Ecosystem-based Adaptation

Action Plan and **Priority Mapping**

environment, forestry & fisheries
Department: Environment, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

2030 NDP

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

SANBI
Biodiversity for Life
South African National Biodiversity Institute

Published by **Department of Environment, Forestry and Fisheries (DEFF)**

Authors **Department of Environment, Forestry and Fisheries (DEFF)**

Contributors **Tony Knowles (The Cirrus Group)** *(Action Plan)*
James Blignaut *(Action Plan)*
Philip Desmet (EcosolGIS) *(Priority Mapping)*

Layout and design **Björn Rothauge**

Photos **Department of Environment, Forestry and Fisheries (DEFF)**

Maps **Philip Desmet (EcosolGIS)**

The Climate Support Programme supported this work in partnership with DEFF. The Climate Support Programme is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) as part of the International Climate Initiative (IKI). The Federal Minister for the Environment, Nature Conservation, and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag.

Citation **Department of Environment, Forestry and Fisheries (DEFF), 2019. Ecosystem based adaptation Action Plan and Priority Areas Mapping report. Pretoria, South Africa.**

1st Edition published in South Africa 2020

Ecosystem-based Adaptation

Action Plan and Priority Mapping

environment, forestry & fisheries
Department:
Environment, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

2030 NDP

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

behalf of:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
he Federal Republic of Germany

SANBI
Biodiversity for Life
South African National Biodiversity Institute

This assessment was conducted by Tony Knowles with assistance from:

- James Blignaut and Philip Desmet (project team members)

The individuals on the Project Steering Committee are thanked for their contributions to the conceptual development of the project, review of outputs, and comments on products and draft reports:

- From Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: Alexa Brown
- From the Department of Environment Forestry and Fisheries (DEFF): Barney Kgope, Ntando Mkhize, Sibonelo Mbanjwa, Alinah Mthembu, Tshifhiwa Munyai, Nozipho Sibiya
- From the South African National Biodiversity Institute (SANBI): Mahlodi Tau, Kennedy Nemutamvuni, Mandy Driver, Mandy Barnett, Fahiema Daniels, Jeffery Manuel and Genevieve Pence

In addition, the following groups and individuals are thanked for their contributions:

- The SANBI Ecological Infrastructure Steering Committee
- The Provincial and Metro Biodiversity Planning Working Group
- Zander Venter (ZSV Consulting)
- Thomas G. King
- Lungile Moyo and Mark Thompson (GeoTerraImage)
- Emily Botts and Dick Cloete for proof editing
- All experts, provincial and national stakeholders consulted during this process.

ACTION
PLAN

Table of Contents

Abbreviations 6

Introduction 7

The Foundation 8

Contextual point of departure 10

The goal and structure of the Action Plan 11

Guiding principles 12

Theory and concepts 13

- Shifting value, rules and knowledge (vrk) to achieve adaptation outcomes 13
- Tactical implementation of the values, rules and knowledge model 15
  - Using pathways to explore options and their requirements 15
  - Changing the framing, perspectives, language and conversations 16
- Communication: Risk as a common currency across sectors 17

Themes emerging from expert and stakeholder engagement that inform the Action Plan structure and process 18

- Effecting change through a comprehensive approach and collective action 18
- Creating an enabling environment through supporting elements 18
- Governance and institutional mandates 19
- Alignment in planning and management between national departments and programmes 19
- Leveraging existing private and public sector capacity and programmes 20
- Starting small with a set of true pilot areas, rather than on a national scale 20
- Addressing drivers of land degradation at all levels 20

Inclusion of urban and peri-urban areas ... 20
Focussing on ecosystem flows as well as stocks ... 22
Unplanned agriculture and other forms of land use ... 23
Poor rangeland management ... 23
Alignment of existing work in a holistic and structured manner ... 23
The need for facilitatory support ... 23

The structure, process and elements ... 24

Suggested immediate course of action ... 28

Annex A: Description of monitoring and incentive elements ... 30

National monitoring and reporting system ... 30
Creating an appropriate incentive model ... 32

Annex B: A logical framework describing the key planning and management parameters of each strategic objective over the suggested 5-year pilot period ... 33

References ... 46

Abbreviations

AIP	Alien Invasive Plant
CARA	Conservation of Agricultural Resources Act
DAFF	Department of Agriculture, Forestry and Fisheries
DALRRD	Department of Agriculture, Land Reform and Rural Development
DEA	Department of Environmental Affairs
DEFF	Department of Environment, Forestry and Fisheries
DMR	Department of Mineral Resources
DMRE	Department of Mineral Resources and Energy
DRDLR	Department of Rural Development and Land Reform
DST	Department of Science and Technology
DWS	Department of Water and Sanitation
EbA	Ecosystem-based adaptation
EPWP	Expanded Public Works Programme
ES	Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
GEF	Global Environment Facility
HR	Human Resource
K	Potassium
LDN	Land Degradation Neutrality
LTAS	Long-term adaptation scenarios
M&E	Monitoring and evaluation
M&R	Monitoring and reporting
MRV	Monitoring, reporting and verification
MTSF	Medium-Term Strategic Framework
N	Nitrogen
NCCAS	National Climate Change Adaptation Strategy
NAP	National Action Programme
NBSAP	National Biodiversity Strategy and Action Plan
NDP	National Development Plan
NEMA	National Environmental Management Act
NRM	Natural resource management
P	Phosphorus
PES	Payment for ecosystem services
REDD+	Reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries
SA	South Africa
SAEON	South African Earth Observation Network
SANBI	South African National Biodiversity Institute
SDG	Sustainable Development Goals
SKEP	Succulent Karoo Ecosystem Programme
SMME	Small Medium Micro Enterprise
UN	United Nations
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
VRK	Values, rules and knowledge

Ecosystem-based Adaptation (EbA) is one of the principal ways in which countries can respond to climate change. The concept is scientifically sound, and implementation often produces a broad set of biodiversity, ecosystem service, social and economic co-benefits. It is a concept that has gained much traction in South Africa, as it could be a means of conserving the country's exceptional biodiversity, while providing necessary ecosystem services to rural and urban communities in a manner that is resilient to climate change. EbA contributes to the aims of the National Development Plan 2030:

> ***Long-term planning to promote biodiversity and the conservation and rehabilitation of natural assets is critical and should be complemented by a strategy for assessing the environmental impact of new developments as an important component of overall development and spatial planning. Where damage cannot be avoided or mitigated, and where the social and economic benefits justify the development, a commensurate investment in community development and the rehabilitation and conservation of biodiversity assets and ecosystem services is required.***
>
> (National Planning Commission 2012, 201)

EbA is also clearly included in South Africa's National Climate Change Response Policy (NCCRP) (DEA 2011) and the Draft National Climate Change Adaptation Strategy (NCCAS) (DEA 2019), which is anchored on the following strategic objectives:

- **Objective 1:** Build climate resilience and adaptive capacity to respond to climate change risk and vulnerability.,
- **Objective 2:** Promote the integration of climate change adaptation response into development objectives, policy, planning and implementation.,
- **Objective 3:** Improve understanding of climate change impacts and capacity to respond to these impacts., and
- **Objective 4:** Ensure resources and systems are in place to enable implementation of climate change responses. (DEA 2019, 7)

It further supports key national strategies within the land domain to combat desertification and mitigate the effects of drought, for example, Outcome 10 of the Medium-Term Strategic Framework (MTSF) and Strategic Objective 2 of the National Biodiversity Strategy and Action Plan (NBSAP, 2015).

Based on this clear need and policy mandate, parties within the Department of Environmental Affairs (DEA) and the South African National Biodiversity Institute (SANBI) co-developed three scoping, strategy and guideline documents, which form a general foundation for the future development of EbA and broader adaptation responses to climate change within the land domain. This Action Plan is the next step in the process, explicitly focusing on the tactics that are required to deliver the strategy and associated implementation in an effective and efficient manner.

Three principal documents form the foundation for the future development of climate change adaptation responses within the land domain in South Africa, namely: Climate Change Adaptation Plans for South African Biomes (DEA 2015b), Strategic Framework and Overarching Implementation Plan for Ecosystem-Based Adaptation (EbA) in South Africa: 2016-2021 (DEA & SANBI 2016), and Guidelines for ecosystem-based adaptation (EbA) in South Africa (DEA & SANBI 2017).

These documents were developed by prominent institutions which have undertaken extensive engagement with leading experts, implementing agencies and stakeholders across the country. They clearly articulate a national vision, mission and objectives, particularly through the strategic framework and guidelines. Furthermore, they introduce key concepts, position EbA within domestic and international policy, and provide a list of appropriate response options for each of South Africa's biomes as described in **Table 1** below. These elements are not replicated or debated here. Rather, this Action Plan builds on the work done to date. Readers are therefore strongly encouraged to review the three foundation documents prior to consideration of this Action Plan.

Table 1: Adaptation options listed in Climate Change Adaptation Plans for South African Biomes (DEA 2015b, 8–48)

Albany thicket	• Switch to wildlife- and biodiversity-based land uses • Restore previously degraded areas • Reduce stress from over-browsing of thickets • Improve irrigation efficiency
Desert and Nama Karoo	• Switch to ecotourism and wildlife management, using appropriately informed management practices, with sufficient advice and support • Restore degraded areas, preferably using a multiple benefits approach, with support for *in situ* conservation
Forest	• Implement fire and alien plant management • Implement spatial planning (often linked to the biomes in which forests are embedded) • Maintain ecosystems in which the forest is embedded and control invasions of the edges • Restore forest margins and degraded forest areas, including the use of invasive alien species stands to allow for forest species recruitment • Remove stress from overutilisation of forests

Fynbos	• Maintain effective land management on state land through water-supply based funding, especially for controlling invasive alien plant species and managing fires • Implement the existing biome-wide and municipal conservation plans, including expanding existing reserve systems, and purchasing high biodiversity value land, especially in the lowlands • Form partnerships between agricultural and conservation sectors to find more effective ways of managing landscapes for biodiversity and ecosystem services, including controlling invasive alien species; public and private sector involvement in biodiversity conservation (partnerships, community-based conservation, citizen science, fire protection associations); *in situ* management of biodiversity on private land through the Biodiversity Stewardship Programme • Monitor plant diversity and invasive species (*in situ* and satellite observations) to track whether ecosystems are responding as anticipated
Grassland	• Fire management • Alien plant management • Spatial planning to minimise fragmentation and ensure strategic conservation of pathways • Protect against overharvesting and overgrazing
Indian Ocean coastal belt	• Implement integrated spatial planning, including strategic conservation and protection of corridors. Reduce land transformation. • Switch to wildlife- and biodiversity-based land uses • Restore previously degraded areas • Manage invasive alien plants • Manage fire • Improve irrigation efficiency
Savanna	• Switch to wildlife- and biodiversity-based land uses • Manage encroaching biomass for bioenergy generation/charcoal production • Identify Critical Biodiversity Areas for expansion of protected area networks
Succulent Karoo	• Support emerging farmers through the development of economically viable SMMEs • Restore previously degraded areas, including mined areas • Mainstream biodiversity best practises into livestock grazing and ostrich farming • Support informal conservation initiatives • Promote coordination between conservation and development projects through SKEP • Monitor and evaluate current initiatives and projects • Improve water use efficiency and establish better coordination between water users • Promote efficient water harvesting and water capture in aquifers • Implement integrated resource management plans aimed at ensuring the delivery of ecosystem services • Build capacity within local government to manage both human and environmental issues

