Research Investment Strategy

Ntabelanga and Lalini Ecological Infrastructure Project

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environmental affairs
Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

NTABELANGA LALINI ECOLOGICAL INFRASTRUCTURE PROJECT
RESEARCH INVESTMENT STRATEGY

MINISTERIAL FOREWORD

The Mzimvubu catchment in the Eastern Cape is currently undergoing a series of developments. The proposed Ntabelanga and Lalini Dams are both part of the ongoing Mzimvubu Water Project (UWP) led by the Department of Water and Sanitation (DWS), and on completion are intended to supply potable water to 730 000 people by 2050 and irrigate about 2 900 ha of land. There is also a small hydropower plant planned at the Lalini Dam site. In order for these dams to be filled with a good quality of water and to reduce sedimentation and other problems which dramatically reduces the lifespan of the dams, it is essential to have healthy upstream ecological infrastructure (EI).

Occasionally opportunities come together to create an exciting "flagship project". The Department of Environmental Affairs (DEA) Natural Resource Management (NRM) Programmes will invest in the catchments around the proposed Ntabelanga and Lalini Dams for at least the next 8 years - in a range of natural resource management and restoration projects, also through investing in a research programme that will address the understanding of the management and restoration, and importantly, the social context of such work.

How did this come about? This is an area of known rural poverty and land degradation; one where local people could act on building a more sustainable future, based on improving natural resources (ecological infrastructure). This makes particular sense given that Ntabelanga and Lalini Dams will silt up prematurely if land degradation in the catchments around them continues.

The vision for the ambitious rehabilitation component, led by DEA, is *"to support sustainable livelihoods for local people through integrated landscape management that strives for resilient social-ecological systems and which fosters equity in access to ecosystem services."* The Natural Resource Management teams, with support from the Expanded Public Work Programme (EPWP), spearheads environmental improvement in various ways and creates additional work opportunities (e.g. invasive alien plant clearing; land and wetland rehabilitation; appropriate fire management through the Working for Ecosystems, Working for Water, and Working on Fire programmes), and at the same time reduce sediment load going into these planned dams. Collectively, these DEA NRM teams will potentially create 558 real jobs in the green economy per year (48 in Working for Forests, 120 in Working for Ecosystems, 15 in Working on Fire and 375 in Working for Water). Over the life-span of the current project this could equate to roughly 714 000 person days, and a major injection into the local economies of the catchments.

The restoration work in conjunction with the *sustainable land use management* implicit in the Ntabelanga Lalini Ecological Infrastructure Project (NLEIP) goals, can be seen as an "insurance policy" for all the DWS investments (and other developments). The investments in restoring and maintaining ecological infrastructure in an optimal condition, will sustain benefits that will accrue from the water infrastructure investments (crops and pastures from the irrigation, power supply from the hydro-electric plant and most importantly potable water for more previously disadvantaged communities).

This will be linked to the activities of the imminent Catchment Management Fora (CMFs) in the area. It is intended that all these joint actions and events will be carried out in a manner that engages and involves local communities, both sensitively and with a view to their own benefits.

Another potential critical success factor is the applied research involvement, supported by many universities, especially those in the Eastern Cape. The way in which this research has to be carried out is guided by the approach in this document and will test the "comfort zones" of many researchers, but concurrently promote links between science, management and society. The key partners supporting the restoration of the ecological infrastructure in the catchment are the Department of Environmental Affairs (DEA), the Department of Water and Sanitation (DWS), the Department of Science and Technology (DST) and the Water Research Commission (WRC), as well as the Proto-CMA, Rhodes University, the University of Fort Hare, University of the Free State, and the Agricultural Research Council (ARC). The intention is to also enlist the help of Walter Sisulu University in the near future.

The frameworks in this report describe sensible and tested ways of carrying out interventions in a complex and changing world. This and the provisional set of research programs and interacting management actions are designed to build more resilient societies – ones which can adapt and hopefully flourish in a changing future.

Independent sediment yield calculations for the Ntabelanga Dam predict that it can silt up between 34 – 49 years if no sediment management is applied (Le Roux *et al.* 2015). Restoration efforts in the Tsitsa River catchment will extend the lifespan of the proposed dams. The exact improved life expectancy of the dams due to restoration efforts are unknown, but can be as high as 30%, and depends on the restoration effort invested and co-operation of the land users and stakeholders in the catchment. What is certain is that restoration efforts will reduce the loss of valuable soil, improve water quality, reduce water treatment costs, prolong and ensure the livelihoods of upstream and downstream land and water users. The NLEIP will also make a solid contribution towards the intergenerational equity for the future local residents, who for the first time may inherit a landscape in better condition than their forebears did.

I wish the participants in this important programme, and especially the communities from the region, all the best, as they go into this important phase of this project and from there into the longer-term future.

MRS B E E MOLEWA, MP

MINISTER OF ENVIRONMENTAL AFFAIRS

DATE: 2016/10/06

Executive summary

The purpose of this document is to develop an initial research investment strategy for the Tsitsa sub-catchment of the Mzimvubu catchment in the Maclear area of the Eastern Cape. The impetus was provided by plans to construct the tenth largest dam in South Africa, Ntabelanga Dam in the ~20 000 km^2 catchment, situated in a high relief landscape with erodible soils and a history of land degradation and lost productive capacity. A subsequent dam, the Lalini Dam, will be constructed slightly lower down in the Tsitsa system. The project has been estimated to cost between R12.5 and R20 billion. Although this report deals with the Ntabelanga Dam research opportunity, the same principles (with further learnings) are foundational for the entire project. The macro-context for the project is provided by government's Strategic Infrastructure Investment Projects (SIPs) and a range of national, provincial and local strategies, plus, importantly, several of the UN's Sustainable Development Goals (the appropriate ones are listed in Appendix A).

DEA-NRM, while not being a primary research funding organization, is interested in supporting research that provides the necessary information, methods and toolkits to inform and enhance evidence-based decision-making, and support more effective ecosystem management interventions.

The construction of the Ntabelanga and Lalini dams and the associated NRM interventions present a window of opportunity which could fundamentally change the direction of development in this area. It could signal a departure from negative social-ecological linkages such as low institutional capacity, loss of ecological infrastructure, low agricultural productivity, dependence on social grants and low adaptive capacity, towards a new future, characterized by

- stronger institutional capacity
- leadership
- strategic restoration of ecological infrastructure
- more productive agriculture
- greater independence and, ultimately,
- increased adaptive capacity and resilience at multiple scales.

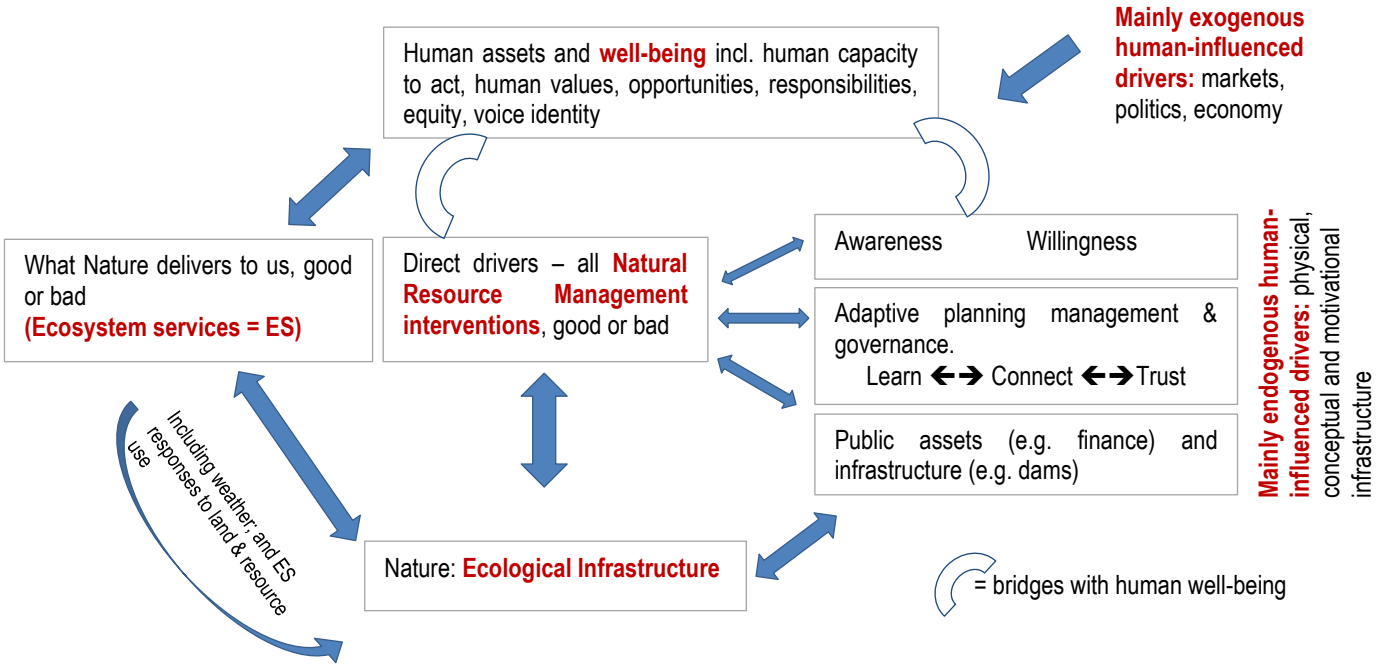
This could be achieved through quality research, high-level commitment, collaboration, good communication and leadership.

The project, when viewed through a social-ecological systems framework, consists of resources, resource users, public infrastructure providers and public infrastructure. The crucial links to strengthen are those between the resource users and the resource; and between public infrastructure providers and resource users. This is described in more detail in Figure 1 in the main document.

An adaptive and reflexive process was followed in arriving at a suite of themes and topics which are worth considering for funding. After an initial workshop in August 2014, two additional expert workshops were held in March and July 2015. At the first workshop (2015), a range of conceptual frameworks were presented and evaluated. A provisional conceptual framework, based on the Intergovernmental Programme on Biodiversity and Ecosystem Services (IPBES) of Díaz *et al*. (2015) and incorporating the Sustainable Livelihoods framework of DfID (DfID 2000), and Social-Ecological Robustness framework of Anderies *et al*. (2004) was adopted. Four broad research themes were identified: system dynamics; land degradation; livelihoods; institutions, actors and governance. A fifth theme, decision support, was later added. A subsequent meeting, with a particular emphasis on the science-management relationship in this Project, was held in November 2015, and presented an important opportunity to critique the two central frameworks once more (Figs. 6 and 8 in the main body of the report) at a thorough level, as well as other key components of this document – the suggested changes have been incorporated in this report. These two frameworks have been copied as such (with captions, but without figure numbering) into this executive summary, as has a summary table of the research themes and their main

components. The conceptual framework to promote integrated social-ecological understanding, appears first, immediately below.

Integrated Social-Ecological Framework – compact technical version



PLUS two key overarching issues to remember throughout:

1. Always think of this playing out at **multiple interconnected scales** (local …. regional …. global) and across multiple corresponding levels of governance
2. Assume a constantly changing and bumpy milieu, with thresholds and tipping points, involving history, power changes, baselines, trends and scenarios

A social-ecological systems framework for integrated natural resource management, understanding and action in the Tsitsa catchment. *At the centre of the hub in our framing are natural resource management interventions which impact on ecological infrastructure (bottom block), in turn influencing ecosystem services (left block; the reason for the curved return arrow is to remind us that sometimes certain exogenous natural happenings like floods or droughts can impact ecological infrastructure without necessarily any human involvement). The ecosystem services in the left block go on to interact with human assets and well-being in the top block. The three closely positioned blocks on the right refer to endogenous "human infrastructures/capitals" which play a key role in influencing NRM, whilst the strong arrow coming from the top right-hand corner depicts exogenous human drivers usually out of our control as local residents or actors. The bridges (open curves) designate overlaps where it may be difficult to place an attribute in one or the other block category, or the two blocks and their links may need more unpacking than shown here, in order to be clear. Two overall messages (1 and 2 at bottom) apply throughout. [More detailed caption notes appear in Box 1 in the main report, and a version using as few technical words as possible in Appendix B to the report].*

The vision adopted at the March 2015 workshop after several rounds of refinement is: *To, through applied research, support integrated landscape management that improves the sustainability of local people's livelihoods, fosters equity in access to ecosystem services and strives for more resilient social-ecological systems.*

The five research themes were further discussed in an expert workshop in July 2015, followed by consultations with DEA-NRM, WRC and DST, to produce a list of topics that fit within the conceptual framework. These were aired again at a Science-Management meeting in November 2015, where very few further changes were

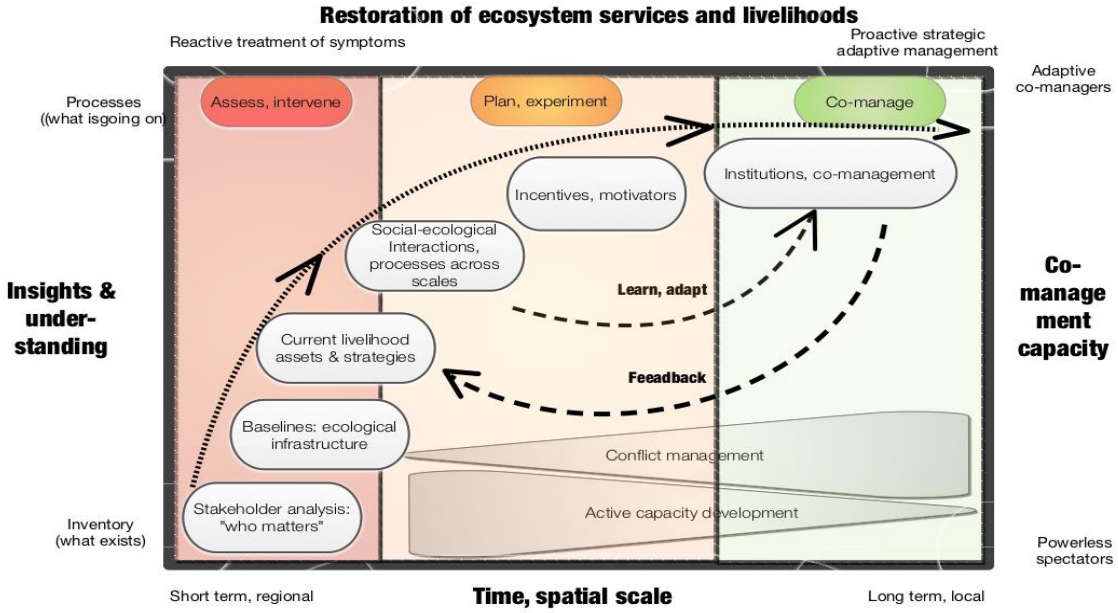
suggested. Additional information and provisional costs are provided in spreadsheet format later in the document. Topics in **bold** are immediate priorities that are both urgent and important. The summary is presented below.

Research themes and topics. Suggested priority topics for immediate funding are in bold

Theme	Research topic
1. Social-ecological system dynamics	***1.1. Driving factors and processes at different scales.*** *1.2 Understanding and predicting the capacity to self-organize and recover from shocks; capacity to learn, adapt and transform* *1.3 Past and future trajectories under different scenarios.* ***1.4 Developing and testing theories of change, incorporating stakeholder goals, drivers and trajectories of change under different scenarios***
2. Land degradation	***2.1 Capacity of ecological infrastructure to retain sediments, water and nutrients*** ***2.2 System's ability to recover to a productive state after shocks and surprise*** ***2.3 Stakeholder beliefs and perceptions of land degradation*** *2.4 Incentives and motivators that would inspire actors to adjust their land management practices.* ***2.5 Impacts of different land use and land management practices (e.g. fire; grazing; cultivation and farming practices, plantation forestry) on ecological infrastructure and sedimentation*** *2.6 Quantification of the value of ecosystem services (including tourism), with and without ecosystem restoration interventions - 'the cost of doing nothing'.*
3. Livelihoods	***3.1 Available livelihood assets*** ***3.2 Current livelihood strategies and their changes over time*** *3.3 Local well-being influenced by economic and political processes at local, national and global levels (including the impacts of non-resident land users and migrants)* *3.4 Pathways into and out of sustainable livelihoods and livelihood strategies* *3.5 Livelihood strategies and assets and their trade-offs with ecological infrastructure management*
4. Institutions, actors and governance	***4.1 Governance processes, interventions, rules and codes of conduct that exist at local, provincial and national levels*** ***4.2 Formal and informal power relations between different institutional actors and its implications for governance*** *4.3 Institutional links and disconnects between decision makers ('public infrastructure providers') and resource users, and their implications for ecological infrastructure and livelihoods* *4.4 Stakeholder perceptions and beliefs about drivers, pressures, state, ecosystem services and responses* ***[see 2.3]*** *4.5* ***Develop and maintain (and concurrently study) an on-the-ground engagement system, with an important part of its emphasis on local communities in the context of NLEIP. This system will be built pragmatically around the existing structures and realpolitik, but also skillfully promote co-construction of necessary change***
5. Decision support	***5.1 Prioritization of landscapes for ecosystem repair / restoration, priority areas for investment*** *5.2 Assessment of the effects of previous and current interventions for ecosystems and human well-being, and development of the most appropriate and cost effective interventions in different contexts* ***5.3 A monitoring system to implement adaptive management*** ***5.4 A learning and decision making system to implement adaptive management***

Theme	Research topic
5. Decision support	*5.5 Stakeholder analysis and social-ecological inventory* *5.6 Time-line and seasonal and events calendar* *5.7 Ecological baselines for critical ecological infrastructure* *5.8 Liaison and facilitation of collective action between researchers, resource users, implementers and decision makers - building on the primary engagement in 4.5 and using the principles generated by that process*

The framework to guide the implementation process (Fig. 8 in the main report) is copied below. It is loosely based on the operational frameworks proposed by Cowling *et al*. (2008) and Stringer *et al*. (2006), tailored to the Ntabelanga-Lalini SES.



