falls far below the range of built infrastructure URVs determined for the region in this study.

The lack of participation in hydrological EI investments can be a result of three main barriers identified and reviewed by Vogl *et al.* (2017). These include 'institutional failure', 'information failure' and 'market failure'. This discussion will focus on the relevance of institutions and information. Given the institutional landscape of South Africa's water sector, the weight of responsibility to plan and implement EI interventions would be carried by the regional institutional level of governance. This includes water boards, catchment management agencies and regional water utilities. Water boards are considered the key stakeholders of WSS management and are responsible for the provision of water services in the form of bulk potable water to other water service institutions within their areas of supply, such as local municipalities (DWS, 2015a). Although DWS compiles the reconciliation strategy studies focused on bulk infrastructure options for each water supply system, it is the responsibility of the water boards to ensure that sufficient water is delivered to their jurisdictional regions through the efficient management of that infrastructure. Therefore, water boards would bear the responsibility of ensuring the effective implementation of EI investments to meet their specific water supply goals. It is recognised that different nations have different institutional landscapes, but it is imperative that the responsibility to carry out key actions are appointed to specific institutions at the appropriate level. EI investment frameworks should be built for the specific institutional landscape of the nation to ensure that each institution is held accountable for the tasks appointed to it. At the same time, EI investments are a multi-institutional, multi-discipline approach which requires coordination between responsible institutions to ensure sufficient interaction, collaboration, and negotiation for smooth running of the operation as a whole. The same is recommended for countries with a similar governing body to uphold responsibility within the institutional landscape.

As the interest in EI investments has grown, so has the demand for tools that can model the potential outcome of conservation interventions regarding return on investments (Vogl *et al.*, 2017b). It is well known that funding for conservation is thinly stretched and has also been a significant barrier to the implementation of conservation programmes, particularly in developing countries (Seddon *et al.*, 2020; Mbopha *et al.*, 2021). However, the need for restoration, maintenance, conservation and protection of EI to be prioritized is becoming more apparent than ever as research on the state of environmental health continues to emerge. South Africa's government remains the primary source of conservation funding in the country, however other partnerships and funds, like the UEIP and GCTWF, have great potential to create momentum in the EI investments scene. Lack of funding, or interest to invest, is often due to a lack of information, termed 'information failure' (Vogl *et al.*, 2017b; Mbopha *et al.*, 2021). Decision-makers require sound information about the feasibility and likelihood of maximising return-on-investment for an intervention before they are willing to invest. To date, there has been limited reliable evidence on the impacts of IAP clearing for securing water supply. This study has helped to provide this evidence and encourages further research into the potential and viability of investing in catchment restoration in at finer scales within South Africa. Moreover, water boards (or similar institutions) are encouraged to direct and facilitate research into determining priority areas for catchment restoration, specifically at the sub-catchment level. This will ensure that limited funds are directed to areas that will have the highest return on investment, offering an opportunity to address some of the sources of uncertainty and risk related to funding that inhibits WSPs and government from establishing EI investment initiatives.

South Africa proved to be a good case study for assessing the cost-effectiveness of EI investments as it revealed the financial viability of investing in catchment restoration to enhance supply from water resources, the complications around institutional responsibility for management of such interventions, and also the usefulness of having a governmental programme dedicated to restorative work in natural systems, namely the Working for Water programme (Marais & Wannenburgh, 2008). Having such an initiative creates opportunity to realize the development goals of the country in an integrative way. South Africa is also a signatory of the United Nations (UN) 17 Sustainable Development Goals (SDGs) which address development towards achieving overall human and environmental well-being in developed and developing nations, an objective that aligns well with South Africa's National Development Plan (United Nations, 2015; Cumming *et al.*, 2017). The country has a strong development agenda that recognises environmental sustainability and resilience as an important part of economic development and the role it plays in ensuring human well-being (Cumming *et al.*, 2017). More holistic approaches to development are likely to become even more crucial in the next decade as the UN has declared 2021-2030 the "UN Decade on Ecosystem Restoration" to encourage global efforts towards restoring ecosystems (UNEA, 2019). Therefore, there is growing pressure to prioritise research and initiatives that pursue socio-economic development in innovative ways.

NbS are highly esteemed for presenting avenues to achieve development goals in adaptive, resilient and efficient ways (Seddon *et al.*, 2020). The EI investments branch of NbS is one such approach that is in direct alignment with SDG15, which aims to “protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss” (Cumming *et al.*, 2017). By investing in catchment restoration, South Africa, and other nations with similar vision, would be effectively pursuing a development strategy with the aim of securing water supply, whist benefitting from a suite of other related SDG targets, as shown in Figure 3.8. (Cumming *et al.*, 2017).

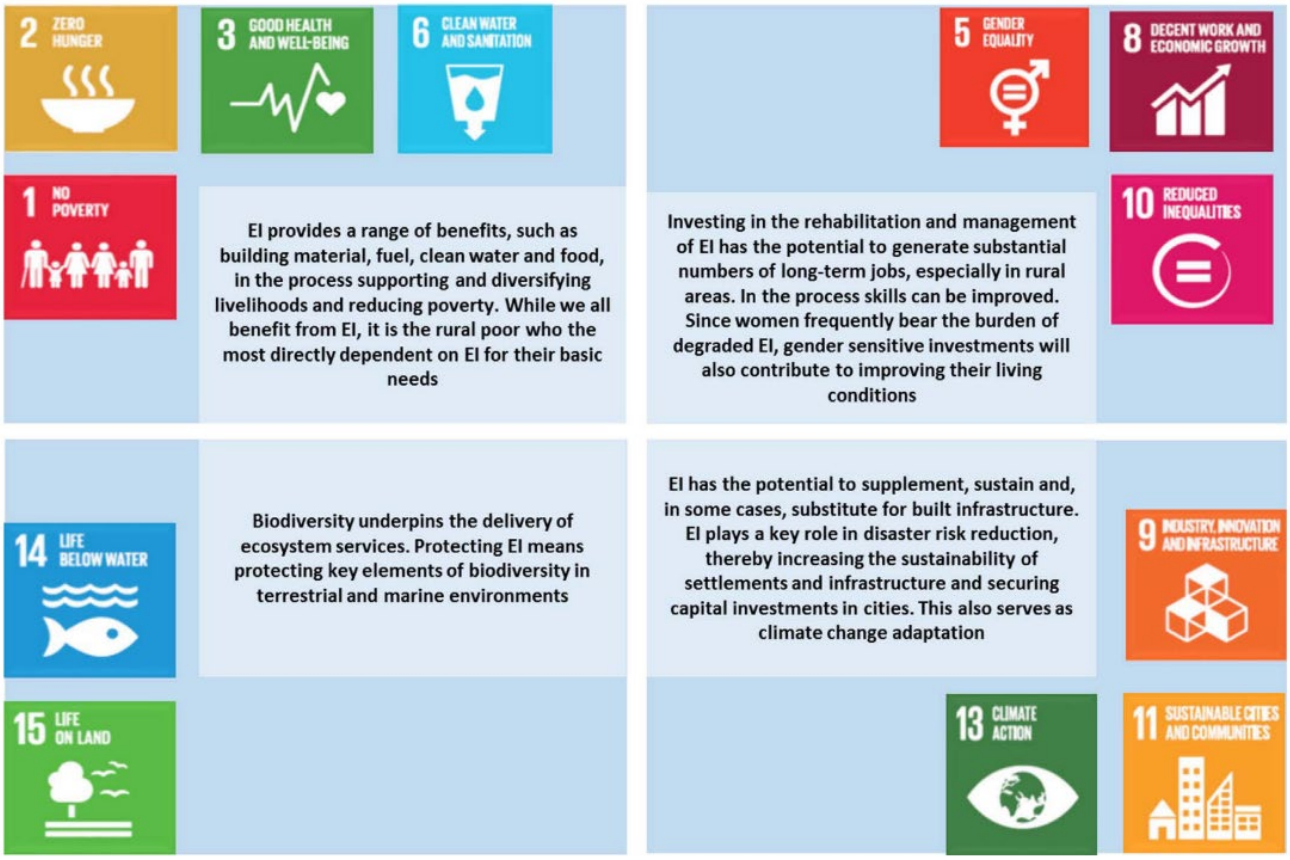


Figure 3.8. Investing in ecological infrastructure (EI) can support a range of Sustainable Development Goals (SDGs). Source: (Cumming *et al.*, 2017)

3.6 LIMITATIONS

The accurate quantification of catchment degradation is challenging. Despite the abundance of literature regarding IAPs in South Africa, an updated, recent spatial dataset of national IAP coverage was not available. While acknowledging the privilege of having access to the NIAPS 2010 dataset, using outdated data about dynamic phenomena creates likelihood for over- or underestimation of current and future estimates of IAP coverage. It must also be noted that new introductions and clearing of IAPs up until the present were not accounted for in the model.

Originally, this research project sought a better understanding of the perspectives of water service providers. However, there was insufficient willingness to participate among the dozen institutions (at the water board level) that were contacted, despite following the necessary avenues of communication. Given the number of

EI benefits demonstrated in this study, government institutions are strongly encouraged to participate in research that seeks to move this field forward.

3.7 CONCLUSIONS

The water supply sector is greatly threatened by increasing water demand driven by human population growth and the effects of climate change. The pursuit of more eco-centric strategies to both secure and maximize water supply from source areas should therefore be a priority. There is evidence that the concept of EI investments aligns with this idea, presenting a ‘win-win-win’ scenario of mutual benefit for the economy, nature and people (SANBI, 2014; Cumming *et al.*, 2017). This study goes beyond valuing ecosystem services by highlighting an opportunity cost incurred by only investing in built infrastructure. The study’s findings add to the growing body of literature that advocates for EI investments to secure hydrological ecosystem services by showing that such approaches are comparable with, and can be more financially and economically viable than, built infrastructure development options. The emphasis here is on delaying the development of future augmentation options, as it has been noted that EI interventions would not be able to replace, but rather enhance existing built infrastructure.

This case study showed that IAP clearing in catchment areas should be considered a formal intervention for securing future water supply alongside built infrastructure options in almost all of South Africa’s water supply systems. IAP clearing would lead to a total water gain of 1595 million m^3 and a yield gain of 997 million m^3 by 2050, equivalent to a quarter of the yield gains through implementation of built infrastructure interventions in the same time frame.

CHAPTER 4: COULD CATCHMENT CONSERVATION BE FUNDED THROUGH INCREASED WATER TARIFFS? A CASE STUDY OF THREE SOUTH AFRICAN CITIES

Du Plessis, N., Turpie, J.K. & Letley, G.K.

4.1 INTRODUCTION

4.1.1 Background

In many parts of the world, particularly arid and semi-arid countries that are physically water-stressed, the demand for water often exceeds supply. According to Mekonnen and Hoekstra (2016), approximately 4 billion people experience severe water scarcity for at least one month a year. By 2050, this is estimated to rise to at least 5.7 billion people (WWAP/UN-Water, 2018, Boretti & Rosa, 2019). Whilst unprecedented growth in human population and urbanisation have caused a significant increase in the demand for water on the one hand, over-abstraction, degradation of water source areas, climate change, and the contamination of freshwater resources have compromised the finite availability of water on the other (Gilbertson, Hurlimann and Dolnicar, 2011; Morokong *et al.*, 2016). Since water is linked to the challenges of poverty reduction, climate change adaptation, and food security, investments in water security are central in achieving global sustainability agendas such as the United Nations 17 Sustainable Development Goals (SDGs).

Water scarcity has traditionally been addressed by increasing water abstraction from surface rivers and investing in 'built' or engineered infrastructure such as dams and inter-basin transfers (Abell *et al.*, 2019). Although these solutions are an essential component of water service delivery, they have detrimental effects to the environment, especially if unregulated (TNC, 2018a). The increase in dam construction and water abstraction has been found to modify natural flow regimes, fragment freshwater habitat, and alter the chemical and physical conditions of downstream environments (Dai, Brouwer & Lei, 2021). Such changes have detrimental impacts on both freshwater species and humans across the globe. For example, whilst dams obstruct migratory fish from reaching spawning and feeding grounds (Dudgeon *et al.*, 2006), over-abstraction of surface water has reduced the amount of water available in rivers, which poses a health risk to humans through increased pollution concentrations (Mander *et al.*, 2010). It is thus becoming increasingly apparent that alternative options to supplement water supply infrastructure is necessary, particularly those that minimise environmental damages.

Investing in ecological infrastructure, is rapidly gaining popularity as a sustainable and cost-effective option of extending the life of existing built infrastructure whilst meeting future water demands (Guswa *et al.*, 2014; Abell *et al.*, 2019). Ecological infrastructure, which is defined as 'naturally functioning ecosystems that deliver valuable ecosystem services to people' (SANBI, 2014), is considered a concept that falls under the broad umbrella of nature-based solutions (NbS) which are interventions to sustainably manage, restore, and protect natural or semi-natural ecosystems that address social challenges adaptively and effectively, whilst providing benefits to humans and biodiversity simultaneously (IUCN, 2020). Ecological infrastructure can provide services to society either directly (e.g. through coastal dunes protecting roads from storm surges), or as part of a broader infrastructure system combined with engineered infrastructure (e.g. catchment areas that function together with dams and pipes to provide water to human settlements) (Pringle *et al.*, 2015).

The delivery of hydrological ecosystem services such as water supply, water purification, flood attenuation, and pollution dilution, is heavily dependent on healthy ecological infrastructure (Guswa *et al.*, 2014). However, through human activities, catchment areas have become degraded, with reduced capacity to deliver beneficial ecosystem services (Nesshöver *et al.*, 2017). The main drivers of catchment degradation worldwide are invasive alien plant species, loss of vegetative cover, soil erosion, and bush encroachment (Reid *et al.*, 2019; Turpie *et al.*, 2021b). Ecological restoration, which includes interventions to assist the recovery of an ecosystem that has become degraded, damaged, or destroyed, is recommended as a tool to improve the health of ecological infrastructure (Gann *et al.*, 2019). Beyond its ecological benefits, ecological restoration has also been found to generate broader co-benefits to society, including recreation and tourism opportunities, protecting built infrastructure, and buffering communities from climate change related impacts (Jones, Hole & Zavaleta, 2012). Restoring degraded catchment areas is thus considered a cost-effective and environmentally sustainable strategy to improve both water yields and the well-being of society.

A significant impediment to the success of catchment restoration and conservation projects, particularly in the Global South, is funding (Shackleton *et al.*, 2017). Insufficient funding is attributed to multiple factors, one of which is a lack of monitoring and evaluation of restoration interventions, resulting in a weak organisational understanding of the societal, economic, and ecological benefits of such interventions (Rebelo *et al.*, 2021). Another factor is that in many developing countries rely solely on state funding as the only source of financing for these projects. Since Global South nations face higher rates of corruption, crime, unemployment, income inequality, and disease than Global North countries (Odeh, 2010), the budget for ecological infrastructure is generally insufficient to ensure long-term success of conservation initiatives. To mitigate this barrier, alternative funding streams beyond state funding need to be considered (Pringle *et al.*, 2015).

One such funding stream that has gained recent attention is that of water pricing. Worldwide, policymakers are confronted by the difficult balancing act of pricing water at a cost that does not impede people's right to access it. Consequently, water is often priced far below the cost to produce it, resulting in economic inefficiencies, wasteful use, and infrastructural decay (Grafton, Chu & Wyrwoll, 2020). However, if designed appropriately, water pricing structures can be an effective instrument in achieving financial and economic goals (Mander & Mander, 2021). In recent years, cities have started to explore the potential of using water pricing as a tool to finance the restoration and protection of catchment areas that supply water to them (Turpie *et al.*, 2021b). For example, in the City of Cape Town, decision-makers are currently exploring the option of charging municipal water users an additional charge to assist in funding the management and restoration of catchment areas supplying water to the Western Cape Water Supply System (Mander & Mander, 2021). To unlock the potential contribution of key water source areas to South Africa's water security, the price paid for water will thus have to be increased over time. A recent report by Cartwright (2021) revealed that only a minor increase (1-2.5%) in the net price of water paid by domestic users could contribute significantly to the annual investment in ecological infrastructure interventions. Capturing some of the untapped willingness to pay for water (i.e. consumer surplus) could thus raise enough revenue to safeguard South Africa's freshwater ecosystems and secure future water supply in the country (Turpie & Letley, n.d.).

4.1.2 Rationale of research

Numerous studies have investigated the opportunities to mobilise financial resources for the investment into water-related ecological infrastructure within the public and private sectors (Bennett *et al.*, 2014; Gómez-Baggethun & Muradian, 2015; Mbopha *et al.*, 2021; OECD, 2022). Other studies have recommended water tariffs as a potential funding mechanism for catchment conservation (Pegram & Palmer, 2001; Pringle *et al.*, 2015; Cartwright, 2021). However, few if any studies, have established whether the additional revenue generated from aggregate household willingness to pay (WTP) for water would be sufficient to secure funds for catchment conservation.

4.1.3 Research questions, objectives, and hypotheses

In this study, interview surveys of residents in the three largest coastal metropolitan municipalities of South Africa were conducted. The overarching question is: Can water tariff pricing for households be used as a sustainable financing mechanism for catchment restoration? To answer this, the study set out to achieve the following objectives: (i) to determine households' willingness to pay (WTP) for their existing water use (ii) to investigate the socio-economic factors influencing household WTP, and (iii) to establish whether their aggregate consumer surplus could cover the costs needed to finance catchment restoration.

Prior to statistical examination of the data, two hypotheses were developed. First, socio-economic factors including income, education, age, trust in the government, satisfaction in municipal service delivery, and household size, will positively influence WTP. Second, aggregate WTP at the municipal scale will be sufficient to cover the costs needed to restore catchment areas supplying water to that municipality.

4.2 LITERATURE REVIEW

4.2.1 Water pricing as a tool to achieve environmental sustainability

The economic policy instrument of water pricing has been recognised as a powerful tool to pursue different water policy objectives (Dinar & Subramanian, 1998).In the past, water policy objectives were linked to social and economic issues such as protecting populations and economic assets from flooding and drought events, providing water as an input for economic activities, and supplying the domestic population with safe drinking water (Griffin, 2012; Pirard, 2012). However, in more recent years, water policy has incorporated the objective of protecting and managing freshwater ecosystems (Mander & Mander, 2021).

Water pricing is unique in that it has both incentive and revenue effects. High water prices have been found to incentivise consumers to reduce water consumption and invest in water-saving technologies (Schleich & Hillenbrand, 2009). For instance, Schoengold, Sunding and Moreno (2006) discovered that setting the price of water at appropriate levels encouraged farmers to adopt efficient irrigation technologies and to change to more productive cropping patterns. Further, the additional revenue generated from charging higher water tariffs can also contribute to the financing of water resource management, which should include the protection and conservation of water source areas (Wilson *et al.*, 2021). Thus, water pricing can be used as a tool to achieve environmental sustainability.

In most countries, the price of water does not cover the costs of its supply which include the costs of producing, treating, distributing, and managing water resources (Andrés *et al.*, 2021). This is particularly apparent in Global South countries where policies are centred around access and affordability (EUWI-FWG, 2012). However, low water prices have serious implications for the sustainability of water utilities, often leading to a vicious cycle of asset deterioration, poor management, and low quality services (Roldán, Sarmiento & Roldán-Aráuz, 2021). According to a worldwide survey conducted in 2004, only 39% of utilities were charging water tariffs at a rate which allowed them to fully recover both short-run and long-term costs (Le Blanc, 2007). Guaranteeing the sustainability of water supply whilst ensuring access to all is thus considered a significant challenge for government authorities (OECD, 2022). This requires some knowledge of societal preferences and potential welfare outcomes.

The revenue generated from water services are referred to as the three Ts: taxes, transfers, and tariffs (OECD, 2009). According to the EUWI-FWG (2012), among the three Ts, water tariffs should be considered the main source of finance for water resource management. This is because water supply is a service, and consumers are generally willing to pay more for efficient and good quality services (Andrés *et al.*, 2021). The gap between what a consumer actually pays for a good or service versus what they are willing to pay is referred to as "consumer surplus"(Wells, 1997). A recent meta-analysis found that in Global South countries, households were willing to pay three times more for water than Global North countries relative to their income (Roldán *et al.*, 2021). Since developing countries tend to have significantly worse water supply systems, residents are willing to pay a greater percentage of their income towards improving the quality and quantity of their water supply.

4.2.2 Environmental goods valuation

In the absence of viable markets, economists have established various methods to estimate the monetary value of environmental goods (Witt, 2019). These methods include the alternative cost method, the travel cost method, the hedonic price method, the replacement cost approach, and the stated preference approach (Makwinja *et al.*, 2022). These methods are important in measuring the value of ecosystem goods and services and are often used in justifying the conservation of natural resources (Makwinja *et al.*, 2022).

One of the most popular methods to value water is the stated preferences approach which uses respondents' statements about their preferences to estimate change in utility with a proposed increase in quantity or quality of a good or service (Bateman *et al.*, 2002). In contrast to the revealed preference approach which aims to deduce respondents' willingness to pay from observed evidence of how they behave when faced with real choices, stated preferences are based on constructed markets. Through carefully designed surveys, the stated preferences approach involves creating a hypothetical market in which respondents must make choices about the environmental good in question (Carson, 2000). The stated preference approach strongly relies on the honesty and participation of respondents, often cited to be the major downfall of the method (Bostan *et al.*, 2020). Despite this, the approach is often used by decision-makers as a starting point to set water prices (Makwinja, Kosamu and Kaonga, 2019). Two of the most widely applied stated preferences techniques are the contingent valuation method and the choice experiment method, both of which have their own advantages and disadvantages.