CONTEXTUAL POINT OF DEPARTURE

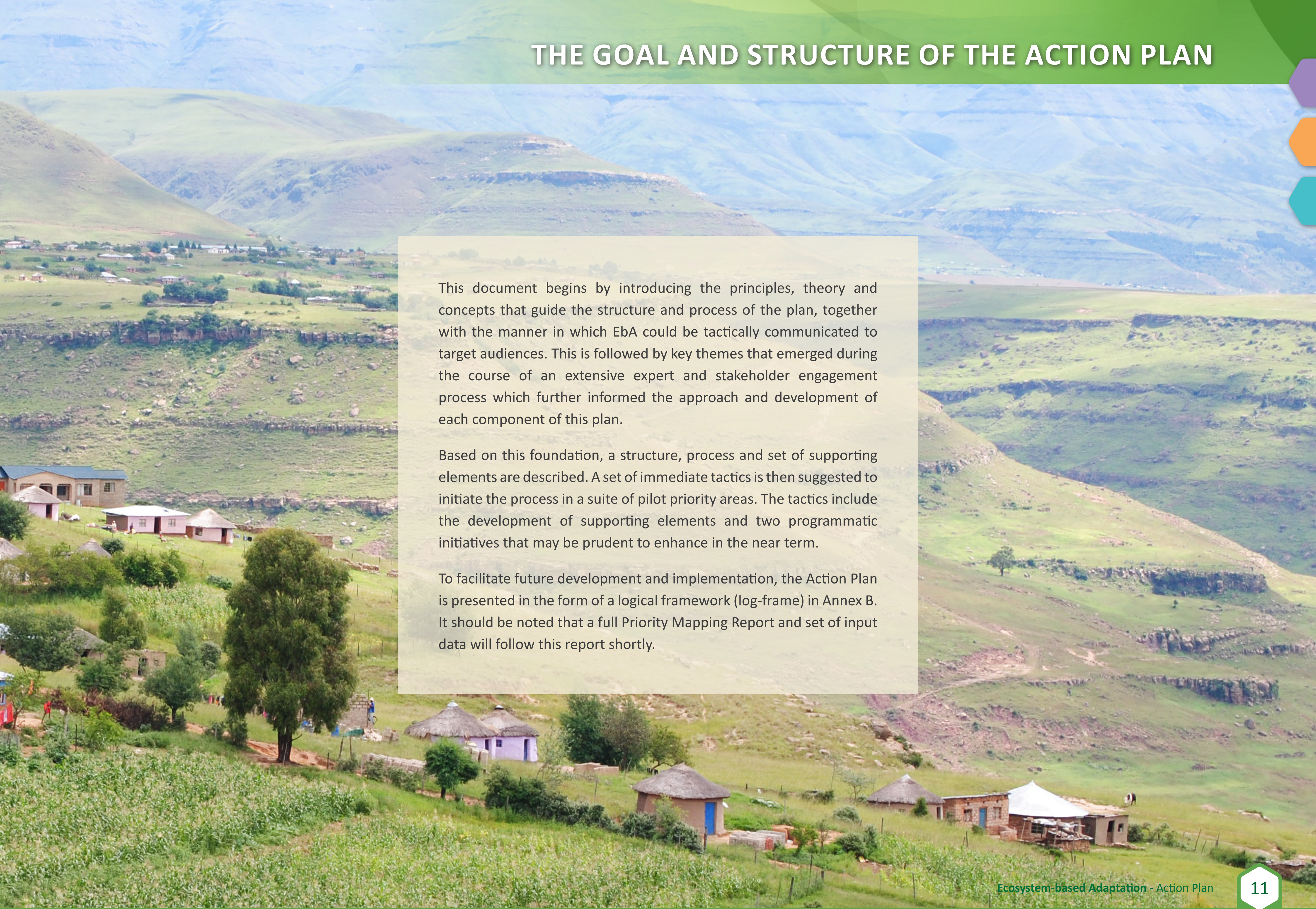
South Africa is well known for its progressive environmental policy and approaches to natural resource management. The country has a wide range and depth of activities and measures aimed at halting, reducing and reversing land degradation, from national policies and programmes, to small-scale projects implemented by non-profit organisations and community groups. A review of EbA related programmes that accompanies this report identified over 160 initiatives currently being implemented by the public and private sectors across the country.

Many activities are being led by other national departments (for example, the Department of Agriculture, Forestry and Fisheries, or other spheres of government (for example, local municipalities). Several are large-scale national programmes with embedded strategies, objectives and planning, for example, Working for Water, Working on Fire, or Land Care. The point of departure for this Action Plan is landscapes that are included in several on-going initiatives that need to be recognised and potentially enhanced in order to realise desired EbA outcomes in an integrated manner.

At the same time, landscapes identified in priority mapping activities are often under the custodianship of existing entities that have their own priorities and needs. These may include mining companies, commercial agriculture organisations, state conservation agencies, as well as communities resident in communal areas. The development of acceptable and sustainable activities and the opportunity to leverage existing capacity within these landscapes often rest on thorough engagement with land custodians and the creation of context-specific implementation models that are acceptable to all parties.

A traditional *top-down*, stand-alone project approach may therefore not realise the set of EbA activities listed in **Table 1** in an effective or locally acceptable manner. Instead, a combination of top-down facilitation and support, together with *bottom-up* participatory development will be needed to create acceptable context-specific implementation models that align with existing programmes and custodianship, while leveraging public and private sector capacity, enhancing local buy-in and addressing gaps in an efficient manner.

The role of providing strategic facilitation and support falls well within the mandate of the DEA, which is to 'provide leadership in environmental management, conservation and protection towards sustainability for the benefit of South Africans and the global community'. This Action Plan focusses on the particular process and structures that might form part of such strategic facilitation and support required to initiate and sustain EbA implementation over time. It is essentially a set of tactics required to realise the vision, strategy and scope of activities articulated in the three foundation documents.



THE GOAL AND STRUCTURE OF THE ACTION PLAN

This document begins by introducing the principles, theory and concepts that guide the structure and process of the plan, together with the manner in which EbA could be tactically communicated to target audiences. This is followed by key themes that emerged during the course of an extensive expert and stakeholder engagement process which further informed the approach and development of each component of this plan.

Based on this foundation, a structure, process and set of supporting elements are described. A set of immediate tactics is then suggested to initiate the process in a suite of pilot priority areas. The tactics include the development of supporting elements and two programmatic initiatives that may be prudent to enhance in the near term.

To facilitate future development and implementation, the Action Plan is presented in the form of a logical framework (log-frame) in Annex B. It should be noted that a full Priority Mapping Report and set of input data will follow this report shortly.

The *Guidelines for Ecosystem-Based Adaptation in South Africa* (DEA 2017), is a set of guiding principles and safeguards. The tactical approach presented in this Action Plan is further informed by the following aims:

- To identify priority areas and response actions based on robust science and clear indications of climate-induced vulnerability.
- To focus on all land within priority areas in a comprehensive manner, including natural and semi-natural areas, cultivated and managed land, as well as peri-urban and urban domains.
- To prioritise the avoidance and reduction of land degradation through comprehensively addressing degradation drivers, in addition to remedial and restoration activities.
- Where appropriate, to leverage existing public and private sector capacity to realise all field implementation activities and supporting elements.
- To remove barriers to entry in the form of required capacity, knowledge and transaction costs.
- To create an enabling environment in which programmes can thrive and be sustained over the long term.
- To balance long-term comprehensive implementation with the realisation of cost-efficient, low-risk, 'no remorse' opportunities.
- To enhance the scale, effectiveness and longevity of actions by shifting values, rules and knowledge (VRK) at a scale that results in systematic change in the system. An integral part of this aim is to change the manner in which EbA is framed and communicated to all parties.

The Action Plan is further informed by the following SMART principles:

S — **Specific** – defining clear and prioritised goals for implementing EbA within a particular biome.

M — **Measurable** – establishing baselines for each biome and practical approaches to measuring, reporting and verifying outcomes against baselines.

A — **Attainable** – taking realistic and practical steps to achieve the goals within a particular biome, including the development of supporting elements.

R — **Realistic** – ensuring that the financial resources, capacity and competency are sufficient to achieve the specific aims. Furthermore, the alignment of all stakeholders is critical.

T — **Timely** – defining clear timelines, including commencement dates, to ensure successful completion of the aims.

Shifting values, rules and knowledge (vrk) to achieve adaptation outcomes

Several entities around the world are facing the common challenge of how to effect the immense level of change required to shift entire landscapes, their inhabitants and biodiversity to a more resilient state. How does one *tactically* reach a point where EbA is mainstreamed? How does one move beyond short-term projects implemented by external entities, to a state where all relevant parties understand the concept, value it and invest their own resources in it? How could the climate change resilient pathways and high-resilience, low-risk state described in the IPCC Fifth Assessment Report be achieved (Fig. 1, Burkett *et al.* 2014)? What tactical structure and process should be followed?