Conceptual framework for implementation phases. *This operational framework depicts three phases: assessment and engagement; planning and experimentation; and co-management. The process starts with a coarse-scale stakeholder analysis, visioning, baselines of ecological infrastructure, and descriptive analysis of current livelihood strategies and assets. It then proceeds to understanding the interactions and feedbacks between elements of the SES, followed by action research on adaptive co-management which includes institutional analysis and active collaboration. Facilitation is essential, with an initial bias towards externally-driven capacity development, shifting towards more internally-driven capacitation and to an increased ability to handle conflict management. Over time, research insights evolve from understanding what exists, to understanding 'what is going on'. Thinking changes from shorter to longer term, the management of agreed-on ecosystem services becomes more pro-active and, through encouraging the use of feedbacks for learning, more adaptive in a structured and strategic way. Unsustainable livelihoods hopefully evolve through management (including at least some forms of co-management) to become more sustainable, in a way that allows a greater sense of genuine agency. [A version using as few technical words as possible is available in Appendix B].*

Operational guidelines for the project include:

1. Research is user-inspired, and feeds as directly as possible into addressing management problems with maximum information flow between users, managers and researchers
2. Researchers abide by a mutually agreed code of ethics
3. All projects are contextualized within the social-ecological systems approach and the adopted conceptual framework

4. The research group is committed to trans-disciplinary learning and reflection and to incorporating a diversity of world views and disciplines
5. There is appropriate and requisite inclusivity in access to research funding, opportunities for learning and knowledge sharing
6. All participants are committed to building relationships and trust, and promoting synergies
7. Stakeholder engagement commences early and happens throughout the process; all project participants engage with stakeholders and each other
8. Capacity building of early career researchers and students, especially those from historically disadvantaged backgrounds, is paramount.

A code of ethics needs to be developed, which must include prior and informed consent, regular communication in the local language, respect, acknowledging people's rights to land and resources, and giving preferential employment and capacity development to local communities. The code of ethics also includes communication with fellow researchers, respect for their knowledge systems and methods, and striving towards maximum synergies with them. A proposed code of ethics is provided in the main document.

This report is a first step towards defining research priorities for the Ntabelanga and Lalini Ecological Infrastructure Project. It has been made available to a wide range of users and researchers for open discussion, as well as subsequent comment and input, and amended accordingly. There is therefore reasonable-to-good agreement by technical stakeholders on the adoption of the conceptual and operational frameworks presented in this document. A more ideal (and longer, more complicated and more expensive) situation to be strived for in future such initiatives is the derivation of the key elements above, *collaboratively with resource use communities* on the ground in the catchment - something that is widely espoused yet hardly ever achieved. This project has made an early yet promising start to a stakeholder engagement process. It is now possible to check acceptability of what has been derived above to local communities living and using resources, and to assist them to garner alternatives. The principles and frameworks provide a basis for approaching forthcoming components of this project in a systemic way that is *broadly* stakeholder-influenced, and not only the result of the decisions of technical stakeholders.

We were fortunate in receiving the NLEIP Stakeholder Analysis (Part 1) just before the release of this report. We have strengthened certain points under the Research Themes because of these recommendations, and will more fully align the first full revision of this RIS - scheduled for the second half of 2017 - with the wider consequences of the learning from the ongoing stakeholder analysis.

Introduction

The purpose of this document is to develop an initial research investment strategy for the Tsitsa sub-catchment of the Mzimvubu catchment in the Maclear area of the Eastern Cape. The impetus was provided by plans to construct the tenth largest dam in South Africa, the Ntabelanga Dam, situated in a high relief landscape with highly erodible soils and a history of land degradation and lost productive capacity. The Mzimvubu Water Project aims to supply water to more than 500 000 people in the Joe Gqabi, Alfred Nzo and OR Tambo District Municipalities for household use and commercial irrigation and will include at least two dams: one at Ntabelanga and another, aimed at hydroelectric power generation, at Lalini. The combined cost of the project is estimated at between R12.5 and R20 billion, affecting a combined catchment of almost 5 000 km^2; 1 966 for Ntabelanga and 2 403 for Lalini. Several key risks have been identified for both dam projects, providing the impetus for the Natural Resource Management (NRM) Programme of the Department of Environmental Affairs (DEA) to embark on a 10 year implementation project (starting in 2014). The project's purpose is to mitigate important risks such as soil erosion and sedimentation through integrated investments in restoration and promote more sustainable land use within these catchments. DEA seeks to demonstrate that investing in, restoring and retaining high quality ecological infrastructure is the most cost-effective and socially equitable solution. The supporting research programme has a strong focus on action research to provide viable solutions and recommendations for implementation, management and collective governance – specifically in the realm of community-based resource management.

The macro-institutional context of this research investment strategy include:

a) International conventions signed by South Africa, including the Convention on Biological Diversity (CBD); the UN Convention to Combat Desertification; the UN's Sustainable Development Goals; and South Africa's commitments to the UN Framework Convention to Combat Climate Change, with DEA as a key role player. *Appendix 1 lists points of overlap with the Sustainable Development Goals.*
b) The National Development Plan, which highlights water resources infrastructure development and specifically mentions the Mzimvubu Water Project (pg..181).
c) The National Biodiversity Strategy and National Environmental Management (Biodiversity) Act.
d) Government's Strategic Infrastructure Project 3 "South-Eastern node & corridor development" (SIP-3) which includes the Mzimvubu Water Project, with the National Council of Provinces (NCOP) as a key role player.
e) The newly-conceptualized Strategic Infrastructure Project (SIP-19) on "Ecological Infrastructure" with SANBI and DEA-NRM as key role players.
f) The Wild Coast Integrated development plan, which is focused on "*building a range of pathways that assist people to strengthen the diversity of their livelihood strategies and the returns they are able to get from them, and to expand their choices*" (Robinson & Philip 2014), with the Eastern Cape Provincial Government as a key role player.
g) The Eastern Cape Vision 2030 Provincial Development Plan, subtitle "Flourishing People in a Flourishing Province", and in particular Goal 4: "*Vibrant and equitably enabled communities*" with "*facilitating integrated land management and spatial planning*" as one of its strategic actions (Province of the Eastern Cape 2014).
h) On the research side, several important partners have enlisted in various ways and are mentioned later in this report – notably at present Department of Science and Technology (DST) and the Water Research Commission (WRC).

The Department of Water Affairs' (DWA) Scoping Report for the Mzimvubu Water Project concludes: *"The Mzimvubu Water Project should thus be promoted as an integrated local development programme in which the activities in the different sectors are coordinated in order to achieve the optimum synergies between them".* (Department of Water Affairs, 2014 - now the Department of Water and Sanitation).

DEA-NRM programmes

The over-arching goal of the Department of Environmental Affairs' Natural Resource Management (DEA-NRM) programme is: "to address the threats to the productive use of land and water, and the functioning of natural systems by invasive alien species, wild fires and land degradation, as well as the opportunities for value added industries (including fibre and furniture production), whilst ensuring meaningful livelihood opportunities are supported for those employed in doing this work". This includes a range of relevant programmes as part of Government's Expanded Public Works Programme.

Working for Water aims to improve the integrity of natural resources by preventing the introduction of new invasive species; ensuring early detection of and rapid responses dealing with emerging invasive alien species; and, management of the impact of established invasive alien species.

The *Working for Ecosystems* programme aims to restore the composition, structure and function of degraded land, thereby enhancing ecosystem functioning, such as carbon sequestration, water regulation and purification.

Working for Forests promotes the conversion of invading alien plant stands, and degraded Category B and C state forests, into utilizable resources for meeting basic community needs as well as sustainable forestry land-use practices. The programme also promotes the conservation of indigenous forests.

The *Value Added Industries* and *Eco-Furniture Programme* seeks to make optimal use of the biomass cleared through the Working for Water programme, in creating work opportunities to make products that help Government to meet its needs.

The *Working on Fire* programme aims to enhance the sustainability and protection of life, livelihoods, ecosystem services and natural processes through integrated fire management.

Working for Wetlands protects, rehabilitates and enhances the sustainable use of South Africa' wetlands through interventions, incentives, disincentives, advocacy and research, based on co-operative governance and partnerships.

The structure of these programmes are well described elsewhere, e.g. www.environment.gov.za and CSIR (2015).

DEA-NRM Operational Support and Planning strategy

DEA's NRM operational support and planning strategy is founded in engaged and user-inspired research, with strong interactive links between research and management and an emphasis on capacity development. This is classical action research, defined as "*a participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview.... It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions*

to issues of pressing concern to people..." (Reason and Bradbury 2001). The focus is on practical solutions, reflection and having a meaningful impact.

The essence of DEA-NRM's evidence-based support strategy (CSIR 2015) is to promote research that addresses:

- "Assessments of the state of ecosystems and the ecological outcomes of management interventions
- Assessments of the full social-economic outcomes and impacts of these NRM interventions, including value-adding enterprises
- Prioritisation of government investments in NRM to ensure that investments are channelled in ways that will yield the greatest benefits to society
- Development of governance systems and institutional arrangements that will optimise government and private sector participation and investment in NRM and open up markets for environmental goods and services, including incentives for private sector involvement
- Advocacy to ensure that South Africans understand the benefits of NRM investments and markets for environmental goods and services
- Optimising the NRM's programme's operational efficiency and effectiveness in practicing adaptive management and administering environmental legislation".

The Mzimvubu Water Project: a window of opportunity for transformation

When systems are in an undesirable state it does not help to merely build resilience (defined as the capacity to return to a previous state, i.e. to 'bounce back'). In the case of Ntabelanga, the system needs to be capacitated and repaired to 'bounce forward', out of its present undesirable state. The next section describing the social-ecological system will provide some evidence that the study area is far from a desirable state; all indications are that the system is on a non-adaptive or maladaptive (adapting yet unintentionally worsening) trajectory. Olsson *et al*. (2004) demonstrated how leadership, and realization of a common threat, could be catalysts for transformation and resilience building in a new direction, provided that a window of opportunity presents itself. The construction of the Ntabelanga dam presents a window of opportunity which could fundamentally change the direction of development in this area. It could signal a departure from negative social-ecological linkages such as low institutional capacity, loss of ecological infrastructure, low agricultural productivity, dependence on social grants and low adaptive capacity, towards a new future, characterized by:

- stronger institutional capacity
- leadership
- strategic restoration of ecological infrastructure
- more productive agriculture
- greater independence and, ultimately,
- increased adaptive capacity at multiple scales.

The tools, knowledge and skills are available to achieve this together with quality research, high-level commitment, collaboration, good communication and leadership.

Study area

The Ntabelanga-Lalini social-ecological system

The social-ecological context can be described, using the robustness-vulnerability framework of Anderies *et al.* (2004), which has been tried and tested elsewhere (Cifdaloz *et al.* 2010; Cox and Ross 2011; Schoon *et al.* 2011). The links between resources, resource users, public infrastructure and public infrastructure providers are depicted in Figure 1.

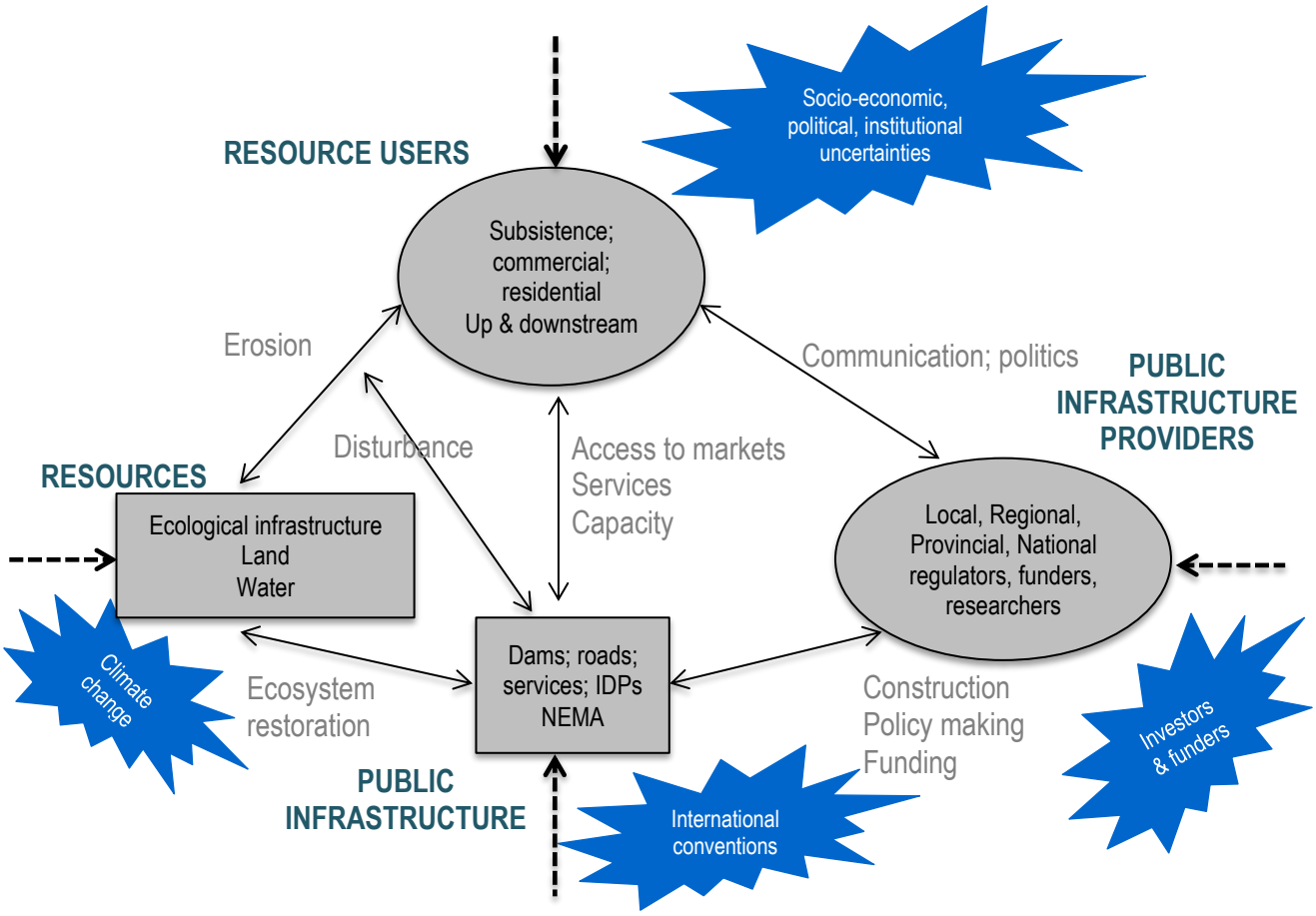


Figure 1. A generalised diagram which can be used to illustrate key social-ecological linkages, also in Ntabelanga. The diagram is adapted from and the terminology follows that of Anderies *et al.* (2004).

Resources

The study site falls within Sub-escarpment Grassland and Sub-escarpment Savanna Bioregions. Vegetation types include the Bisho Thornveld, Drakensberg Foothill Moist Grasslands, Eastern Valley Bushveld, Eastern Griqualand Grassland (vulnerable), Mthata Moist Grassland (endangered), and Southern Mistbelt Forest (Mucina and Rutherford 2006).

Habitat units include rocky outcrops, montane grassland, pockets of Afro-montane forest, Acacia savannah and, important to DEA's intervention, wetlands and riparian zones with pockets of highly erodible soils, especially on abandoned cultivated lands. Using digital elevation and sediment yield data, Le Roux *et al.* (2015) estimated sediment yield from gully erosion in the catchment around the dams (T35) to be 22.4 t/ha/year with a total sediment output of almost 10 000 000 t/year. They predicted the life expectancy of the dam to range from 34 to

49 years without siltation prevention measures (Le Roux *et al*. 2015). Siltation prevention measures could substantially increase the life-span of the dam with major direct economic benefits: every 5% increase in the life-span of the dam could save roughly R1 billion in 2015 currency.

Ecological infrastructure is the greatest natural asset to the social-ecological system. It not only protects the direct benefits from ecosystems, such as fertile soil for agriculture, but also safe-guards people and ecosystems against natural disasters such as floods, fires, wind and droughts. Ecological infrastructure provides three main functions to human well-being: *provisioning services*, e.g. water, productive grazing, cultivated crops, firewood, building materials and medicinal plants; *cultural services* – identity and place attachment; and *regulating services* such as sediment retention, water absorption, flood regulation and drought resilience. In the case of the Ntabelanga and Lalini dams, the most valuable ecological infrastructure is robust, fertile soils that can resist erosion and provide a basis for improved agricultural production. The further degradation of ecological infrastructure in these catchments is the greatest threat to the adaptive capacity of people and ecosystems. The robustness of ecological infrastructure can be enhanced by increasing the natural vegetation cover, improving the organic content of soils, restoring wetlands, and protecting the banks of rivers and riparian zones.