Contingent valuation is a survey-based method during which respondents are directly asked how much they are willing to pay in monetary terms for a specified environmental good (Carson, 2000). Willingness to pay (WTP) thus reflects the value the respondent places on the good (Littlefair, 1998). There are three main elements of the contingent valuation method: the hypothetical market (in which no actual transactions are made), the description of the environmental good to be valued (e.g. clean air or water), and the payment vehicle (how respondents are hypothetically expected to pay for the good) (Gyrd-Hansen, 2014). The contingent valuation method is an widely used, easy to understand, and flexible way to collect high volumes of data from the target population (Bostan *et al.*, 2020). However, there are several limitations and biases which researchers need to try and control to ensure the validity and reliability of their results when using this method. One of the most difficult biases to control is the hypothetical bias, which arises because respondents do not have to support their choices with any real monetary commitments (Venkatachalam, 2004). Generally, hypothetical biases arise when respondents give an answer that is socially desirable, rather than true. The interviewer has to therefore accept that the respondents' answers are true, unless they can validate the findings with a real market (Lewis *et al.*, 2018). Strategic bias is another issue linked to contingent valuation studies, whereby respondents either 'free-ride' or 'over-pledge' (Venkatachalam, 2004). Whilst free riding occurs when respondents understate their true WTP on the assumption that other people will pay enough for the good or service, over-pledging occurs when respondents assume that their WTP value will impact the provision of the good or service in reality (Bateman *et al.*, 2002; Venkatachalam, 2004). Controlling these biases can be achieved through careful survey design, developing a convincing hypothetical scenario, and using appropriate eliciting formats and payment vehicles (Carson, 2000).

The choice experiment method is often applied in studies to predict human behaviour (Bostan *et al.*, 2020). The choice experiment, which was developed by (Louviere & Hensher, 1982) states that the utility from a good or service is derived from its individual attributes or characteristics rather than from the good itself. During this technique, the context in which consumers ordinarily make choices is simulated among a set of competing alternatives, designed according to several attributes and levels that are independent and systematically varied according to experimental design (Carson *et al.*, 1994). Generally, two or more alternatives are presented as choice tasks to respondents where one option represents the status quo (i.e. describes the current state). Respondents are then invited to select which choice task or scenario they prefer (Koemle & Yu, 2020). The number of choice tasks offered is dependent on the number of attributes and levels (Turpie & Letley, 2018). The assumption is that consumers will select the alternative that will provide the highest utility to them. Including cost or price as one of the attributes is often used to estimate individuals' willingness to pay. The advantages of this method are that it allows the simultaneous analysis of multiple impacts on respondents and is an useful tool for policy and decision-makers (Bostan *et al.*, 2020). However, the downfalls are that the method is time-consuming, and relies on precise pre-testing and statistics (Dai *et al.*, 2021).

Over the last few decades, there has been a rise in the number of contingent valuation and choice experiment studies regarding willingness to pay for different purposes and implications. These two methods have been widely used in literature from developing country contexts. For instance, households have been found to be willing to pay more money to guarantee safe and reliable drinking water in Malawi (Makwinja *et al.*, 2019), Nicaragua (Vásquez, Franceschi & Van Hecken, 2012), and Kazakhstan (Tussupova *et al.*, 2015). Other studies have also demonstrated that people are willing to pay more towards efforts to restore nearby freshwater ecosystems, such as for wetlands in Ethiopia (Asmare, Bekele & Fentaw, 2022), and urban rivers in China (Li *et al.*, 2014; Khan *et al.*, 2019).

4.2.3 Factors influencing willingness to pay for water

In most cases, there is a positive relationship between willingness to pay (WTP) for water and socio-economic factors such as income, education, age, and household size (Littlefair, 1998; Del Saz-Salazar, González-Gómez & Guardiola, 2015; Akinyemi, Mushunje & Fashogbon, 2018). WTP to avoid water restrictions has also been found to be influenced by internal circumstances such as having a garden or a swimming pool, as well as by external factors including the duration and severity of water restrictions imposed on households by the city (Wilson *et al.*, 2021). Few studies have investigated the extent to which institutional trust impacts WTP, but for those that have, a positive relationship has also been reported (Makwinja *et al.*, 2019, 2022). More studies, however, need to be conducted to understand the impact of institutional trust and satisfaction on household WTP, particularly in countries where service delivery is poor, and where factors such as corruption and political instability are common.

4.2.4 Institutional context of water supply and management in South Africa

At present, surface water resources account for 77% of South Africa's water supplies and according to Kanyoka, Farolfi and Morardet (2009), most of these resources are either overdrawn or fully utilised. The dominant water user is agriculture (67%), followed by urban use (18%), mining (5%), and rural households (3%), with the remainder distributed amongst forestry, power generation, and other uses (Mutamba, 2019). Threats to the country's future water security are numerous and include that South Africa is physically water scarce, ranked as the 30th driest country in the world; demand for water is growing due to an increasing population; water infrastructure is aging with high water losses; institutions have failed to adequately and equitably manage water resources and its associated infrastructure; and catchments are threatened by ecosystem degradation caused by human activity (Mutamba, 2019). Considering these threats, the demand for water in South Africa is projected to outstrip supply by 2030 unless water pricing is adjusted substantially (Colvin *et al.*, 2016). As such, South Africa needs to efficiently manage and protect its water resources, particularly its catchment areas.

To understand challenges relating to household water supply and security at the local scale, it is necessary to acknowledge the institutional context of water at the national scale. South Africa's long history of inequality in the water sector stems from several pieces of legislation that unfairly allocated water to specific groups' (Madigele, 2018). This was brought about by several pieces of legislation which unfairly allocated water to the white minority, such as the Irrigation and Conservation of Water Act which favoured white farming communities, granting them rights to riparian water whilst limiting access to black farming communities (Jegede & Shikwambane, 2021). As a consequence of these policies, only 59% of the population (38 million people) had access to basic water supplies before 1994 (Adom & Simatele, 2021).

Post-apartheid, the new South African government introduced a series of policy reforms aimed to redress past injustices in the water sector (Hove *et al.*, 2019). In 1996, water was enshrined as a basic human right in section 27(1) (b) of the 1996 Constitution, and in 1997, the Water Service Act (Act 108 of 1997) sought to empower citizens with the right of access to basic sanitation and water supply (Adom & Simatele, 2021). Reforms introduced by the Water Services Act included the establishment of water management institutions such as, water user associations, irrigation boards, and Water Boards (Meissner *et al.*, 2013; Adom & Simatele, 2021). Further the National Water Act (Act 36 of 1998), enacted in 1998, provided the legislative framework to effectively manage water resources in South Africa, placing all water resources in the country under the custodianship of the Minister of the (then) Department of Water Affairs and Forestry (Cartwright, 2021). Under this act, service provision and water supply were devolved from central government to municipalities between 2003 and 2006 (Jegede & Shikwambane, 2021). However, the ambitious decentralisation of water provision came with multiple challenges at the local level including financial distress, inability to raise revenue, debt, financial mismanagement, and corruption of public procurement (Hove *et al.*, 2019).

To alleviate the failing system, 19 Catchment Management Agencies were established across the country to manage water resource planning and management at the catchment level; thus taking up responsibility for local governance (Meissner *et al.*, 2013). However, due to a lack of capacity and accountability as well as poor decision-making, establishment of Catchment Management Agencies has been poor, and to date, only two are operational (Cartwright, 2021). Thus, although these policies and programmes have been internationally regarded as some of the most progressive pieces of legislation on water, they have failed to address challenges in the water sector, particularly regarding governance at the catchment level (Adom & Simatele, 2021).

Although the Department of Water and Sanitation (DWS) is mandated to develop, monitor, regulate and evaluate the water sector, it has transferred its responsibility of implementation to specific municipalities. All municipalities that are considered category A municipalities (metros) are permitted to provide water to the population. Smaller local municipalities (category B) are authorised in some instances, and several district municipalities (category C) are authorised in others (Lehohla, 2016). In total, 169 metropolitan, local, and district municipalities have been designated as Water Services Authorities, which have the responsibility of providing water and sanitation services within their areas of jurisdiction (Cartwright, 2021). Often, authorised municipalities appoint other organisations or municipalities to provide water services on their behalf. These organisations are known as Water Service Providers (National Treasury, 2011). Since 2000, metropolitan municipalities have taken on increasing responsibility and influence in the water sector.

4.2.5 Water pricing in South Africa

Donnenfeld, Crookes and Hedden (2018) argue that the most fundamental constraint preventing the effectiveness of water policies in South Africa is that water is significantly under-priced, resulting in a failure to cover the costs of water resource management at the catchment level. However, since water is a basic need, it must be priced at a level that does not impede people's right to access it but should also be priced at a level that ensures water is not being overused. This relationship between the price of water and consumption is known as price elasticity, whereby consumption decreases as price increases (Hoffman & Du Plessis, 2013). However, this relationship is not entirely linear and there are specific points at which the relationship becomes inelastic whereby an increase in price has no impact on consumption levels (Hoffman & Du Plessis, 2013). In modelling the expected consumption due to a change in tariff using South Africa as a case study, Hoffman & Du Plessis (2013) found that demand was relatively inelastic, with water savings typically lower than the increase in revenues that were induced by the higher cost. In other words, higher prices increase revenues more than they reduce consumption. Therefore, increasing the water tariff is likely to increase revenues with water saving being a secondary benefit (Hoffman & Du Plessis, 2013).

Pricing water in South Africa is therefore a complicated balancing act, and as a result, the DWS are reluctant to increase water prices to reflect full-cost accounting due to the risk of alienating water users. The scope for raising water prices is also limited by the institutional capacity to collect money at current prices and spend additional money efficiently. The DWS (2019) reported that across South Africa, "non-revenue water" resulting from leaks, illegal connections, and the under-collection of tariffs, accounted for 41% of the water distributed by Water Service Authorities, representing a loss of R9.9 billion in 2018.

To combat the challenge of affordability in South Africa, the government has implemented an inclining block tariff (IBT) structure for water which aims to recover the costs of constructing and maintaining infrastructure whilst protecting the poorest households from unaffordable water prices (Walsh, Shai & Mbangata, 2019). Regarded as a pro-poor tariff structure, the IBT is a volumetric form of non-linear pricing whereby low-consuming households pay lower prices for water (Le Blanc, 2007). This is based on the assumption that high-income households tend to consume water at higher levels than low-income households. IBTs thus intend to capitalise on wealthier households' higher willingness to pay for water to cross-subsidise the cost of water for the poorest households. In most municipalities in South Africa, the first 'block' (6 kl/month) is provided free to indigent households under the Free Basic Water policy of 2002 (Mpofu, Kruger & Reddick, 2020). Individual municipalities have the authority to decide (i) the cost of the water tariff charged per litre above the first block, (ii) the amount of water that is free above 6 kl per month (i.e. some provide as much as 14 kl free), and (iii) which households are considered indigent. To date, 136 out of the 169 Water Service Authorities provide free water to some residents that have been identified as indigent by that municipality, 29 provide free basic water to everyone (rich or poor), and four small municipalities do not supply free water to any of their residents (Colvin *et al.*, 2016).

Although IBTs have been successfully implemented in some large municipalities, the design of the system has received some criticism. For most utilities in South Africa, the operating and maintenance costs are generally recovered from the highest block users, but not for the lowest block users (Dikgang *et al.*, 2019). This is a serious issue for poorer municipalities that do not have enough customers in the higher-use blocks to cross subsidise the lower-use blocks (National Treasury, 2011). The failure of IBTs to recover costs has resulted in inadequate investment in water-related infrastructure and management, which has led to water supply shortages in municipalities such as Makhanda in the Eastern Cape (Pamla, Thondhlana & Ruwanza, 2021). Additionally, the system discriminates against low-income households that consume high amounts of water due to large household sizes and age composition (Grafton *et al.*, 2020). Lastly, due to the arbitrary guidelines of the IBT structure, water is currently considered affordable for high-income households, but not so for low-income households (Dikgang *et al.*, 2019). This was revealed during the recent droughts experienced by the Western Cape and Eastern Cape, whereby the biggest users of water were from affluent suburbs. With the country expected to face more frequent droughts in future, it is necessary to design the IBT in a way that will maximise the ability of the richer households to pay for water. Investigating household willingness to pay (WTP) for water at the municipal scale will be important first step in redesigning the tariff structure of South Africa.

4.3 METHODS

4.3.1 Ethics statement

The methods used in this study were approved by the University of Cape Town Faculty of Science Research Ethics Committee under the approval number 'FSREC 017 – 2022'. Prior to fieldwork involving in-person interactions with human participants, approval from the Departmental COVID-19 compliance officer and Head of Department was obtained. Additionally, permission to conduct surveys outside Home Affairs offices was granted by the Directorate of Research Management for the Department of Home Affairs.

4.3.2 Study area

Three coastal metropolitan municipalities in South Africa were selected as survey sites: the City of Cape Town in the Western Cape, Nelson Mandela Bay in the Eastern Cape, and eThekwini in KwaZulu-Natal (Figure 4.1). These municipalities were selected as they represent three of the eight largest municipalities in South Africa, are dependent on strategic water source areas for their municipal water supply, have made initial investments towards catchment restoration, and have unique socio-economic, water supply and water service provision contexts. Additionally, water funds, which are "funding and governance mechanisms that enable collective action between the public and private sector to employ nature-based solutions such as catchment restoration", have already been established, or are in the process of being established in all three municipalities (Bonthuys, 2019). In 2016, these three municipalities had a combined population of 8 334 502 people, which is approximately ~16% of the total South African population (Small, 2017).

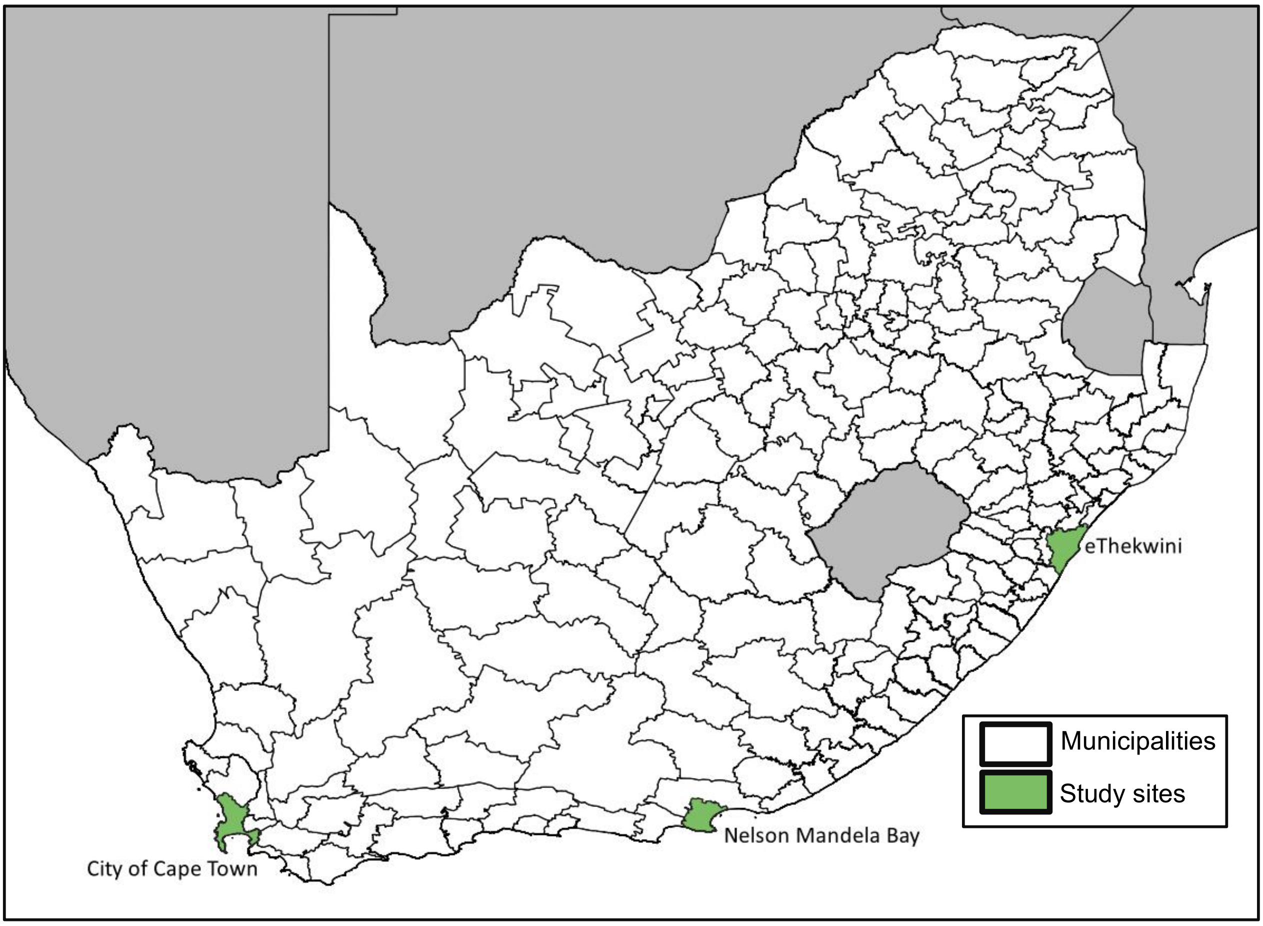


Figure 4.1. Map of the three coastal municipalities selected as study sites in South Africa.

4.3.2.1 City of Cape Town

The City of Cape Town is a coastal municipality in the Western Cape. In 2016, the city had a total population of 4 million people (Small, 2017). The region experiences a Mediterranean climate, with cool wet winters and hot dry summers (Enqvist & Ziervogel, 2019). The mean annual rainfall is 749 mm, and most precipitation is experienced between May and August (Otto *et al.*, 2018). Cape Town receives 98.4% of its surface water from three of South Africa's 22 strategic water source areas: the Boland mountains, the Groot Winterhoek, and

Table Mountain (Le Maitre *et al.*, 2019). Water is transferred from these catchment areas via a system of dams and pipelines which is referred to as the Western Cape Water Supply System (WCWSS). The WCWSS is run by the City of Cape Town and the Department of Water and Sanitation (DWS) (Colvin *et al.*, 2016). There are six major dams in the WCWSS, predominately situated within the upper regions of the Berg and Breede River catchments (Adams, Jones & Du Preez, 2018).

The Table Mountain strategic water supply area is approximately 90 000 ha in size and of this, only 19.7% is formally protected. Since Table Mountain is located within a city, much of the land cover has been transformed into urban and light industrial areas and alien plantations have replaced a large extent of the native vegetation. The larger Boland and Groot Winterhoek mountains cover just over 600 000 ha and are more extensively protected (46%). Although the Boland strategic water surface area is mostly natural vegetation, 20% of the area is under cultivation, and most of the catchments have been invaded by invasive alien plants to some degree. Le Maitre *et al.* (2019) estimated that at present, baseline invasions are reducing water yields by 38 million m^3 per year in the WCWSS. If no efforts are made to clear these invasions, these reductions in yield will increase to 130 million m^3 per year in 45 years' time. During periods of low rainfall, impacts of invasive alien species are felt most acutely.

Between 2015 and 2017, three consecutive years of below average rainfall brought Cape Town close to reaching "Day Zero", a day when the city was predicted to run out of water. The City's response was to limit water users to 50 litres per day, as well as to invest in alternative options to meet demand such as water recycling, groundwater, and desalination (Colvin *et al.*, 2016; Le Maitre *et al.*, 2019). However, many of these projects have since been decommissioned due to high operating costs (Otto *et al.*, 2018). The city also made initial investments in clearing invasive alien plants in the catchments above the main water supply dams to enhance water security.

More recently, a non-governmental organisation, The Nature Conservancy, established a Business Case for the Greater Cape Town Water Fund, a project which aims to pool funding from multiple sources to restore and maintain ecological infrastructure in the WCWSS (TNC, 2018a), based on an analysis of the costs and benefits of clearing invasive aliens by Turpie *et al.* (2019b). The Business Case revealed that an investment of R372 million would increase water flows into water supply dams by more than 55 billion litres per year relative to the business-as-usual situation within six years, increasing to 100 billion litres over 30 years. This corresponds closely to the estimate provided by Le Maitre *et al.* (2019a) of 130 million $m^3 \cdot a^{-1}$ that could be achieved by year 45. This will be necessary to alleviate water scarcity in the city, whilst creating jobs through alien plant clearing.

4.3.2.2 Nelson Mandela Bay

The Nelson Mandela Bay Metropolitan Municipality is situated in the Eastern Cape, one of the most rural and populous provinces of South Africa. Nelson Mandela Bay includes one of South Africa's largest cities: Gqeberha (previously Port Elizabeth), as well as the smaller towns of Kariega and Despatch. In 2016, the population of Nelson Mandela Bay was 1.26 million people (Statistics South Africa, 2018a).

The climate of Nelson Mandela Bay is warm and temperate, with mean annual precipitation ranging from 500 to 650 mm per year (Nelson Mandela Bay Municipality, 2022). Around 1.1 million people in the municipality receive water for domestic use from the Algoa Water Supply System which is subdivided into the Western, Central, and Eastern systems. The Western System supplies water to approximately 70% of the residents in Nelson Mandela Bay municipality and is made up of three important catchment areas: the Baviaanskloof, Kromme and Kouga. The Central and the Eastern systems supplement the Western System through a system of dams, transfer schemes and springs (DWA, 2011).