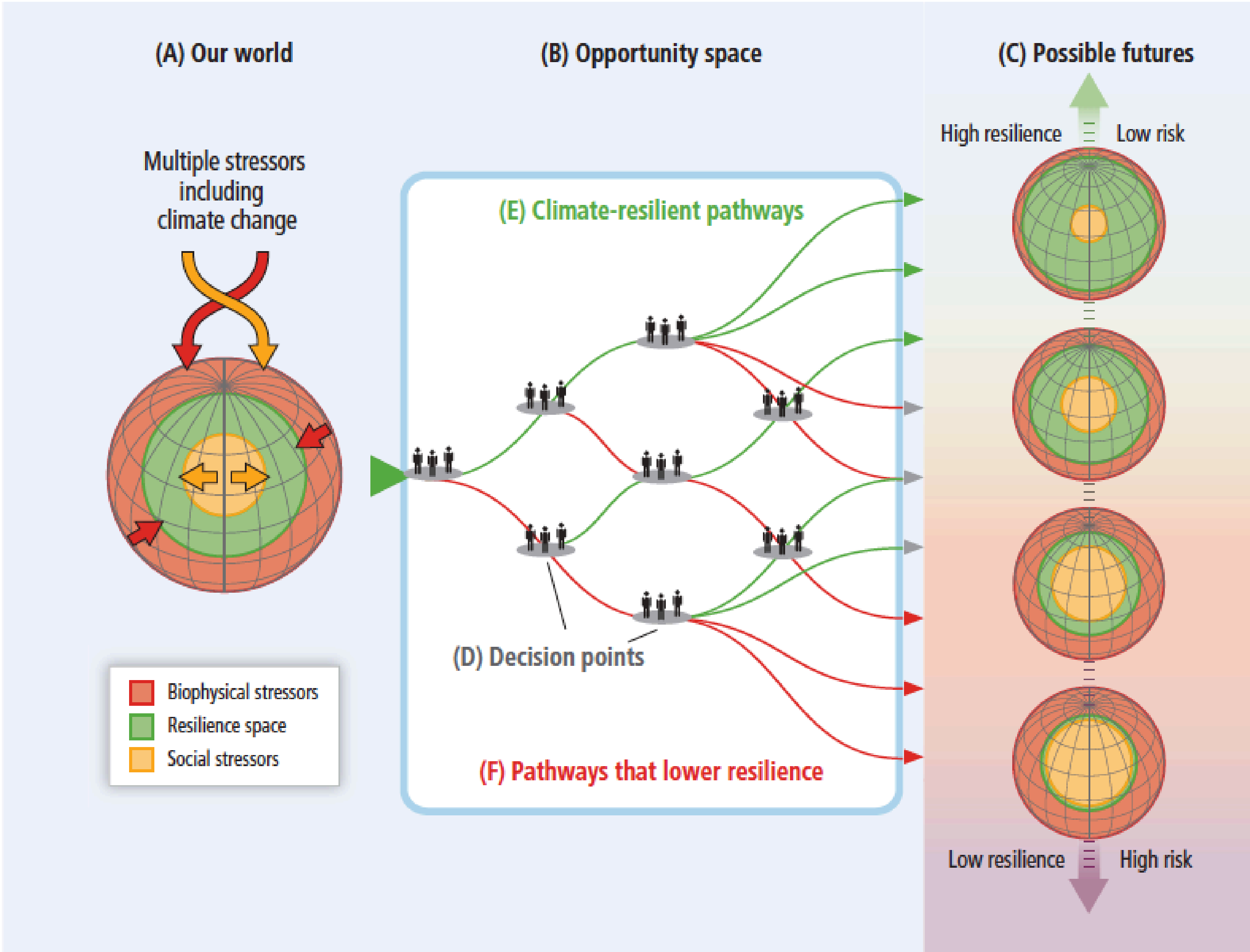


Figure 1: The potential to create climate-resilient pathways within the opportunity space (credit: Burkett *et al.* 2014, 182)

Strategy developers working predominantly in Australia and New Zealand (Abel *et al.* 2016; Gorddard *et al.* 2016), as well as those in South Africa, have been faced with similar dilemmas. For example, how does an entity:

- Step out of the small-scale, short-term project cycle that often addresses only a small part of the landscape in an insular way, to affecting change in terms of broader values, visions, rules and structures (Fig. 2)?
- Engage meaningfully with all parties across the landscape – for example, commercial agriculture, mining and urban developers – to implement required EbA activities in an effective and efficient manner over the long term?
- Create buy-in and ownership of the process by all parties?
- Identify and address drivers of land degradation in a comprehensive manner over the long term?
- Co-create a process that includes relatively short-term and easy-to-implement responses, with longer-term shifts in values and visions that aim to deliver real change at the required scales?

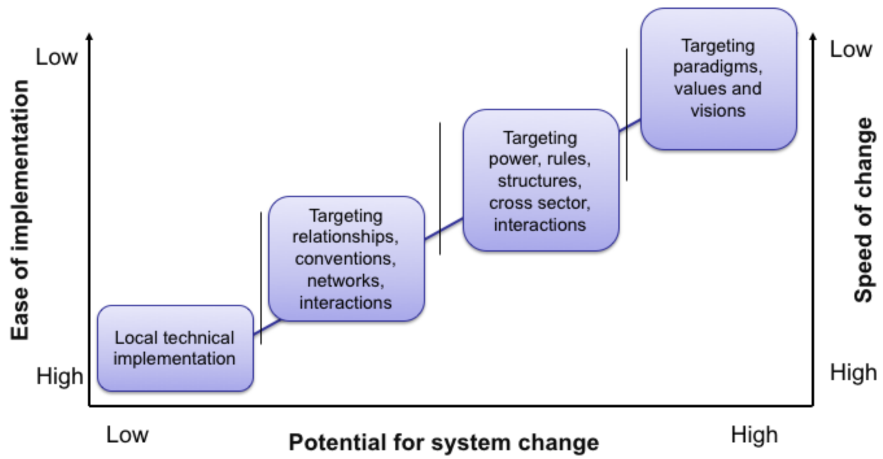


Figure 2: The often-found relationship between the potential for system change, the speed of change and ease of implementation (credit: Paul Ryan from Australian Resilience Centre, personal communication, June 2018)

Through much trial and error, it has been found that merely expanding the scope of entities involved in the process, does not necessarily lead to desired outcomes and independent investment of time and resources. EbA often remains *a green, nice to have* idea instead of a core component of development approaches over time. This is often due to an entity's decisions and choice of options being defined by their 'decision making perspective' which is constrained by their values, principles, regulations and state of knowledge (Gorddard *et al.* 2016). Furthermore, established perspectives are often not suitable for addressing the contested, complex and cross-scale problems that climate change adaptation frequently presents. This often limits the potential scope of adaptive management strategies and responses.

This 'decision making perspective' can be described as an interconnected system of values, rules and knowledge (vrk) (Gorddard *et al.* 2016). Wyborn *et al.* (2016) define each element as follows:

- **Values** represent the personal, cultural and ethical factors that lead to the preferences that people express when confronted with certain knowledge and rules.
- **Rules**, or institutions, represent legislation, regulations, constitutions, guidelines, and other formal factors, as well as societal and personal norms and behaviours.
- **Knowledge** refers to the evidence, beliefs and judgments about how the social-ecological system works, providing an understanding of future changes and the consequences of different decisions.

The vrk model is introduced briefly above, but the reader is encouraged to see Abel *et al.* (2016), Gorddard *et al.* (2016) and Colloff *et al.* (2017) who provide a broader background to the concept and its practical application in a number of significant catchment areas.

Two web-based blogs:

https://i2insights.org/2017/06/20/values-rules-knowledge-and-transformation/

https://i2insights.org/2017/01/19/operationalizing-co-creation/

Tactical implementation of the values, rules and knowledge model

Using pathways to explore options and their requirements

A problem in the development of adaptation measures to date has been the fact that parties often view landscapes as being static. As a result, many activities and measures have been technically driven, with little consideration of the broader, coupled socio-economic system in which they reside. In reality, the observed state of landscapes is the outcome of a biophysical template (e.g. geology, soils and climate), as well as current and historical drivers. Unless these drivers are fundamentally changed, the current state and trends are likely to continue. For example, unless one addresses the fundamental drivers that result in accelerated erosion in a particular area (e.g. overgrazing), short-term erosion control measures are unlikely to succeed or significantly change matters over the long term.

In this context, the concept of alternative stable states may be useful to describe and communicate the change in drivers that may be required (Fig. 3). As noted, the current observed state (e.g. position A, Fig. 3) is the outcome of a basic ecological template, together with a broader set of social and economic values, regulations and knowledge of how to manage landscapes. These drivers form 'feedbacks' which keep the system in its current state. What is required is a significant shift to an alternative, more resilient state (e.g. position B, Fig. 3), in which the collective set of determining drivers has been changed to maintain the system in a more resilient, lower risk state.

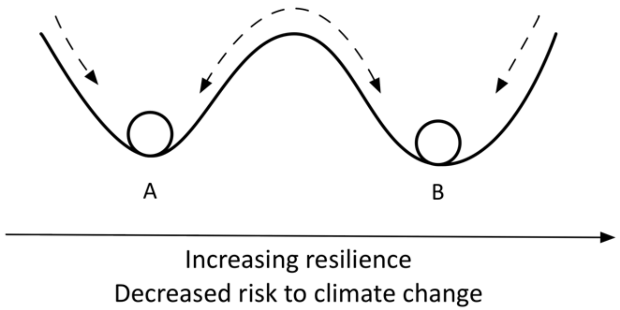


Figure 3: Alternative stable states that are often created by positive feedbacks. The concept can be applied to understanding observed landscapes where the current state is the net outcome of a set of ecological, socio-economic and management drivers.

When considering the application of this concept to the development of an area-wide response, it is useful to add a time dimension to it, in order to understand and communicate how a change in drivers, decisions and options could lead to alternative future states that are more resilient to climate change (Fig. 4, Abel *et al.* 2016). There is a multitude of potential future pathways and states that an area could follow, each with its own benefits, trade-offs and requirements.

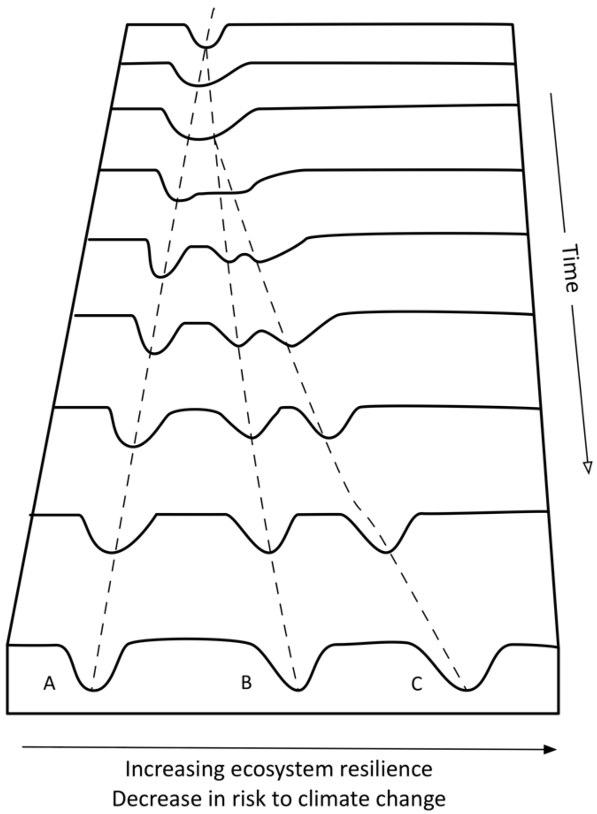


Figure 4: Observed landscapes should not be viewed as static or fixed, but rather continually changing over time and defined by past and current drivers (be they ecological, economic or regulatory). The intention during the pathway development process is to first understand the drivers that have led to the current state and understand the potential outcome over time (A); and then explore alternative scenarios where drivers of degradation are addressed, and rehabilitation measures are implemented, leading to a more resilient system and decreased risk over time. There is not necessarily one alternative scenario, but several that can be explored, during which options and trade-offs are considered (B, C). The initial concept is described by Abel *et al.* (2016).