The sub-catchments involved include T35 A-M (Figure 2), and the Ntabelanga dam will be situated in T35E and the Lalini in T35L.

Resource users

- Communities are spread out over several municipal areas:
    - Joe Gqabi District Municipality (DC14) – Elundini Local Municipality (EC141);
    - O.R. Tambo District Municipality (DC15) - Nyandeni Local Municipality (EC155); Mhlontlo Local Municipality (EC156)
- An area of 55 km^2 will be inundated (40 km^2 by Ntabelanga and 15 km^2 by Lalini), including 62 dwellings, public infrastructure and arable fields (Figure 2).
- Initially, 539 000 people will be affected in various potential ways (positively and negatively), increasing to 790 000 people later.
- An irrigation scheme of 2 900 ha is planned near Tsolo.
- Preliminary work in the area suggests that many people do not understand or admit to the anthropogenic causes of land degradation and erosion.
- Population densities range from 14 (Joe Gqabi DM) to 110 people / km^2 (Alfred Nzo DM)
- High HIV/Aids prevalence; high proportion of female-headed households; high dependence ratios.
- Mostly negative population growth rates due to urbanization. However, many owners of land and livestock are absent and levels of migrant labour are high.
- Low economic activity – mostly agriculture (sheep, cattle) with a low proportion (<20%) of fields being cultivated.
- High expectations of improved livelihoods linked to the dam – almost all public comments linked to the EIA process are expressions of interest for work.

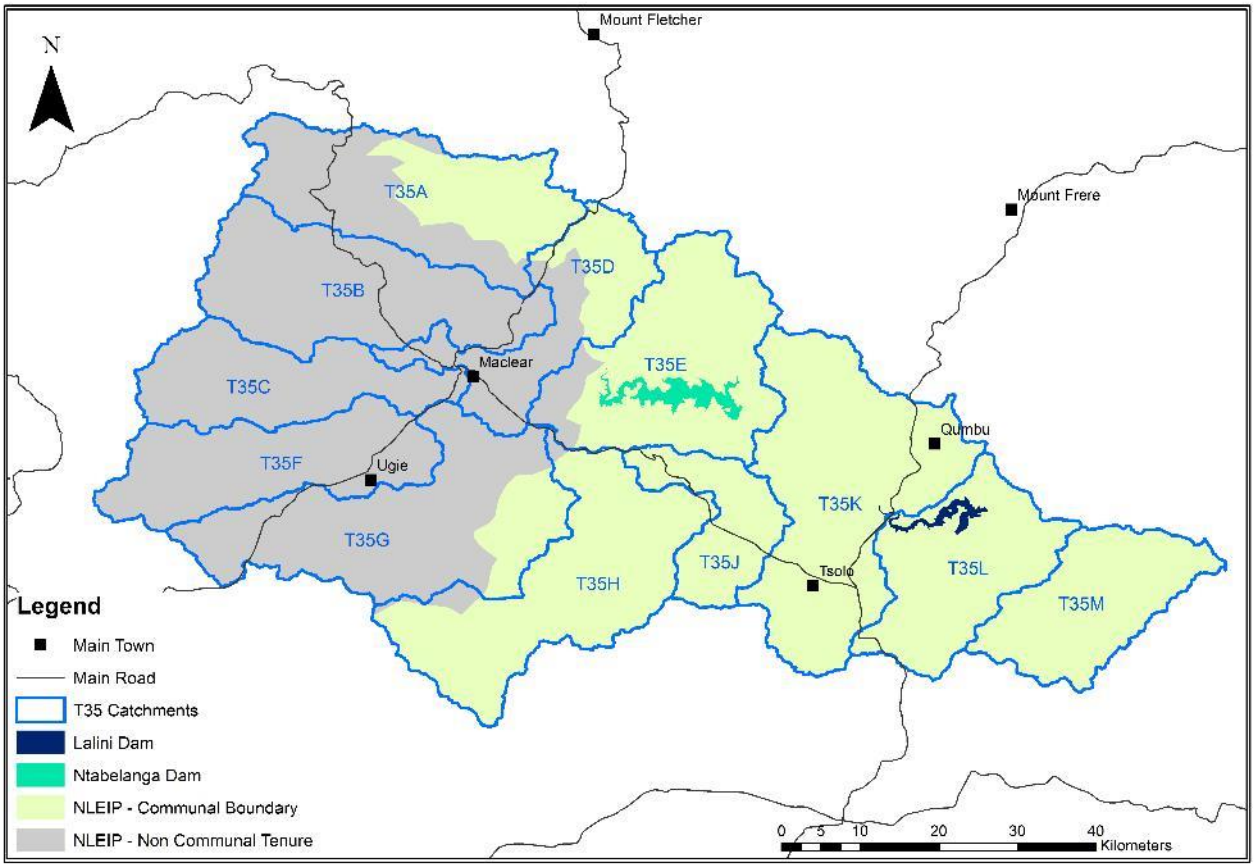


Figure 1. Sub-catchments of the Upper Tsitsa River and the NLEIP

Public infrastructure providers

National government departments include Department of Water and Sanitation (DWS); Department of Environmental Affairs (DEA); Department of Rural Development and Land Reform (DRDLR) as well as Department of Agriculture Forestry and Fisheries (DAFF). Provincial departments include the Department of Agriculture and Land Affairs; Provincial Department of Economic Development, Environmental Affairs and Tourism; three district municipalities and five local municipalities (identified in the previous section outlining the resource users). The Expanded Public Works Programme (EPWP) is a major provider of public infrastructure. The forestry industry and individual farmers are additional providers of public infrastructure such as road networks, shops, fire-breaks and fences. Research is a form of public infrastructure provision, provided in this study by the Universities of Fort Hare, Rhodes, Free State, and in future also the Walter Sisulu University, and the Agricultural Research Council and private consultants. Research strategies and funding provided by DEA-NRM, WRC and DST.

Public infrastructure

Public infrastructure is weak but improving due to bulk water and electricity provision. Land tenure insecurity is a major challenge. The Ntabelanga Dam will catalyse a massive injection of public infrastructure into the region, accompanied by new roads, communication infrastructure, bulk water provision, skills and expertise. New markets will emerge for agricultural produce and ecosystem services. Restored and repaired ecological infrastructure, for example wetland and riparian zone restoration, soil conservation and gully stabilisation are major sources of public infrastructure.

Policies are part of public infrastructure. Relevant policies include the National Development Plan with Strategic Investment Projects (SIPs), including the Mzimvubu Water Project; the National Water Resources Strategy and National Water Act; the National Environmental Management (Biodiversity) Act and the National Environmental Management Act; the Wild Coast Integrated Development Plan; the Conservation of Agricultural Resources Act; and Eastern Cape Vision 2030 of the Eastern Cape Planning Commission.

Research strategies appropriate for complex adaptive systems

Complexity research that links directly into use and management must enable researchers and decision makers (public infrastructure providers) to work more efficiently and effectively and has at least 12 defining characteristics. It:

i. Adopts a social-ecological systems perspective.
ii. Incorporates diverse knowledge, world views, goals and aspirations of stakeholders.
iii. Defines the social-ecological context in an integrated manner, e.g. social and ecological history; social relations between actors and organizations; available social, human, financial, physical and natural assets; historical and contemporary interventions; livelihood strategies; and local knowledge.
iv. Identifies critical ecological, social, human, financial, physical and institutional assets,
v. their thresholds of potential concern or limits of acceptable change and
vi. the feedbacks from and to the immediate as well as root causes of change,
vii. at multiple scales.
viii. Identifies the societal benefits and values of future conditions, to
ix. assist with focusing on a desirable future condition, i.e. a concrete vision and goals.
x. Identifies social, financial, institutional and ecological barriers and bridges to the attainment of the most desirable future condition. (An important and often overlooked social barrier is the “disconnection” between humans and Nature that has taken place over the last seventy years due in no small measure to Apartheid betterment policies).
xi. Promotes co-identification and testing of management strategies and interventions that would overcome the barriers and promote attainment of project goals (for instance, a healing process to deal with the past will likely be very helpful).
xii. Incorporates regular reflection, learning, adaptation, re-visioning and co-design amongst all stakeholders.

Methods in searching for an appropriate conceptual framework

The challenge is to identify conceptual framework(s) that encapsulated the 12 principles outlined above, and to refine the framework during the course of the project.

Literature survey of conceptual frameworks

A literature review was conducted of appropriate conceptual frameworks for social-ecological systems. A table of their strengths and weaknesses was then constructed. A group of experts then evaluated and refined the frameworks, to produce a provisional framework founded in social-ecological systems principles.

Co-formulating a vision

At a planning workshop facilitated by DEA-NRM in Maclear August 2014 an initial vision was formulated. This vision was refined and presented at a March 2015 meeting as:

"To optimise restoration and land management practices to ensure a sustainable and resilient state to optimise the quality of water delivered by the Ntabelanga and Lalini Dams."

The vision was interrogated further and revised to represent a new, more people-centred paradigm:

"To support sustainable livelihoods for local people through integrated landscape management that strives for resilient social-ecological systems and which fosters equity in access to ecosystem services."

There are therefore 4 core elements to be striven for throughout:

- Sustainable livelihoods for local people
- Integrated landscape management
- Resilient socio-ecological systems
- Equity in access to ecosystem services.

A process framework proposed by Cowling *et al*. (2008) was adopted regarding the mainstreaming of ecosystem services. Initial assessments of regional land cover change and sediment flow were conducted. Thereafter a framework, strategies and priority projects were co-created by a moderately small yet representative groups of researchers, policy implementers and practitioners.

Co-creating a framework and strategy

The framework and strategy was incrementally refined over a nine month period in four design workshops. The first subsequent full workshop took place on 6 March 2015. Its purpose was "to develop a provisional conceptual framework to inform research and engagement priorities for the Ntabelanga catchment", with a refined vision as an unintended positive outcome. Forty three (43) officials, managers and researchers directly involved in NRM projects and programmes attended it. The workshop commenced with presentations by DEA-NRM about the study area and progress to date, followed by a general discussion. Thereafter, participants presented a variety of relevant conceptual frameworks for consideration. Participants then formed break-away groups consisting of 5-8 individuals who discussed four topics: **livelihood strategies**; **actors**, their **institutions and governance systems**; **ecosystem degradation** processes; and tangible **assets** available to local people. Participants then

re-convened to present their deliberations and recommended a conceptual framework which they deemed appropriate for the challenges their group identified. The workshop ended with a synthesis and recommendations for a provisional conceptual framework. A workshop report was circulated to participants who were asked to provide comments and feedback.

A second workshop, on 21 July 2015, was attended by 13 researchers and practitioners. Its aims were to clarify research commissioned to date; re-visit and finalize the vision and conceptual framework developed on 6 March; develop a first-order research investment strategy for Ntabelanga that would lay the foundation for further refinement and consultation with the broader research community and decision makers; identify priority research thematic areas for Ntabelanga-Lalini; and identify a set of priority research questions. The workshop was facilitated in four steps. First, best available knowledge and information about the Ntabelanga and Lalini Ecological Infrastructure Restoration project and Tsitsa catchment was presented, with a focus on progress that has been made since previous meetings. Information on existing and on-going research projects was presented. Second, a facilitated open discussion took place. Third, the provisional integrated conceptual framework was presented for discussion and possible refinement. Finally, participants convened in smaller groups to discuss priority research questions linked to four themes: livelihoods; degradation; actors and institutions; and assets; and to assess whether the main elements of the conceptual framework had been covered by the research questions and themes.

During a third workshop, on 21 September 2015, the refined yet provisional conceptual framework and set of priorities were presented to DEA middle managers, project managers and potential co-funders. Further input was obtained, leading to another round of refinement.

A Science-Management Forum for this Programme was run in late November 2015 and well attended. It had the brief, amongst others, of definitively critiquing this report, especially the frameworks. This led to a few important changes also in content and presentation.

Field visits

During a visit to the Ntabelanga catchment the authors and Rhodes project manager (Mike Powell) met with DEA-NRM project managers who work on the ground and assessed the social and ecological features of the study area. This provided a good overview of the logistical challenges, geographic footprint of the study site, infrastructure and landscape features.

Consultations

DEA project managers involved in research and implementation of NRM were continuously consulted and informed, and future consultations with NRM managers, decision makers and the research community are being planned. This included two face to face meetings and consultations during the field visit and regular telephonic interaction.

A consultative meeting with DEA-NRM project managers, Department of Science and Technology (DST) and the Water Research Commission (WRC) on 21 September 2015 was facilitated to obtain additional inputs into research frameworks and priorities. The meeting was also aimed at promoting coordinated funding priorities between DEA, DST and WRC. At this meeting the provisional conceptual framework was displayed in poster form, and all meeting participants were asked to stick their two most immediately important research topics in appropriate places on a conceptual framework (Figure 3). These were taken into consideration in the refinement

of Tables 2-6 (summarized in Table 1) and will need to be updated as new insights emerge when the research programme deploys under DEA-NRM, DST, WRC and other emergent funders.

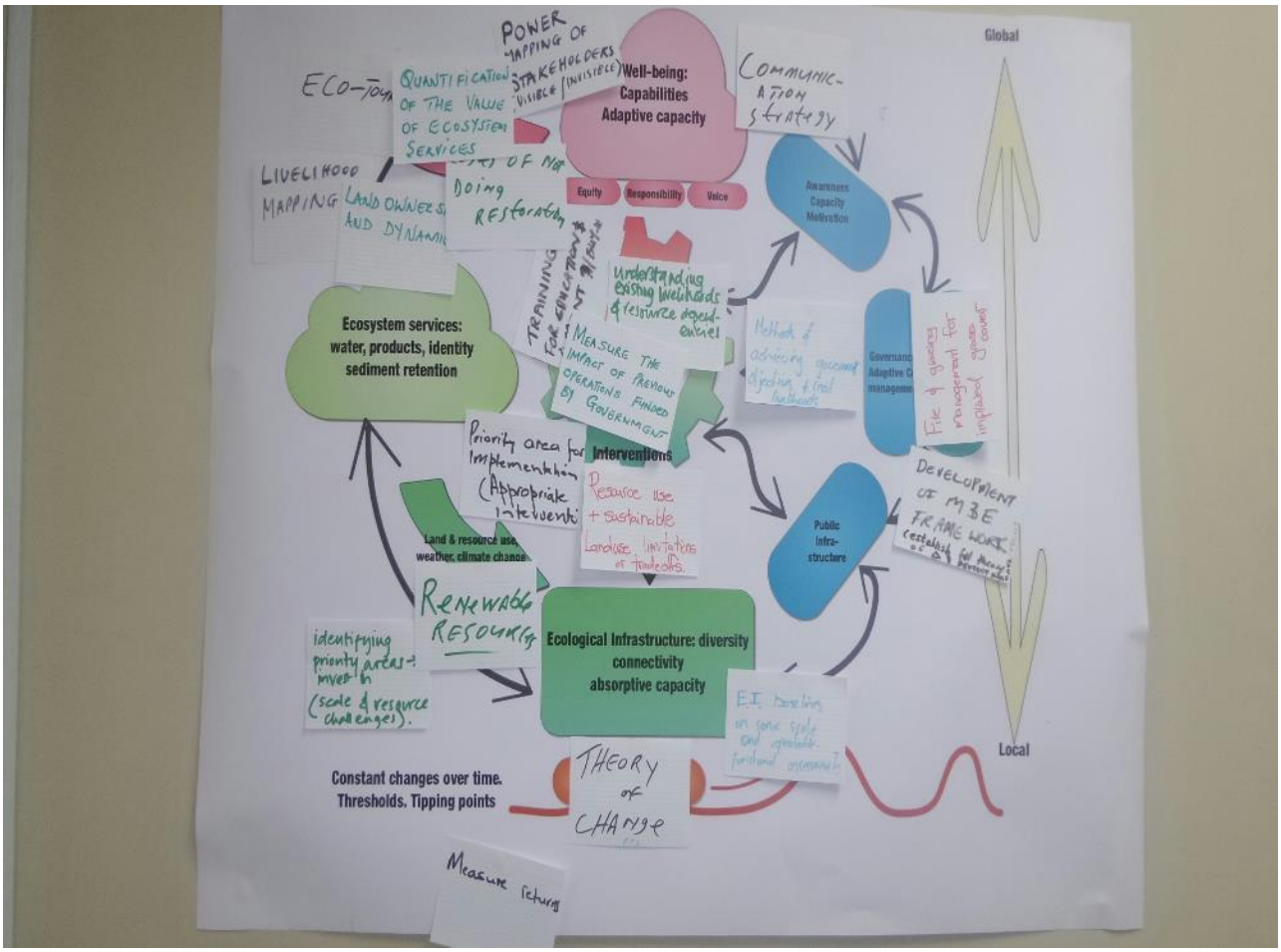


Figure 3. Draft conceptual framework as available then, with priority research issues pasted onto it by participants at the consultative meeting of 21 September 2015.

This intuitive response from the senior persons attending the meeting produced multiple pointers, in rough order of popularity below.