Although a significant portion of the Kouga river catchment is protected, there has been significant degradation outside of these areas. Pine trees have invaded most of the Tsitsikamma Mountains in the south, and capital-intensive deciduous fruit farms in the Langkloof valley have resulted in an increase in the construction of illegal dams, as well as overextraction of water from nearby rivers. Degradation of these catchments have led to an increase in regional floods and water shortages (Nelson Mandela Bay Municipality, 2015).

At present, the municipality is experiencing one of its worst recorded water shortages to date (Mahlalela *et al.*, 2020). Experts have attributed the current water crisis to a variety of factors including seven years of well-below average rainfall due to climate change, municipal mismanagement of funds, budget and procurement bottlenecks, a lack of diversified water sources, and a growing population (Nelson Mandela Bay Municipality, 2022). As of June 2022, combined dam levels were at 12.26%, and emergency schemes were being put into action.

Mander *et al.* (2010) found that restoring 225 000 ha of invaded and overgrazed land in the Kromme, Kouga, and Baviaanskloof catchments could increase water yields and baseflows by 11 and 14 million m^3 per year respectively, and reduce sediment loads by 22 million m^3 per year. Predictions from this model also indicated that restoring these catchments would also result in a bundle of co-benefits including biodiversity-based tourism, and carbon sequestration. In 2015, the municipality estimated that R252 million over 30 years would be needed to restore these three catchments, primarily through alien clearing, revegetation, and fire management (Nelson Mandela Bay Municipality, 2015). However, to date, Nelson Mandela Bay municipality has spent most of its drought relief fund on constructing and maintaining grey infrastructure and on demand management measures (Pietersen, 2021).

4.3.2.3 eThekwini

In 2016, eThekwini metropolitan municipality had a population of 3.7 million people, which is approximately 33.5% of the total population of KwaZulu-Natal province (Statistics South Africa, 2018b). In contrast to the other metropolitan municipalities, eThekwini is situated in a high rainfall area, receiving over 1000 mm of precipitation per year (Olanrewaju & Reddy, 2022). The municipality frequently experiences flooding events, which are expected to increase in magnitude as a consequence of climate change (Mander *et al.*, 2017).

The major cities of Durban and Pietermaritzburg receive most of their water from the Greater uMngeni catchment, a relatively small but significant catchment (Gokool & Jewitt, 2019). Despite being less than 5% of the surface area of the KwaZulu-Natal province, the catchment provides water to over 42% of the population (Pringle *et al.*, 2015). However, at present, the available yield of the catchment (383 million m^3 per year) is not enough to meet the demand for water (406 million m^3 per year). As a result, the catchment has been fully developed to accommodate this demand, with four storage dams constructed over the years (Umgeni Water, 2021). Water supply is further augmented by transfers from the Mooi River through the Mooi-Mgeni Transfer Scheme (Pringle *et al.*, 2015).

Land use and land cover activities have significantly altered the Greater uMngeni catchment. Intensive commercial afforestation and agricultural land are the dominant land use activities characterising the upper reaches of the catchment (Gokool & Jewitt, 2019). These activities have led to the encroachment of sugarcane crops and livestock farming into riparian zones and wetland areas, as well as siltation of dams and soil erosion (Cartwright, 2021). Further downstream, the catchment is characterised predominantly by industrial and densely-populated urban areas which have led to pollution from urban areas, and the invasion of invasive alien plants (Mander *et al.*, 2017). Riparian invasions are estimated to reduce mean annual runoff in the Greater uMngeni catchment by around 90 million m^3 per year (Le Maitre *et al.*, 2019).

The eThekwini municipal government are aware of the current risks to the Greater uMngeni catchment and have recognised the importance of maintaining and restoring ecological infrastructure. Stakeholders including the municipality, the Department of Water and Sanitation, SANBI and WWF have formed an alliance to enhance ecological infrastructure in the Greater uMngeni catchment with the aim of improving water quality and quantity. This group has over 36 signatory members and is formalised as the uMngeni Ecological Infrastructure Partnership (UEIP) (Hughes *et al.*, 2018).

An estimated 018 years to eradicate invasive alien plants from the Greater uMngeni Catchment to improve water yields in the short term and to buffer communities from climate change in the long-term (Cartwright, 2021). However, Umgeni Water has not allocated a single cent of its Water Resource Management levy, which is approximately R16 million, towards alien clearing.

4.3.3 Data collection

Data for this study were collected between 21 March and 14 April 2022 from household residents in the three municipalities. Willing participants were only interviewed if they were over 18 years old, lived in the surveyed municipality, considered themselves a financial contributor or a decision-maker in their households, and received piped municipal water to their house (hereafter referred to as the ‘interview criteria’). Face-to-face interviews were conducted in three localities over three days in Cape Town, in two localities over four days in Nelson Mandela Bay, and in two localities over three days in eThekwini.

In each municipality, a team of local postgraduate students were hired and trained to enumerate the interviews (hereafter, referred to as ‘enumerators’). Answers to questions were captured on electronic tablets using an application called Kobo Collect (Kobo Inc., 2021). During training sessions, the questionnaire was pre-tested by enumerators and supervisors. Pre-testing is essential before conducting formal surveys to improve the flow of questions, to reword ambiguous questions, and to exclude any variables that may be irrelevant to the study (Majumdar & Gupta, 2009). In this study, pre-testing was also necessary to correct any formatting errors in the electronic questionnaire as well as to ensure that any context-specific questions accurately reflected the current situation in each municipality.

Surveys were conducted in waiting queues outside of several offices of the Department of Home Affairs (DHA) in the home language of each participant (English, Afrikaans, Xhosa, and Zulu). Due to time constraints, only a few DHA offices in each municipality could be visited. Three DHA offices were selected as survey sites in the largest municipality (City of Cape Town) and two DHA offices were selected from the smaller two municipalities. To broaden the geographical representation of the sample in each municipality, one DHA office had to be located in the central business district (CBD), and at least one other DHA office had to be located more than 15 kilometres from the CBD. Sites selected in the City of Cape Town included one in the CBD of Cape Town (Barrack Street), one in the northern suburbs (Bellville), and one in the southern suburbs (Wynberg). In eThekwini, the main survey site was located in the CBD of Durban (Umgeni Road), and the other site was located in the urban outskirts (Pinetown). In Nelson Mandela Bay, one DHA office was located in the centre of town (Govan Mbeki Avenue), and the other in Cleary Park.

The DHA’s core functions are to issue identification documents, issue travel documents and passports, manage birth, death, and marriage certificates, grant citizenship, issue residency permits to foreigners, and to administer admissions into the country. Due to the range of identification services that the DHA offers to the citizens of South Africa, these queues are frequented by a wide representation of household residents. Although surveying people in a queue is a form of convenience sampling which could be subject to unknown biases, it can also be considered a cost-effective and an efficient alternative to conducting *in situ* household surveys. Further, the authors have also previously experienced a wealth bias when conducting door-to-door surveys in South Africa, since wealthier people are generally unwilling to conduct these types of surveys (Turpie and Letley, in review).

4.3.4 Questionnaire design

The survey questionnaire, which took between 12 and 15 minutes to administer, was divided into four main themes including: (i) general household characteristics, (ii) willingness to pay (WTP) for existing water use, (iii) trust in municipality, and (iv) socio-economic status (see questionnaire in Appendix B).

Similar to Turpie and Letley (in review), the first section covered general information about the respondents' household such as their suburb, household size, and whether their property had a garden, swimming pool, borehole, wellpoint, rainwater tank and/or pumped greywater system. Respondents were also asked about their average household monthly electricity and water bills, how they pay for their utilities (if at all), and how confident they felt about their reported utility bills (since respondents could not access their actual bills during the interview). Confidence was indicated on a five-point Likert-scale from "Not at all confident" to "Extremely confident".

The second section dealt with WTP for existing water use. The most widely used contingent valuation techniques to elicit WTP are the dichotomous choice, payment card, bidding game, and open-ended formats (Bateman *et al.*, 2002). Following similar studies by Welle and Hodgson (2011), and Makwinja, Kosamu and Kaonga (2019), this study employed the dichotomous choice format. The dichotomous choice format is often referred to as the 'take it or leave it' approach and can either be single-bounded or double-bounded. In the single-bounded dichotomous choice method, respondents are posed with a single question for which they must answer either yes or no. For example, 'Would you be willing to pay R100 for the water you are currently using'. With the double-bounded dichotomous choice format, a follow-up question is asked to reduce the variance in WTP estimates (Lee, Ma & Cheung, 2021). If the respondent answers positively to the first bid, the second amount offered is higher. However, if respondents reject the initial bid, the second amount offered is lower. Four possible outcomes thus arise: both answers are yes (yes-yes); yes followed by no (yes-no); no followed by yes (no-yes); and both answers no (no-no). The double-bounded dichotomous choice question format reduces estimate uncertainty and provides more information about the respondents' WTP. Due to this, the double-bounded dichotomous choice format is more statistically efficient and thus a more popular approach than the single-bounded dichotomous choice (VanSong *et al.*, 2019).

In most contingent valuation studies, bid amounts are finalised prior to surveying, and are generated randomly (Carson, 2000). However, this may lead to starting point bias (Majumdar & Gupta, 2009). This study aimed to mitigate this bias by offering an initial bid that was 1.5 times respondents' current water bill, thus offering a bid within the respondent's range. This is a similar approach to Makaudze (2016) who used the average water bill of the study area as the initial bid. If the response to the initial bid was 'yes', the subsequent bid was increased to double the respondents' current water bill. However, if the response to the initial bid was 'no', the subsequent bid was lowered to 1.25 times their current water bill. If respondents did not have any idea of how much they were paying for water per month, a random starting bid was generated. These bids ranged from R200 to R800. Similarly, if the respondent accepted the random starting bid, the follow-up bid was increased by 1.5. However, if the random starting bid was rejected, the follow-up bid was decreased to 1.25 times the random starting bid. Households that currently receive free water (i.e. those who are part of the indigent support programme) were excluded from the dichotomous choice questions (n = 119) to ensure that the analysis only included households who currently pay for water. Outliers were also removed from the dataset (those with a current water bill of ≥ R3000; n = 11). Similar to Peletz *et al.* (2020), the dichotomous choice questions were followed with an open-ended question asking respondents to state their maximum WTP for water. This offers an opportunity to check whether respondents answers were consistent across both questions (Majumdar & Gupta, 2009).

The third section included questions about the respondents' degree of trust and satisfaction in the municipality. Respondents were asked to indicate their level of satisfaction with the way the municipality manages water supply and sanitation in their neighbourhood on a five-point Likert scale, from "Very dissatisfied" to "Very satisfied". Respondents were also asked whether they think the municipality should be charging more for water, and whether they would be able to trust that their municipality would use the funds to improve water security if they increased the water price. Lastly, respondents were asked whether they would be able to trust that their municipality would use the funds to improve water security if they increased the water price.

The final section dealt with the socio-economic background of respondents. Data were collected on income, race, age, and education. Income categories for the questionnaire were based on the 2011 Census income groupings.

4.3.5 Statistical analysis

For the statistical analysis of WTP, the dataset was cleaned to remove all outliers and to remove those individuals who had provided "prefer not to say" answers for income related questions and those that did not have an income. The outliers were identified by assessing the value that was reported by respondents as their monthly water bill. This value was deemed outside (higher) than what was expected based on the following factors:

- How the water bill compared to the stated electricity bill;
- The respondent’s income category;
- How the income category related to the stated water bill;
- The suburb in which the respondent lived;
- The number of people in the household; and
- Whether the stated water bill when high corresponded to having a garden or swimming pool.

This resulted in a dataset with 728 responses. To model the responses from the double-bounded dichotomous choice format, the utility difference approach was employed (Hanemann, 1984). Utility refers to the satisfaction that an individual receives from consuming a good or service. Utility theory is based on the assumption of rationality whereby individuals will act in a rational manner to maximise their utility according to individual preferences. The function "dbchoice" in the "DCchoice" package of R 4.0.2 was used to carry out the analysis of the study (Nakatani, Aizaki & Sato, 2021; R Core Team, 2022). This package employs the generalised linear model (GLM) function which contains a binomial logit argument (i.e. log-logistic distribution). The outputs from this function include three estimates of WTP: expected mean WTP based on the unmodified error distribution, truncated mean WTP calculated under the assumption that the error distribution is truncated at the maximum bid, and median WTP. The summary output also included the assumed error distribution, Akaike's information criterion (AIC), value of the log-likelihood at estimates, and the likelihood ratio statistic for the current model. WTP estimates were calculated for each income group within each municipality.

Bootstrapping was used to estimate the confidence intervals for the estimates of WTP (Krinsky & Robb, 1986). For each of the four WTP estimates, this method generated a lower and upper bound of the interval. To validate the results, the data were examined in terms of variables including municipality, household income, gender, age, satisfaction with municipality, trust in municipality, and highest educational level of the respondent.

To calculate aggregate willingness to pay at the municipal scale, average willingness to pay per year was multiplied by the total number of households with a municipal water supply (i.e. the household has access to a tap within their home) in each income category where households earned more than R6401 per month as per the national census (Statistics South Africa, 2012). The lower income categories were not included as these households were considered eligible for the indigent programme.

4.4 RESULTS

4.4.1 Descriptive statistics of respondents

Among the 1959 individuals who were approached, 1500 agreed to complete the interview (77% response rate). Of these, 1244 individuals met the interview criteria.

Across all municipalities, the average age of respondents was 42, and more than half of the respondents were between the ages of 18 and 39 (51.1%) (Table 4.1). Respondents came from a total of 276 suburbs, and mean household size of respondents was 4.6 (±2.1, range 1-10). A quarter of respondents did not disclose their household income level, and 4.1% did not disclose their highest level of education (i.e. chose ‘Prefer not to say’). Prefer not to say categories were not included in the calculations for Table 4.1. 35.5% of those who did disclose their education had passed matric (final school year), and 30% had a tertiary level qualification (either a degree or diploma). Mean income per household per month was R39 038 in eThekwini, R34 987 in the City of Cape Town, and R12 637 in Nelson Mandela Bay.

In terms of income representation per municipality, there were significant differences in household monthly income for respondents in both Cape Town and eThekwini compared to that of the most recent census (Figure 4.2) (Statistics South Africa, 2012). eThekwini’s population differed the most ($X^2 = 118.2$, $p < 0.001$), followed by the City of Cape Town ($X^2 = 58.1$, $p < 0.001$). There was, however, no significant difference between that of the income categories collected for Nelson Mandela Bay in this study compared to the national census ($X^2 = 6.1$, $p > 0.05$). When the lowest income category was removed, there were no longer significant differences between the census population and that of this study. The lowest income category was thus considered to be households earning between R1 and R400 per month.

There were significant differences in race composition of the sample for Nelson Mandela Bay ($X^2 = 23.3$, $p < 0.001$) and the City of Cape Town ($X^2 = 8.7$, $p < 0.05$), with a bias towards coloured and away from black households in both municipalities compared to the national census (Statistics South Africa, 2012). The sample from eThekwini, however, accurately portrayed the race composition of the population ($X^2 = 6.3$, $p > 0.05$) (Statistics South Africa, 2012). In terms of education, the samples were biased towards respondents who had completed higher education (i.e. matric or tertiary level) and away from respondents who had only completed secondary school across all three municipalities.

Overall, 64% of respondents owned their property as opposed to renting, 80.9% lived in a house, 40.7% had a garden, 17.3% had a rainwater tank, 9% had a swimming pool, 5.5% had a greywater system, and 4.6% had their own borehole or well-point.

Table 4.1: Demographic characteristics of sample (n = 728)

	Cape Town	Nelson Mandela	eThekwini	All municipalities
Income category[39] (%)				
No income	3.0	17.3	2.3	8.3
R1-R400	3.5	2.5	5.0	3.5
R401-R800	3.8	4.7	3.7	4.1
R801-R1 600	8.4	11.7	8.3	9.7
R1 601-R3 200	8.7	15.4	15.6	12.8
R3 201-R6 400	12.3	16.2	12.8	13.9
R6 401-R12 800	14.7	11.2	14.2	13.3
R12 801-R25 600	17.4	9.2	8.7	12.3
R25 601-R51 200	12.5	8.7	13.8	11.3
R51 201-R102 400	7.4	1.7	6.4	5.0
R102 401-R204 800	4.1	0.3	2.3	2.2
R204 801 or more	4.1	1.1	6.9	3.6
Race (%)				
Black	28.0	78.1	46.0	49.9
Coloured	55.5	5.2	43.9	36.1
White	15.6	6.8	9.2	10.5
Other	0.9	9.9	0.9	3.5
Education level (%)				
None	0.8	1.4	0.9	1.0
Primary	3.0	4.4	4.7	3.9
Secondary	25.7	16.7	34.7	26.7
Matric	34.0	39.9	38.5	37.0
Tertiary	36.5	37.5	21.2	31.3
Gender (%)				
Male	40.1	47.5	36.2	40.7
Female	59.9	52.5	63.8	59.3
Age group (%)				
18-29	20.9	26.5	16.5	20.8
30-39	29.8	31.8	29.7	30.3
40-49	26.5	24.7	31.1	27.7
50-59	16.8	9.9	16.5	14.9
60-69	5.6	6.2	5.7	5.8
>70	0.4	0.9	0.5	0.6

[39] Income measured in Rand per household per month

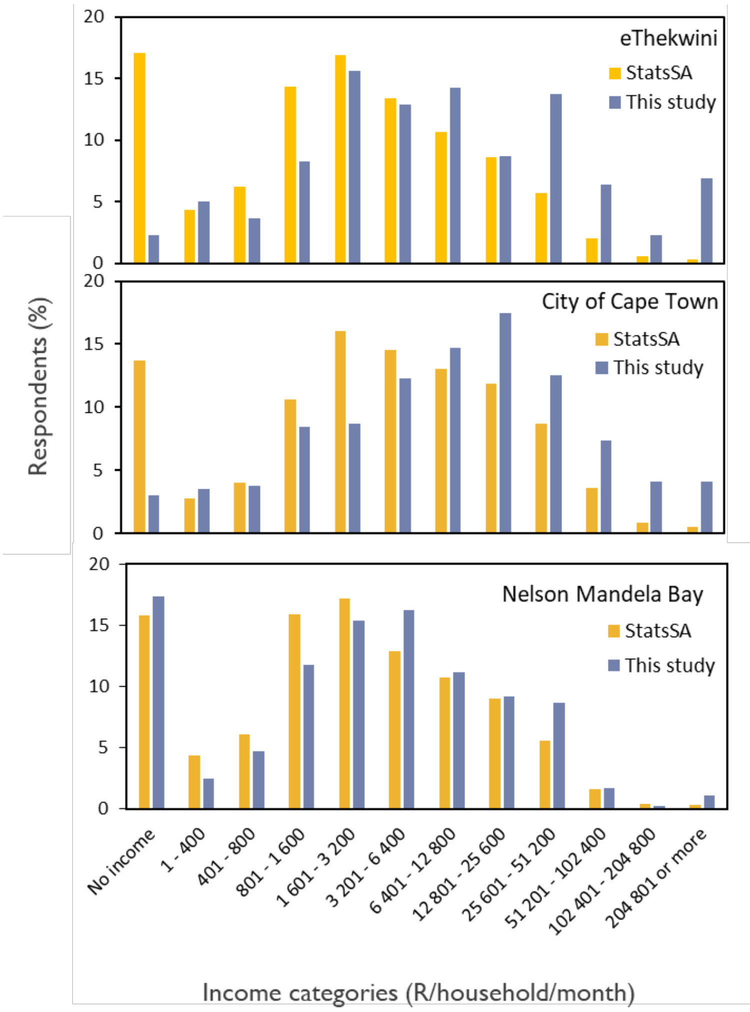


Figure 4.2: Comparison of household income categories between the population in this study versus that of the most recent national census of 2011.

4.4.2 Contextual information – municipal trust and satisfaction

Most respondents in eThekwini (91.7%) did not think the municipality should be charging more for water. This was also the case for majority of respondents in Nelson Mandela Bay (90.4%), and Cape Town (88.2%). The reasons for not wanting the municipality to increase the water price included the inability to afford higher water tariffs (43.3%), not believing it would make a difference to service delivery (39.1%), as well as other reasons (7.4%). Other reasons specified were that “water should be free since it is a basic need”, “the municipality is corrupt and is charging too much already”, “there is a surplus of water so it should be free”, and “our water bill does not match our use, so we do not want to pay for it”.

Nearly 70% of respondents from Nelson Mandela Bay expressed some level of dissatisfaction towards municipal water service delivery, with 40% claiming to be ‘very dissatisfied’ (Figure 4.3). In eThekwini, the proportion of dissatisfied households was fewer, with more than half claiming they were either very dissatisfied (32%) or just dissatisfied (24%). Only 26% of respondents in the City of Cape Town felt some level of dissatisfaction with municipal service delivery in their neighbourhood.