Interviewed experts and implementers (Annex C) see the process of envisioning and debating future pathways as being valuable for a number of reasons:

- It shifts parties' understanding of observed landscapes from what is often a static view to a broader recognition of ecosystems as dynamic, coupled systems that can be changed through a systematic shift in drivers.
- It provides entities with an opportunity to explore alternative, more resilient options. For example: *'This is the trend, this is going to be the outcome, are we happy with that or shall we change matters and if we do what are the benefits and consequences of such a change?'*
- It improves understanding of the level and nature of change that is required, the types of drivers that need to be addressed, or new actions that need to be developed.
- It provides an opportunity for a more participatory process with active multiple stakeholder involvement. This is not only highlighted as a necessary approach in the literature (Ostrom 1990, IPBES 2018), but more often, stakeholders living in landscapes are stating that they need to be part of the process – **'nothing for us without us'**.

Changing the framing, perspectives, language and conversations

The structure and nature of the process is crucial in order to achieve the level of buy-in required and desired outcomes. A vital element in shifting from individual projects to broader changes in values, rules and knowledge is communication of EbA (Fig. 5). As mentioned above, there is a clear need to 'start out of the green corner' by changing the framing, perspectives, language and conversations used when engaging with all parties, ranging from commercial farmers to mining companies or town planners. An outcome of this approach is that it often unlocks changes in thinking and behaviour at scale, and prompts the process of self-regulation. New options emerge in addition to current and historical implementation models, often led by industries that were previously not part of the process.

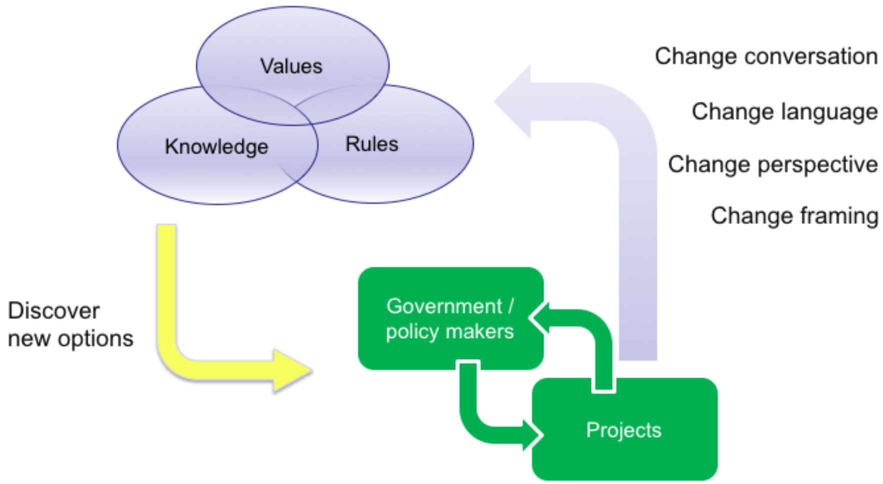


Figure 5: Effecting the level of change required by moving beyond short-term and small-scale projects to a systemic change in values, rules and knowledge within a broader system (credit: Paul Ryan from Australian Resilience Centre, personal communication, June 2018).

The process should be developed in a context-specific manner, but there are several attributes that seasoned developers view as being important:

- Bring all parties to the table. Consider especially those who are often excluded from EbA and biodiversity engagements but could fundamentally affect the success of activities and measures.
- Change the framing, perspective, language and conversation from the start.
- Set rules of engagement and governance of the process to ensure that all parties have the power to contribute appropriately. It may be prudent to bring in an external facilitator who does not have vested interests within the landscape under consideration, or a particular sector.
- Understand the kind of process and instruments that can lead to the desired outcomes.
- Set an end point.

Whereas a full scope of potential future pathways should be explored, the facilitator should keep the process reasonably bounded and practical. Following the exploration of pathways, options and necessary decisions and actions, it is advisable to identify 10 major shifts or activities that are needed to affect the level of change required and then to take those forward into implementation. This is not necessarily an absolutely strict number, but a balance does need to be struck between exploring a vast range of options and moving ahead with a discrete set of practical, well-defined responses for execution.

Communication: Risk as a common currency across sectors

As mentioned, a fundamental component of the VRK model is changing the framing, perspective, language and conversation from the start. Entities across sectors, from mining companies to town planners, need to understand why they should invest time and resources in the process. Yet, implementers interviewed in this study noted that the use of terminology commonly used within the EbA domain often fails to relay the importance of adaptation measures, which often results in adaptation being viewed as part of the 'green agenda' and even 'anti-development'. It may therefore be prudent to reframe how an EbA programme is communicated to sectors from the start. Importantly, it is not suggested the process becomes less scientifically robust, or that one alters the language and terminology used internally; rather it is part of a broader tactical approach to engage effectively with parties in other sectors, and to effect desirable changes in VRK and resultant adaptation outcomes.

An option may be to use the concept of risk as a common currency across sectors. It is a well understood concept in most fields, including those of climate change, biodiversity, agriculture, industry, finance, mining and social development (Fig. 6). It is broadly used within the National Development Plan (NDP) 2030 (NPC 2012), Outcome 10 of the Medium-Term Strategic Framework (MTSF) (RSA 2014), as well as the Long-Term Adaptation Scenarios (LTAS) Programme (DEA 2013). An EbA programme could be broadly communicated as 'an opportunity to reduce the risk of climate change to water, crops, livestock, industry and biodiversity through restoring and maintaining healthy landscapes'; but would need to be further calibrated depending on the particular sector under consideration.

A crucial benefit of adopting risk as a common currency is that it is measurable and reportable, so that entities can evaluate progress over time towards a certain goal. In general, entities would be able to estimate the risks presented by climate change and how these could be reduced through avoiding, reducing and reversing land degradation over time. This is explored further in a later section in this plan on creating a national monitoring system.

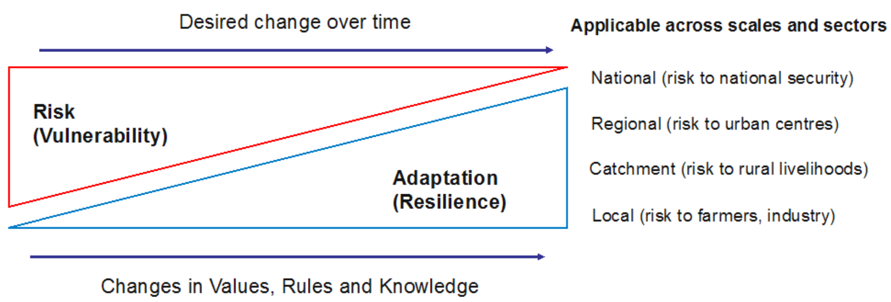


Figure 6: The concept of risk could form a common currency through which to communicate and measure the value of EbA across sectors.

THEMES EMERGING FROM EXPERT AND STAKEHOLDER ENGAGEMENT THAT INFORM THE ACTION PLAN STRUCTURE AND PROCESS

Two engagement sessions were held during the development of this Action Plan and Priority Mapping Report. The first five themes presented in the following sub-sections emerged principally through the initial engagement with experts. The remaining seven themes are prominent outcomes of the provincial and national engagements that were held across the country between October 2018 and February 2019.

Effecting change through a comprehensive approach and collective action

The term 'collective action' is used by Abel *et al.* (2016) to describe the broad suite of activities often required to effect changes in values, rules and knowledge. South African implementers independently raised the point that individual, isolated projects seldom achieve their broader envisioned objectives or remain in place after an initial 3 to 4-year grant period. Firstly, there needs to be a broadening of scope of on-the-ground activities, for example, from only land restoration to the development of alternative land-use options, value chains and local extension support services, among other initiatives. Secondly, on-the-ground activities need to be supported through regulation and policy, as well as by directly addressing drivers of degradation (e.g. market or societal drivers) that are beyond the control of implementing parties.

Creating an enabling environment through supporting elements

A recent report focussing on the mainstreaming of EbA in South Africa (GIZ 2018) found that a disproportionate number of early EbA programmes were led by a

'champion' who forged ahead, making use of ad hoc opportunities as they arose. When asked what factors inhibit the expansion of initial programmes or the emergence of champions elsewhere, a common answer was that there is a lack of an enabling environment for passionate local leaders to thrive within the public and private sectors.

The first concern often raised was financial constraints, particularly access to sustained, consistent income over time. In addition, parties identified a broader set of barriers that need to be addressed, notably access to equipment, supplies and particularly expertise and networks of similar practitioners. Certain activities – for example, conservation agriculture or clearing invasive alien species – are inhibited by a lack of access to equipment. A broader concern is access to expertise and extension services. Parties noted that 'collective competence' is often required to implement measures, especially when implementing on a significant scale or in an area that includes several different land custodians and land-use types (for example, in the context of a biosphere reserve). The implementing entity requires a broad range of skills, including ecological, agricultural, financial, human resource management, project management, regulatory, monitoring skills, as well as grant writing and administration expertise. Few individuals have such competencies alone and therefore assistance is required to build them in a collective manner, through extension services and the further development of programmes that tackle a particular need, for example, a cost-efficient national monitoring and reporting system.

A further enabling component that was often highlighted as being important and effective is the creation of *communities of practice*. Several of these already exist in certain forms, for example, the Soil Conservation committees of the past, or the current No-till Club in KwaZulu-Natal (http://www.notillclub.com/). It is strongly suggested that these types of communities should be encouraged in order to enhance the sharing of insights, peer-review and self-regulation.