- Measuring impacts, which includes the necessity of obtaining adequate baselines for ecological infrastructure, an overall monitoring and evaluation system, measuring impacts of previous such initiatives, measuring returns on investment, and refinement/clearer articulation of the theory of change
- Quantification of ecosystem services, possibly linkable to livelihood mapping, resource dependencies, and trade-offs and limitations in resource management in the area
- Greater clarity on prioritisation of both research funding and implementation
- Land ownership and dynamics, possibly linkable to visible/invisible overall power mapping of stakeholders
- Training and education for understanding and buy-in, along with an overall communication strategy.

Several other points came up as individually-raised issues:

- Ecotourism (individual raising this kept saying it was being overlooked by the project)
- Particular attention to *methods* that government requires to reach these objectives, esp. the ultimate goal - livelihood improvement (this will overlap with some of the above)
- Cost of NOT carrying out this program
- Fire and grazing management as key.

Although this exercise and analysis can be criticised for being superficial, we should not underestimate the distilled experiential value of a group of senior staff from the key agencies supporting this program. The analysis shows, when all their opinions as to immediate priorities are taken together (after their considerable joint exposure in the development of the program) that the issues they raised needed attention from early on. No single silver bullets appeared.

Iterative refinement

The research strategy is designed to be refined in a cyclical manner through constant consultation, reflection and refinement (Figure 4). The feedback arrow is an important step in the process. This theme (cyclical refinement) was taken further at a Science-Management Forum meeting in November 2015, where principles of strategic adaptive management were discussed, with the use of additional diagrammatic material, available in those minutes. This Forum meeting did not only focus on research prioritisation, but also dealt with ways in which researchers and managers might gainfully interact ('dance together' was one simple metaphor used) on a continuous basis as the Programme takes off. The evolution of the conceptual framework is summarized in **Appendix B.**

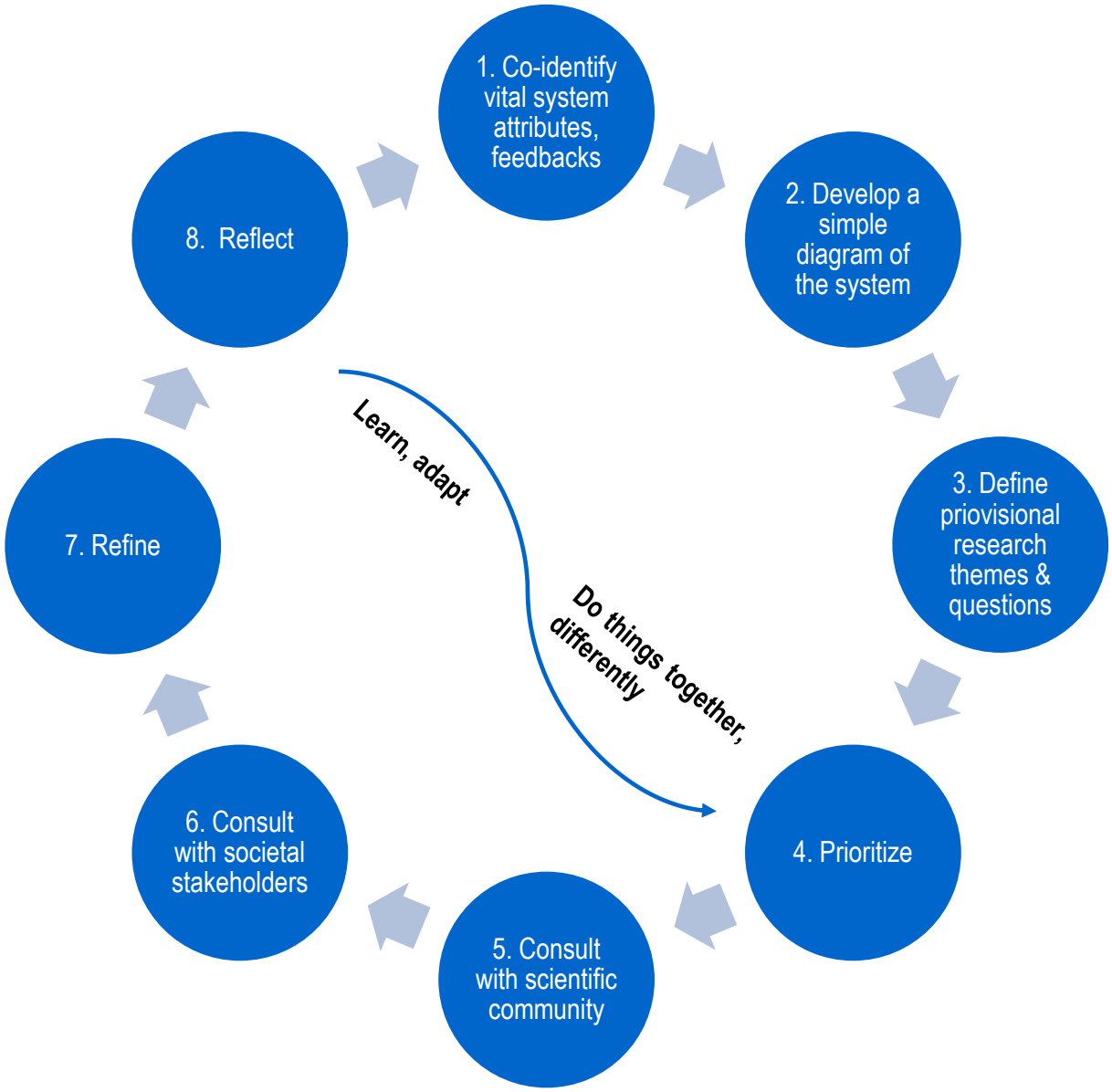


Figure 4. The adaptive process of research prioritization.

Selecting a conceptual framework: key features to consider

Shared conceptual frameworks are essential in complex, multi-stakeholder contexts such as collaborative integrated catchment management (Allen *et al*. 2011). Their purpose is to provide space for shared 'mental models' (Du Toit *et al*. 2011) and to act as an umbrella which improves communication, promotes shared epistemes (meaning justified knowledge – how the holder got to that belief) and provides common ground (Díaz *et al*. 2015) for interaction between researchers, public infrastructure providers and resource users (*sensu* Anderies *et al*. 2004).

An appropriate framework for the Project should be compatible with the objectives of applied, user-engaged complex adaptive systems research. This is no trivial undertaking: a host of frameworks have been reviewed (e.g. Tomich *et al*. 2010; Fortuin *et al*. 2011; Chapman 2014; Fisher *et al*. 2014). In the context of collaborative catchment management, an appropriate framework should promote six key objectives: i) convert research into use; ii) promote trans-disciplinarity and multiple knowledge systems; iii) integrate links and feedbacks between system components (resources, resource users, governance and public infrastructure providers); iv) incorporate linkages and feedbacks from and to other spatial and temporal scales; v) be sensitive to non-linear, abrupt change; and vi) promote learning and adaptive refinement.

i) Conversion of research into use

An appropriate framework should be accessible to managers and resource users and accepted by them. It should promote feedback between strategic and operational decision making and research as well as learning. The best frameworks are co-designed by researchers and practitioners (Caudron *et al*. 2012) and programmes may fail during implementation stages if this aspect is neglected (Lombard *et al*. 2010).

ii) Trans-disciplinary research and praxis[1] and multiple knowledge systems

Trans-disciplinarity is promoted through boundary objects (an object different communities might, perhaps especially initially, use in slightly or very different ways e.g. a map) such as shared conceptual frameworks, and through respect for other knowledge and partly shared identities. A well-understood conceptual framework enables each discipline to acknowledge the shortcomings of isolation and the strengths when insights are combined (Mattor *et al*. 2013). Jahn (2012) summarized this beautifully in Figure 5, modified slightly here.

According to Jahn (2012), trans-disciplinarity starts with a common problem: in this case, the problem can be framed, for instance, as a fundamental problem of too many people on too little land; as land use practices that fail to conserve ecological infrastructure and ecosystem services; as land degradation and its proximate impacts on human well-being; and, from a water security perspective, rapid siltation of the dam resulting in premature failure of the Mzimvubu Water Project. The scientific problem can be framed as: understanding the negative linkages and feedbacks resulting in a maladaptive (non-adapting and worsening) pathway and how to transform them to positive linkages that result in a change in trajectory, towards an adaptive pathway. The joint problem leads to production of new knowledge, stimulated by societal and scientific discourses. This ultimately feeds back to changed scientific and societal practices. This is what the Ntabelanga and Lalini Ecological Infrastructure Project Research Investment Strategy should try to achieve.

[1] Praxis is the actual putting into practice of knowledge, often taken to imply an ongoing two-way interaction between theory and action.

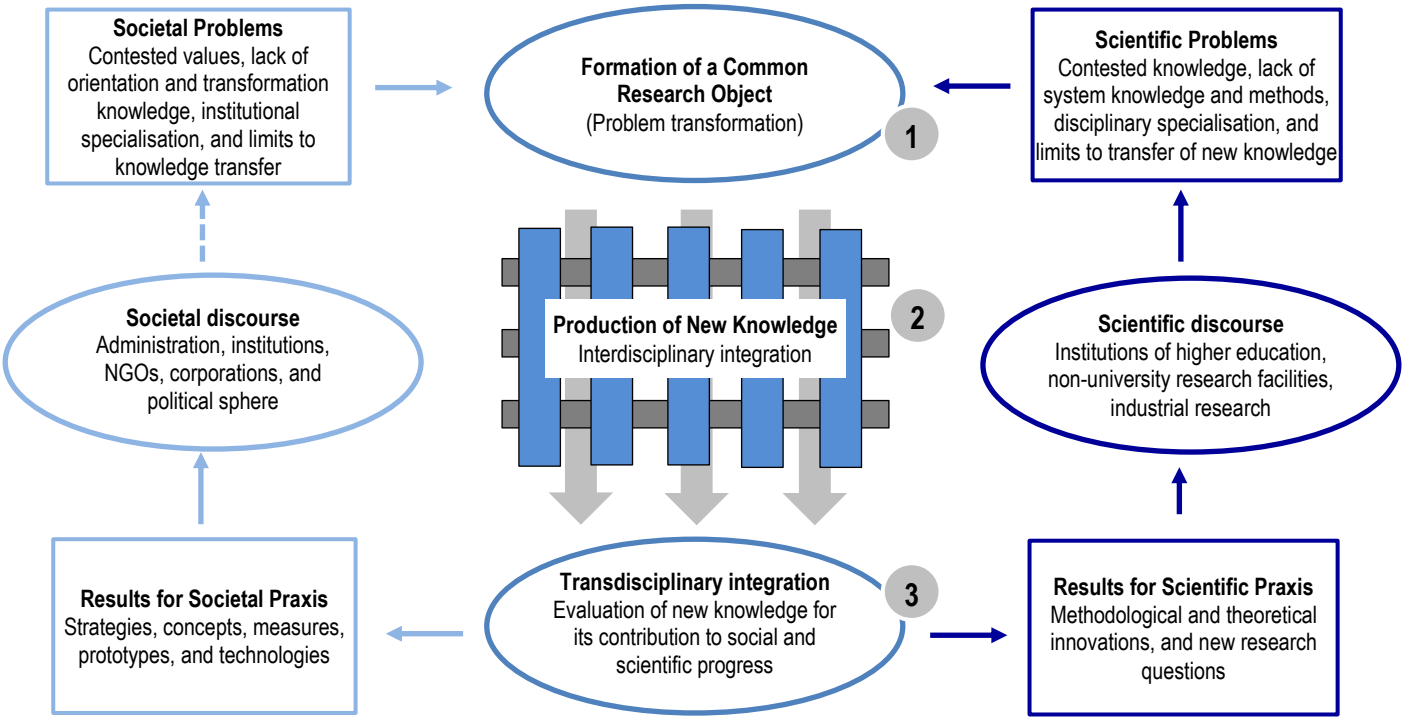


Figure 5. Trans-disciplinarity starts with a common problem, which leads to the production of new knowledge (inter-disciplinarity) and culminates in trans-disciplinary integration, with benefits for societal and scientific praxis, from Jahn (2012).

In practice this implies allowing space for different knowledge systems (inter-disciplinarity), including local and traditional knowledge, to contribute to the evidence base. It also means that the community facilitation and research engagement processes should be closely coupled and constantly interact, paving the way for trans-disciplinary integration. A further implication is that objects and processes that can bridge the divide between different disciplines and knowledge systems should be at the forefront, and visible (Mattor *et al*. 2013). Such objects may include place-based images and metaphors, for example maps and photographs; shared stories and experiences; a logo that everyone can relate to; and, at a deeper level, a conceptual framework of which everyone should understand and feel part.

iii) Links and feedbacks between system components

The elements of social-ecological systems constantly interact, and these interactions are critical to understand the system's dynamics and its self-organizing processes. It is often the interactions, rather than the properties of system elements, that provide answers to the question: "what is really going on here". Cifdaloz *et al*. (2010), for example, demonstrated the importance of understanding the interaction between public infrastructure providers and public infrastructure in comprehending the dynamics of an irrigation system.

iv) Feedback across scales

Interactions and feedback *across* scales can have major impacts on local events. Changes or shocks which take place at finer and/or coarser scales than the focal scale can create surprises at the focal scale if these links are not foreseen and the possibility of such surprises monitored (Allen *et al*. 2014). Global political, climatic and economic events, for example, can have cascading impacts on local livelihoods while individual or household factors such as crime or illness can cascade upward and impact the entire system, especially when multiple events coincide and collide. It is therefore important that conceptual frameworks should include more than one

spatial and temporal scale, and focus on a scale above, and below, the focal scale respectively (Olsson *et al*. 2006).

v) Non-linear abrupt change

When systems cross thresholds, change can be abrupt and surprising. Rocha *et al*. (2015) demonstrated that the drivers of these abrupt shifts often operate at the global scale, with profound impacts on local people's lives, especially when abrupt change is overwhelming. When resilience is low systems then 'collapse' and underlying properties of systems change irreversibly. It is therefore important that monitoring systems incorporate non-linear change in models and frameworks. Monitoring need to come to grips with thresholds of potential concern and the system's capacity to adapt or re-organize in response to different intensities of shocks (Biggs *et al*. 2011).

vi) Learning and adaptive refinement

Frameworks for complex adaptive systems research should be flexible enough to enable their refinement when new insights and knowledge become available. This should be done with the participation of users, decision makers and managers. To prevent confusion, frequent, transparent and accessible communication is essential. This is a crucial function of both the conceptual and operational framework.

Examples of complex adaptive systems frameworks

Social-ecological systems (Oström 2009)

This framework is essential to identify and understand the key interactions between governance, resource users, resources, resource systems. Most of the resources and resource systems are common pool resources; governance is therefore important to prevent 'tragedy of the commons' (Hardin 1968) scenarios. Benefits and incentives are important to motivate people for long-term sustainable land use practices and it highlights the importance of a (spatial and temporal) multi-scale approach (Oström 2009).

Robustness and vulnerability of institutions (Anderies *et al*. 2004)

This framework is intended to aid understanding of and depict the interactions between four elements of social-ecological systems: resources, resource users, public infrastructure providers and public infrastructure, in the management of common property systems. It focuses on linkages and feedbacks between these elements, and assesses the functionality of these links in the context of vulnerability or robustness of the system as a whole. It also suggests design principles for robust social-ecological systems.

From coping actors to adaptive co-managers (Fabricius *et al*. 2007)

This framework, based on a large sample of community-based assessments of the Millennium Ecosystem Assessment (MEA) demonstrates that without appropriate institutions, leadership, enabling policies and minimum endowments people remain trapped as powerless spectators, or may at best become 'coping actors'. Adaptive co-management is a desirable state, which requires a major investment in institutional development (Fabricius *et al*. 2007).

Sustainable Livelihoods framework (Carney 1998)

This framework emphasises people's vulnerability in local contexts and focuses on governance as a crucial element. Livelihood assets are more than just finances and natural resources but also social and human assets and physical infrastructure. The multiple dimensions of livelihoods (Donohue and Biggs 2015) provide new insights into risk, vulnerability and adaptive capacity linked to livelihoods and poverty (Carney 1998; DfID 2000).

IPBES framework (Díaz *et al*. 2015)

The IPBES framework, used by the Intergovernmental Programme on Biodiversity and Ecosystem Services (IPBES), responds to a global acknowledgement of complexity. Its foundations are in the Millennium Ecosystem Assessment conceptual framework, which in turn has its roots in the classical Driver, Pressure, State, Impact, and Response (DPSIR) conceptual model. The IPBES diagram focuses on multiple knowledge systems and interactions across multiple scales, and is intended to be the 'common language' for integrated ecosystem assessments world-wide. It represents the elements of nature and society that are at the main focus of the Platform. Inclusive categories should be intelligible and relevant to all stakeholders involved and embrace western science as well as other knowledge systems. The interactions between the elements change over time and occur at various scales in time and space. Factors acting at finer and coarser scales than the focal scale influence the system.

Examples of operational frameworks

Conceptual frameworks need to be supported by operational frameworks that outline ways and sequences of doing, reflecting and learning. Three operational frameworks were considered: cycles of sustainability research, used in the context of participatory monitoring by Stringer *et al*. (2006); an operational model for monitoring and evaluation of social-ecological systems (Chapman 2014) and an operational model to mainstream ecosystem services into planning proposed by Cowling *et al*. (2008).

Cycles of sustainability research (Stringer *et al*. 2006)

Stringer *et al*. (2006) outlined a cyclical process for engaging with communities to develop indicators based on local and scientific knowledge. They suggest starting with defining system boundaries before establishing goals and visions, identifying current practices and knowledge systems, and identifying indicators before establishing baselines, thresholds, monitoring change and reflecting.