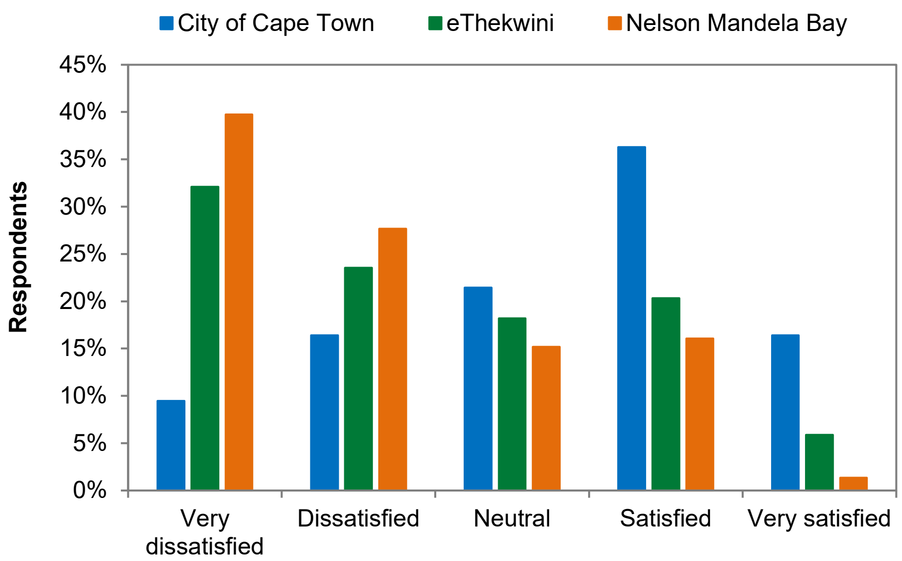


Figure 4.3: Respondents degree of satisfaction with the way the municipality manages water supply and sanitation their neighbourhood.

4.4.3 Contextual information – water and electricity bill

Respondents were asked an open-ended question as to what they currently pay for electricity per month, and how confident they were about this value on a Likert Scale. Respondents were then asked to indicate how much they pay per month for water, and how confident they were about this value using the same Likert scale as for electricity. In South Africa, electricity is generally much more expensive than water, thus this question was asked first to get respondents to reflect on the relative price of water.

Fewer respondents could provide an estimate of their monthly water bill (71%) compared to their monthly electricity bill (88.3%). The average water bill for respondents across all municipalities was R393 per household per month and the median was R350. At the municipal level, the average water bill ranged from R366 in Nelson Mandela Bay to R416 in the City of Cape Town (Table 4.2). In contrast, the mean electricity bill was significantly higher than the mean water bill for all three municipalities, with residents from Nelson Mandela Bay having the lowest average electricity bill (R634) and residents from eThekwini having the highest (R1078).

Table 4.2: Mean and median monthly reported water bill per household per month (n = 587) compared to the mean and median electricity bill per household per month (n = 890) across the three metropolitan municipalities: the City of Cape Town, Nelson Mandela Bay, and eThekwini.

	Water bill		Electricity bill	
	Mean	**Median**	**Mean**	**Median**
City of Cape Town	416	350	951	800
Nelson Mandela Bay	366	350	634	500
eThekwini	396	400	1078	800
All municipalities	393	350	879	600

As expected, across all three municipalities, there was a strong positive relationship between water bill and household income (R^2 = 0.87) (Figure 4.4).

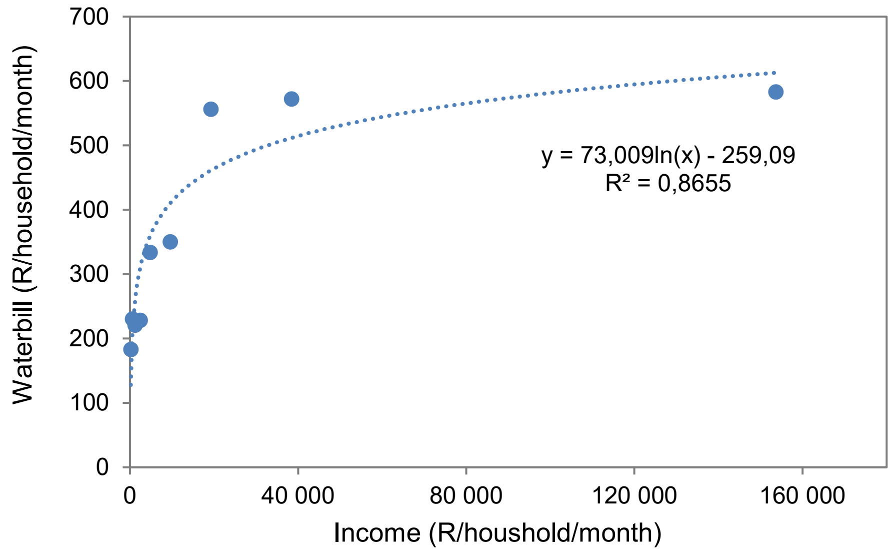


Figure 4.4: Mean water bill per income category midpoint for all three municipalities combined.

Half of the respondents who could provide an estimate for their average monthly electricity bill (without looking at their actual bill) felt extremely confident about the amount they had reported (51%), whilst only a small proportion reported some degree of uncertainty about their estimated bill (3%) (Figure 4.5a). Interestingly, respondents had similar levels of confidence in their reported water bill as they did in their electricity bill (Figure 4.5b). Respondents from Nelson Mandela Bay were the most confident about their reported electricity and water bills compared to the other two municipalities. The reason for such high confidence in respondents' utilities bills could be because a large proportion of the sample pay their utilities directly to the municipality (65.4%) and thus have a handle on how much they spend per month. Another plausible reason may be because 83% of respondents have a prepaid electricity meter which track usage and costs. Such a high degree of confidence in the estimated monthly cost of respondents' water bills was beneficial to the study because these values were used to calculate the initial bid of the double-bounded dichotomous choice questions.

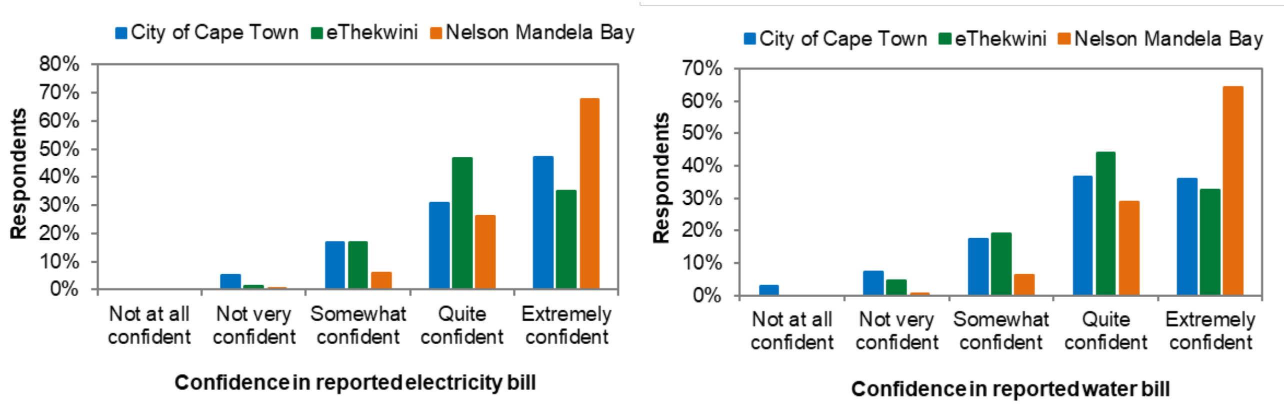


Figure 4.5: Degree of confidence in reported monthly (a) electricity bill per household per month (n = 652) versus (b) water bill per household per month (n = 502).

4.4.4 Willingness to pay – double bounded dichotomous choice

When asked if they were willing to pay more for water than what they currently are, more than half of the respondents (54%) rejected both the initial bid as well as the lower follow up bid (No-No) (Figure 4.6). This was most pronounced for Nelson Mandela Bay, followed by eThekwini and Cape Town. 20% of respondents in all three municipalities agreed to pay the initial bid but were unwilling to pay the higher follow-up bid (Yes-

No). This was greatest in Cape Town (24%), closely followed by eThekwini (22%). 16% of respondents declined the initial bid but agreed to pay the lower second bid (No-Yes), and only a small group of respondents (9%) were willing to pay both the initial and the follow-up bid (Yes-Yes). This was as high as 13% in Cape Town and as little as 4% in Nelson Mandela Bay.

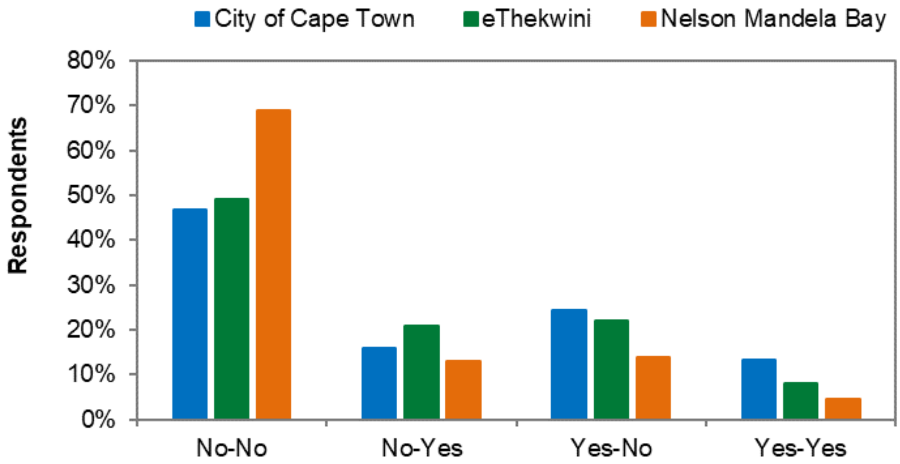


Figure 4.6: Percentage of respondents who (i) rejected both WTP bids (No-No), (ii) rejected the first and accepted the follow-up bid (No-Yes), (iii) accepted the first and rejected the follow-up (Yes-No), (iv) or accepted both bids (Yes-Yes). Outliers were removed; n = 728.

4.4.4.1 Probability of saying yes

The contingent valuation questions were used to estimate how much respondents were willing to pay for water. The WTP probability distribution plotted from the survey data depicts how the likelihood of paying the proposed bid amount decreases as bid amounts increase (Figure 4.7). Since the initial bid offered to each respondent was 1.5 times their current water bill (or a randomly generated value if they could not recall their water bill), 77 initial bid amounts were generated ranging from R30 to R4 200. Thus, to visualise the WTP probability distribution, the final bid offered to respondents were categorised into four groups: R1-400, R801-R1 600, R1601-R3200, R3201-R6400. Across all three municipalities, 34% selected 'yes' to bids in the lowest bid group (R1-R400), and only 1% selected 'yes' to bids in the highest bid group (R3201-R 6400). The fit of the overall model was strong with an R^2 of 0.86 ($p < 0.001$). The probability of selecting yes for the different bid amounts varied slightly across the three municipalities with residents from the City of Cape Town having a lower probability of selecting yes to the higher bid amounts compared to eThekwini and Nelson Mandela Bay. However, in general, all three municipalities demonstrated similar results across all the bid groups. The greatest difference between two municipalities was for the R801-R1600 bid category, whereby a higher proportion (25%) of residents from Nelson Mandela Bay accepted the bid amount compared to the City of Cape Town (19%).

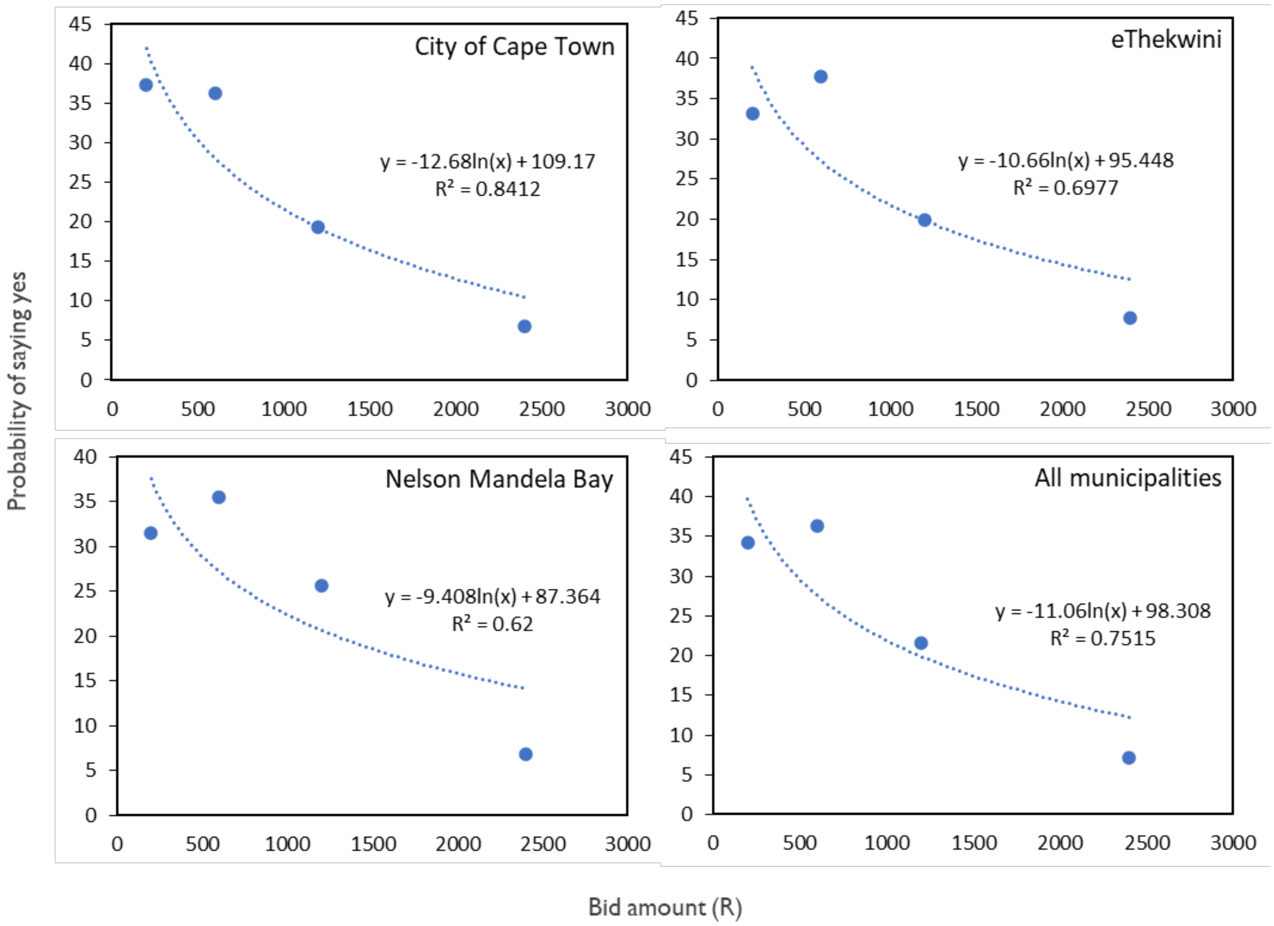


Figure 4.7: WTP probability distribution plotted from survey data for each municipality and for the overall sample. Outliers and protest bids were removed. The model was plotted against the midpoint of each bid group.

4.4.4.2 Model estimation results

The results from the generalised linear model for validating the double-bounded dichotomous choice questions are presented in three models in Table 4.3. The number of observations differed per model, since questions about education and income had "prefer not to say" categories which were not included in the analysis. Model 1 represents the constant-only model, Model 2 includes several covariates, and Model 3 represents the estimation results when all non-significant predictors were removed from Model 2 as recommended by Jiang *et al.* (2019).

The results followed expectations in that the coefficients of the bid variable were negative across all three models, indicating that as the bid amount increased the probability of a respondent selecting 'yes' declined, which is in line with Figure 4.7. After removing the non-significant covariates, Model 3 shows that the significance and magnitude of each variable did not change much compared with Model 2, verifying the robustness of the statistical model.

Table 4.3: Estimate results of the double-bounded dichotomous choice model

Variable	Model 1	Model 2	Model 3
Intercept	9.647 (0.501)***	8.568 (0.725)***	9.111 (0.622)***
Municipality: Cape Town		0.339 (0.201)	0.388 (0.200)
Municipality: eThekwini		0.410 (0.225)*	0.410 (0.223)*
Age		-0.017 (0.006)*	-0.018 (0.007)**
Satisfied with municipality_Yes		0.356 (0.169)*	0.401 (0.165)**
Trust in municipality_Yes		0.175 (0.183)	
HH income		0.182 (0.046)***	0.202 (0.037)***
Education		0.134 (0.119)	
HH Size		0.092 (0.029)**	0.083 (0.028)**
log(Bid)	-1.702 (0.082)***	-1.822 (0.088)***	-1.826 (0.088)***
Log-likelihood (LR-test statistic)	-997.076	-956.950	-965.256
Akaike information criterion (AIC)	1998.15	1979.7	1946.5
No. obs	728	719	728

Robust standard errors in brackets, ***p < 0.001, **p < 0.01, *p < 0.05

Age, income, municipality, satisfaction with municipality, and household size significantly influenced willingness to pay. Age had a negative influence on WTP, indicating that as the age of the respondent increased, the probability of selecting 'yes' to a proposed bid amount decreased. As expected, WTP was directly proportional to income, meaning that wealthier households were willing to pay more for water than poorer households. Similarly, those who were satisfied with municipal water supply were willing to pay more for water compared to those who were dissatisfied or neutral. Interestingly, as the size of respondents' households increased, the probability of selecting 'yes' to a proposed bid increased (i.e. bigger households were willing to pay more for water compared to smaller households). There was a significant difference between WTP in eThekwini compared to the WTP in Nelson Mandela Bay, but not between the City of Cape Town and Nelson Mandela Bay. On the other hand, education and trust in municipality had no significant influence on willingness to pay which is due to the correlation between trust and satisfaction in the municipality and between education and income.

Based on the outputs of Model 3, the mean WTP per household per month in all three municipalities ranged from R452-582 and the unadjusted mean willingness to pay was estimated to be R506 (Table 4.4). Median WTP ranged from R263-316, with an estimate of R291. Whilst mean WTP was two times higher in eThekwini compared to Nelson Mandela Bay (Table 4.3), median WTP was highest in Cape Town but similar across all three municipalities with a range of R235-336. Across all income categories and municipalities, unadjusted mean WTP (R506) was about 10% higher than the average reported water bill (R461).

Table 4.4: Estimated willingness to pay (Rand/household/month) for water from the best fitted double-bounded dichotomous choice (Model 3). n = 728.

	Mean WTP of all municipalities			Mean WTP per municipality		
	Estimate	Lower bound	Upper bound	City of Cape Town	Nelson Mandela Bay	eThekwini
Mean	506	452	582	517	352	730
Truncated mean	463	424	507	479	336	564
Median	291	263	316	336	235	306

For the City of Cape Town, the mean WTP across all income categories (R517) was 16% more than the reported water bill. WTP amounts, however, differed per income category. Depending on income level, households were willing to pay 6-121% more than the amount they currently pay for water in the City of Cape Town, and between 10-40% more in eThekwini. On average, respondents in Nelson Mandela Bay were not willing to pay more than what they are currently paying, indicating that people feel they are already paying too much for their water.

WTP per income category for each municipality was also calculated to understand the effect of income on WTP at the municipal scale. This was done through the Krinsky and Robb (1986) approach which uses the mean of the outputs from the double-bounded dichotomous choice model (Model 3) (Table 4.3). Household income had a powerful influence on mean willingness to pay at the municipal scale (
Figure 4.8). The range in WTP from the lowest income category to the highest income category was greatest for Cape Town (R332-R787), followed by eThekwini (R380-R764) and Nelson Mandela Bay (R222-R560). The relationship between income and mean WTP per income category was strong for all three municipalities (R^2 =0.95-0.98;
Figure 4.8).