Governance and institutional mandates

South Africa has a significant and strong non-governmental environmental sector that often leads extensive natural resource management programmes. However, there are clear limitations to their mandate, especially in the domain of intra-governmental engagement. Implementing changes in the VRK process, or any integrated area-wide type of response will require the participation of all government departments that influence land-use policy and practice within the landscape (for example, Department of Environment, Forestry and Fisheries DEFF), Department of Agriculture, Land Reform and Rural Development (DALRRD), Department of Water and Sanitation (DWS), Department of Mineral Resources and Energy (DMRE). Their respective visions and programmes will need to be aligned in order to ensure that the principal drivers of degradation are addressed, and to avoid overlap between initiatives and inefficiencies, for example, between Expanded Public Works Programme (EPWP), LandCare and the Land Degradation Neutrality Programme. Whereas the private sector can play a substantial role in implementation, leadership of the process will need to be undertaken by a government entity with the required mandate, for example, the local or provincial government, or a national programme.

Alignment in planning and management between national departments and programmes

When asked about potential response options and models that may be currently missing, several stakeholders noted the need for greater alignment in planning and implementation between national departments and programmes. South Africa is fortunate enough to have a large number of natural resource management programmes that are being implemented by a range of public and private entities at numerous scales. However, this can lead to overlap on-the-ground and associated inefficiencies.

Parties noted that there may be significant opportunities not only to reduce redundancy, but to leverage existing capacity and expertise located within other programmes. Some stakeholders even recommended that a VRK-type process be followed at a national scale between national departments, to allow the creation of a common vision for particular catchments, which in turn would result in improved efficiencies and outcomes. At a minimum, it was suggested that communication should be improved between national programmes (for example, EbA and Land Degradation Neutrality) and on-the-ground programmes (for example, EPWP, LandCare and NGOs).

Leveraging existing private and public sector capacity and programmes

As mentioned above, there is an immense number of existing public and private sector natural resource management programmes across South Africa, ranging from national flagship programmes (for example, EPWP, LandCare and the Biodiversity Stewardship Programme), to the implementation of conservation agriculture through DALRRD and industry organisations, to smaller scale community-based initiatives often led by non-profit organisations. The challenge is to build on the work already underway in a structured and efficient manner. Part of this requirement is to create the enabling environment noted above. Furthermore, there is a need to catalogue and map the spatial extent of programmes in order to understand where gaps exist. Interviewed parties noted that while there are hubs of great activity in certain areas and in particular land-use types, there are large sections of the country in which implementation is largely absent.

Starting small with a set of true pilot areas, rather than on a national scale

In line with the notion of collective action, entities advised that activities should be pursued at all levels, but in a balanced and reasonable manner. Established 'no regret' programmes (for example Biodiversity Stewardship and conservation agriculture) should be given further support as soon as possible. However, it may not be prudent to develop the VRK model at a full national scale immediately. Parties suggested focusing resources on 4 to 5 pilot areas which would be identified through the prioritisation mapping process. These pilot areas would be approached in a more experimental manner, clearly acknowledging from the start that there is space for development and calibration. Furthermore, the pilot areas could perform as demonstrations, thereby illustrating proof of concept and encouraging uptake in neighbouring areas. The developers of conservation agriculture programmes noted that one of the most effective ways to expand uptake is to establish demonstration projects in target areas that illustrate the nature of implementation and associated benefits and risks in a local context.

Addressing drivers of land degradation at all levels

From the early developers of reforestation and avoiding deforestation (REDD+) activities to the more recent analysis of land degradation by IPBES (2018), entities have found that avoiding land degradation is far more effective and efficient than attempting to implement restoration measures on land that has already been transformed. Whereas the extent of land clearing and deforestation may be limited in South Africa in comparison to countries located in the tropics where it is confounded by expanding bush encroachment, there are specific areas (for example, the sub-tropical thicket biome) in which the annual rate of clearing indigenous vegetation is higher than the rate of restoration and where an enhanced focus on drivers of degradation is necessary.

Inclusion of urban and peri-urban areas

On reviewing the initial list of EbA activities and this Action Plan, stakeholders were quick to note that urban and peri-urban areas are largely absent from national EbA strategies to date. DEA (2015) (which focusses on adaptation plans in each biome), as well as earlier strategy documents, tend to focus inherently on indigenous areas where there is low human impact. A concept that may be useful in communicating and mapping this outcome is the concept of 'anthromes'. First proposed by Ellis and Ramankutty (2008), anthropogenic biomes (or anthromes) are identified primarily at the level of human impact on an area (**Table 3**).

Table 3: The 18 anthromes clustered into six groups (Source: Ellis & Ramankutty 2008, 442)

Group	Anthrome	Description
Dense settlements		***Dense settlements with substantial urban area***
	Urban	Dense built environments with very high populations
	Dense settlements	Dense mix of rural and urban populations, including both suburbs and villages
Villages		***Dense agricultural settlements***
	Rice villages	Villages dominated by paddy rice
	Irrigated villages	Villages dominated by irrigated crops
	Cropped and pastoral villages	Villages with a mix of crops and pasture
	Pastoral villages	Villages dominated by rangeland
	Rainfed villages	Villages dominated by rainfed agriculture
	Rainfed mosaic villages	Villages with a mix of trees and crops
Croplands		***Annual crops mixed with other land uses and land covers***
	Residential irrigated cropland	Irrigated cropland with substantial human populations
	Residential rainfed mosaic	Mix of trees and rainfed cropland with substantial human populations
	Populated irrigated cropland	Irrigated cropland with minor human populations
	Populated rainfed cropland	Rainfed cropland with minor human populations
	Remote croplands	Cropland with inconsequential human populations
Rangeland		***Livestock grazing; minimal crops and forests***
	Residential rangelands	Rangelands with substantial human populations
	Populated rangelands	Rangelands with minor human populations
	Remote rangelands	Rangelands with inconsequential human populations
Forested		***Forests with human populations and agriculture***
	Populated forests	Forests with minor human populations
	Remote forests	Forests with inconsequential human populations
Wildlands		***Land without human populations or agriculture***
	Wild forests	High tree cover, mostly boreal and tropical forests
	Sparse trees	Low tree cover, mostly cold and arid lands
	Barren	No tree cover, mostly deserts and frozen land

The existing strategy tends to focus on the rangeland, forested and wildland anthrome groups, perhaps with the inclusion of pastoral villages. Stakeholders noted the need to explicitly expand the scope to dense settlements and other village anthromes. A primary reason for placing emphasis on the urban and peri-urban domain is that it is an area where stakeholders are seeing growing human pressure and an associated degradation of landscapes and ecosystem services. In nearly all provincial stakeholder meetings, 'migration', 'unplanned urbanisation', 'unplanned conversion of wetlands and grasslands' and 'unplanned roads and other infrastructure', feature prominently in the list of drivers of degradation that parties are observing on a daily basis. Urbanisation is predicted to double by 2050 in sub-Saharan Africa and parties on the ground are observing its potential negative ecological impact if it continues in an unplanned and unmanaged manner.

Appropriate spatial planning falls under the mandate of local municipalities. EbA is already considered to a certain degree in spatial planning through the Spatial Planning and Land Use Management Act, 2013 (Act No. 16 of 2013) (SPLUMA 2013) and the roll-out of the 'Let's Respond Toolkit' (www.letsrespondtoolkit.org) across the country; yet municipal officials

attending the stakeholder engagements noted that further spatial planning and implementation support is required.

In addition to spatial planning elements, South Africa is viewed as a leader in the urban EbA domain, particularly due to the broader programme and activities being implemented by eThekwini Municipality. There is a need and a good opportunity to expand an eThekwini-type programme to other metropoles across the country, delivering both EbA and employment benefits.

Focusing on ecosystem flows as well as stocks

In addition to focusing on anthromes that are less impacted by humans, stakeholders noted that the list of identified EbA activities in earlier strategy documents does not necessarily include the 'flow' of ecosystem services, particularly the importance of riverine health and riparian and wetland areas that often link the source of hydrological services with end-users. This is understandable, since previous analyses of options focused on the biome level; but future EbA development should clearly include these elements to ensure that adaptation to changes in rainfall and temperature is achieved, as well as reducing the impact of intense flood events. There are several early riparian and wetland rehabilitation programmes across the country (for example Working for Water, Working for Wetlands, as well as individual projects in the eThekwini Municipality) from which insights can be gained on how to structure and manage implementation over the long term in a way that creates sustainable employment. At the same time, waste water treatment needs to be enhanced to ensure that water services generated through EbA are usable.

Unplanned agriculture and other forms of land use

Stakeholders in the Eastern Cape, Western Cape and KwaZulu-Natal noted that unplanned agriculture is a clear driver of degradation across biomes ranging from sub-tropical thicket to more open savannas and grasslands. The expansion of both commercial and smallholder agriculture is often unplanned and non-compliant, leading to the conversion of indigenous areas that are of EbA and biodiversity importance. The issue is particularly acute in the Eastern Cape and KwaZulu-Natal where large areas of endemic vegetation are being converted into cropland and orchards.

There is a clear need to enhance the monitoring, reporting, authorisation and policing of land cover across the country to address this issue, if EbA outcomes are to be realised. An early initiative between members of SAEON, EPWP and Rhodes University has started to track and report changes in land cover in the Eastern Cape on an almost daily timescale, using emerging cloud-based remote sensing techniques. This type of approach, linked to agricultural authorities and local law enforcement, needs to be enhanced in order to halt land degradation at a national scale.

Poor rangeland management

In line with the EbA options identified in DEA (2015), parties identified the poor management of grazing, fire and erosion as a principal driver of rangeland degradation across the country. Stakeholders often voiced their concern over the viability of rangeland production and the need to shift to sustainable practices to ensure healthy herds, as well as the provision of ecosystem services in a resilient manner. Based on progressive approaches being pioneered by non-profit organisations in the Eastern Cape and elsewhere, there is an opportunity to significantly improve animal husbandry and veld and fire management practices in areas under communal land tenure, thereby potentially restoring ecological infrastructure and associated services. At the same time, the trade in livestock in such areas provides clear income streams to often impoverished communities.

Alignment of existing work in a holistic and structured manner

Closely related to the theme above numerous stakeholders in several provinces raised the need to coordinate an often substantial number of programmes in a particular area. The review of existing EbA-related activities (which forms part of this project) highlights the considerable scope and depth of natural resource management projects across the country. A repeated message emerging from several engagements is that one should start by leveraging existing activities as well as existing public and private sector capacity, mapping their current extent and filling in gaps in a systematic and efficient manner.