Monitoring and evaluation of adaptive co-management (Chapman 2014)

Chapman (2014) developed a framework that incorporates six processes: program need, program activities, pathway processes, moderating processes, outcomes, and program value.

- "Need" includes identification of key resources, ecosystem services and livelihood assets.
- "Program activities" involves a description of the programme's operations, e.g. hectares restored; change in the proportion of agricultural fields being cultivated; number of village management committees that regulate natural resource use.
- "Processes" include mediating and moderating factors, exogenous and endogenous factors that may affect outcomes. It may include evidence of joint decision making; awareness; self-organizing activities; as well as external processes such as rainfall, changes in markets, and political and economic drivers from outside the system.
- "Outcomes" refer to the goals of ecosystem restoration to improve livelihoods and reduce sediment yields to increase the life-span of the proposed dam.
- "Values" include improvements in livelihood assets, ecosystem services and human well-being and can be tangible (cash equivalents) or intangible, and direct or indirect.

Operational model for mainstreaming ecosystem services for implementation (Cowling *et al*. 2008)

The Cowling *et al*. (2008) model outlines three phases: assessment; planning; and management. The model describes a process to arrive at an end goal: management for resilience by empowered local stakeholders. The

assessment phase starts with a social assessment, followed by a biophysical assessment that is user-inspired, and which explicitly documents changes in resources that matter to stakeholders rather than abstract and top-down assessments. The valuation sub-component focuses on monetary and non-monetary benefits, and should focus on values assigned by local people to inform decisions about land use, and priorities for implementation of restoration activities. Finally, opportunities and constraints for implementation are collaboratively identified. This could include scenario exercises and facilitated dialogues where participants become aware of alternative possibilities and futures.

The *planning* phase involves collaborative identification of strategies to achieve desirable outcomes by experts and non-experts. Scientists are "enablers" and do not normally give instructions and neither tell, nor sell. Strategies should aim at generating both long term benefits and short term gains to keep role players motivated. The mainstreaming sub-component of planning ensures that strategies are incorporated in land use plans and, in the case of Tsitsa, Integrated Development Plans and provincial development strategies. Flexibility and responsiveness to windows of opportunity should form part of the mainstreaming strategy. The *management* phase involves an adaptive, 'learning by doing' process with constant reflection, learning and feedback. Research, monitoring, social facilitation and management are complementary elements of management and implementation. Learning groups and communities of practice, led by key individuals, are important for adaptive co-management to succeed (cf. Roux and Foxcroft 2011).

Provisional conceptual framework for the Research Investment Strategy

Evolution of the conceptual framework

After considering the criteria for effective conceptual frameworks and the possible options at the 6 March 2015 workshop, participants in the July 2015 workshop greed on a hybrid framework with its foundations in the Millennium Ecosystem Assessment and Intergovernmental Programme on Biodiversity and Ecosystem Services frameworks (IPBES), the social-ecological systems framework of Anderies *et al*. (2004) and Oström (2009), and the Sustainable Livelihoods framework of DfID (2000). This provisional conceptual framework was then presented at the July 2015 workshop and further refined, based on more detailed inputs received. The refined version was presented at a 21 September 2015 workshop with decision makers and funders. Following presentation and inputs received from participants at the Science Management Forum in November 2015, the most recent version of the conceptual framework was developed (Figure 6). The various conceptual frameworks developed during the process and their iterative refinement over a 9-month period are presented in **Appendix B**. The next section below sketches important caveats of which the readers should take note.

Dealing with varying needs and levels of co-construction and understanding of the frameworks

At the November 2015 meeting a big issue was made of the fact that this document (including the two key conceptual frameworks) had indeed been almost entirely the product of the work of technical stakeholders. The assertion was made that "nobody from the catchment was present". Another assertion was that there was an imbalance in funding allocated to technical research and community engagement. On the one hand there is the intention to conduct research that would involve and benefit local resource users and, paradoxically, inadequate investment in stakeholder engagement which everyone agrees should be included from the outset. [Fortunately a stakeholder survey and analysis, which was presented at that workshop, has subsequently begun]. If this Project is indeed serious about community participation and local benefits then the stakeholder engagement component needs to be strongly and continuously nurtured into the future.

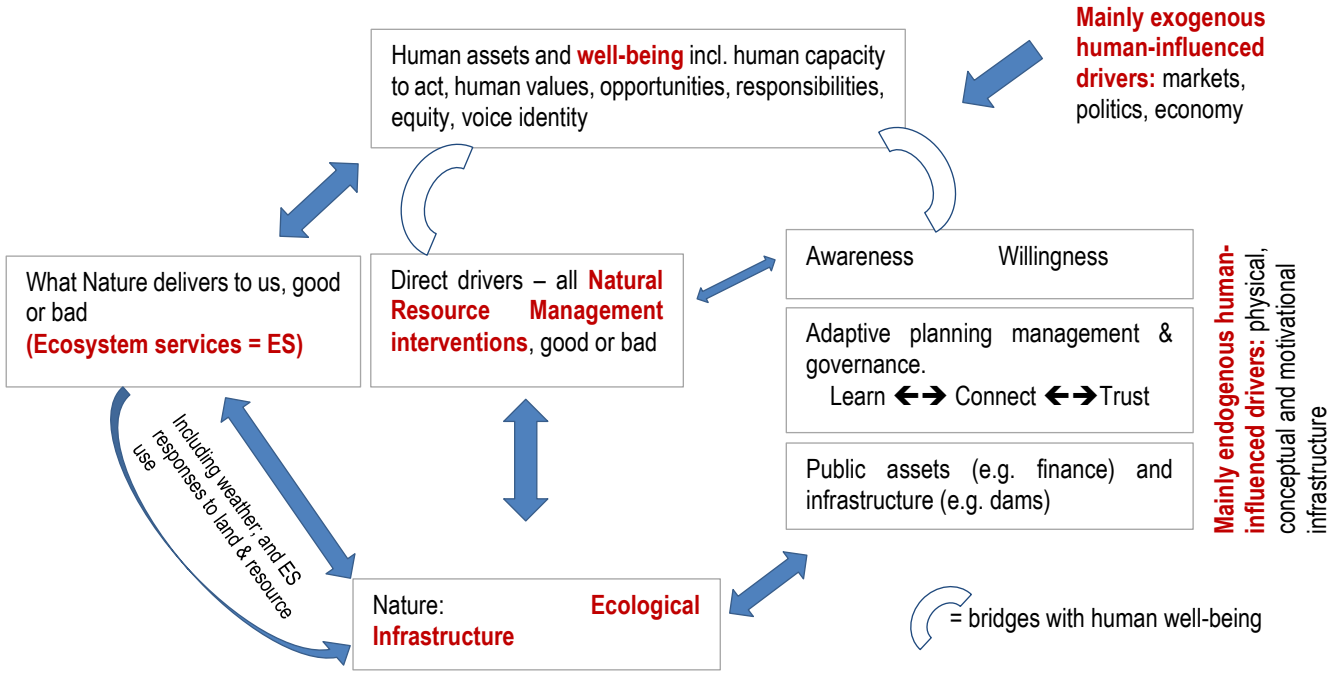
Bridging the gap between different stakeholders' knowledge and understanding

The captions to Figures 6 and 8 use several technical terms and the vocabulary can be considered of moderate technical complexity. Nevertheless, many participants in the November 2015 workshop mentioned the unnecessary esoteric jargon and long captions to the Figures 6 and 8, whilst others appeared to understand the need for rigorous academic framing and the need for readers to apply their minds in detail. It is accepted that Figures 6 and 8 were drawn by technical people but ones indeed concerned with the catchment and the well-being of its residents. In spite of this debate there was near unanimity amongst meeting participants around the validity, acceptability and usefulness of the frameworks per se – the issue was about their accessibility and technical origins.

To help to some extent bridge this gap, the same diagrams but with more everyday vocabulary, some of it from other knowledge systems, feature in **Appendices C and D** respectively. The figures in these appendixes and the accompanying explanation may prove helpful to researchers attempting to explain what technical folk were thinking, to a wider group – of e.g. resource users or grassroots practitioners. Some readers of this report may

even find themselves making use of the more everyday labelling in the appendices, which all will illustrate that we have reached a wider readership more comfortably.

At the other extreme, it is possible to include far more technical detail, as exemplified by the caption and particularly the supporting body text in Díaz *et al*., 2015, the original inspiration for this. Because of the centrality of the SES framework in the figure above, the caption in Appendix C provides ***more detail*** than the caption, for those interested in augmenting understanding with examples of issues rather than simply the process outline. Such persons may want to also read the full Díaz *et al*. 2015 as well, bearing in mind that the publication is generic, and not tailored to our situation or scale. **Box 1** provides a schematic example of the evolution of possible SES configurations, historically and in future.



PLUS two key overarching issues to remember throughout:

1. Always think of this playing out at **multiple interconnected scales** (local …. regional …. global) and across multiple corresponding levels of governance
2. Assume a constantly changing and bumpy milieu, with thresholds and tipping points, involving history, power changes, baselines, trends and scenarios

Figure 6: A social-ecological systems framework for integrated natural resource management, understanding and action in the Tsitsa catchment.

At the centre of the hub in our framing are natural resource management and sustainable resource management (SRM) interventions which impact on ecological infrastructure (bottom block), in turn influencing ecosystem services (left block; the reason for the curved return arrow is to remind us that sometimes certain exogenous natural happenings like floods or droughts can impact ecological infrastructure without necessarily any human involvement). The ecosystem services in the left block go on to interact with human assets and well-being in the top block. The three closely-positioned blocks on the right refer to endogenous "human infrastructures/capitals" which play a key role in influencing natural resource management, whilst the strong arrow coming from the top right-hand corner depicts exogenous human drivers usually out of our control as local residents or actors. The open curved shapes (bridges) designate overlaps where it may sometimes be difficult to place an attribute in one or the other block category, or the two blocks and their links may need more unpacking than shown here to be clear. Two overall messages (1 and 2 at bottom) apply throughout. For most purposes in this project, arrows tend to *usually* proceed in clockwise direction.

BOX 1: Likely changes in the SES framework over time-eras: past, present and into the future

Discussion at the November 2015 meeting led a participant to suggest one could reasonably speculate as to a time-series of (here simplified) SES frameworks and how they evolved in the past to reach the current state, and imagine possible future scenarios that assisted constructive thinking about the catchment trajectory. He drew Figure 8 below and presented it on day two. The audience deemed this very useful and suggested its inclusion into the report.

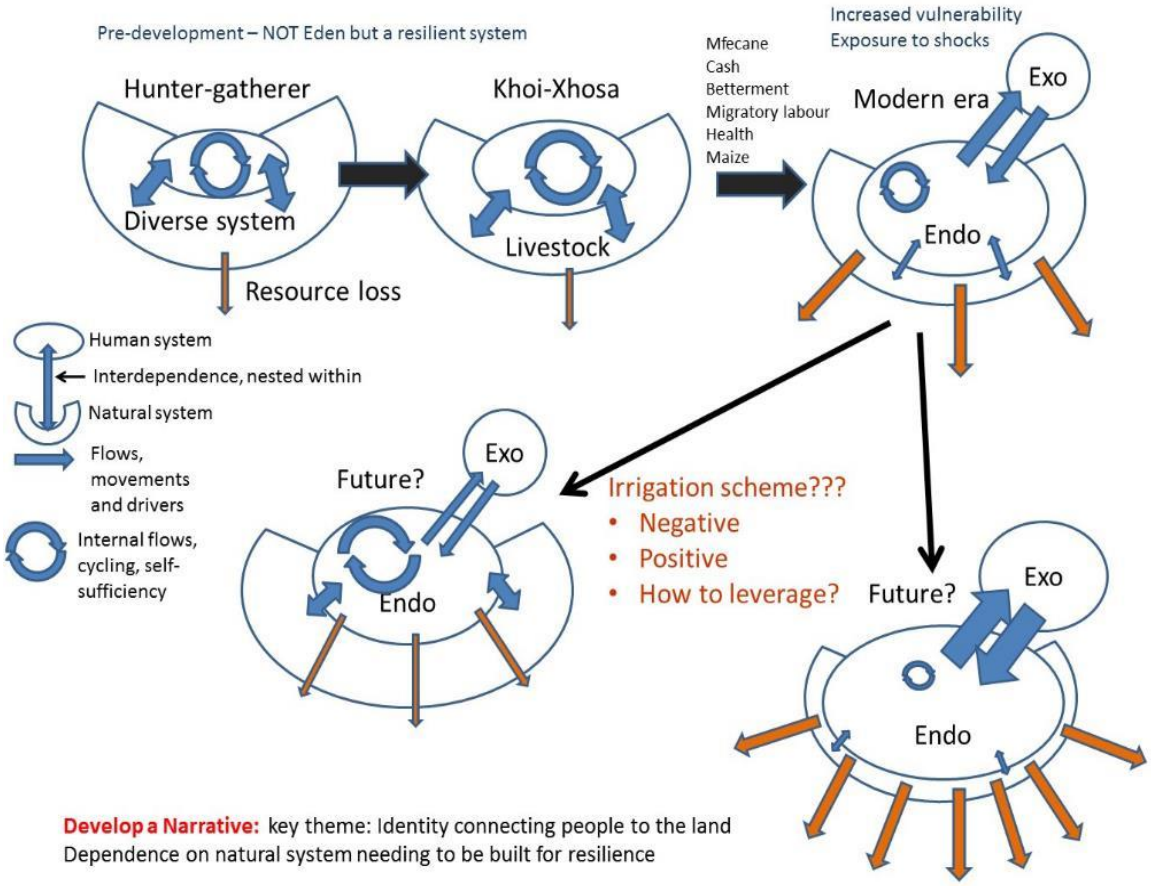


Figure 7: Possible changes over time eras in the Tsitsa catchment SES (provided by D. le Maitre).
Two historical eras are represented (hunter-gatherer and Khoi-Xhosa) followed by the current modern-day situation, followed by two provocative but plausible future scenarios. Each particular era's SES has the same basic structure – a human system nested in a natural system, with two-way interactions between these; an interlinked internal and endogenous human activity cycle; brown arrows indicating resource loss; and in the current and two possible future eras when influences from *outside (of the catchment)* are deemed significant, blue arrows connecting endogenous to these outside (exogenous) influences. The two (resilient) historical eras show no or little outside influence, and low resource loss even though the second era has a slightly higher human system imprint. The vulnerable modern era shows an even larger internal human system, with strong back-and-forth links to significant outside influence, yet much resource loss (degradation). Two possible futures, diverging depending on how, inter alia, the "irrigation scheme" is handled, show (in the left hand one) that external dependencies can be reduced and a containable human imprint with stronger internal activity and system resilience could lead to lower resource loss. Alternately (right hand scenario) the human imprint can grow, but with little or even negative growth in internal activity, escalating dependency on outside, and possibly even greater resource loss.
While Figure 7 is not necessarily accurate, it depicts related elements which do prompt the opportunity to think systemically over time. With refinement, engagement and appropriate presentation, it may possibly act as a basis for a compelling "high road vs low road" portrayal.

Thematic research areas

Guided by the conceptual frameworks, five thematic areas and altogether 21 topics, to the total value (over three years) of R14 million, were identified (Table 1): 1) social-ecological system dynamics; 2) land degradation; 3) livelihoods; 4) institutions, their governance and the actors governing them; and 5) decision support. A more detailed description of each project is in Tables 2-6.

In addition to the topics listed under each theme, every project must also address the implications of findings for management interventions aimed at repairing ecological infrastructure and improving social-ecological adaptive capacity. Every project must also incorporate multiple knowledge systems and evidences and, to varying extents, engage with stakeholders at multiple levels.