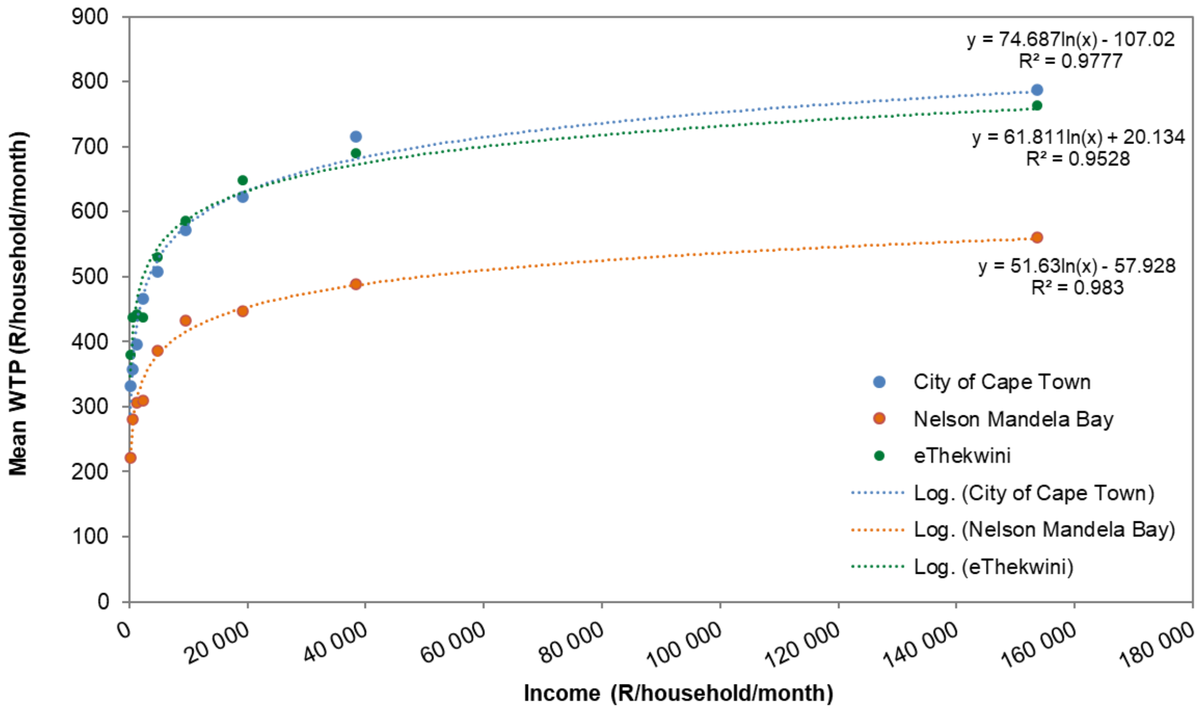


Figure 4.8: The average willingness to pay for water (R/household/month) calculated with the double-bounded dichotomous choice Model 3 outputs for each household income category per municipality: City of Cape Town, Nelson Mandela Bay, and eThekwini. The midpoint of the income categories were used as per the national census (Statistics South Africa, 2012)*.*

It is common practice to identify protestors in studies that aim to inform policy, since these responses have been found to bias the sample (Majumdar & Gupta, 2009; Makwinja *et al.*, 2019). Protestors are considered individuals who indicate a zero WTP amount, not because they cannot afford it, but because they are unwilling to spend money on water because they either think it should be free or are unsatisfied with municipal service delivery (Du Preez, Tessendorf & Hosking, 2010). Table 4.5 shows the distribution of household WTP responses classified as positive, genuine zero, protest, and no response. These categories were determined by investigating respondents' water bills in relation to their open-ended maximum willingness to pay answers. 98% of respondents gave a positive value for both water bill and maximum willingness to pay ('positive response'), indicating that they were willing to pay for water. 1.6% of respondents were considered 'protestors' for reporting positive water bill values, but zero values for maximum WTP. Lastly, only 1 respondent declined to give a maximum WTP value ('no response'). These responses were not included when estimating WTP.

Table 4.5: Distribution of willingness to pay (WTP) responses for the open-ended WTP question

Type of response	Number of respondents	Percentage of respondents
Positive response	493	98.2
Protest	8	1.6
No response	1	0.2
Total	502	100

The open-ended WTP follow-up question solicited the maximum amount that respondents were willing to pay for water. The total number of observations used to investigate variation in WTP with the open-ended question was 1205 when protest responses were excluded. The effect of including protest responses generally lowers the WTP value, creating a bias in the true valuation of the good (Gyrd-Hansen, 2014). In contingent valuation studies, the standard procedure is to exclude protest responses from the analysis (Dziegielewska & Mendelsohn, 2007). Thus, the mean stated WTP per household per month across all municipalities was R474 (Table 4.6). Although this value is lower than the mean of the double-bounded dichotomous choice method, it still falls within the lower and upper bounds of the truncated mean WTP output from the logit model (Table 4.4). This indicates that respondents' answers were consistent across both questions, which validates that the respondents were consistent when answering the double-bounded dichotomous choice questions.

Table 4.6: Distribution of the open-ended willingness-to-pay with and without protest responses (R/household per month)

	Mean WTP (open-ended)	
Municipality	**Without protest responses**	**With protest responses**
City of Cape Town	447	447
Nelson Mandela Bay	451	436
eThekwini	401	398
All municipalities	434	429

4.4.5 Aggregate willingness to pay

Aggregate WTP for water was estimated for income categories with earnings higher than R6401 per month. The mean WTP within each of these categories was multiplied by the total number of households with access to municipal water supply, extracted from the national census. Aggregate WTP was R2.9 billion per year for the City of Cape Town, R1.2 billion per year for eThekwini municipality, and R297 million per year for Nelson Mandela Bay municipality. By comparing these estimates with what people are currently paying in each municipality based on their stated water bills, this translated into a consumer surplus of some R756 million for the City of Cape Town, and R186 million for eThekwini. There was no consumer surplus for Nelson Mandela Bay, as residents indicated that they were not prepared to pay more than what they are currently paying for water.

The present value of the consumer surplus over five years (at 8%) equates to R3.7 billion for the City of Cape Town and R930 million for eThekwini.

4.5 DISCUSSION

Although many countries have recognised the potential of investing in the restoration, rehabilitation, and protection of freshwater ecosystems to secure future water supply services, there is a lack of sustainable financing mechanisms to fund these interventions, particularly in developing countries (Dikgang *et al.*, 2019). This has resulted in further degradation of these ecosystems, threatening future water supply. One financing mechanism which has not yet received much attention, is that of water pricing. If regulated correctly, water pricing policies can have both incentive and revenue effects. Whilst water pricing has been found to encourage users to manage their water consumption (Dikgang *et al.*, 2019); increased water tariffs can generate increased revenue that can be used to fund water resource management and/or investment in ecological infrastructure. However, since water is a basic need, reforming water pricing policies must be based on a comprehensive understanding of consumers' demand for water services and conservation (Makwinja *et al.*, 2019).

Using three South African cities as a case study (the City of Cape Town, Nelson Mandela Bay, and eThekwini), this study set out to establish whether consumer surplus at the municipal scale is sufficient to cover the costs required to restore catchments supplying water to the municipalities in question. The results from this study show that in two of the three municipalities, the additional revenue that could be generated from household willingness to pay (WTP) for water (i.e. consumer surplus) is more than sufficient to cover the estimated costs required to restore catchment areas supplying water to those municipalities. Factors that were found to significantly influence WTP included socio-economic factors such as age, income, and household size, as well as institutional satisfaction (Welle & Hodgson, 2011; Makwinja *et al.*, 2019; Wilson *et al.*, 2021).

Further analysis revealed useful information about household preferences, particularly pertaining to WTP for non-use related water conservation benefits as well as for use-related water security benefits (i.e. avoiding future water restrictions). This study is novel in that it demonstrates to policymakers that there is significant potential to raise revenues from water tariffs in municipalities that have a good service delivery track record, a relatively high average household income, and a low average age. This study is particularly pertinent given that coastal cities in South Africa are expected to face more frequent water shortages in future due to climate change (Otto *et al.*, 2018).

Although the sample of Nelson Mandela Bay was representative of its population (Statistics South Africa, 2012), the sample was biased away from poorer households and toward wealthier households in the City of Cape Town and eThekwini. This mismatch in wealth resulted from underrepresentation in the lowest income category compared to population statistics from each municipality retrieved from the most recent national census. This wealth bias is likely due to the sampling strategy used. Since one of the main services provided by the Department of Home Affairs (DHA) is issuing travel documents (visas and passports), the queues outside of these localities are often frequented by people who can afford to travel. There is also the possibility that the selection of DHA localities for this study may have affected the wealth representation of the sample. For example, the sampling sites in eThekwini and the City of Cape Town may have been inaccessible to poorer residential areas. However, since most no-income households rely almost exclusively on free basic water, it is therefore unlikely for people in this group to be realistic about their willingness to pay. Thus, to avoid overstating willingness to pay, respondents that reportedly had no income were excluded from the analysis of mean and aggregate WTP.

4.5.1 Willingness to pay for current water supply

It is somewhat misleading to compare the results of this type of study to studies of a similar nature in other countries due to differences in socio-economic context and water service provision history. Thus, to mitigate this, Latinopoulos (2014) recommend comparing the results with findings of other recent stated preference approaches carried out in the same country. Thus, in accordance with previous contingent valuation studies in South Africa, this study reveals that at the national scale, household residents are willing to pay higher water tariffs for the water they are currently receiving, despite having high levels of dissatisfaction in water service provision (Snowball, Willis & Jeurissen, 2008; Kanyoka *et al.*, 2009; Rananga & Gumbo, 2015; Makaudze, 2016; Nkoana *et al.*, 2019). Of these, the WTP of households in this study correspond closest to that of Makaudze (2016) who measured WTP for water of residents living with HIV and AIDS in three districts (urban, peri-urban, and rural) across South Africa and found it to be R428.60 per month (R564.81 at 2022 price levels).

These figures are comparable to this study, whereby the average WTP of households across the three urban municipalities was R506 per month.

However, when analysed at the municipal level, there was a wide range in the WTP of households between municipalities. Households in eThekwini had the highest WTP on average, which was R730 per month, corresponding to about 50% more than the reported water bill of the municipality. This was followed by households in the City of Cape Town, who were willing to pay R517 per month (16% more than the reported current water bill of the municipality). The reason for such a high WTP in eThekwini could be attributed to the survey period coinciding with a flooding event that was caused by heavy rains. This flood, which has since been considered the worst the region has seen in three decades, was responsible for damaging raw water pipelines between the Nagle Dam and the Durban Heights Water Treatment Plant, resulting in majority of households in eThekwini not having access to water during the survey period. Thus, during the time of the interviews, people were likely desperate for water and were thus willing to pay more. On the other hand, the reason for a higher WTP for water in the City of Cape Town could be attributed to high levels of satisfaction towards municipal water service delivery.

Interestingly, the WTP of Nelson Mandela Bay was half that of eThekwini, with residents only willing to pay R352 for water, which is less than the reported mean water bill of the municipality. When WTP is less than or equal to the real price of the good or service, this indicates that people are not willing to pay a higher price for that particular good or service (Li *et al.*, 2014). Although there were some households with high WTP in Nelson Mandela Bay, it seems that most households in Nelson Mandela Bay are already paying the maximum amount that they are willing to pay for water. To understand why Nelson Mandela Bay residents are not willing to pay more for water, it is necessary to consider the contextual findings of the study. At the time the surveys were conducted, Nelson Mandela Bay was currently experiencing one of its worst droughts to date. To encourage households to consume less water during the crisis, the municipality had raised domestic water tariffs and imposed severe water restrictions on the population (Pietersen, 2021). This has had two noticeable impacts. First, relative to income levels, households in Nelson Mandela Bay are paying significantly more for water than the other two municipalities, which is evident when comparing the average water bill and income level of households in Nelson Mandela Bay to the other municipalities. By illustration, whilst the average water bill of households in Nelson Mandela Bay was similar to the other two municipalities (only ~4% less than the average water bill of eThekwini and 4% more than the average water bill of City of Cape Town), the average income of respondents in Nelson Mandela Bay was 71% less than the City of Cape Town and 54% less than eThekwini. Second, due to the mismanagement of water supply, residents in Nelson Mandela Bay are extremely frustrated with the municipality. This was demonstrated through the much greater proportion of households in Nelson Mandela Bay who were dissatisfied with municipal service delivery compared to households in eThekwini and households in the City of Cape Town. By comparison, nearly 70% of residents in Nelson Mandela Bay expressed some level of dissatisfaction with the municipality, whilst 56% were dissatisfied in eThekwini and only 26% were dissatisfied in the City of Cape Town. This is in accordance with a recent study by Nkoana *et al.* (2019) who discovered that 73% of residents in a local municipality in South Africa were dissatisfied with the provision of water and electricity services. In this study, residents commented that they were dissatisfied with the mismanagement of services, which has in part, caused the current water crisis that the municipality is currently experiencing. Since residents in Nelson Mandela Bay are paying a lot of money towards a service they are generally dissatisfied with, people were not willing to pay any more for water than what they currently were paying (Andrés *et al.*, 2021).

4.5.2 Factors influencing willingness to pay for urban domestic water

As other studies have done, this study provides insight into how socio-economic factors and institutional context influence household WTP (Welle & Hodgson, 2011; Makwinja *et al.*, 2019; Wilson *et al.*, 2021). As hypothesised, there was a significant positive relationship ($p < 0.001$) between WTP and income across all three municipalities. This suggests that wealthier households were prepared to pay more for water than poorer households. This finding is consistent with international WTP studies in both developed and developing countries (Halkos & Matsiori, 2014; Latinopoulos, 2014; Akinyemi *et al.*, 2018; Makwinja *et al.*, 2022). This is largely a matter of affordability, with lower-income households less able to tolerate increases in water tariffs compared to higher-income households. This is illustrated by Grafton *et al.* (2011) who found that across 10 countries, the proportion of household income spent by two lowest income groups is two to three times higher than the proportion spent by the richest. In this study, at the municipal scale, there was a strong positive relationship between income and WTP for all three cities (R^2= 0.95-0.98).

To address the issue of affordability in South Africa, the government has established an inclining block tariff (IBT) structure which is designed to provide affordable water to low-volume users, who are generally lower-income households without swimming pools and gardens (Dikgang *et al.*, 2019). Whilst eThekwini and the City of Cape Town have both divided the water tariff into five volumetric blocks, with the first 6 kilolitres free to indigent households, Nelson Mandela Bay has divided the water tariff into six blocks, with the first 8 kilolitres free to indigent households. Higher-use blocks are thus meant to cross-subsidise tariffs in the lower-use blocks (National Treasury, 2011). However, in municipalities that do not have enough customers in the higher-use blocks to subsidise those in the lower-use blocks, the costs to produce and manage water are seldom recovered. This results in asset deterioration, poor management, and low-quality services, which causes water shortages. This is the case for Nelson Mandela Bay population who were significantly poorer on average than the other two municipalities.

By contrast, age of the respondent had a significantly negative impact on WTP ($p < 0.05$), indicating that younger respondents were willing to pay higher prices for water compared to older respondents. This finding is consistent with several other contingent valuation studies on water (Makwinja *et al.*, 2019, 2022; Mu *et al.*, 2019; Kim *et al.*, 2021). Halkos and Matsiori (2014) proposed that older respondents tend to have worse health, higher economic dependence, and higher expenditures on food, resulting in lower WTP for water since their disposable income is more stretched. Vásquez, Franceschi and Van Hecken (2012) speculated that the relationship may be because older respondents have an ‘accumulated dissatisfaction’ from low quality services over a longer period of time. It must be noted that the relationship between age and WTP, however, is not always negative (see Akinyemi, Mushunje and Fashogbon, 2018).

Results indicated that residents’ level of satisfaction for the way the municipality manages water supply in their neighbourhood had a significant positive influence on WTP ($p < 0.01$). Thus, those who were more satisfied with the municipality were willing to pay higher prices for water. This was anticipated, since consumers tend to be willing to pay more for services they are satisfied with (Andrés *et al.*, 2021). This was clearly illustrated by households in Nelson Mandela Bay, who had the highest levels of dissatisfaction towards the municipality, and the lowest WTP for water. Many stated that paying more for water would not improve the service they were getting, so there was no point in paying more. However, if the question was phrased ‘would you be willing to pay more for an improved water supply’, the reverse would probably be true (i.e. those less satisfied would be willing to pay more).

Another factor that had a direct relationship on willingness to pay was household size ($p < 0.01$); this implies that households with more members were more likely to accept a given bid. A similar observation was made by Wilson *et al.* (2021) who found that in Brisbane, bigger households were willing to pay more than smaller households to avoid water restrictions. This was also true for a contingent valuation study which estimated WTP for water quality improvements in the Bac Ninh Province of Vietnam (VanSong *et al.*, 2019). The reason for this relationship may be because larger households generally consume more water, and people tend to justify higher water costs with this.

Although institutional trust also had a positive impact on WTP, the relationship was not significant. This finding is similar to that of Roldán, Sarmiento and Roldán-Aráuz (2021) who found that developing countries are generally willing to pay more for water, but do not trust their governments. In this study, nearly 59% of people did not trust that their municipality would use the funds appropriately if water tariffs were increased. Distrust is common in South Africa and is borne out of high levels of corruption in the country and a lack of capacity (Lehohla, 2016), which has resulted in frequent water interruptions, failing infrastructure, and poor water quality in all three municipalities. Education also did not have a significant impact on households' WTP, but was strongly correlated to household income.

4.5.3 Consumer surplus

Increasing water tariffs to generate additional revenue for catchment conservation can only be implemented in areas where households are willing to pay higher prices for water. Consumer surplus, which is the difference between what a person is willing to pay versus what they actually pay, was established by calculating the difference between aggregate WTP and aggregate water bill per income category for each municipality. Interestingly, the results indicated that whilst both the City of Cape Town and eThekwini had a positive consumer surplus of R756 million and R186 million respectively, there was no consumer surplus in Nelson Mandela Bay. This indicates that there is significant potential to raise water tariffs in the City of Cape Town and eThekwini, but not in Nelson Mandela Bay municipality, where households are not willing to pay any more than what they currently are paying for water.

At present, water pricing cannot be used as a tool to secure funding for the restoration and maintenance of catchments supplying water to Nelson Mandela Bay and alternative funding sources must be secured such as private-public partnerships or through market-based instruments (e.g. Payments for Ecosystem Services schemes or carbon credits) (Mander & Mander, 2021). However, for the two municipalities that had a positive consumer surplus, there is potential to increase the water tariff to cover the costs of catchment conservation. It is proposed that R372 million would be sufficient to generate water gains over 30 years in the City of Cape Town (TNC, 2018a), with initial costs of clearing estimated at R225 million and a further R147 million required for follow-up. In this study, the estimated cost of clearing IAPs from the WCWSS was estimated to be in the region of R326 million (see Table 3.5). If the domestic water tariff was raised in accordance with WTP, R756 million in additional revenue could be generated, which would be enough to cover what is required to clear invasive alien plant species from the catchments that supply water to the City of Cape Town over 30 years. Similarly, the additional revenue that could be generated from untapped WTP in eThekwini (R186 million per year) would over a 30-year period be more than sufficient to clear IAPs from the Greater uMngeni catchment which has been estimated to cost R250 million per year over five years by Cartwright (2021) and R1.2 billion over 30 years in this study (see Table 3.5). While these estimates may be inflated somewhat, they do suggest that there is significant potential for raising tariffs and that people would be willing to pay quite a bit more than what they are currently paying.

According to Cartwright (2021), financing ecological infrastructure interventions could be achieved through a 2.5% increase in the net price of water paid by industrial and domestic users in the City of Cape Town, and a 1% increase in eThekwini. As mentioned previously, this study found that households were willing to pay significantly more than this in both cities and that this was the case across all of the higher income categories. This indicates that raising the domestic water price in accordance with the inclining block tariff (IBT) would be tolerated by all income categories included in the study. Increasing water tariffs, however, would need to be accompanied by the improvement of water revenue collection, as well ring-fencing the additional revenue for the maintenance and restoration of ecosystems (Mpofu *et al.*, 2020). This study has shown through the case of Nelson Mandela Bay that leveraging user fees hinges on functioning institutions that provide satisfactory services to their residents.

4.5.4 Limitations

This study faced some limitations. First, many respondents refused to report their household monthly income (selecting the "prefer not to say" option), which reduced the sample size used in the model. Respondents generally refuse to answer questions relating to income when they fall in the highest or lowest income categories, thus, this may be why the study is biased away from these income categories (Makwinja *et al.*, 2019). This was, however, mitigated by removing the lowest income category from the analysis to ensure the sample was representative. Second, when respondents were asked whether they were willing to pay a certain amount for water, respondents may have felt obliged to answer ‘yes’ when truthfully they wanted to say ‘no’. This was probably most prominent amongst respondents that fell within the indigent group, as they would not have been expected to pay anything for their water (up to a certain amount). This is relatively common in survey responses and is referred to as the ‘yea-saying’ bias which arises when respondents answer positively to please the enumerator (Heinzen & Bridges, 2008). This bias was controlled through rigorous training, whereby enumerators were trained how to ask questions in a way that did not influence the answers of interviewees. Third, although the findings are meaningful and indicate that many households are willing to pay more for water, many municipalities face the problem of residents not paying their water bill. Lastly, the legacy of apartheid is such that there still exists a geographic segregation between the rich and poor, with the rich living in wealthier suburbs that are better serviced while the poor are still located in marginal areas that receive a minimum level of services (Sartorius and Sartorius, 2016). Richer areas tend to be better serviced because municipal planners often prioritise the rich because of their political power and ability to pay for services (Ajwad & Wodon, 2007). Thus, there may have been a correlation between the income and satisfaction with spatial variables, which was not investigated in this study.

4.6 CONCLUSION AND POLICY IMPLICATIONS

To determine whether revenue generated from urban willingness to pay (WTP) can cover the costs of catchment management and conservation, the WTP of households was estimated using the contingent valuation approach. Surveys in three metropolitan municipalities of South Africa were conducted to elicit WTP at both the national and local (municipal) scale. The results obtained from the double-bounded dichotomous choice model indicated that overall, households had a higher willingness to pay for water and that WTP was positively influenced by household income, age, and satisfaction with municipal water service delivery. This was corroborated by respondents who revealed that their lack of willingness to pay higher water tariffs was either because they had a low confidence in the municipal governments’ ability to manage water supply services, or an inability to afford higher water tariffs. However, at the municipal scale, WTP differed significantly between municipalities, largely due to differences in satisfaction and income.

This study showed that there is significant potential to raise domestic water tariffs. However, the study has also shown that leveraging user fees hinges on functioning institutions. Satisfied residents who have some degree of trust in their municipality are more likely to be willing to pay higher prices for their water.

CHAPTER 5: A DECISION SUPPORT FRAMEWORK TO GUIDE INVESTMENTS IN ECOLOGICAL INFRASTRUCTURE FOR WATER SECURITY

Letley, G.K & Turpie, J.K.