The need for facilitatory support

Stakeholders repeatedly raised the need for facilitatory support of four types:

- An open platform is needed to bring key decision makers together in an open and informed manner, giving parties the time and space to explore future development pathways within a landscape. This opportunity is absent at present, which often leads to a 'silo effect', with resulting conflicts, overlaps, repetition and inefficiencies.
- Operational expertise is often lacking and needs to be enhanced. In particular, small and emerging implementers do not have the broad range of financial, legal and human resource management skills required to manage projects appropriately. This issue could be addressed through training or by providing collective outreach assistance at a landscape scale.
- Sustained communication, education and outreach are necessary. Stakeholders noted the efficiency of working groups or communities of practice in certain landscapes around the country in achieving EbA outcomes. These need to be formally enhanced and supported.
- Improved law and regulatory enforcement are crucial in order to halt and reduce land degradation even before it occurs. This role is beyond the mandate of the private sector and needs to be enhanced in a systematic and comprehensive manner across the country.

THE STRUCTURE, PROCESS AND ELEMENTS

Based on the three guiding strategy documents (DEA 2017; DEA & SANBI 2017) and the theory and emerging themes discussed above, a structure and process are suggested to lead entities from the initial prioritisation of areas through to the development of each element (Fig. 7). A number of the suggested elements are already included in two of the principal guidance documents. The intention is not to duplicate them here, but merely to illustrate how this Action Plan considers them within the process that would unfold in each priority area.

The first step is to identify priority areas based on clear climate-induced vulnerability and the ability to reduce it through ecosystem-based approaches. The approach, methods and data used to identify and map priority EbA areas are described in a separate document attached to this report.

Within each chosen area, the next steps are to assess the principal direct and indirect drivers of land-use decisions and land degradation. This will include mapping the principal regulations, institutions and parties that are affecting the relevant drivers. An important component of this stage is to map past and current land degradation patterns, to understand not only the nature and magnitude of drivers, but also the extent and type of restoration efforts required.

Thereafter, the VRK model (as described above) would be facilitated within each area. The aim is to include all pivotal parties either directly or indirectly driving land-use decisions in the engagement and pathway development process. This may include entities that are not physically located within the landscape, but whose actions drive land-use decisions that affect risk and vulnerability outcomes (for example, a national department that defines policy and regulations).

The outcome of the pathway development process will be the identification of a set of activities and measures that are required to effect the level of sustained change required, together with an understanding of who the implementing agents will be in each particular landscape.

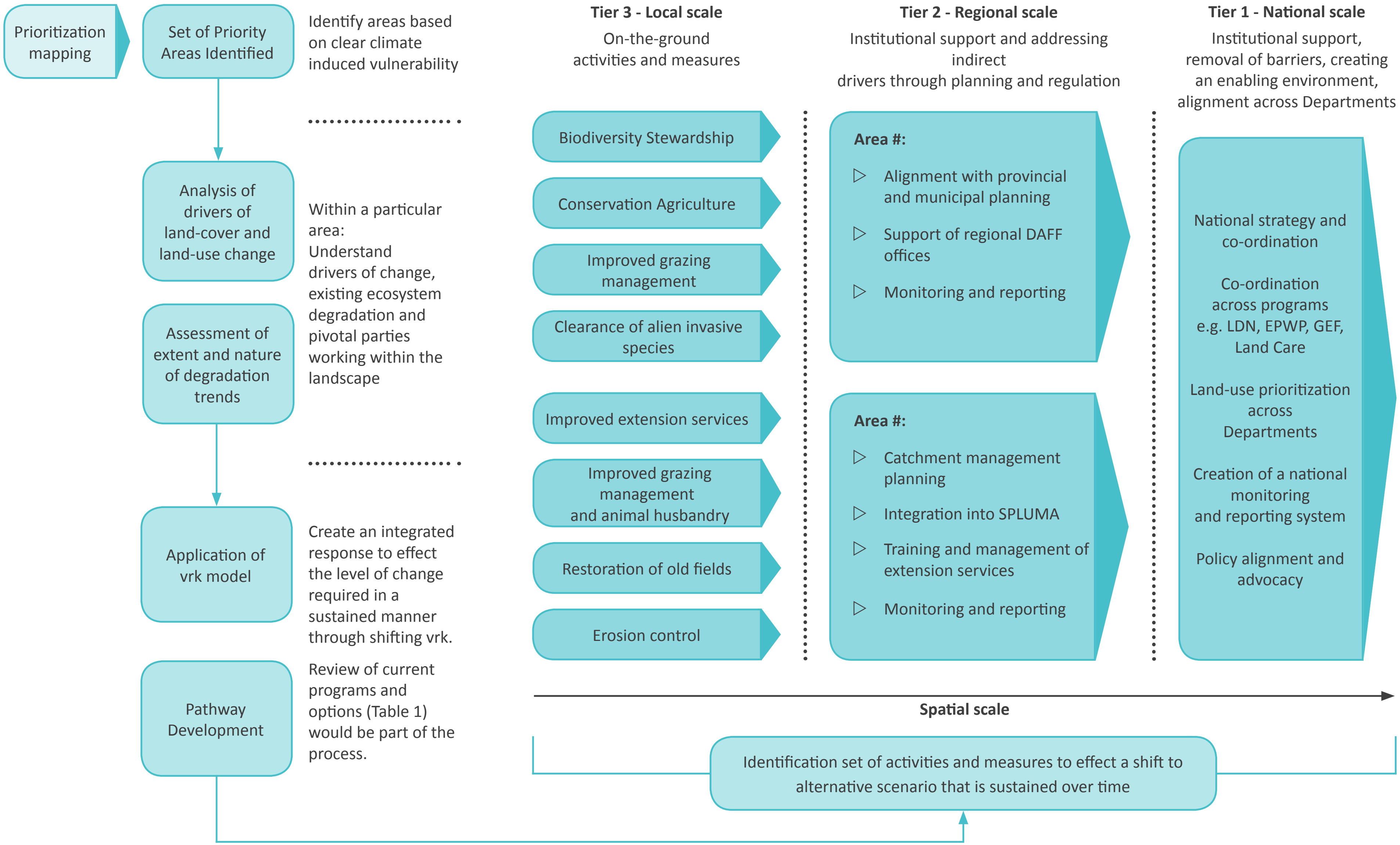


Figure 7: The process of identifying required activities and measures at local, regional and national scales to effect the level of change required in each area identified in the prioritisation process.

To improve efficiency, the intention would be to work with large land custodians (for example, commercial forestry and agriculture) and existing programmes, prior to the development of new Greenfields programmes. The actions on the ground will need to be supported by activities at provincial and national scales (for example, integration into spatial planning, enforcement of regulations), and nested within an enabling environment that sustains implementation over time (for example, incentivised and monitored in an effective and efficient manner).

The concept of 'tiers' in an implementation context was initially introduced in a report focused on addressing barriers and unlocking opportunities for land-use based climate change mitigation activities in South Africa (DEA 2017b, 14). In similar circumstances to the current development of adaptation responses within the land domain, developers were faced with a broad set of necessary activities at spatial scales ranging from field implementation to national policy alignment. To articulate the general scale at which an activity would be implemented and the type of entity that would execute it, the three tiers structure was developed. It describes actions that would typically occur on the ground at a local scale (Tier 3), at a provincial scale by provincial government (Tier 2), and at a national scale (Tier 1) (**Table 4**). The concept of tiers is equally applicable to rural landscapes, urban areas and riparian zones.

Table 4: Typical activities implemented in each tier. (The lists are meant to be illustrative and not exhaustive)

Tier 1: National scale in range and implemented by national government
▷ National strategy and co-ordination of programmes.
▷ Engagement and alignment with other national departments that influence land use and the health of ecosystems (e.g. DALRRD, DMRE, DWS).
▷ Co-ordination across natural resource management programmes (e.g. EPWP, Land Care and Degradation Neutrality (LDN), Global Environment Facility (GEF).
▷ Creation of a national monitoring and reporting system.
▷ Creation of an incentive model for appropriate land management.

Tier 2: Pertaining to a particular province and led by provincial government and conservation agencies
▷ Integration of EbA into land-use planning at provincial and municipal scales.
▷ Enforcement of existing rules and regulations (permit system – National Environmental Management Act, 1998 (Act No. 107 of 1998) NEMA; Conservation of Agricultural Resources Act, 1983 (Act No. 43 of 1983) CARA; National Forests Act, 1998 (Act No. 84 of 1998).
▷ Extension support to land custodians.
▷ Engagement with organised agriculture.

Tier 3: On-the-ground implementation at a landscape or catchment scale. Led by either government agencies or the private sector; typically developed in a bottom-up, context-specific manner
▷ Government natural resource management programmes e.g. EPWP, Land Care, Biodiversity Stewardship.
▷ Led and facilitated through local municipalities e.g. eThekwini Municipality.
▷ Implemented through organised commercial agriculture and plantation forestry entities.
▷ Facilitated through the Biosphere Reserve Programme e.g. the Gouritz Cluster Biosphere Reserve.
▷ Implemented through non-profit conservation or environmental organisations.

An overview of each supporting element that would be required to initiate and sustain appropriate and efficient implementation is detailed in Fig. 8. Each of these elements is required to effectively choose important areas, understand and address the principal drivers of degradation, develop alternative future pathways (in a multi-stakeholder, participatory manner), implement restoration measures on the ground, mainstream EbA into future planning and strategy across departments and provide an enabling environment for outcomes to be sustained within particular landscapes over the long term. The intention is for most of the process to be coordinated by the DEA, leveraging existing capacity, programmes and processes where at all possible.

The 'national monitoring and reporting system' and the 'incentive system' are expanded upon in **Annex A**.