Table 1. Research themes and topics emerging from workshops and consultations

Theme	Research topic
1. Social-ecological system dynamics	***1.1 Driving factors and processes at different scales*** *1.2 Understanding and predicting the capacity to self-organize and recover from shocks; capacity to learn, adapt and transform* *1.3 Past and future trajectories under different scenarios.* ***1.4 Developing and testing theories of change, incorporating stakeholder goals, drivers and trajectories of change under different scenarios***
2. Land degradation	***2.1 Capacity of ecological infrastructure to retain sediments, water and nutrients*** ***2.2 System's ability to recover to a productive state after shocks and surprise*** ***2.3 Stakeholder beliefs and perceptions of land degradation*** *2.4 Incentives and motivators that would inspire actors to adjust their land management practices.* ***2.5 Impacts on different land use and land management practices (e.g. fire; grazing; cultivation and farming practices, plantation forestry) on ecological infrastructure and sedimentation*** *2.6 Quantification of the value of ecosystem services (including tourism), with and without ecosystem restoration interventions - 'the cost of doing nothing'.*
3. Livelihoods	***3.1 Available livelihood assets*** ***3.2 Current livelihood strategies and their changes over time*** *3.3 Local well-being influenced by economic and political processes at local, national and global levels (including the impacts of non-resident land users and migrants)* *3.4 Pathways into and out of sustainable livelihoods and livelihood strategies* *3.5 Livelihood strategies and assets and their trade-offs with ecological infrastructure management*

Theme	Research topic
4. Institutions, actors and governance	***4.1 Governance processes, interventions, rules and codes of conduct that exist at local, provincial and national levels*** ***4.2 Formal and informal power relations between different institutional actors and its implications for governance*** *4.3 Institutional links and disconnects between decision makers ('public infrastructure providers') and resource users, and their implications for ecological infrastructure and livelihoods* *4.4 Stakeholder perceptions and beliefs about drivers, pressures, state, ecosystem services and responses [see 2.3]* ***4.5 Develop and maintain (and concurrently study) an on-the-ground engagement system, with an important part of its emphasis on local communities in the context of NLEIP. This system will be built pragmatically around the existing structures and realpolitik, but also skillfully promote co-construction of necessary change.***
5. Decision support	***5.1 Prioritization of landscapes for ecosystem repair / restoration, priority areas for investment*** *5.2 Assessment of the effects of previous and current interventions for ecosystems and human well-being, and development of the most appropriate and cost effective interventions in different contexts* ***5.3 A monitoring system to implement adaptive management*** ***5.4. A learning and decision making system to implement adaptive management*** ***5.5 Stakeholder analysis and social-ecological inventory*** ***5.6 Time-line and seasonal and events calendar*** ***5.7 Ecological baselines for critical ecological infrastructure*** ***5.8 Liaison and facilitation of collective action between researchers, resource users, implementers and decision makers - building on the primary engagement in 4.5 and using the principles generated by that process***

Table 2. Topics under the social-ecological systems dynamics theme

Theme 1. Social-ecological system dynamics		
Theme Objective: Understanding and depicting the general resilience and transformability of the social-ecological system		
Research topic	**Rationale**	**Approach and methods**
1.1 Driving factors and processes at different scales	Understand influences from and feedbacks to processes and dynamics at local, provincial, national and global scale - Panarchy	Annotate and populate Ntabelanga conceptual framework with reliable information and data, incorporating the Panarchy model (Gunderson and Holling 2009). Specialist workshop, 15-20 systems researchers and managers. Refine and popularize conceptual framework.
1.2 Understanding and predicting the capacity to self-organize and recover from shocks; capacity to learn, adapt and transform	Social-ecological resilience and adaptive capacity are key goals in restoring the social-ecological system. Learning is pivotal. This needs to be tracked over time.	Develop resilience and adaptation assessment system, implement and test. Include community workshops, questionnaire surveys, and participatory assessment. Encourage innovative ground-breaking research, using the resilience workbooks published by the Resilience Alliance as departure points. Link with and learn from other resilience assessment programmes globally.
1.3 Past and future trajectories under different scenarios	Important for stakeholders to realize there are multiple pathways and to make choices about the trajectories they want to navigate towards.	Participatory scenario development with 'Future Search' approaches incorporating dynamic systems models, available biophysical data and projections, narratives and historical analysis. May include forum theatre and other innovations.
1.4 Developing and testing theories of change, incorporating stakeholder goals, drivers and trajectories of change under different scenarios	The purpose of social-ecological restoration is to influence the trajectory of the social-ecological system, towards more positive connections and greater adaptive capacity. This involves a number of intermediate processes, elucidated by change theory.	Develop theoretical frameworks and models to predict the influencing factors. Workshop with participants to get their responses. Test the model under different scenarios, and ground truth over the course of the project, using real data.

Table 3. Topics under the land rehabilitation theme

Theme 2. Land degradation		
Theme Objective: Understand the drivers, pressures, state, ecosystem services, and responses underpinning land degradation, within the Ntabelanga SES Interventions framework		
Research topic	**Rationale**	**Approach and methods**
2.1 Capacity of ecological infrastructure to retain sediments, water and nutrients	Capacity to retain nutrients, water and sediments is crucial for local livelihoods and life-span of the proposed dam	Field studies and models to refine the work of Roux *et al.* (2015) at a finer resolution. Spatial delineation of critical ecological infrastructure using remote sensing and GIS
2.2 System's ability to recover to a productive state, after shocks and surprises	Climatic, economic and political shocks and surprises are common; current capacity to transform to a productive state and build resilience in the new direction is low and needs to be strengthened	Use a resilience lens, adopting the principles outlined by Biggs *et al.* 2012 and 2014 focusing on connectivity and diversity as proxies for resilience. Analyse historical aerial and satellite images to assess recovery time after disturbance. Identify bench-mark sites
2.3 Stakeholder beliefs and perceptions of land degradation	Decision makers need to understand reigning beliefs and perceptions in order to design effective interventions that increase awareness and motivate local actors (see 4.4.)	Analyse mental models, perceptions and dominant paradigms of different stakeholder groups, using social science instruments developed for that purpose, supplemented by semi-structured interviews and participatory learning and action methods
2.4 Incentives and motivators that would inspire actors to adjust their land management practices	After transformation, the system needs to build resilience in a new direction. This will require lasting benefits that motivate people to maintain land use practices that maintain functioning ecological infrastructure	Participatory methods e.g. participatory mapping, with cost-benefit analysis and motivational theory.
2.5 Impacts on different land use and land management practices (e.g. fire; grazing; cultivation and farming practices, plantation forestry) on ecological infrastructure and sedimentation	Current and novel land use practice have positive and negative impacts on ecological infrastructure and livelihoods. These trade-offs and feedbacks need to be assessed at a fine scale, modelled and tested over larger areas	Assessments of ecological impacts on biodiversity, bundles of ecosystem services, ecological infrastructure across gradients of land use types and biophysical conditions
2.6 Quantification of the value of ecosystem services (including tourism), with and without ecosystem restoration interventions - 'the cost of doing nothing'.	The costs of ecosystem restoration need to be compared to the gains in ecosystem services, and their direct and indirect values to different user groups at different scales	Resource economics methods coupled with participatory workshops

Table 4. Topics under the livelihoods theme

Theme 3. Livelihoods		
Theme Objective: Understand the Drivers, Pressures, State, Ecosystem services, and Responses underpinning the sustainability of livelihoods and livelihood strategies within the Ntabelanga SES Interventions framework		
Research topic	**Rationale**	**Approach and methods**
3.1 Available livelihood assets	Interventions must use existing assets, including knowledge, as their departure points and aim to strengthen those, before introducing new practices, assets and technologies. However, the proposed dam will bring a range of new assets into the area which need to be incorporated into the local asset base	Detailed livelihoods assets analysis, adopting a multi-scale approach and assessing historical and contemporary livelihood assets and strategies. GIS for spatial delineation of distribution of livelihood assets. Use SRL frameworks developed by DfID (2000) and ESPA Fisher *et al*. (2015), with a strong focus on risk and vulnerability linked to assets
3.2 Current livelihood strategies and their changes over time	Effective interventions take current livelihood strategies into account and work towards strengthening their financial and ecological sustainability, while improving local people's capacity to exploit new opportunities. Capacity to self-organize and adapt is an integral part of sustainable livelihoods	Detailed livelihoods strategy analysis, adopting a multi-scale approach and assessing historical and contemporary livelihood strategies. Use SRL frameworks developed by DfID (2000) and ESPA Fisher *et al*. (2015), with a strong focus on risk and vulnerability reduction and adaptation as outcomes. Interviews, questionnaire surveys
3.3 Local well-being influenced by economic and political processes at local, national and global levels (including the impacts of non-resident land users and migrants)	Global processes are changing at a faster than ever pace and can have a major impact on local dynamics. Local actors are often unaware of these. Processes at provincial and national levels, for example the Mzimvubu Water Project, bring new challenges and opportunities, and actors from outside the area such as migrant workers and absentee resource users may influence ecological infrastructure and livelihood strategies in subtle ways	Desk-top study of policies, strategies and interventions affecting the study area, supplemented by participatory workshops and key informant interviews, especially with older residents, to develop time-lines
3.4 Pathways into and out of sustainable livelihoods and livelihood strategies	Sustainable livelihoods can follow multiple trajectories, depending on the way drivers are managed or serendipitously emerge. All actors need to understand the implications of their actions for trajectories towards or away from resilient or vulnerable futures	Historical analysis of human well-being and livelihood indicators, time-lines linked to system drivers represented in the Ntabelanga SES framework. Participatory scenario development (see 1.4).

Theme 3. Livelihoods		
Theme Objective: Understand the Drivers, Pressures, State, Ecosystem services, and Responses underpinning the sustainability of livelihoods and livelihood strategies within the Ntabelanga SES Interventions framework		
Research topic	**Rationale**	**Approach and methods**
3.5 Livelihood strategies and assets and their trade-offs with ecological infrastructure management	Interventions aimed at repairing ecological infrastructure may have positive and negative impacts on local resource users. Some of the negative impacts may exceed the benefits, whether real or perceived, with important implications for the sustainability and acceptability of interventions	Gradient analysis of different land use strategies and associated ecological infrastructure, focusing on comparison of soil fertility, erosion, connectivity and diversity. Use participatory mapping, GIS and participatory workshops

Table 2. Topics under the institutions, actors and governance theme

Theme 4. Institutions, actors and governance		
Theme Objective: Understand the Drivers, Pressures, State, Ecosystem services, and Responses underpinning the links between different institutional actors, their governance systems and codes of conduct within the Ntabelanga SES Interventions framework		
Research topic	Rationale	Approach and methods
4.1 Governance processes, interventions, rules and codes of conduct that exist at local, provincial and national levels	Important to understand existing institutions and governance systems, their associated uncertainties, strengths, positive and negative impacts on the system's adaptive capacity and trajectory, before introducing institutional and governance innovations	Overlaps with 3.5
4.2 Formal and informal power relations between different institutional actors and its implications for governance	Historical and contemporary power relations influence beliefs and perceptions and may either empower or disempower actors to pursue their objectives. Experience has shown that power dynamics have an important influence on the ability and/or willingness of actors to make choices about land use, governance and codes of conduct	In-depth interviews for critical discourse analysis, social network analysis and 'who counts' matrices. Link this to a social-ecological inventory and analysis of system drivers (see 1.1)
4.3 Institutional links and disconnects between decision makers ('public infrastructure providers') and resource users, and their implications for ecological infrastructure and livelihoods	The functionality of interactions between decision makers and resource users may influence the robustness of institutions and could have important impacts on governance and, ultimately, ecological infrastructure. This is the central tenet of cooperative governance and adaptive co-management	Use Institutional Analysis and Development (IAD) framework of Oström (2005) and robustness-vulnerability framework of Anderies *et al*. (2004) to assess strengths and weaknesses of institutional connections and how these have changed over time. Desk-top studies, supplemented by participatory workshops and in-depth interviews with key actors
4.4 Stakeholder perceptions and beliefs about drivers, pressures, state, ecosystem services and responses	Decision makers need to understand reigning beliefs and perceptions in order to design effective interventions that increase awareness and motivate local actors (see 2.3)	Instruments such as Dominant Social Paradigm and New Environmental Paradigm tools, elicitation of mental models, using methods such as participatory learning and action, photo-voices, narratives, discourse analysis and in-depth interviews

Table 3. Topics under the decision support theme

Theme 5. Decision support		
Theme Objective: Provide tools to improve the effectiveness and efficiency of decision making		
Research topic	**Rationale**	**Approach and methods**
5.1 Prioritization of landscapes for ecosystem repair / restoration, priority areas for investment	Essential to first focus on areas which are either a) critical to ecological infrastructure; b) can demonstrate short-term advantages; c) a large impact can be demonstrated at low cost	Rule-based models linked to GIS, to proactively identify urgent and important areas for ecosystem restoration
5.2 Assessment of the effects of previous and current interventions for ecosystems and human well-being, and development of the most appropriate and cost effective interventions in different contexts	An understanding of present and past impacts is an important departure point for learning about appropriate interventions, and designing innovations	
5.3 & 5.4. A monitoring, learning and decision making system to implement adaptive management	Management wishes to follow the principles of adaptive co-management. This requires frequent monitoring and reflection, with robust monitoring systems and logical decision flows	Set goals, identify indicators, collect monitoring data, set decision rules and identify methods for reflection, learning and adaptation. Workshop to deliberate and refine
5.5 Stakeholder analysis and social-ecological inventory	Project participants need to understand 'who does what, where' as a departure point for future work	Snowball sampling, linked to social network, database and GIS indicating functionality of links, management activities, responsibilities, activities, and organizational characteristics linked to legitimacy, and compatible or conflicting goals
5.6 Time-line and seasonal and events calendar	The project needs to have an historical baseline as well as a community calendar of events and activities to be able to plan its activities	Desk-top analysis, time-lines and participatory community annual, seasonal and weekly calendar

Theme 5. Decision support		
Theme Objective: Provide tools to improve the effectiveness and efficiency of decision making		
Research topic	**Rationale**	**Approach and methods**
5.7 Ecological baselines for critical ecological infrastructure	Baselines for critical ecological infrastructure are essential to be able to evaluate progress with ecosystem repair	In addition to sediment yield study: remotely sensed NDVI indices at 30x30 m resolution; water run-off; sediment yields in individual streams; landscape connectivity indices using remote sensing and ground truthing; agricultural yields for randomly sampled fields, and for the study area as a whole; inventory of landscapes actively being managed to improve provisioning; cultural; regulating and supporting ecosystem services; hectares of land in different degradation/ productivity categories. Fixed point photographs (geo-referenced). Data should be incorporated in GIS.
5.8 Liaison and facilitation of collective action between researchers, resource users, implementers and decision makers	Maintain and communicate up to date information about role players, and to promote synergy, cooperation and trust between role players mentioned above through regular communication, dialogue, information sharing and social learning. This should lay the foundation for adaptive co-management of ecological infrastructure, and the formation of an appropriate and legitimate local governance structure. [The development of such governance structure does not form part of this assignment]. Communication, networking, learning and information sharing crucial for adaptive co-management and requires skilled facilitation	The consultant(s) will; familiarize themselves with the study area through an extensive literature review and interviews; maintain an up to date database of role players, their issues and interactions; maintain regular (bi-monthly) personal contact with all key role players through monthly site visits; proactively identify areas of potential synergy and conflict, and use appropriate methods to promote positive interaction towards adaptive co-management; provide leadership, mentoring and capacity development to local community facilitators; develop codes of conduct for all researchers working in the study area; develop relevant researchers' capacity to enact the code of conduct through ethical research in a rural community setting; keep all role players informed of developments through information materials, written and verbal communication, the media, facilitated dialogues and six-monthly information sharing workshops; make a special effort to communicate with illiterate and marginalized role players

Operational framework

A framework to guide the implementation process is presented in Figure 8. It is loosely based on the operational frameworks proposed by Cowling *et al*. (2008) and Stringer *et al*. (2006), tailor-made for the Ntabelanga-Lalini SES.

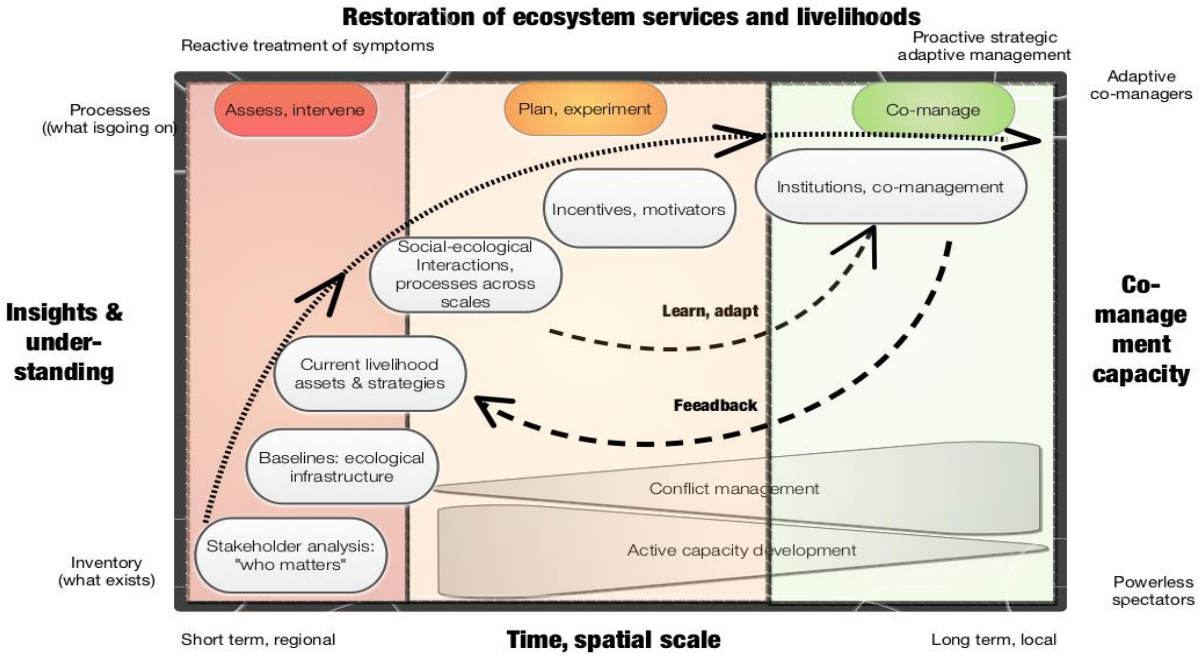


Figure 8. Conceptual framework for implementation phases.