5.1 OVERVIEW

Based on the research outputs of this project, literature and past experience, a decision support framework has been designed to guide investments in ecological infrastructure for water security in South Africa. The practical, user-friendly framework aims to provide high-level guidance to decision-makers on the potential opportunity and viable approaches for investing in hydrological ecosystem services, taking into account spatial variation in the nature and scale of the problem in the water supply areas in relation to water demand, the institutional and socio-economic context of the problem areas, suitable options for intervention and potential costs of addressing the problem, the water services institutional context, and the potential user willingness to pay to cover some or all of these costs. The analytical framework lays out in a stepwise approach the "what, where, who and how" of conservation actions for tackling catchment restoration with the aim of supporting decision making backed by scientific and economic data. The framework includes four main steps, with sub-steps (Figure 5.1).

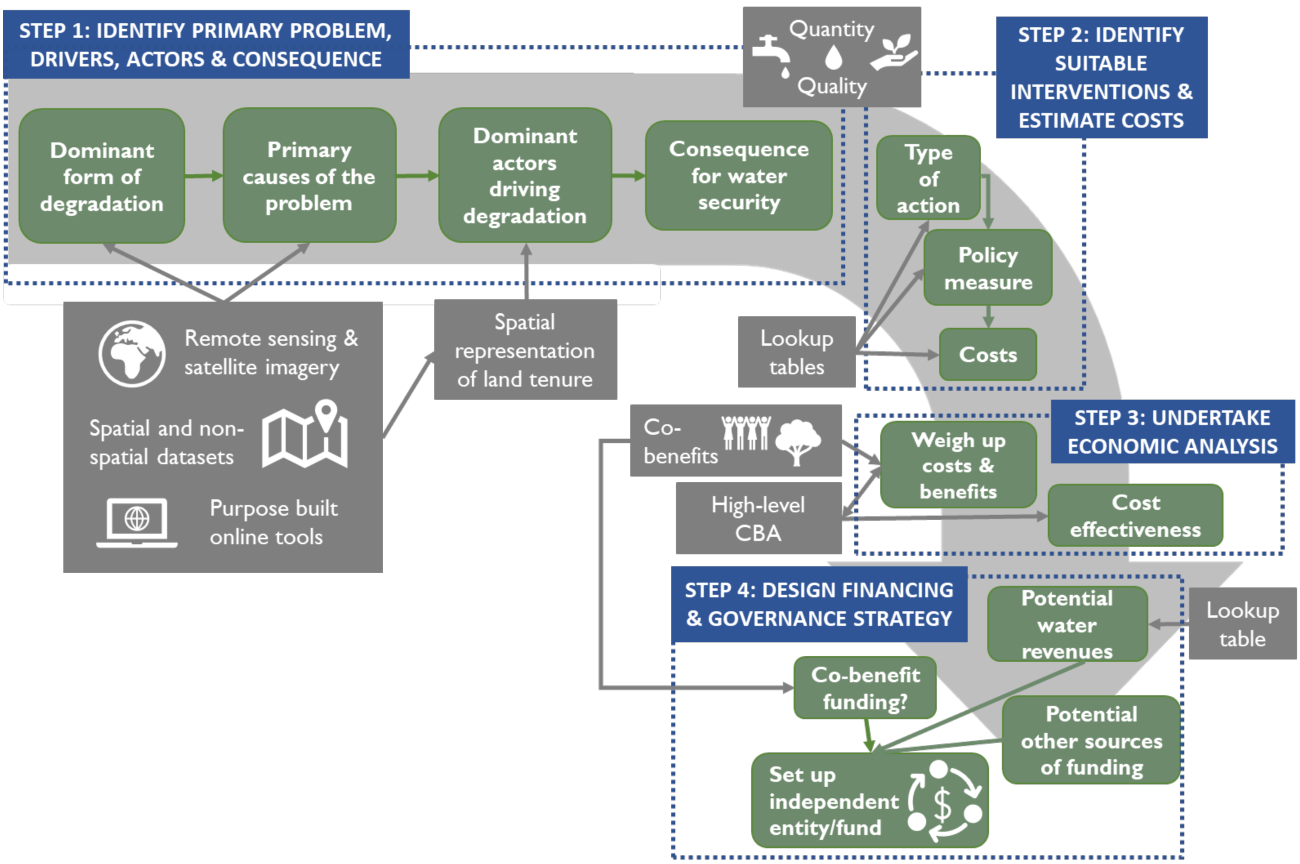


Figure 5.1. The analytical decision support framework follows a stepwise approach in terms of the "what, where, who and how" of conservation actions for tackling catchment restoration.

The framework operates at the scale of water supply systems (see Figure 3.3, Figure 3.4, Table 3.2) which are regions delineated by the South African government related to institutional water supply services. Data are summarised at this broader scale with the idea that local level analysis can be undertaken if necessary, following the suggestions outlined in the framework. This framework is primarily for use by Water Service Authorities and Water Service Providers (municipalities, water boards, DWS) and also for practitioners and policy makers from DFFE, conservation authorities and NGO's who are involved in catchment management in South Africa.

The framework is seen as a starting point for providing useful, context specific information on a wide range of elements for planning and guiding decisions for policy design and informing investment in ecological infrastructure to secure hydrological ecosystem services in South Africa's key water supply areas. The idea is that the framework be used as a tool to provide guidance on how to undertake a rapid assessment of environmental problems in catchment areas, how best to tackle them, whether or not investing in nature-based solutions would be economically feasible and providing guidance on options for financing their implementation and management. The layout, structure and data provided in the framework is intended to simplify the assessment process, reducing the time and costs needed for practitioners to undertake the work.

5.2 STEP 1. IDENTIFY THE PRIMARY PROBLEM, ITS DRIVERS, ACTORS AND TYPE OF CONSEQUENCES

The first step is to identify the primary environmental problem at play in the area of interest, the main drivers of the problem, the actors that are responsible for driving the problem and the type of consequences that result. The identification of these elements determines the types of management actions that are necessary and/or suitable and their associated cost implications (Step 2).

What is the dominant form of degradation?

In South Africa, there are four dominant forms of ecosystem degradation that are directly threatening the supply of hydrological ecosystem services (see Figure 5.2):

- The spread of invasive alien plants (Table 5.1);
- Loss of vegetation and soil cover in agricultural lands, as a result of poor management practices, such as livestock overstocking, poor fire management, poor farming practices (e.g. excessive tillage);
- Bush encroachment (increases in woody vegetation) in grassland and savanna biomes as a result of poor grazing and fire management practices; and
- Point source pollution from wastewater treatment outputs and mining, and non-point source pollution from agricultural activities.

Table 5.1 shows the estimated extent of IAPs (% coverage and area infested) within each WSS in South Africa in 2022 and what this would look like in 2050 under a do-nothing approach.

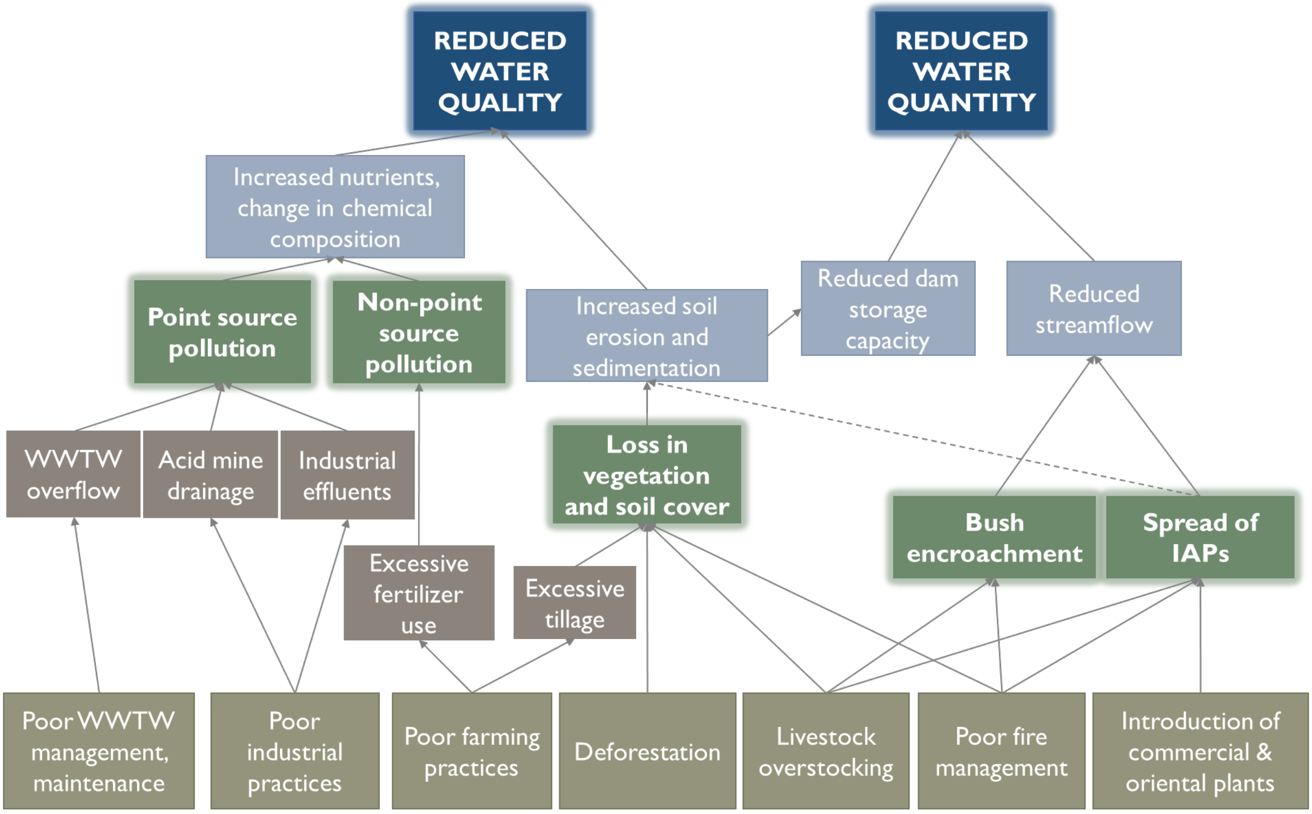


Figure 5.2. A causal chain showing the main types of environmental problems impacting on water security. The primary problems are shown in the green boxes.

Table 5.1. The estimated overall extent of IAPs (% IAP coverage and area invested) within each water supply system (WSS) in 2022 and 2050.

Water Supply System	% IAP coverage		Area infested (c.ha)	
	2022	2050	2022	2050
Algoa WSS	7.26	28.68	36 861	145 657
Amatole WSS	22.00	58.22	35 064	92 804
Crocodile West WSS	5.43	20.35	62 869	235 377
Integrated Mgeni WSS	9.84	35.12	63 786	227 610
Integrated Vaal River System	3.61	16.30	204 452	922 233
Limpopo WMA North	1.40	7.50	11 499	61 764
Luvuvhu-Letaba WSS	1.14	7.10	3 992	24 929
Olifants WSS	9.96	36.51	143 161	524 977
Orange River System	0.27	1.61	7 543	45 818
Richard's Bay WSS	6.03	27.50	41 221	188 057
Western Cape WSS	11.97	45.49	12 186	46 326

Source: this study based on NIAPS dataset

What are the primary causes of the problem?

For each of the dominant forms of degradation it is necessary to identify the primary causes of the problem as this will guide the choice of response. Table 5.2 provides a description of the primary causes and outlines some of the available datasets and tools that are available to help identify and asses these.

Table 5.2. Primary causes that are typically identified for each problem.

Primary problem	Primary causes	Description and potential ways of identifying the problem
Invasive alien plants	• Introduction of commercial and oriental plants • Increased dispersal of propagules due to human-mediated disturbance. • Poor land management	IAPs spread into native vegetation as a result of past introductions elsewhere in the landscape, occurring through dispersal of propagules (wind, birds, animals). Their spread is fuelled by human-mediated disturbance. Poor fire and livestock management are known to increase the spread of IAPs. IAPs displace native plant communities disrupting ecosystem processes. The National Invasive Alien Plant Survey (NIAPS) dataset and remote sensing data can be used to determine the extent and coverage of IAP infestation.
Loss of vegetation and soil cover	• Livestock overstocking • Poor tillage practices • Poor fire management • Deforestation (permanent destruction of indigenous forests and woodlands)	The removal of the biologically productive topsoil is caused by human activities and is exacerbated by poverty and a changing climate. Poor land and resource management, in particular on communal lands is the primary cause. Overstocking of livestock in rangeland areas and poor agricultural practices, such as excessive tillage, have resulted in the in the loss of vegetative cover which increases erosion and soil loss. The loss of trees from the landscape through agricultural expansion and the unsustainable harvesting of woody resources for fuelwood and timber are also drivers of degradation. In South Africa, 71% of all tree cover loss between 2001 and 2021 was in KwaZulu-Natal and Mpumalanga (Global Forest Watch). National and provincial land cover datasets can be used to assess LULC change and freely available purpose-built online tools such as Trends.Earth and Global Forest Watch provide statistics on tree loss and changes in NDVI over time.
Bush encroachment	• Livestock overstocking • Poor fire management	Bush encroachment occurs as a result of poor land management practices, mainly overgrazing and active reduction in the intensity or frequency of fires and is also facilitated by increased carbon in the atmosphere. It reduces commercial and communal rangeland productivity, since grassy biomass is reduced, and may lead to further damage from overgrazing in a negative feedback as suitable grazing areas shrink. Most bush encroachment has occurred in grassland and open woodland habitats. National and provincial land cover datasets can be used to assess changes in land cover to woodier classes over time and identify areas that have been bush encroached.
Point-source pollution	• Wastewater treatment works • Mines • Factories • Concentrated animal feedlots	This is pollution originating from a single, identifiable source, such as a discharge pipe from a wastewater treatment works or a factory, regulated by government. These sources of pollution can be monitored through water quality sampling and in the case of wastewater treatment works are regulated through the Green Drop Programme. The presence of poisonous chemicals results in the death of fish and other aquatic life as well as human health impacts – the first sign that there are pollution issues.
Non-point source pollution	• Cropland • Roads and settlements	This type of pollution is harder to identify and address, and refers to pesticides, herbicides, and fertilizers from agricultural lands, and nutrients and sediments that are washed off roads and settlements into watercourses. Their presence causes eutrophication in rivers and dams, increasing algal blooms and anaerobic water conditions, and indication that non-point source pollution is an issue.

Who are the dominant actors driving the problem?

In each case, the cause of the problem is being driven by an actor. The actor can be defined into four broad categories:

1. Private farmers
2. Communal farmers
3. Industry
4. Government

The actor has implications for the choice of suitable and effective management intervention, usually guided by land tenure/property rights. What works effectively on private land may not be suitable for the communal land context, or certain interventions may only be suitable for use within a specific context. For example, the NRM Working for Water teams operate mostly on communal or state land, and payments for ecosystem services as an intervention on communal land requires sufficiently clear property rights or the creation of property rights systems to ensure success. Activities being undertaken on private land are likely to be more difficult to control and are likely to require strong incentives to bring about change. The choice of management action and policy measure will be based on the knowledge of who is responsible for the problem, their location in the catchment and the scale at which they operate. A spatial representation of land tenure is useful for mapping out potential causes of degradation and the interventions best placed to address them.

What is the dominant type of consequence for water security?

In terms of water security, each of the primary forms of degradation cause a reduction in water quality, reduction in water availability, or both (Table 5.3). The main impact of IAPs on water security is the increased evapotranspiration of available water causing a reduction in streamflow (Figure 5.2). The loss of vegetation and soil cover in agricultural lands as a result of poor management and farming practices has an impact on both water quality and water quantity. Bush encroachment, also the result of poor management and farming practices, has an impact on water availability by reducing stream flow. Pollution from wastewater treatment outputs, mining activities and fertilisers have an impact on water quality (Figure 5.2). It is likely that in many catchments in South Africa all of these problems exist at some level and with some overlap. However, it is necessary to determine the dominant problem and its consequence from the outset as this has a bearing on efficiency and prioritisation in selecting suitable management interventions.

Table 5.3. The dominant type of consequence for water security typically associated with each problem.

Primary problem	**Effect**	**Dominant consequence for water security**
Invasive alien plants	Increased evapotranspiration of available water leading to a reduction in streamflow (mean annual runoff) and in particular an impact on dry season flows which leads to a reduction in yields from water supply dams. Also, increased erosion particularly along riverbanks.	Water quantity and quality
Loss of vegetation and soil cover	A loss in vegetation and soil cover results in increased soil erosion and sedimentation of rivers and streams, leading to poor water quality and a reduction in dam storage capacity.	Water quality and quantity
Bush encroachment	Increase in woody vegetation cover in grasslands and savannas has an impact on soil infiltration rates, groundwater recharge and surface runoff.	Water quantity
Point source and non-point source pollution	Both point source and non-point source pollution in the form of acid mine drainage, wastewater overflow, industrial effluents and agricultural chemicals have a negative impact on water quality by increasing the nutrients in streams and rivers or by changing their chemical composition.	Water quality

5.3 STEP 2. IDENTIFY THE SUITABLE MANAGEMENT INTERVENTIONS AND COSTS

The outcomes from Step 1 determine the types of actions that are necessary to achieve the desired result and the associated cost implications. The choice of management intervention depends on how critical the outcome is, the relative costs and benefits to the actors versus the rest of society, and who the beneficiaries are.

What type of action is necessary?

Based on the selections made under Step 1, identify the type of action that is necessary to bring about change (Table 5.4).

Table 5.4. Examples of management actions needed to bring about change.

Primary problem	Management action	Type of action
Invasive alien plants	Active restoration	• IAP clearing with follow up
Loss of vegetation and soil cover	Active restoration or rehabilitation	• Tree planting, assisted natural regeneration, reseeding, stabilisation, fixing dongas, wetland rehabilitation
	Conservation measures to recover and maintain ecosystem health	• Protection of riparian areas • Improved agricultural practices (conservation agriculture) • Sustainable resource management • Sustainable rangeland (grazing) management
Bush encroachment	Conservation measures to recover and maintain ecosystem health	• Up to a point (about 45% tree cover) bush encroachment can be reversed by improving land management practices such as rotating livestock and ensuring adequate fire regimes are used.
	Active restoration	• De-bushing with follow up
Point source pollution	Conservation measures to recover and maintain ecosystem health	• Improved treatment of wastewater and industrial effluent • Protection of riparian areas
Non-point source pollution	Conservation measures to recover and maintain ecosystem health	• Improved agricultural practices (conservation agriculture) • Improved land management • Protection of riparian areas

What arrangement or policy measure best gets this done?

The choice of policy measure to achieve these ecosystem management changes depends on the extent and scale of the primary problem, the location of the problem and the socio-economic context. The above management changes can be brought about by one or a combination of the following:

- Economic incentives such as taxes or charges, stewardship programmes, PES
- Non-monetary incentives such as public recognition through certification schemes
- Regulation (formal protection and enforcement)
- Government/donor support – information, extension services, major investments

For example, because improved agricultural practices (e.g. conservation agriculture) is generally a win-win solution, such actions may only need financial and technical inputs in the start-up phase. On the other hand, curbing the unsustainable use of rangelands or resources and encouraging practices to allow their recovery requires stronger and ongoing regulation and/or incentives (such as payments for ecosystem services or stewardship) and offset payments or taxes, as well as supporting measures such as investment in extension services and enforcement measures. Table 5.5 lists examples of management interventions that can be used and provides examples where appropriate.

Table 5.5. Examples of interventions/policy measures that can be used to address degradation.