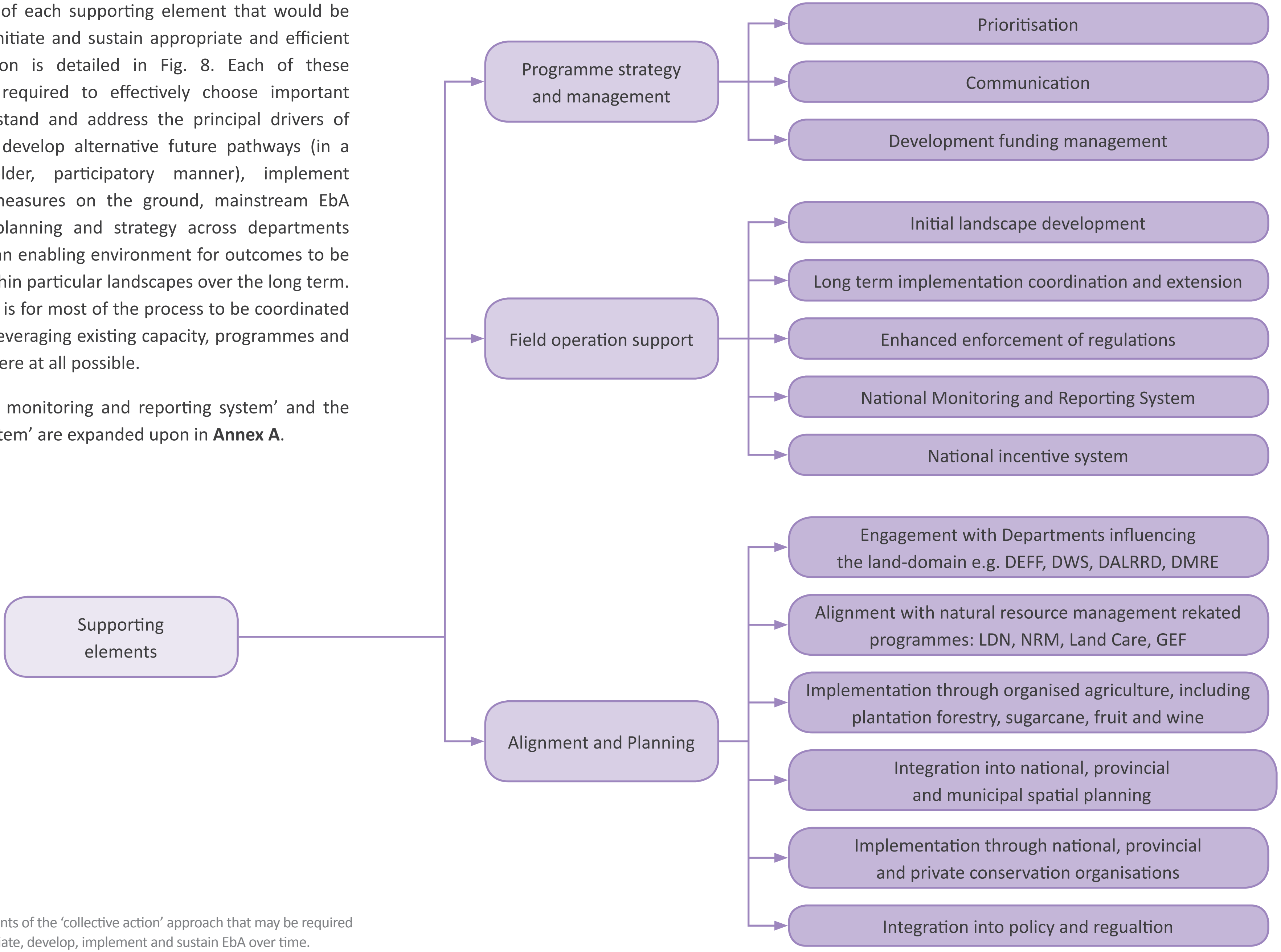


Figure 8: Elements of the 'collective action' approach that may be required to initiate, develop, implement and sustain EbA over time.

A crucial question is where to start with the proposed Action Plan, and what tactics to apply to work up to a full, comprehensive national programme. Many interviewed experts and seasoned implementers strongly recommended not starting at a full national scale, but rather with a pilot phase during which all elements – from field implementation to alignment with other national departments and programmes – would be trialled and tested. The findings of the pilot phase would be used to improve the effectiveness and efficiency of implementation as the scale is increased.

The pilot phase would include the development of two to three pilot landscapes (preferably significant catchments) and 2 to 3 urban / peri-urban areas in which the full VRK process would be tested as a means of realising the type of system change that is required. These would be true 'pilots' in that they would be typical of a broader area, and selected specifically to provide required knowledge to increase the scale of implementation over time in an effective manner. The pilot areas would be chosen based on the prioritisation process (see the Priority Mapping Report) and implementation would follow the structure and process illustrated in **Figure 7**. Particular pilot areas could be located in landscapes where early implementation is already underway. This may reduce the initial investment and risk associated with completely new green fields programmes. However, several parties noted that existing implementation measures should be subject to in-depth assessment and scrutiny prior to adoption to avoid encouraging programmes that are fundamentally ineffective.

The pilot phase includes the early development and testing of all elements of the suggested process and structure illustrated in **figures 4**, **5**, **7** and **8**. Work will take place within landscapes that may be home to rural and peri-urban communities, as well as existing agricultural or mining enterprises and ongoing initiatives. The intention is to pioneer the process of considering alternative future development pathways and to possibly shift values, rules and knowledge to allow the realisation of more sustainable and climatically resilient landscapes and communities over time. Although it is imperative to leverage and build upon existing programmes and capacity, additional on-the-ground implementation models – together with monitoring and incentive systems – would be explored and developed where necessary. Furthermore, the initial pilot areas would be used as a test case to conduct required alignment and planning work with other national departments that are working within the same landscapes. A logical framework describing the key planning and management elements over the suggested 5-year pilot period is included in **Annex B**.

Focussing on concise, specific areas will allow engagement with other departments, programmes, organised agriculture and spatial planning processes to be more focused, shifting from abstract intentions to more specific interventions in particular areas. Again, the emphasis during the pilot phase should be on providing the space to explore engagement, alignment and planning processes, with a view to identifying preferred processes to be adopted during future implementation.

Throughout the initial pilot phase, it should be recognised that EbA is in an early experimental period during which it is prudent to experiment (within reason and with a clear purpose) with all elements of field operations, supporting components, and alignment and planning. Several experts and stakeholders noted that having the space to explore, test, fail and improve is crucial in order to understand appropriate implementation models. Resources should be allocated to adequately monitor, document and report success and barriers, so that early lessons can inform future expanded implementation. The quality of interventions and what is produced is vital from the start.

Together with the set of pilot areas in which the VRK model and supporting elements would be developed (**Figure 7**), two further early and more programmatic responses are suggested:

- First, it would be prudent to enhance established low-risk, inexpensive programmes that improve natural resource management at scale within priority areas, for example, Biodiversity Stewardship and conservation agriculture. Importantly, these programmes have been implemented in fixed areas over the long term and can therefore be more easily monitored and incentivised. Over time, these areas would be gradually included in the expansion of the initial pilot areas.
- Second, the capacity of provincial authorities needs to be enhanced to ensure adequate enforcement of regulations that govern the conversion of land.

The choice of these early pragmatic responses is not ad hoc, but is informed directly by the principle of addressing climate-induced vulnerability to water, food, industry and biodiversity through responses that are efficient and measurable.

Lastly, while acknowledging that EbA will need to be consistently considered for decades to come, it would be appropriate to set a medium-term end point to the pilot phase, at which stage the entire set of supporting elements should have been developed and tested. It would also be an appropriate point to pause and reflect, and to plan future expansion based on the outcomes of the pilot phase.

National monitoring and reporting system

The ability to monitor, report and verify outcomes is crucial for the development of effective and efficient response options within the climate change domain. It is an underlying necessity for results-based payment systems, be it payment for water, carbon or other ecosystem services, and a requirement of most domestic and international funding agencies. It is for these reasons, among others, that Strategic Outcome 9.1 of the NCCAS (DEA 2019, 8) is aimed at developing a national monitoring and reporting M&R system to track vulnerability, resilience and implementation.

At present, however, the need for M&R often presents barriers for implementing agencies who are unaware of the required attributes that they should measure, suitable field methodologies and analyses, and reporting procedures. Furthermore, the cost of monitoring, especially of soil attributes, can be prohibitively expensive, particularly if conducted at a small scale, on a project-by-project basis. This situation is not unique to South Africa, but commonly found around the world where parties are attempting to report on the outcome of land-based climate change response programmes.

Part of creating an enabling environment is designing a monitoring and reporting system specifically to reduce barriers to entry in the form of knowledge, capacity and costs. It should focus on all elements of the data supply and analysis chain, from remote sensing and field measurement, to laboratory capacity, to the capture and transfer of data, data storage and analytics. Many interviewed experts noted that, where reasonable in terms of costs and capacity, monitoring and reporting should go beyond biophysical attributes to include social, economic and operational metrics. Again, these measures will assist in informing and calibrating programme design and implementation over time.

A well-designed and well-managed system has the ability not only to fulfil climate change adaptation reporting needs, but also a broader range of domestic and international reporting requirements, for example, the three Rio Conventions (United Nations Framework Convention on Climate Change (UNFCCC), United Nations Convention on Biological Diversity (UNCBD), United Nations Convention to Combat Desertification (UNCCD)). Domestic and international funders often require data on social, economic and operational metrics in order to communicate the human benefits of implementation to a broader audience.

In terms of tactics, it would be prudent to develop the monitoring system, including the full data supply chain, based on the set of pilot project sites. A first step would be to review current monitoring programmes and capacity within government structures that may be able to undertake certain elements of monitoring and reporting in a cost-efficient and sustained manner over time.

Attributes → **Measures** → **Indicator** → **Target audience**

Attributes

Structure

Plant
- Woody
  - Tree height
  - Canopy cover
  - Basal cover
- Herbaceous
  - Height
  - Aerial cover
  - Basal cover

Soil
- Texture
  - Sand / silt / clay
- Organic content
- Nutrients
  - N, P, K,
- pH, EC

Consumption

Species richness

Species abundance

Function

Stability

Infiltration

Nutrient cycling

Operational

Time

Cost

Activity – e.g plants surviving

Measures

Woody biomass

Herbaceous biomass

Fuel load

Terrestrial carbon stock

Water infiltration

Planting success

Indicator

- Water services
- Soil health
- Erosion
- Carbon stocks
- GHG emissions
- Landscape production
- National capital
- Rural livelihoods

Target audience

Treasury

NRM, EPWP

National reporting –
UNFCC, UNCCD, UNCBD

National Strategy and Planning –
- Halting, reducing and reversing degradation
- Land use based mitigation
- Ecosystem based adaptation

Applied science –
- Global change community
- Rural livelihoods

Figure 9: The measurement and reporting of a basic set of attributes would provide the opportunity to meet a broad range of management, strategy, science and national and international reporting needs. *(N Nitrogen, P Phosphorus, K Potassium; pH Acidity or Alkalinity, EC Electrical Conductivity; GHG Greenhouse Gas; NRM Natural Resource Management, EPWP Expanded Public Works Programme)*

Creating an appropriate incentive model

An integral part of initiating and sustaining changes in land use over the long term is the provision of adequate incentives. These can be in the form of an increase in production and direct income, a further financial benefit, or non-financial incentives that are of value to land custodians. Although the development of incentive models has often focused solely on financial benefits, interviewed experts were quick to note the value placed on non-financial incentives in the form of access to extension services, communities of practice, equipment and supplies. Access to expertise, support and fellow land managers in a similar situation is highly valued and should be a core component of future incentive models.