This operational framework depicts three phases: assessment and engagement; planning and experimentation; and co-management. The process starts with a coarse-scale stakeholder analysis, visioning, baselines of ecological infrastructure, and descriptive analysis of current livelihood strategies and assets. It then proceeds to understanding the interactions and feedbacks between elements of the SES, followed by action research on adaptive co-management which includes institutional analysis and active collaboration. Facilitation is essential, with an initial bias towards externally-driven capacity development, shifting towards more internally-driven capacitation and to an increased ability to handle conflict management. Over time, research insights evolve from understanding what exists, to understanding 'what is going on'. Thinking changes from shorter to longer term, the management of agreed-on ecosystem services becomes more pro-active and, through encouraging the use of feedbacks for learning, more adaptive in a structured and strategic way. Unsustainable livelihoods hopefully evolve through management (including at least some forms of co-management) to become more sustainable, in a way that shows a greater feeling of agency.

A version of the same diagram but with less technical wording, is provided in **Appendix D**. All the same discussion that features under *Dealing with varying needs and levels of co-construction and understanding of the frameworks* on page 18, applies here, though no need was seen for a more detailed caption – the role of the more detailed caption in the appendix.

Project governance, feedback and interaction

Operational principles of the project

1. Research is user-inspired, and feeds as directly as possible into addressing management problems with maximum information flow between users, managers and researchers.
2. Researchers abide by a mutually agreed code of ethics
3. All projects are contextualized within the social-ecological systems approach and the adopted conceptual framework
4. The research group is committed to trans-disciplinary learning and reflection and to incorporating a diversity of world views and disciplines
5. There is appropriate and requisite inclusivity in access to research funding, opportunities for learning and knowledge sharing. Research investment is linked to implementation.
6. All participants are committed to building relationships and trust, and promoting synergies
7. Stakeholder engagement commences early and happens throughout the process; all project participants engage with stakeholders and each other
8. Capacity building of early career researchers and students, especially those from historically disadvantaged backgrounds, is paramount.
9. The direction and outcomes of action and trans-disciplinary research cannot be predicted at the start of the process, so that researchers, programme managers and funders have to be flexible; i.e. have to take an adaptive management approach to the research process. Although sensible control is necessary over this process, deliverables may indeed have to evolve and even be changed along the way.

Project oversight and monitoring

A project steering committee, consisting of 4-6 specialist researchers and managers who are not direct recipients of the NLEIP research grants, should initially meet six-monthly to appraise:

- the research projects' consistency with the operational and conceptual frameworks
- inter-agency coordination and communication
- whether learning and adaptive management is occurring and
- whether project teams have responded to feedback provided.

The steering committee should be convened and chaired by the relevant DEA-NRM manager who should convey its recommendations to the respective principal investigators of funded projects.

Promoting learning and interaction between researchers

Trans-disciplinary learning should be promoted through quarterly meetings and six-monthly colloquiums convened by a project coordinator, whose job description should include knowledge integration. In addition, working groups should include one or more individuals with an aptitude for or interest in trans-disciplinary integration. The trans-disciplinary learning process in the research group and across stakeholder groups should ideally be monitored and documented. The Jahn (2012) framework presented earlier is a useful departure point for this.

Working groups could be established around the five research themes outlined above. Their main purpose should be to share information, promote learning and organize knowledge sharing events. Communication and coordination with other organizational role players (public infrastructure providers and resource users) is essential. A dedicated liaison person or team should be appointed for this purpose.

Research ethics

The research should be guided by the 14 ethical principles adopted by the Society for Ethnobiology:

1. Acknowledgement of prior rights to land and resources
2. Self-determination and empowerment of local people
3. Inalienability of resources and land
4. Working with traditional guardians and stewards
5. Active participation of all stakeholders
6. Full disclosure of objectives and findings
7. Prior informed consent
8. Confidentiality where required
9. Respect
10. Active protection of local rights and heritage
11. Precaution
12. Compensation and equitable sharing where local people are incurring indirect or direct costs
13. Developing local capacity
14. Conducting research in a dynamic interactive cycle.

In addition, researchers should be aware of the potential for conflict and take the necessary steps to proactively address these, via the community facilitation team. Researchers should develop their own skills in active listening and should be open to feedback. They should cultivate an awareness of the area in which they are working as a whole, as well as an appreciation of the area's history and its consequences.

The following guidelines are adapted from Laird (1998), who was inspired by the guidelines for Pew Scholars assessing and exploring biodiversity. Text in square brackets are the authors' modifications.

"When engaging with a community, organization or individual, every researcher:

1. Should communicate information about their project [in English and isiXhosa] to local stakeholders
2. Must explain the nature and purpose of their proposed research, including its duration, the geographic area in which research would take place, and research methods, to community leaders and the community at large
3. Obtain permission to conduct research in an area via appropriate leadership structures
4. [Should as far as possible employ local people as field assistants and local individuals or groups for workshop and field catering]
5. Must explain the foreseeable consequences of the research for resources, people and stakeholders, including the potential commercial value
6. Should explain the potential non-commercial values, such as academic recognition and advancement for the researcher [and the community]
7. Should be open about social and/or cultural risks with stakeholders
8. Must regularly inform stakeholders, including other researchers and local people, about the research process and findings
9. Should be willing to provide copies of relevant project documents, or summaries thereof, in the local language
10. Must agree on a protocol of acknowledgements, citation, authorship, respecting requests for anonymity
11. Must not engage in bribery or making false promises.

[12. Should respect the needs, methods and knowledge systems of other researchers and as far as possible share information with them].

Because of the large component of early career researchers in this and similar initiatives appropriate support and training needs to be put in place. This would require regular supervision and training to deal with the following (list provided by A. Copteros):

- Ability to deal with failures and difficulties
- The importance of self-awareness, own history and identity
- Awareness of the limitations of the study and of research as a whole.
- Researchers (early career researchers may need special attention) should be encouraged to answer the following questions, some of which overlap with material above:
  - How does 'the community' benefit from my research?
  - How do I 'leave' this community once my research is done?
  - How do I/we build in reflexivity?
  - How do I/we 'use' / 'employ' local people
  - How do I/we 'use' / 'employ' colleagues who are not students or researchers who assist us with the research?
  - How do we work with tangible benefits for local people through our research?
  - How do we share / use our networks?
  - How do we tap into existing networks?
  - How do we keep our research relevant and responsive?
  - How do we contain complexity in ourselves and with our research groups?
  - How do we deal with difficulties / conflicts when they arise?
  - Who are the people / organisations who support me in my work?

Next steps

Given that this report contains sufficient buy-in from technical stakeholders, especially regarding the conceptual frameworks, the publication of this report marks an official start to a co-designed process, by mutual agreement. Starting from that foundation, there was also technical co-operation and agreement regarding the basic outline of themes, with illustrative project titles and budgets - which could be seen as a version 1 outline with which the Project can begin.

Next steps include (1) ensuring wider and urgent stakeholder consultation, to be funded more heavily and to continue, and ensuring as far as possible that the consequences of this indeed lead to benefits to catchment residents and resource users, and particularly that upstream and dam-site communities are not left without benefits, and (2) setting up the administrative processes including a panel to deal with project selection recommendations, for at least the applications for DEA research funding; co-ordination with grants from other funders; plus a range of allied issues mentioned in the report, and which will emerge as the Project grows.

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APPENDIX A: Direct and indirect outcomes of the NLEIP and related research will contribute to the UN's Sustainable Development Goals adopted at the United Nations Sustainable Development Summit 2015, 25 - 27 September 2015, New York

Direct outcomes

GOAL 6 *Ensure availability and sustainable management of water and sanitation for all*

6.6 By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes

6.b Support and strengthen the participation of local communities in improving water and sanitation management

GOAL 15 *Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*

15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements

15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally

15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development

15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

15.8 By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species

15.9 By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts

15.a Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems

15.b Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation

GOAL 17 *Strengthen the means of implementation and revitalize the global partnership for sustainable development*

17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships

Indirect outcomes

GOAL 1 *End poverty in all its forms everywhere*

1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day

1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions

1.3 Implement nationally appropriate social protection systems and measures for all, including floors, and by 2030 achieve substantial coverage of the poor and the vulnerable

1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance

1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters

1.A Ensure significant mobilization of resources from a variety of sources, including through enhanced development cooperation, in order to provide adequate and predictable means for developing countries, in particular least developed countries, to implement programmes and policies to end poverty in all its dimensions

1.B Create sound policy frameworks at the national, regional and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions

GOAL 2 *End hunger, achieve food security and improved nutrition and promote sustainable agriculture*

2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment.

2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.

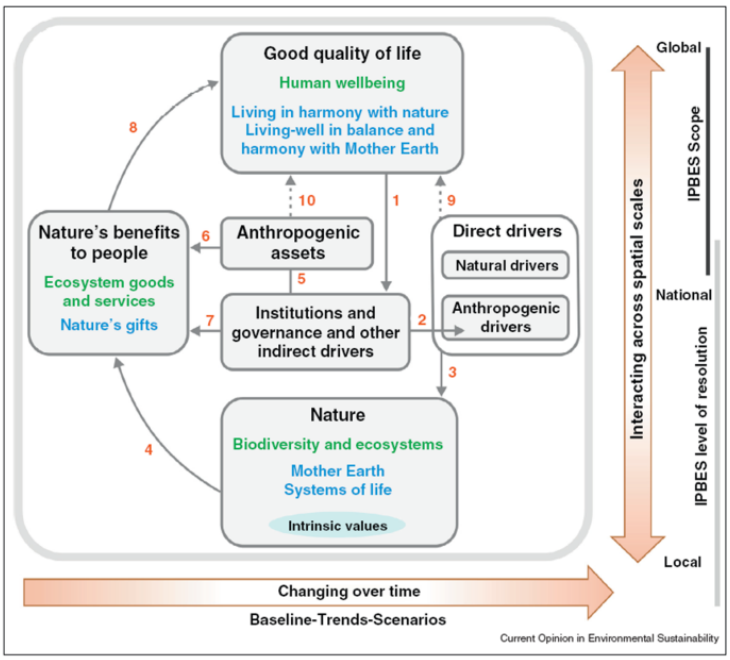
APPENDIX B: Evolution of the co-created Ntabelanga-Lalini conceptual framework

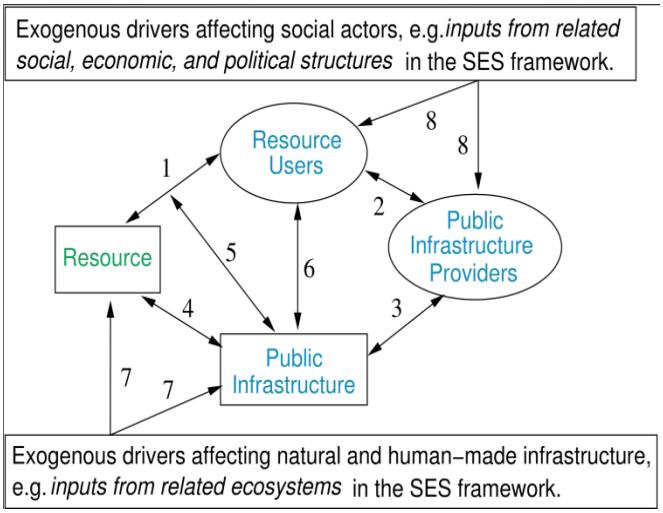
March 2015: Ntabelanga and Lalini research framework

Focus: Develop a provisional conceptual framework to inform research and engagement priorities for the Ntabelanga and Lalini catchments

Framework description: Various possible frameworks for the design and management of social-ecological systems, as presented by workshop participants, e.g. Social-ecological systems (Oström 2009) framework; Robustness and vulnerability of institutions (Anderies *et al*. 2004); Sustainable Livelihoods framework (Carney 1998); IPBES framework (Díaz *et al*. 2015).

Diagrammatic representations:





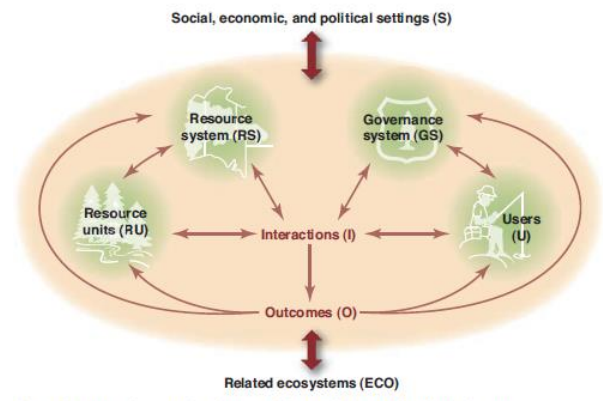
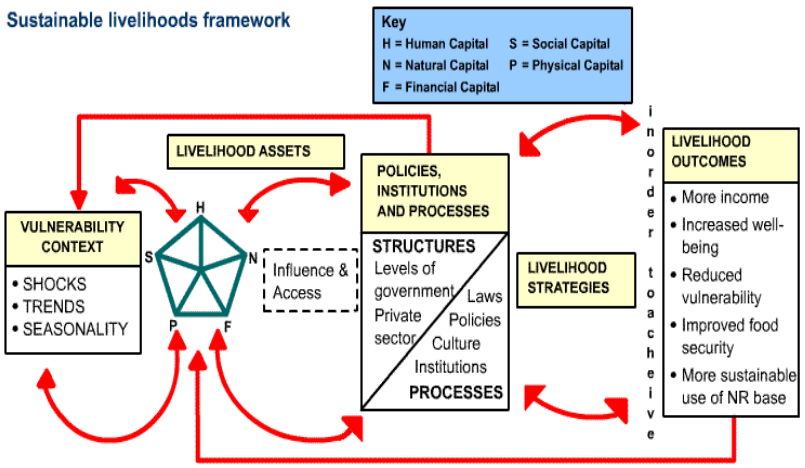


Fig. 1. The core subsystems in a framework for analyzing social-ecological systems.



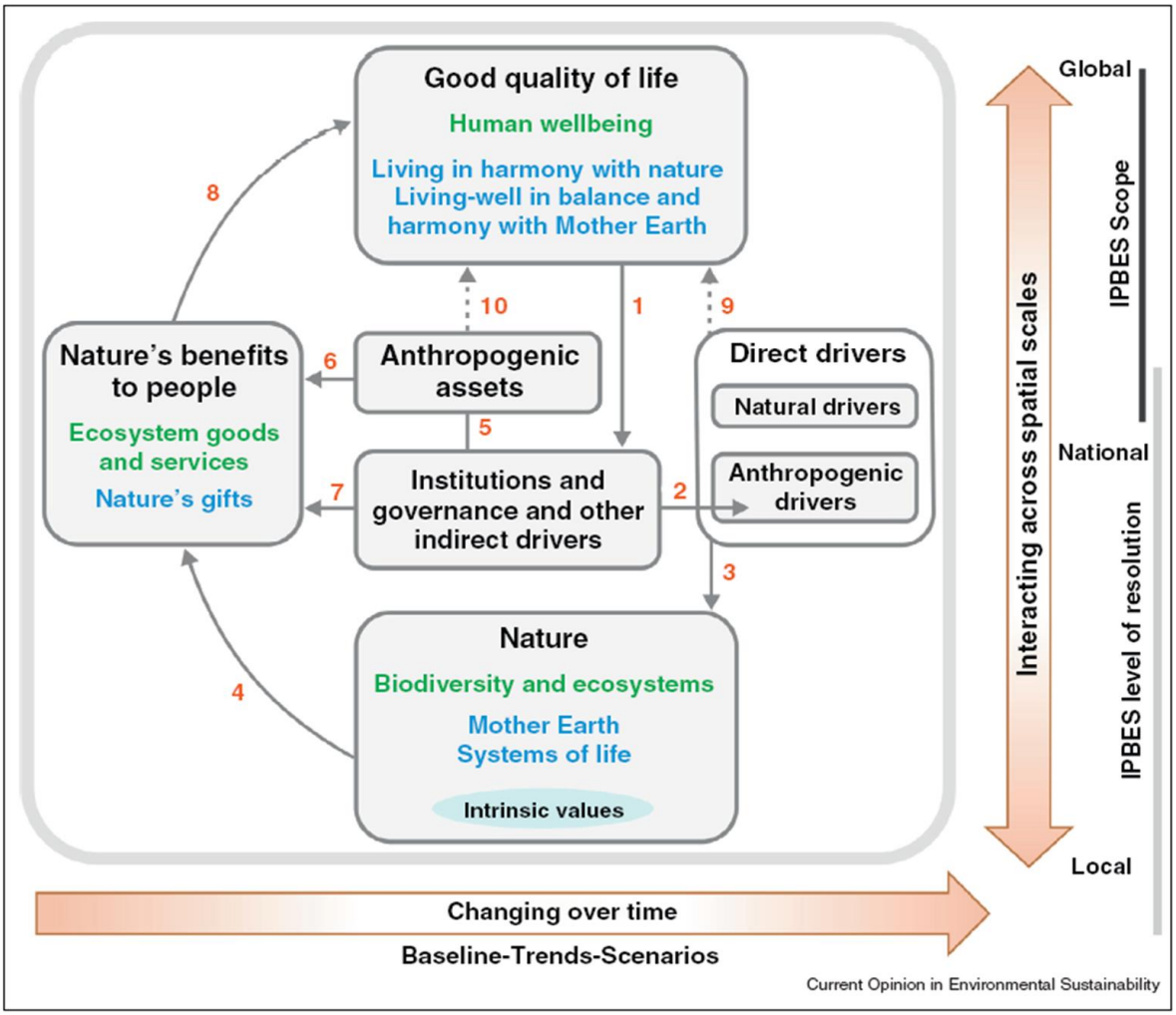
July 2015: Ntabelanga & Lalini research priorities