Type of action	Intervention	Description and examples
IAP clearing or de-bushing with follow up treatment	Devise a clearing/ de-bushing plan and pay specialist teams to undertake restoration.	This can be done through the NRM Working for Water or Working for Land programmes (state or communal land) or through private companies that offer IAP clearing or de-bushing (private land).
	Incentives to create affordable clearing operations	In certain contexts, it is possible to encourage the development of aligned business opportunities in the form of bankable projects to produce biochar, charcoal, furniture, etc. to offset the costs of clearing (i.e. developing green value chains). The method of producing biomass products from IAPs has become an effective way to control them by reducing the overall control cost (Vera *et al.*, 2022; Yang *et al.*, 2022). Green value chains can catalyse private sector financing and provide energy alternatives. Furthermore, a certification scheme could be created for IAP biomass and increased price incentive could be placed on these products (sustainable land management; see https://rsb.org/ and Western Cape Government, 2018).
		A payment scheme that re-invests the offset value of water gained through alien clearing and restoration activities (see Western Cape Government, 2018). An Alien Clearing Water Charge would constitute a payment by the water service authority to the landowner for initial clearing and maintenance. The magnitude of the water charge may vary depending on the marginal cost of water supply, negotiated between the landowner and the WSA/WSP. This arrangement could work on private land and where the WSA consumer base has sufficient consumer surplus to cover the costs.
Tree planting, assisted natural regeneration, reseeding, stabilisation, fixing dongas, wetland rehabilitation	Devise a rehabilitation plan and pay specialist teams to undertake restoration or rehabilitation activities	This can be done through the NRM Working for Water or Working for Wetland programmes (on state or communal land) or through private companies/NGOs that undertake restoration activities (on communal and private land). Examples include Greenpop, One Tree Planted.
	Biodiversity Stewardship.	Voluntary commitments from landowners to support conservation and sustainable land management, with tax breaks provided as an incentive for landowners to invest in EI activities.
Protection of riparian areas and wetlands	Incentivise landowners through payments for ecosystem services or stewardship programmes	Potential to engage communities and private landowners to do this under a stewardship programme or through Corporate Social Investment (CSI). Sections of rivers or streams are maintained by cooperatives which are responsible for removing IAPs, rubble and any solid waste pollution blocking the free flow of water down the stream or river and maintaining the grass and other vegetation along the banks to prevent erosion. Examples include Wise Wayz Water Care (WWWC) Project in KZN, SAB Miller, Coca-Cola, SANBI Biodiversity Stewardship programme, WWF-Mondi Wetland Programme.
Improved agricultural practices, e.g. conservation agriculture, organic farming, etc.	Long-term extension services, equipment, inputs	When small-scale farmers are provided with ongoing training, support and inputs on how to best implement improved agricultural practices on their land (such as low tillage, mulching, etc.), then they start to realise benefits of improved farm productivity, net farm income and food security (Khwidzhili & Worth, 2019) while at the same time having positive environmental impacts, providing a win-win situation (Swanepoel, Swanepoel & Smith, 2018).
	Certification	Certification of agricultural produce (price premium) can incentivise farmers to employ organic farming techniques which are less harmful to the environment. In South Africa there is the

Type of action	Intervention	Description and examples
		SAOSO Standard for Organic Production and Processing. The certification assures consumers that no harmful chemicals have been applied for at least three years, annual certification inspections have been done, a detailed record of practices and an audit trail exist, and ecologically-friendly methods and substances have been used to improve the soil and control pests. Other examples include Rooibos Rainforest Alliance standard, Biodiversity & Wine Initiative, WWF's Conservation Champions.
Sustainable rangeland (grazing) management	Taxes/charges	Tradeable grazing rights can strengthen the control of grazing pressure within a communally managed grazing system. This is a cap-and-trade arrangement, where the number of grazing permits is capped according to grazing capacity and production objectives (traditional wealth systems under open access tend to be at full capacity, commercial production systems focusing on income typically optimised at half capacity). Permits are freely tradeable.
	Incentivise communities with improved access to meat markets and other benefits	On communal land rural communities can voluntarily commit to implement planned grazing of their livestock to minimize overgrazing, remove IAPs that hamper grass growth and water availability, adopt human-wildlife conflict mitigation practices among other measures. In turn, they receive support to improve quality of their livestock, reduce animal losses from wildlife predators, access facilitated livestock markets. Examples include Meat Naturally Pty, and Herding 4 Health and the associated Pro-nature Enterprises for the People of Southern Africa Project.
Improved treatment or disposal of wastewater and industrial effluent, and improved management of mining activities	Legislation	Taxes or subsidies implemented to bring about a desired outcome. Better enforcement needed.
	Incentivise wetland rehabilitation or constructed treatment wetlands	Wetland rehabilitation or the construction of treatment wetlands as a measure to address water quality can be incentivised through corporate/industry water stewardship programmes or through Corporate Social Investment.
	Offsets (wetland, water, biodiversity)	Offsets seek to minimise the environmental impacts of development, industry or mining by ensuring damage in one place is compensated for elsewhere, e.g. Sasol "Metsimaholo Water Loss Reduction Project"

What would this cost?

The choice of policy measure informs the level of investment that is required to achieve the management action. Based on the choice of measure(s) it is possible to then estimate the overall costs of the interventions. The cost of an intervention is usually broken into two parts: upfront implementation costs and ongoing monitoring/maintenance costs. To determine the overall costs the area of influence (usually hectares, but can be households, for example) is multiplied by a per unit cost over time. The ongoing or follow-up costs may not be necessary every year following initial intervention and could either be every alternative year or could be for the first five years after implementation. Such decisions are made depending on the type of problem and the extent and severity of the problem. The costs presented here provide a point of departure and are high-level based on mean costs for different types of intervention extracted from existing projects and the literature. The source of the cost information is provided in each table. These costs are indicative costs to be used to inform the initial viability assessment. If detailed costing information is available at the local scale, it is recommended that these be used instead. Following the initial viability assessment, it is recommended that detailed cost estimates be made based on local conditions. The indicative costs presented here are in 2022 Rands and should be adjusted accordingly for the year of the assessment (see Table 5.6, Table 5.7, Table 5.8, Table 5.9 and Table 5.10).

Table 5.6. Indicative estimates of costs to address invasive alien plants: Active restoration.

Intervention	Cost information	Initial upfront cost	Ongoing/follow-up costs
IAP clearing with follow up	Based on person-day cost of R500 derived from data collected over the lifespan of the WfW programme. Mean per ha cost by broad IAP group.	Wattle: R12 500/c.ha Gum: R10 700/c.ha Pine: R10 500/c.ha	Wattle: R5500/c.ha Gum: R4300/c.ha Pine: R1800/c.ha

*c.ha = condensed hectare. Source: this study based on NIAPS dataset; Working for Water (WfW) programme data; Blignaut *et al.*, 2007; Turpie *et al.*, 2021.

Table 5.7. Indicative estimates of costs to address loss of vegetation and soil cover: Active restoration/rehabilitation.

Intervention	Cost information	Initial upfront cost	Ongoing/follow-up costs
Restoration to recover and maintain indigenous tree cover	Active tree planting & direct seeding into deforested/riparian areas, mean per ha cost	R24 000/ha	R3500/ha (years 2-5)
	Assisted natural regeneration including weed control, protection against disturbances, mean per ha cost	R8500/ha	R1300/ha (years 2-5)
Restoration of denuded and eroded grassland	Active restoration of denuded grassland areas with reseeding and rehabilitation of gully erosion, mean per ha cost	R125 000/c.ha gully erosion, R13 500/ha reseeding.	Year 3: 70% of original cost Year 5: 30% Year 7: 10%

*c.ha = condensed hectare. Source: Maloti Drakensberg Transfrontier Project, 2007; Dugan, 2011; Vogl *et al.*, 2017a; Brancalion *et al.*, 2019; Gumbo, 2020; Bodin *et al.*, 2021; FAO, 2022.

Table 5.8. Indicative estimates of costs to address bush encroachment: Active restoration.

Intervention	Cost information	Initial upfront cost	Ongoing/follow-up costs
De-bushing with follow up	Manual bush clearance + follow up herbicide treatment, mean per ha cost	R3800/ha	R550/ha

Source: Data from key informants in Turpie *et al.*, 2019a

Table 5.9. Indicative estimates of costs to address loss of vegetation and soil cover: Conservation measures to recover and maintain ecosystem health.

Intervention	Cost information	Initial upfront cost	Ongoing/follow-up costs
Extension services to incentivise improved agricultural practices and sustainable land management	Extension and training of farmers, costs of equipment & inputs required (e.g. erosion control structures or small-scale water harvesting infrastructure), mean per ha cost.	High end: R8800/ha Med: R3000/ha Low end: R800/ha	High end: R1600/ha Med: R550/ha Low end: R400/ha
PES or stewardship agreements to incentivise improved land & resource management	Incentivise landowners to improve rangeland management through a reward/payment approach using permits, cap and trade, stewardship agreement, etc., mean per hectare cost.	R500/ha	Dependent on opportunity costs (R/ha/y) + a management cost of R200/ha/y

Source: WOCAT, 2007; Bond *et al.*, 2008, 2010; Williams *et al.*, 2008; Fisher *et al.*, 2011; Zaballa Romero *et al.*, 2012; Turpie, Warr & Ingram, 2014; Turpie *et al.*, 2019a; UNCCD, 2015.

Table 5.10. Indicative estimates of costs to address pollution: Conservation measures to recover and maintain ecosystem health

Intervention	Cost information	Initial upfront cost	Ongoing/follow-up costs
Stewardship agreements to incentivise improved river and riparian protection	Incentivise landowners to improve protection/enforcement of riparian areas using a reward-based stewardship approach (can be communities or businesses through Corporate Social Responsibility), mean per ha cost.	R500/ha	R200-850/ha
Construction of treatment wetlands	Pay to construct an artificial treatment wetland. Economies of scale at play, cost based on log relationship and in 2002 AUS $, to be converted using CPI.	Construction cost (AUS $) = 343,913 x Ln * (surface treatment area in ha) + 738,607	Maintenance Costs (AUS $) = 9842.20*(surface treatment area in ha)^0.4303

Source: James, Green & Paine, 1999; Lloyd, Wong & Chesterfield, 2002; Bond *et al.*, 2010; Fisher *et al.*, 2011; Lindsey *et al.*, 2018; Chardonnet, 2019

5.4 STEP 3. UNDERTAKE AN ECONOMIC ANALYSIS

Step 3 involves undertaking an economic assessment to evaluate the viability and desirability of interventions or policies based on their costs and benefits over time, and how they compare to alternative options for water security. This analysis is used to determine whether catchment restoration and conservation is economically viable from a societal point of view. Once the justification has been made then the next step is to determine how to go about financing it.

Does the value of the gain in hydrological services plus other co-benefits outweigh the cost of intervention?

Investment into the conservation and restoration of key ecological infrastructure has shown to have numerous positive impacts on water security, in the form of:

- Reduced sediment loads into rivers and streams
- Reduced sediment concentrations (TSS) in rivers and streams
- Reduced nutrients into rivers and streams
- Improved base flows, especially during the dry season
- Gains in water yields
- Improved flood attenuation
- Lower risk of water supply shortfalls

The benefits of catchment conservation and restoration are the gains in hydrological services, valued in the following way (see Table 5.11). As well as security in water supply, investing in critical ecological infrastructure could bring wider benefits. These include climate change resilience through gains in carbon storage, biodiversity gains and associated positive impacts on nature-based tourism, gains in crop and livestock production, and gains in harvested wild resources (Table 5.12). These co-benefits can be significant and including them in the economic analysis is important to demonstrate the overall viability of intervention.

Table 5.11. Hydrological ecosystem services and suggested valuation approaches. Based on: Turpie *et al.*, 2016, 2017a, 2021a, 2021c, 2022; Debus *et al.*, 2021; Letley *et al.*, 2022.

Ecosystem service	Description	Valuation approach
Water supply	Ecosystem contribution to water flow regulation to the supply of water of to users for various uses including household consumption.	Provision of water to users, valued as the avoided losses of yield using sales price of water (tariff price).
Water quality amelioration	Ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the breakdown or removal of nutrients and other pollutants by ecosystem components that mitigate the harmful effects of the pollutants on human use or health.	A reduction in treatment costs due to a reduction in the amount of chemicals needed to treat raw water, valued as avoided water treatment costs.
		Backwashing water that is lost to the system and represents a revenue loss in terms of treated water that could have been reticulated to paying consumers, valued as avoided water losses.
		Also valued by estimating the cost of treatment wetlands, which provides an approximation of the replacement cost if no purification were being performed by natural ecosystems.
Soil and sediment retention	Reducing soil loss and sediment transportation to downstream environments through holding soils in situ (by vegetative cover) or through trapping eroded sediments (by slowing down movement of water through the landscape, e.g. in a wetland).	Elevated catchment erosion either incurs dredging costs or shortens the lifespan of dams and related infrastructure. Valued in terms of the avoided costs of constructing measures to prevent damaging sediments from reaching waterbodies where the service would be demanded (e.g. using replacement cost of lost storage capacity through raising dam walls, constructing a substitute dam at a new site or constructing check dams to prevent sediment entering the dam or lake), or valued as avoided dredging costs.
Seasonal flow regulation	Smoothing of flow over the longer duration through infiltration and storage, reducing need for storage to achieve a given yield.	Valued using a replacement cost, based on the cost of construction dams to store an equivalent amount of water to the additional recharge facilitated by ecosystems.
Flood attenuation	Smoothing of fluvial flows during storm events through interception, infiltration, storage and landscape roughness, reducing the flood peak volume, velocity and flood height in the receiving area.	Valued using the lower of either flood damages avoided or the avoided costs of replacing the natural systems with alternative flood mitigation options. The avoided damage costs are the extra costs that would be incurred in the form of incremental losses from increased flooding if the natural ecosystems were lost. The replacement cost method involves estimating the costs of infrastructure that would be required to provide the same level of flood mitigation as the natural systems.

It is necessary to assess whether these benefits outweigh the costs of intervention. This can be done by undertaking a cost-benefit analysis or return on investment analysis whereby the costs and benefits are analysed over time and a net present value (NPV), cost-benefit ratio, or return on investment (ROI) is produced as an indicator for assessing whether a project is feasible, or economically viable or as a measure of cost-effectiveness. Cost-benefit analysis is used to guide policy and decision making. Usually, a scenario approach is used to analyse the impact of a conservation scenario (conservation interventions) when compared to a do-nothing or business-as-usual scenario. The difference between the two scenarios is recorded as a net gain or net loss. The cost-benefit analysis can be used as a business case to provide an economic and scientific basis for attracting private and public sector engagement and investment. Typically, an economic analysis uses a relatively low rate of discounting, known as the social rate of discount, which takes a longer-term view than a financial analysis. The social discount rate for South Africa is 3.66% (see Addicott, Fenichel & Kotchen, 2020).

Table 5.12. Some of the co-benefits associated with catchment restoration and conservation and suggested valuation approaches.

Co-benefit	Valuation
Crop production gains from improved agricultural practices	Implementation of on-farm soil conservation interventions reduce soil losses and improve water retention and increase crop yields. Improved crop yields multiplied by market price.
Livestock production gains from improved rangeland management	Improved livestock and rangeland management can improve the quality of livestock which then fetch higher prices.
Gains in harvested wild resources	The sustainable management of land and resources can have a positive impact on the stocks of woody resources and non-timber forestry products which are harvested by rural households. These are valued as the gain in these resources.
Increase in tourism and recreation opportunities	Restoration and improved protection of catchment areas can have a significant positive impact on biodiversity which is closely linked to tourism and recreation. Healthy ecosystems are critical for maintaining a strong tourism industry. The value of nature-based tourism can be estimated using a combination of tourism data, patterns of geotagged photographs uploaded to the internet (e.g. Flickr), and spatial data on land cover. See InVEST visitation model.
Carbon gains	Natural systems play a critical role in the global carbon cycle. The conservation and restoration of ecological infrastructure thus helps to reduce the rate at which greenhouse gases accumulate in the atmosphere and the consequent impacts of climate change. Based on global datasets derived from satellite data it is possible to estimate how much carbon is stored in vegetation and soils and how this could change with restoration and protection. Improved agricultural activities can also facilitate the increased uptake of soil carbon by areas under conservation tillage.
Biodiversity gains	Biodiversity and important wildlife areas are valued by South African citizens and global society. There is a great number of people, including many who may never visit South Africa, who would have a positive willingness to pay for conservation of these important landscapes. These non-use values are difficult to capture but can be significant.

Estimation of hydrological ecosystem services typically relies on complex hydrological and hydraulic modelling (e.g. using SWAT, HEC-RAS, PC SWMM), in conjunction with water treatment and engineering data (e.g. water treatment production and cost data, dam construction costs, dredging costs). The free, open-source software Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) suite of models which are used to map and value ecosystem goods and services are helping to bridge the gap and make the physical estimation and valuation of this group of services more manageable.

In the case of IAPs the main benefit of catchment restoration is the saving in stream flow reduction (i.e. the yield added to the supply system after clearing). The average increase in yield (in m^3) for every condensed hectare of IAP cleared is summarised by water supply system and dam catchment (Table 5.13). Across all water supply systems in South Africa, the mean saving is 462 m^3/c.ha. This value is highest in the Western Cape Water Supply System and the Integrated Mgeni Water Supply System.

For sediment impacts, the benefit is measured as the change in sediment loads and sediment concentrations in rivers and streams which is valued through replacement cost of lost storage and avoided water treatment costs. Restoration and protection of ecological infrastructure can reduce sediment loads (measures in tonnes or m^3) and sediment concentrations (measured as TSS, mg/l). The difference as a result of intervening can be used to determine cost savings by estimating the difference in sediment loads before and after intervening through the use of hydrological and hydraulic modelling and the impact this could have on water supply dams in terms of replacement costs of lost storage. There is no specific spatial dataset for sheet erosion in South

Africa. However, there is a spatial representation of gully erosion (i.e. dongas) which could be used as an indicator for sheet erosion, in conjunction with the grazing capacity and various LULC maps.

Table 5.13. Increase in yield associated with the clearing of one condensed hectare of IAPs within (A) each water supply system and (B) within each dam catchment.

A: Water supply system	Increase in yield with IAP clearing (m^3/c.ha)
Algoa Water Supply System	301.1
Amatole Water Supply System	459.9
Crocodile West Water Supply System	152.1
Integrated Mgeni Water Supply System	659.6
Integrated Vaal River System	370.5
Limpopo Water Management Area	152.7
Luvhuvhu & Letaba Water Supply System	265.5
Richard's Bay Water Supply System	508.9
Olifants Water Supply System	367.3
Orange River Water Supply System	312.6
Western Cape Water Supply System	1 532.3

B: Dam catchment	Increase in yield with IAP clearing m^3/c.ha	B: Dam catchment	Increase in yield with IAP clearing m^3/c.ha
Albert Falls Dam	677.1	Ludeke Dam	714.0
Berg River Dam	806.8	Magoebaskloof Dam	247.8
Binfield Park Dam	459.9	Mearns Dam	609.2
Bloemhof Dam	371.0	Middle Letaba Dam	286.3
Bospoort Dam	152.1	Midmar Dam	677.1
Cata Dam	459.9	Mnyameni Dam	459.9
Churchill Dam	710.1	Moloko Dam	152.1
De Hoop Dam	368.8	Nagle Dam	677.1
Doorndraai Dam	152.1	Nahoon Dam	459.9
Duiwenhoks Dam	1 882.3	Nungwane Dam	677.1
Ebenezer Dam	286.3	Pongolapoort Dam	514.4
Flag Boshielo Dam	366.8	Roodekoppies Dam	152.1
Gariep Dam	312.6	Roodeplaat Dam	152.1
Glen Alpine Dam	152.7	Rooikrantz Dam	459.9
Goedertrouw Dam	474.4	Sandile Dam	459.9
Groendal Dam	207.7	Spioenkop Dam	609.2
Grootdraai Dam	371.0	Spring Grove Dam	609.2
Gubu Dam	332.6	Theewaterskloof Dam	1 882.3
Hazelmere Dam	677.1	Tzaneen Dam	247.8
Henley Dam	677.1	Vaal Barrage Dam	371.0
Hluhluwe Dam	474.4	Vaal Dam	369.6
Impofu Dam	710.1	Vaalkop Dam	152.1
iMvutshane Dam	677.1	Voëlvlei Dam	806.8
Inanda Dam	677.1	Wagendrift Dam	609.2
Knellpoort Dam	284.5	Wemmershoek Dam	806.8
Kouga Dam	459.9	Woodstock Dam	816.3
Laing Dam	459.9	Wriggleswade Dam	332.6

Source: This study (chapter 3).

Does the return on investment exceed alternative engineered options for water security?

The economic analysis is used to determine if the benefits of intervention exceed the overall costs and that there is a positive return on investment, i.e. that it is economically viable. The ROI or cost-benefit ratio is determined by simply dividing the present value of the benefits by the present value of the costs. The economic analysis and return on investment can be done at the catchment level or at a smaller sub-catchment scale whereby an overall project ROI is determined as well as ROI values for each sub-catchment. If the analysis is performed at a smaller scale, then it becomes possible to determine where intervening would be most cost-effective, i.e. priority areas for intervention can be identified. This would then allow for a phased approach whereby sub-catchments are prioritised according to their ROI.

The economic analysis can also be used to determine if the return of investment in catchment conservation and restoration is more cost-effective than other engineered options. This is achieved by calculating the Unit Reference Value which is a common measure in South Africa to assess the economic efficiency of proposed water projects. Simply, the URV is derived by dividing the present value of the costs with the present value of the water supplied to get a R/m^3 estimate. URV's are available for most water resource projects as described in the Reconciliation Strategies for all of South Africa's water supply systems. In the context of investment in EI this indicator can be used to decide on whether to implement nature-based solutions instead of a traditional grey infrastructure (or engineered) solution, or to decide between different alternatives and when best to implement them. If the nature-based solution is more cost-effective, then its implementation could delay the need for more expensive engineered solutions, reducing costs over the long-term, and at the same time generating a range of co-benefits. The URV of IAP clearing for each water supply system is shown in Table 5.14.

Table 5.14. URV of built infrastructure planned and the URV for IAP clearing in each WSS. Source: This study

Water supply system	Range of built infrastructure URVs (R/m^3)	URV IAP clearing (R/m^3)
Algoa WSS	6.77-25.62	2.99
Amatole WSS	8.46-28.66	1.97
Crocodile West WSS	12.38-44.36	7.18
Integrated Mgeni WSS	4.54-21.91	1.43
Integrated Vaal River System	11.80-17.61	2.78
Limpopo WMA North	*17.95	2.53
Luvuvhu-Letaba WSS	**3.98-17.32	2.60
Olifants WSS	4.50-31.92	2.82
Orange River System	0.48-0.84	2.45
Richard's Bay WSS	2.22-19.36	2.01
Western Cape WSS	2.57-18.77	0.79

Source: this study (chapter 3).
*Only one planned BI intervention.
**Values based on the average URVs of similar projects due to deficient data.

5.5 STEP 4. DESIGN FINANCING STRATEGY AND ORGANISATIONAL ARRANGEMENTS

The purpose of this step is to develop a specific and pragmatic financing and governance strategy that can deliver water security for the area of interest. Drawing on outputs from Steps 1-3 identify a long-term financial mechanism (i.e. a sustainable financing strategy) and explore various options for attracting investors and sourcing finance.

To what extent could water user fees be leveraged to fund nature-based solutions?

This step seeks to investigate if there is a high enough willingness to pay from the domestic customer base to cover the costs of catchment restoration and protection, i.e. is there consumer surplus to cover all or some of these costs? This is seen as an effective mechanism to generate sustainable finance for catchment management from water users. This has been investigated through extensive surveys in three coastal cities of South Africa (City of Cape Town, Nelson Mandela Bay, and eThekwini) where over 1000 households were interviewed. Table 5.15 shows the mean monthly consumer surplus per household within each census income category. These values can be used as a guideline to determine if in your municipality there is sufficient consumer surplus and opportunity for raising water tariffs. The data show that in the lowest income categories the consumer surplus is zero (people are not willing or able to pay more than what they already pay), whereas in the higher income categories the consumer surplus is close to R2000 per year.

To calculate the aggregate consumer surplus, multiply the number of households in each income category that have access to municipal water supply by the mean annual consumer surplus. Note that this is a guideline based on surveys undertaken in three cities only, and that further research is needed to capture how these values may change geographically.

Table 5.15. Estimated mean consumer surplus (R per month) per census income category.

Income categories (R/month)	Mean consumer surplus (R/month)	Mean consumer surplus (R/year)
6 401-12 800	63	761
12 801-25 600	111	1333
25 601-51 200	134	1614
51 201 or more	174	2089

Source: This study (chapter 4).

Could the co-benefits associated with the interventions bring about other funding?

In Step 3 the co-benefits of the intervention were valued as part of the economic analysis. In this step the aim is to identify whether any of these co-benefits can generate additional funding such as climate, developmental, biodiversity or carbon funding? For example, there could be opportunities for international payments for ecosystem services (e.g. REDD+) through ecosystem-based adaptation measures, or through biodiversity conservation where land use practices and interventions promote the protection and sustainable use of biological diversity.

What sources of funding can be leveraged?

Assuming that water service providers do not have sufficient resources available, or their resources are fully committed, and the potential for raising finance through co-benefits is deemed minimal, then what other options are available? Figure 5.3 broadly summarises the types and sources of funding that are available. The potential of each of these funding options should be investigated in relation to each individual project being undertaken, taking cognisance of the scale of the problem and the institutional and socio-economic conditions at play. Projects that make a strong economic and financial case for investing in nature-based solutions (based on strong science) and can demonstrate influence and low levels of risk are likely to succeed in attracting private sector finance. Potential options for consideration include:

- **Payments** from households through water pricing to fund restoration and conservation.
- **Green bonds**: may come with tax incentives to enhance their attractiveness to investors. The bond issuer borrows a fixed amount of capital from investors over a defined period of time (the maturity of the bond), repays the capital when the bond matures, and pays an agreed-upon fixed amount of interest during that period. Green bonds are less risky than some of the other green financial products.
- **Water stewardship and offsets:** water-intensive industry and business (e.g. bottling, hotels, breweries) actively reduce water consumption through stewardship or offset programmes.

- **Environmental certification and creating markets for products from restoration:** in certain contexts, there are opportunities to produce products such as biochar, charcoal, and furniture to offset some of the costs of active restoration, such as IAP and bush clearing (i.e. developing green value chains) or a certification scheme could be created for IAP biomass and an increased price incentive could be placed on such products.

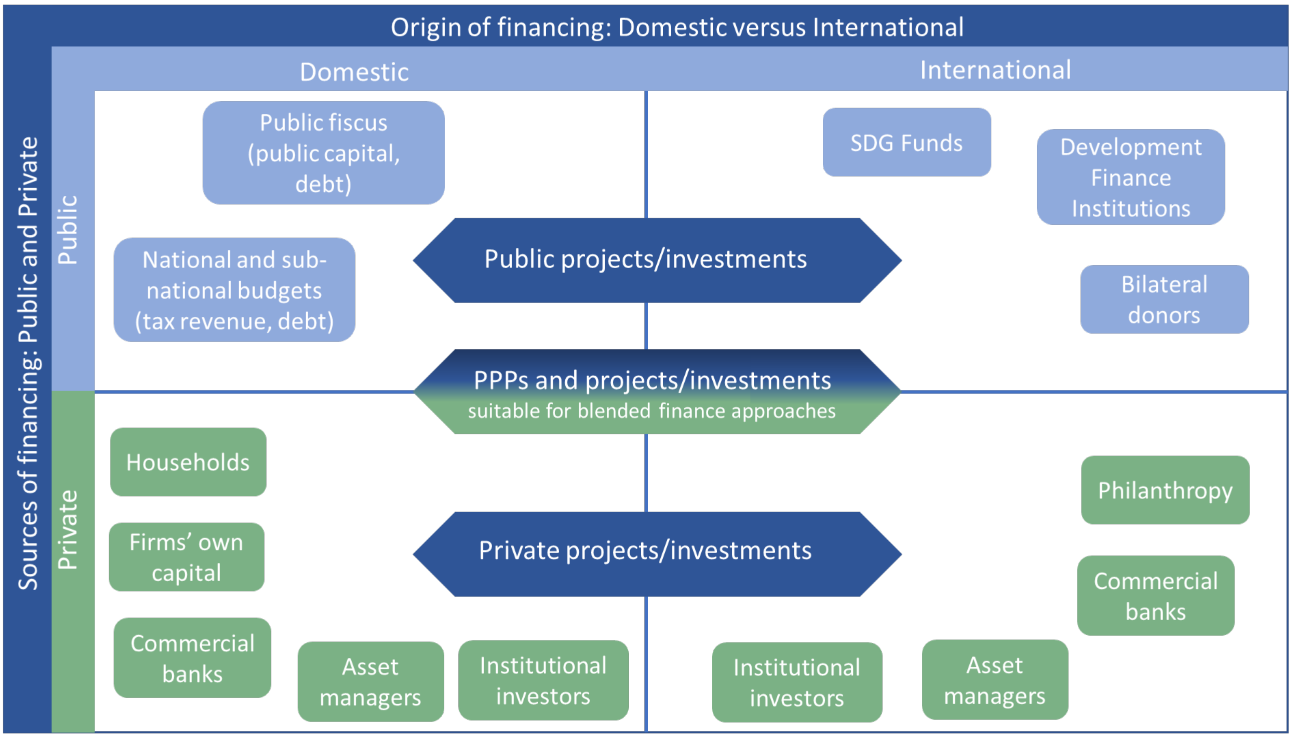


Figure 5.3. Types and sources of funding available for financing catchment restoration and conservation. Source: World Economic Forum.

Explore the potential for setting up a dedicated, independent fund.

Setting up an independent fund for pooling of finance, either as an endowment fund or pooled financing facility, has been proven to be a successful approach to securing and managing funds, in particular in developing countries where corruption is a major concern, i.e. through water partnerships and water funds. The private sector, as well as philanthropic donors, are more likely to invest if they know that their money is being ring-fenced for conservation and is well managed. A dedicated financing and governance structure provides this stability. Achieving this institution requires a strong stakeholder engagement process which should include the involvement of key stakeholders throughout the strategic planning process and ensuring that influential and institutional stakeholders are well aligned.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This study has shown that securing hydrological ecosystem services through catchment restoration and conservation is cost-effective and should be considered as a priority action for achieving water security in South Africa. Furthermore, the study has identified that there is untapped willingness to pay for water which could be captured through tariff increases and channelled through appropriate organisations to pay for catchment restoration. This study suggests that with an appropriate, trusted institutional set-up, there is potential to make a significant contribution towards closing the funding gap in this way.

Given that water service providers, as the main beneficiaries of catchment restoration, stand to gain significantly from such improvements through cost savings, their apparent low willingness to invest in ecological infrastructure requires further investigation. However, this study suggests that this should not impede investment and implementation, as there are other avenues, such as water funds and water source partnerships, that have proven to be successful in securing financing for catchment restoration and conservation.

Finally, context is important. Funding can come from numerous sources and interventions can be financed through a number of mechanisms, all of which are suitable under different contexts, varying spatially depending, for example, on the nature and scale of the problem, the institutional and socio-economic context of the problem, the costs of addressing the problem, the water services institutional context, and the potential user willingness to pay. The decision support framework that has been developed aims to provide high-level guidance to decision-makers and catchment managers on the potential opportunity and viable approaches for investing in hydrological ecosystem services.

The following recommendations are made:

1. Provide training on the use and application of the decision support framework with specific groups of individuals that are involved in water services delivery and catchment management in South Africa so that they are able to learn the necessary skills and improve performance and efficiency with regards to tackling catchment restoration and conservation across key water supply areas.
2. Establish Water Funds in each water supply system, along the lines of those that have already been or are in the process of being established. This will not only help to secure donor and investment funding but will also support the raising of revenues from water tariffs. The private sector, as well as philanthropic donors, are more likely to invest if they know that their money is being ring-fenced for conservation and is well managed. A dedicated financing and governance structure provides this stability and should be explored for all water supply areas in the country.
3. Design and implement a ringfenced domestic water user fee involving increases in line with the inclining block tariff structure. This could be implemented incrementally and in an experimental fashion to test revenue and consumption effects and ensure that there are no regressive effects.
4. Expand the viability analysis to include other forms of ecosystem degradation. Due to the availability of data, the quantitative aspects of this study have focused on dealing with the effects of IAPs on water supply. While IAPs tend to have the most major effects, erosion, bush encroachment and pollution also pose significant threats to water security. Further research should be directed towards quantifying the viability of investing in the rehabilitation of eroded land and wetlands, as well as addressing bush encroachment in catchment areas as suitable options to secure hydrological ecosystem services. It is likely that measures to address these could also be cost-effective when compared to engineered solutions over the long-term or could significantly extend the lifespan of existing built infrastructure.

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APPENDIX A: Supplementary information – Chapter 3

Table A.1. List of the large dams included in this study to determine the cost of investing in ecological infrastructure to secure hydrological ecosystem services. The dam's name, capacity in million m^3, province and water supply system in which it occurs, and the water service provider responsible for its management are listed.

Dam name	Capacity (million m^3)	Province	Water Supply System	Water Service Provider
Albert Falls Dam	289.20	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Berg River Dam	126.40	Western Cape	Western Cape Water Supply System	Overberg Water
Binfield Park Dam	36.83	Eastern Cape	Amatole Water Supply System	Amatole Water
Bloemhof Dam	1 218.10	Free State	Integrated Vaal River System	Rand Water
Bospoort Dam	18.20	North West	Crocodile West Water Supply System	Magalies Water
Cata Dam	12.10	Eastern Cape	Amatole Water Supply System	Amatole Water
Churchill Dam	35.70	Eastern Cape	Algoa Water Supply System	*NMBM
De Hoop Dam	351.00	Limpopo	Olifants Water Supply System	Lepelle Northern Water
Debe Dam	6.00	Eastern Cape	Amatole Water Supply System	Amatole Water
Doorndraai Dam	44.20	Limpopo	Limpopo Water Management Area	Lepelle Northern Water
Duiwenhoks Dam	6.00	Western Cape	Western Cape Water Supply System	Overberg Water
Ebenezer Dam	70.00	Limpopo	Luvuvhu & Letaba Water Supply System	Lepelle Northern Water
Flag Boshielo Dam	104.00	Limpopo	Olifants Water Supply System	Lepelle Northern Water
Gariep Dam	5 342.93	Free State	Orange River Water Supply System	Bloem Water
Glen Alpine Dam	18.90	Limpopo	Limpopo Water Management Area	Lepelle Northern Water
Goedertrouw Dam	301.30	KwaZulu-Natal	Richard's Bay Water Supply System	Mhlathuze Water
Groendal Dam	12.40	Eastern Cape	Algoa Water Supply System	NMBM
Grootdraai Dam	356.00	Mpumalanga	Integrated Vaal River System	Rand Water
Groothoek Dam	1.30	Free State	Greater Bloemfontein Supply Area	Bloem Water
Gubu Dam	8.79	Eastern Cape	Algoa Water Supply System	Amatole Water
Hazelmere Dam	17.90	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Henley Dam	5.40	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Hluhluwe Dam	25.90	KwaZulu-Natal	Richard's Bay Water Supply System	Mhlathuze Water
Impofu Dam	106.90	Eastern Cape	Algoa Water Supply System	NMBM
iMvutshane Dam	3.10	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Inanda Dam	251.70	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Knellpoort Dam	136.20	Free State	Orange River Water Supply System	Bloem Water

Dam name	Capacity (million m^3)	Province	Water Supply System	Water Service Provider
Kouga Dam	128.50	Eastern Cape	Algoa Water Supply System	NMBM
Laing Dam	19.90	Eastern Cape	Amatole Water Supply System	Amatole Water
Ludeke Dam	14.50	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Magoebaskloof Dam	4.80	Limpopo	Luvuvhu & Letaba Water Supply System	Lepelle Northern Water
Mearns Dam	5.54	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Mhlabatshane Dam	1.60	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Middle Letaba dam	173.00	Limpopo	Luvuvhu & Letaba Water Supply System	Lepelle Northern Water
Midmar Dam	175.10	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Mnyameni Dam	2.00	Eastern Cape	Amatole Water Supply System	Amatole Water
Moloko Dam	146.00	Limpopo	Crocodile West Water Supply System	Lepelle Northern Water
Nagle Dam	24.60	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Nahoon Dam	19.20	Eastern Cape	Amatole Water Supply System	Amatole Water
Nandoni Dam	164.00	Limpopo	Luvuvhu & Letaba Water Supply System	Lepelle Northern Water
Nsami's Dam (Giyani)	29.50	Limpopo	Luvuvhu & Letaba Water Supply System	Lepelle Northern Water
Nungwane Dam	2.40	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Pongolapoort Dam	2 267.07	KwaZulu-Natal	Richard's Bay Water Supply System	Mhlathuze Water
Roodekoppies Dam	102.60	North West	Crocodile West Water Supply System	Magalies Water
Roodeplaat Dam	1.40	Gauteng	Crocodile West Water Supply System	Magalies Water
Rooikrantz Dam	5.00	Eastern Cape	Amatole Water Supply System	Amatole Water
Rustfontein Dam	71.20	Free State	Greater Bloemfontein Supply Area	Bloem Water
Sandile Dam	27.50	Eastern Cape	Amatole Water Supply System	Amatole Water
Spioenkop Dam	272.30	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Spring Grove Dam	139.50	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Steenbras Lower Dam	3.50	Western Cape	Western Cape Water Supply System	City of Cape Town
Steenbras Upper Dam	32.50	Western Cape	Western Cape Water Supply System	City of Cape Town
Sterkfontein Dam	2 617.00	Free State	Integrated Vaal River System	Rand Water
Theewaterskloof Dam	480.40	Western Cape	Western Cape Water Supply System	Overberg Water
Tzaneen Dam	157.30	Limpopo	Luvuvhu & Letaba Water Supply System	Lepelle Northern Water
Vaal Barrage Dam	55.40	Gauteng	Integrated Vaal River System	Rand Water

Dam name	Capacity (million m^3)	Province	Water Supply System	Water Service Provider
Vaal Dam	2 609.80	Free State	Integrated Vaal River System	Rand Water
Vaalkop Dam	56.10	North West	Crocodile West Water Supply System	Magalies Water
Voëlvlei Dam	168.20	Western Cape	Western Cape Water Supply System	Overberg Water
Wagendrift Dam	55.90	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Welbedacht Dam	11.70	Free State	Orange River Water Supply System	Bloem Water
Wemmershoek Dam	58.80	Western Cape	Western Cape Water Supply System	City of Cape Town
Woodstock Dam	373.30	KwaZulu-Natal	Integrated Mgeni Water Supply System	Umgeni Water
Wriggleswade Dam	93.20	Eastern Cape	Algoa Water Supply System	Amatole Water

Table A.2. Factors for the quantity of water saved (million m^3 per condensed hectare) based on estimated flow reduction and extent of IAP invasion in South African primary catchment areas. Source: Le Maitre et al. (2016).

Primary catchment	Estimated extent of IAP invasion (c.ha)	Estimated flow reduction (million m^3)	Quantity of water saved (million m^3/c.ha)
A	86 510	24.44	0.0003
B	123 328	61.79	0.0005
C	138 557	64.25	0.0005
D	54 383	31.57	0.0006
E	4825	3.65	0.0008
F	795	0	0.0000
G	92 970	111.36	0.0012
H	45 164	126.21	0.0028
J	25 438	11.69	0.0005
K	60 951	102.51	0.0017
L	24 228	10.86	0.0004
M	23 662	11.64	0.0005
N	39 906	0.89	0.0000
P	12 432	3.31	0.0003
Q	30 385	4.83	0.0002
R	45 414	42.92	0.0009
S	59 130	46.58	0.0008
T	220 942	321.96	0.0015
U	111 698	154.35	0.0014
V	81 139	100.87	0.0012
W	154 984	148.66	0.0010
X	58 025	59.19	0.0010

APPENDIX B. Supplementary information – Chapter 4

Location: _____________ Date: ________ Interviewer: _____________ Supervisor______________
Hello, my name is XXXX. We are undertaking a short survey for the University of Cape Town to investigate public opinion on the price of water. The survey is anonymous. Would you be willing to answer some questions on behalf of your household? It will take about 15 minutes. Thank you/No problem.
If refused, check the box and close.

1. Do you live in the Cape Town [/Nelson Mandela Bay/eThekwini] Metro area? Yes ☐ No ☐
2. Are you a decision maker or financial contributor in your household? Yes ☐ No ☐
3. Do you have a municipal water supply (piped water to your house)? Yes ☐ No ☐

☐ ***If NO to any of the above, END the interview and tally.***

4. Are you here for ☐ a passport/travel documents or ☐ for something else (e.g. ID, birth certificate etc.)?

About your home

5. Which suburb do you live in? ____________________________ (choose from drop down list)
6. Including you, how many people live in your household? _______adults (≥ 18) _____ children (< 18)
7. Do you rent or own your property? ☐ Own ☐ Rent
8. Do you live in a house, apartment or shack? ☐ House (includes semi-detached) ☐ Apartment ☐ Shack
9. Does your property/complex have a:
    a. Garden ☐ Yes ☐ No
    b. Swimming pool ☐ Yes ☐ No
    c. borehole or wellpoint? ☐ Yes ☐ No ☐ Don't know.
    d. rainwater tank(s)? ☐ Yes ☐ No ☐ Don't know.
    e. grey water system? ☐ Yes ☐ No ☐ Don't know.
10. If you receive water from other sources, can you estimate what % of your water used is municipal water? ___%
11. Does your property have a water demand management device? Yes ☐ No ☐ Don't know
12. How does your household pay for its water use? ☐ Directly to the municipality ☐ included in rent ☐ included in building levies ☐ part of the indigent support programme ☐ Don't know

Willingness to pay for existing water use

13. Roughly how much does your household pay per month for electricity at present? R____
    ☐ Don't know
14. How confident are you that you indicated the correct amount that you pay for electricity every month?

☐ Extremely confident ☐ Quite confident ☐ Somewhat confident ☐ Not very confident ☐ Not at all confident

15. Roughly how much does your household pay per month for water at present (directly or via rent or levies)?
    R____☐ Don't know (use this value for next WTP questions)
16. How confident are you that you indicated the correct amount that you pay for water every month?

☐ Extremely confident ☐ Quite confident ☐ Somewhat confident ☐ Not very confident ☐ Not at all confident

17. Would your household be willing to pay R 1.5x current water bill per month for the water you are currently using?

18a) If yes --> Would your household be willing to pay R 2x current water bill per month for the water you are currently using?

18b) If no --> Would your household be willing to pay R 1.25x current water bill per month for the water you are currently using?

19. What is the most your household would be willing to pay monthly for the water you use at present? _______(open ended) ☐ Don't know

Trust in municipality

20. Please indicate your level of satisfaction with the way that the municipality manages water supply and sanitation in your neighbourhood, on a scale from 1-5 where 1 = extremely dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, 5=extremely satisfied _____
21. Do you think the municipality should be charging more for water? ☐ Yes ☐ No ☐ Don't know
22. Why yes? ☐ to improve water security ☐ To increase municipal revenues for service delivery generally ☐ Other _____
23. Why no? ☐ Difficult to afford. ☐ It won't make any difference to service delivery. ☐ Other __
24. Do you trust that your municipality would actually use the funds to improve water security if they increased the price of water? ☐ Yes ☐ No

Socioeconomic status

Finally, I need some information about you and your household:

25. Please indicate your highest level of education

☐ None ☐ Primary ☐ Secondary ☐ Matric ☐ Diploma ☐ Degree ☐ Prefer not to answer

26. Please indicate your **household's** total **monthly income before tax** in Rands? ***(tick one option)***

0-400	☐	12 801 - 25 600	☐
401-800	☐	25 601 - 51 200	☐
801 - 1 600	☐	51 201 - 102 400	☐
1 601 - 3 200	☐	102 401 - 204 800	☐
3 201 - 6 400	☐	204 801 or more	☐
6 401 - 12 800	☐	Prefer not to answer	☐

27. What is your age? ____

For enumerator only:

Rate the quality of the interview ☐ High ☐ Medium ☐ Low

Race of respondent: ☐ Black ☐ White ☐ Coloured ☐ Other

Gender of respondent ☐ Male ☐ Female ☐ Other