Focus:

- Clarify DEA-NRM's desirable research outcomes and progress
- Re-visit and finalize the conceptual framework developed on 6 March
- Develop a first-order research investment strategy
- Identify priority research thematic areas and questions

Framework description: Composite framework, based on integrating the IPBES framework (Díaz *et al*. 2015) with the Robustness-Vulnerability framework (Anderies *et al*. 2004) and the Sustainable Livelihoods framework (DfID 2000)

Diagrammatic representation:



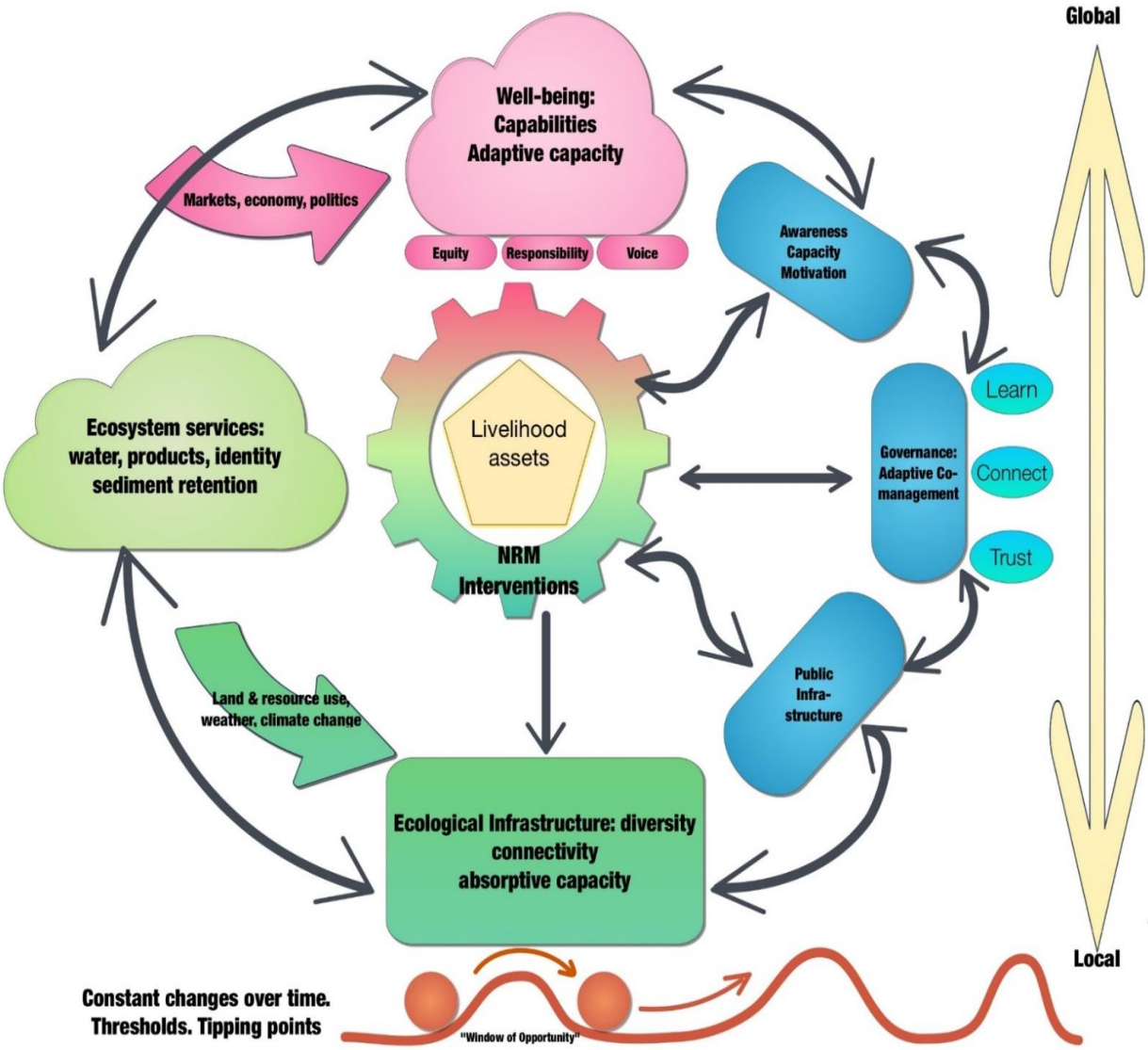
September 2015: Feedback and consultation with project managers and funders

Focus:

- Provide feedback to project managers and potential funders on recommended key research areas
- Give funding stakeholders insight into the process, and thinking
- To deepen our understanding and to ensure better alignment of the various government funded investments that are made.

Framework description: Further refinement of the composite framework, making it more applicable to natural resource management interventions.

Diagrammatic representation:



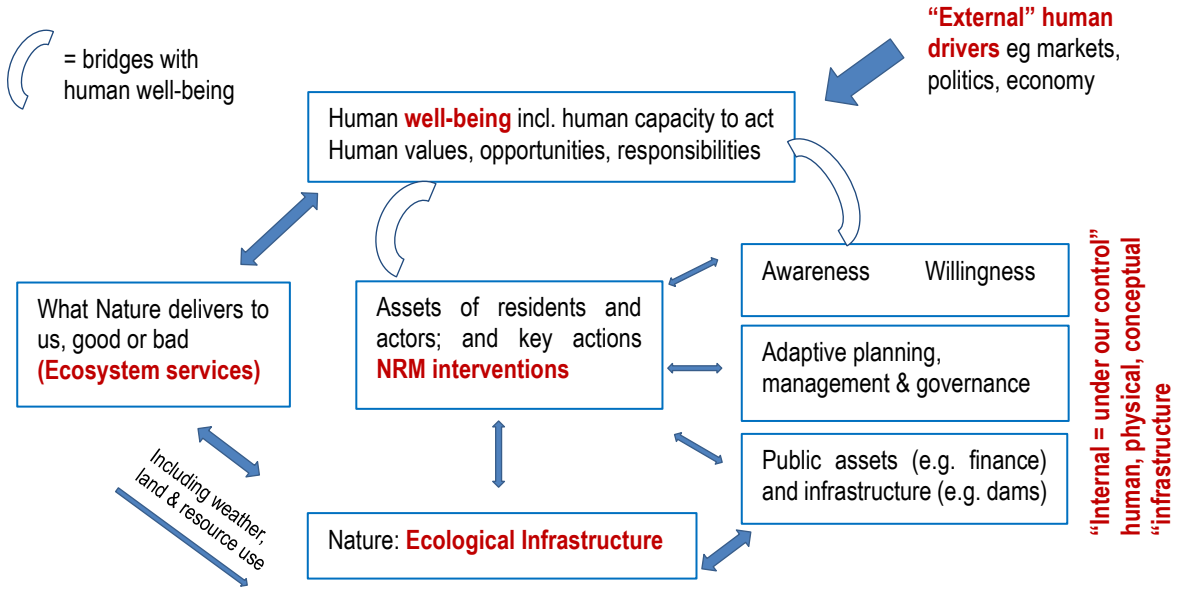
November 2015: Ntabelanga & Lalini Science/Management Forum

Focus:

- Ensure effective communication and knowledge exchange between researchers, students, supervisors, government officials, practitioners, NGOS and other stakeholders
- Particular emphasis on the central framework (a social-ecological one relevant to our context) and where each of all projects fit.

Framework description: Further refinement of the composite framework, making it more applicable to natural resource management interventions.

Integrated Social-Ecological Framework

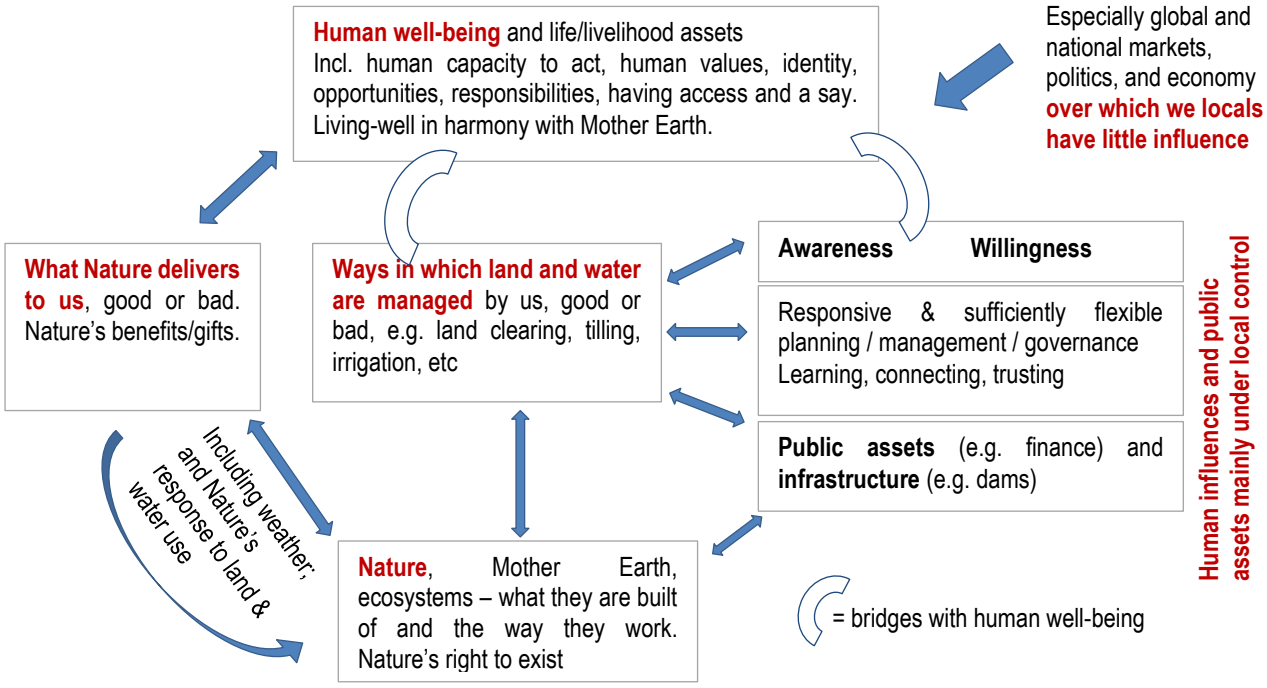


PLUS two key overarching issues to remember throughout:

1. Always think of this playing out at **multiple interconnected scales** (local …. regional …. global) and across multiple corresponding levels of governance
2. Assume a constantly changing and bumpy milieu, with thresholds and tipping points, involving history, power changes, baselines, trends and scenarios

APPENDIX C: Integrated Human-Nature Framework – towards a version with fewer technical words

This is the same diagram as Figure 6 in the main report, but uses fewer technical words.



Finally, 2 things to remember throughout:

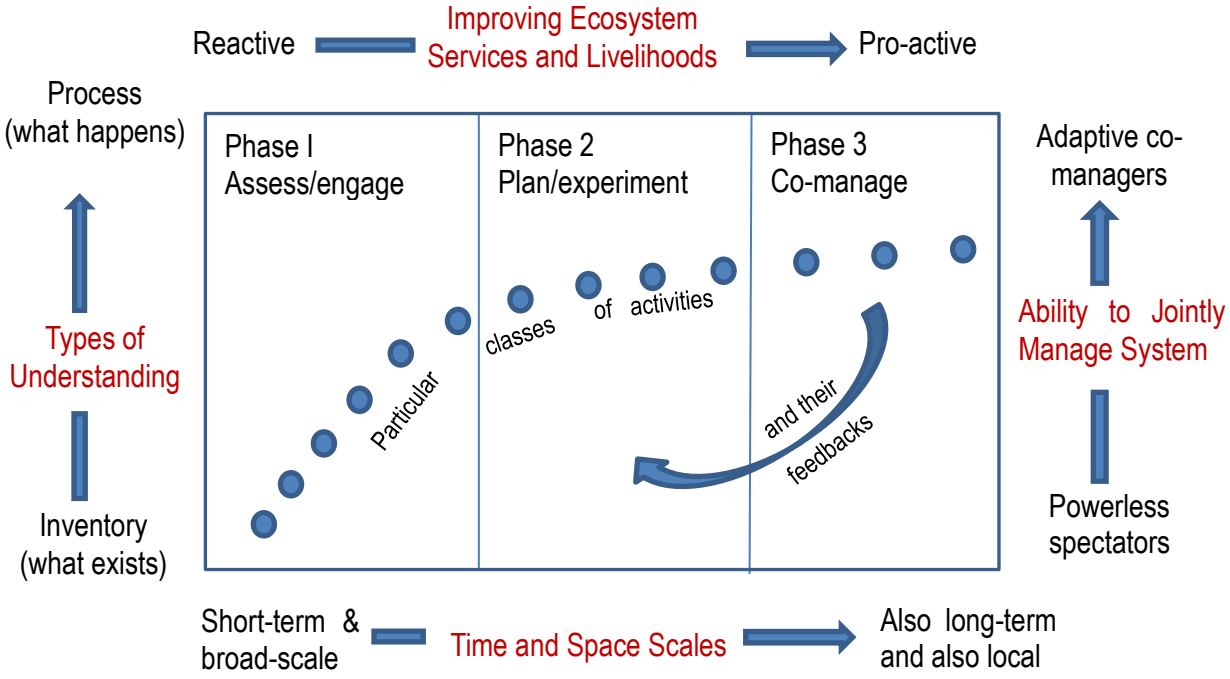
1. We need to grasp that **all this is happening at many joined levels from local to global**
2. We need to anticipate a **constantly changing and often bumpy** progression of this system

The bridge shown between human well-being and sustainable resource management (SRM) interventions includes (inter alia) the fact that SRM interventions are strongly related to existing livelihood assets. These interventions are aimed at repairing ecological infrastructure (bottom box), and particularly their diversity, connectivity and absorptive capacity, e.g. capacity to absorb moisture, retain nutrients. This improves the delivery of ecosystem services (left box), particularly water, agricultural production and retention of sediments and nutrients, but also cultural services that create a strong sense of identity (top box), loyalty and attachment to the landscape – the foundation of care-taking (stewardship). Ecosystem services, and improved governance, awareness, motivation and capacity have positive impacts on human well-being: nutrition, financial security, health, social relations (top box). Interventions (middle box again) influence, and are influenced by, public infrastructure such as proposed dams, roads, communication networks, and rules and regulations (part of right box group). Interventions are also aimed at promoting adaptive co-management i.e. (going further in the rightmost box group) the collective management of the system, 'learning by doing' approaches through connecting, communication and trust building. Collective action is stimulated through creating awareness (below rightmost bridge), motivation (including incentives) and capacity development (top box) which in turn influences the intervention through a reinforcing feedback. Other influences that arise as practices such as resource extraction, grazing, cultivation) influencing Nature and can cause ecosystem services to alter, and thus re-influence Nature (semi-circular arrow from ecosystem services to ecological infrastructure. Weather and its sequelae (such as floods and drought) can often act independently via the same route. Important political and macro-economic factors about which little can be done locally are shown as a strong arrow coming from top right. The system operates at multiple interconnected scales, constantly changes, and has to continuously

overcome obstacles and re-organize. The construction of the proposed dam and SRM and DEA NRM interventions (i.e. natural resource management or nrm) should be seen as a 'window of opportunity' which, if approached correctly, could transform the system and build resilience in a new direction. At the centre of the hub in our framing are natural resource management (nrm) and SRM interventions which impact on ecological infrastructure (bottom block), in turn influencing ecosystem services (left block; the reason for the curved return arrow is to remind us that sometimes certain exogenous natural happenings like floods or droughts can impact ecological infrastructure without necessarily any human involvement). The ecosystem services in the left block go on to interact with human assets and well-being in the top block. The three closely-positioned blocks on the right refer to endogenous "human infrastructures/capitals" which play a key role in influencing NRM, whilst the strong arrow coming from the top right-hand corner depicts exogenous human drivers usually out of our control as local residents or actors. The open curved shapes (bridges) designate overlaps where it may sometimes be difficult to place an attribute in one or the other block category, or the two blocks and their links may need more unpacking than shown here to be clear. Two overall messages (1 and 2 at bottom) apply throughout. For most purposes in this Project, arrows tend to *usually* proceed in clockwise direction.

APPENDIX D: A schema for thinking about the order in which we implement steps in the Tsitsa Human-Nature system, and about what overall changes should be anticipated over time

This is the same diagram as Figure 8 in the main report, but uses fewer technical words.



There are three phases: assessment and engagement, planning and experimentation, and finally improved (often joint) resource management. The suggested sequence starts in the bottom left-hand corner and proceeds upward and to the right. The four axes (top, bottom, right and left) show an expected change in (respectively) how we influence what nature delivers, how thinking becomes longer-term, how livelihoods improve, and how our understanding moves from "what" to "how". The internal cells in the figure each have text describing the key question or issue to be addressed more or less in that order over several years, as the large curved arrow shows. It is important to emphasise that there are multiple feedbacks (back-and-forth) between these internal cells as they unfold and we learn from how they inform one another. Over time, local resource users and other stakeholders (such as local team leaders, facilitators and scientists) who are more directly linked with the catchment, become better at mediating the inevitable conflict that arises as joint adapting management matures, and can fill more of the various capacity needs for running such a system effectively.

APPENDIX E: Contributors and Workshop attendees

List of contributors and workshop attendees as at 31 July 2016.

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