Additional financial benefits can be derived in a number of ways, for example, payments for ecosystem service (PES) and tax incentives. An emerging programme is the Biodiversity Tax Incentive led by Birdlife South Africa that provides a tax benefit to land custodians who engage in Biodiversity Stewardship. While there is a rich history with respect to PES investigative studies within an African context, few have actually matured from project or pilot stage into fully-fledged system-wide interventions that leave a lasting legacy of prudent natural resource management use and sustainability. Three key reasons for this lack of PES maturity are:

- Institutional failure, or the failure to embed PES within a well-resourced and capacitated statutory institution officially mandated for PES, thus leaving PES initiatives at the project or pilot stage
- Difficulties experienced in dealing with bundled ecosystem services (ES), namely, where a single intervention generates a stream of multiple ESs, such as soil stabilisation, soil productivity enhancement, carbon sequestration and water treatment. Because of this complexity, most PES schemes have resorted to a single service focus, notably water or carbon. This narrowed scope could potentially even lead to perverse consequences, such as afforestation for the sake of carbon sequestration, at the cost of agricultural production and water flows (if the plantation's water consumption is higher than that of the indigenous vegetation). Such adverse consequences are referred to as maladaptation).
- A lack of demand for carbon offsets.

These impediments to a lasting land-use incentive-based scheme can, however, be bridged. Firstly, a statutory institution should be mandated with the responsibility for designing and managing incentives. This agency will have the responsibility to co-ordinate the activities of the various organs of state in concert with private sector and civil society operations. Secondly, the South African Carbon Tax Policy and associated offset mechanism is likely to provide good demand for land-use based carbon offsets within the country.

However, interviewed parties noted that greater emphasis should be placed on removing barriers to accessing the forms of financial and non-financial benefits mentioned above. At present, accessing PES and most other benefits is beyond the capacity of typical land managers, and therefore the opportunity is not realised. In line with Strategic Intervention 8 of the NCCAS (DEA 2019, 7) (which is 'enable substantial flows of climate change adaptation finance from various sources'), it would be tactically prudent to enable the agency function described above to administer the bundling and distribution of funds from various sources, thereby enhancing sustained cash flows to implementing parties.

ANNEX B: A LOGICAL FRAMEWORK DESCRIBING THE KEY PLANNING AND MANAGEMENT PARAMETERS OF EACH STRATEGIC OBJECTIVE OVER THE SUGGESTED 5-YEAR PILOT PERIOD

The log frame is attached to this report in spreadsheet format to allow for easier amendments and updates over time. As they are strongly context dependent, the timeframe as well as resource and input allocation for each task, remain to be completed once the particular pilot areas have been identified. Nevertheless, the last two columns have been included to illustrate the complete structure of the logical framework.

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
Development of 3 pilot landscapes	**Pilot 5-year implementation completed in 3 landscapes**	**Identification of 3 pilot landscapes**	Strategic choice of pilot catchments based on priority mapping, existing programmes, capacity and further considerations	Engagement with existing national departments and programmes to understand aligned planning.	DEFF National Office
				Review of priority mapping process to identify initial set.	DEFF National Office
				In early set, engage with provincial government and private sector to review potential and risks. May be iterative before final set is chosen.	DEFF National Office
		Landscape Preparation phase	Ecological template	Map current land cover and land use.	DEFF National Office
				Map of current above- and below-ground carbon stocks.	DEFF National Office
				Map historical land-use change (at least since 1980).	DEFF National Office
				Baseline assessment of ecosystem status – land degradation (including AIPs), water flow, sedimentation, and river and wetland health.	DEFF National Office

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
			Socio-economic template	Assessment of demographic, economic and Sustainable Development Goals (SDG) data for area.	DEFF National Office
			Institutional template	Institutional assessment (public and private entities).	DEFF National Office
				Land tenure assessment and map.	DEFF National Office
				Existing programme and capacity assessment (e.g. Land Care or monitoring, reporting and verification (MRV)).	DEFF National Office
			Drivers and pressures template	Assessment of direct and indirect drivers of change.	DEFF National Office
			Climate change response model	Assessment of project climate change in pilot area.	DEFF National Office
				Development of a first order vegetation, land-cover change, water and erosion model to explore future pathways.	DEFF National Office
			Identification and establishment of landscape facilitator	Identification of suitable government institution to lead development of landscape.	DEFF National Office
				Potential recruitment of 'champion' to position within government entity.	DEFF National Office
		Landscape Development Phase	Identification of participating parties and a facilitator	Identification of principal public and private sector parties within the landscape. Will include members of each pertinent government department.	DEFF National Office

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
			Communication: Climate change science and EbA in appropriate language and format	Tailor framing, perspective and language to particular audience.	Landscape Facilitator
			Start of engagement with particular sensitive parties	Bilateral meeting with key parties before open discussions.	DEFF National Office, Landscape Facilitator
			Facilitation of values, rules and knowledge (VRK) process, changing perspectives and exploring future alternative pathways. Establish a clear end point.	Series of structured meetings to explore future alternatives, more resilient pathways and associated implications and costs.	Landscape Facilitator
			Initial landscape response plan focusing on 10 primary actions	Identification of 10 primary climate change response options.	Landscape Facilitator
				Definition of roles and responsibilities.	Landscape Facilitator
		Early Implementation Phase	Inter-departmental alignment on Ecosystem-based Adaptation (EbA) and natural resource management (NRM) in the area	Engagement with other national departments within the land domain to ensure early alignment of priorities and programmes e.g. DALRRD, DWS.	DEFF National Office

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
			Leverage and enhancement of existing programmes and capacity in the area. ('Enhancement' refers to an increase or expansion.)	Enhancement of private sector capacity.	Landscape manager
				Enhancement of Biodiversity Stewardship.	Landscape manager
				Enhancement of biosphere reserves.	Landscape manager
				Enhancement and guidance of NRM programmes.	Landscape manager
				Enhancement of conservation agriculture and Land Care.	Landscape manager
				Enhancement of provincial and local government initiatives.	Landscape manager
			Enhancement of law and regulatory enforcement	Engagement with DALRRD and DEFF officials in a particular landscape to address particular drivers.	DEFF National Office, Landscape manager
			Development of new emerging implementation models that address gaps	Clear articulation of drivers or rehabilitation that need to be addressed.	DEFF National Office, Landscape manager
				If possible, development of implementation model that leverages existing capacity and employs local residents in an efficient manner.	DEFF National Office, Landscape manager
				Development of business plan that articulates all operational, financial, risk, human resource (HR), governance and reporting elements.	DEFF National Office, Landscape manager
				Assistance with raising funds and finance – see Implementation support section.	

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
		Medium-term implementation and testing	Continued facilitation of VRK process	Establishment of Landscape Working Group to drive and continually develop the VRK process.	Landscape management
				Hosting Landscape Working Group meetings to report on progress and develop new targeted scopes of work.	Landscape management
				Host informal events to provide a better understanding of certain elements or an emerging topic.	Landscape management
				Compile annual report to record progress, costs, emerging constraints and opportunities.	Landscape management
			Operational support: Collective expertise	Establishment of Landscape Facilitation Office, including premises, equipment and vehicles. The intention is to leverage existing capacity as far as possible.	DEFF National Office, Landscape manager
				Based on clear needs identified in initial facilitation process, provide targeted support on necessary elements e.g. financial, HR, proposal writing, reporting or ecological expertise.	DEFF National Office, Landscape manager
				Potential operational support to implementers on necessary elements, especially to address barriers to entry for emerging farmers and community participation.	Landscape manager
			Operational support: Field monitoring	Daily management of field monitoring operations.	Landscape manager

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
				Establishment of local office and purchase and management of equipment.	Landscape manager
				Recruitment, employment and hosting of field monitoring teams.	Landscape manager
				Deployment and maintenance of fixed monitoring hardware.	Landscape manager
				Management of data entry and transfer process.	Landscape manager
			Facilitation of applied research	Support of research personal while in the field. Operations, hosting, access and introductions.	Landscape manager
			Enhancement of law and regulatory enforcement	Continued engagement with DALRRD and DEFF officials in every particular landscape to address particular drivers based on monitoring.	DEFF National Office, Landscape manager
Development of 3 urban pilot areas	**Pilot 5-year implementation completed in 3 urban areas**	**Identification of 3 pilot urban areas**	Strategic choice of pilot urban areas	Review of priority mapping process to identify initial set.	DEFF National Office
				Review of existing programmes and projects (e.g. C40 cities, Lets Respond Toolkit).	DEFF National Office
				In early set, engage with local government to decide on final set. May be an iterative process.	DEFF National Office
		Urban Preparation phase	Ecological template	Map current land cover and land use.	DEFF National Office
				Map of current above- and below-ground carbon stocks.	DEFF National Office

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
				Map historical land-use change (at least > 1980).	DEFF National Office
				Baseline assessment of ecosystem status – land degradation (incl. AIPs), water flow, sedimentation, and river and wetland health.	DEFF National Office
			Socio-economic template	Assessment of demographic, economic and SDG data for area.	DEFF National Office
			Institutional template	Institutional assessment (public and private entities).	DEFF National Office
				Land tenure assessment and map.	DEFF National Office
				Existing programme and capacity assessment.	DEFF National Office
			Drivers and pressures template	Assessment of direct and indirect drivers of change.	DEFF National Office
			Climate change response model	Assessment of project climate change in pilot area.	DEFF National Office
				Development of first order water and erosion model to explore future pathways.	DEFF National Office
			Identification and engagement with local municipal authority	Open engagement with provincial and local municipalities to identify appropriate lead in government.	DEFF National Office
		Urban Development Phase	Identification of participating parties and a facilitator	Identification of principal public and private sector parties within urban domain.	DEFF National Office

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
			Communication: Climate change science and EbA in appropriate language and format	Compilation of municipality specific information package. Strongly based on existing tools and documents for EbA within an urban domain.	DEFF National Office
			Bilateral meetings with key parties to initiate dialogue before open discussions	Bilateral meeting with key parties before open discussions.	DEFF National Office
			Facilitation of VRK process, changing perspectives and exploring future alternative pathways. Clear end point	Series of structured meetings to explore future alternative, more resilient pathways and associated implications and costs.	DEFF National Office, Municipality Lead
			Initial urban response plan focussing on 5 primary actions	Identification of 10 primary response actions.	Municipality Lead
				Definition of roles and responsibilities.	Municipality Lead
		Urban Implementation Phase	Leverage and enhancement of existing programmes and capacity in the area	Enhancement of private sector capacity.	Municipality Lead
				Enhancement and guidance of NRM programmes.	Municipality Lead
				Enhancement of provincial and local government initiatives.	Municipality Lead
			Enhancement of law and regulatory enforcement	Engagement with provincial, municipal, DALRRD and DEFF officials in particular landscape to address particular drivers	DEFF National Office, Municipality Lead

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
			Development of new emerging implementation models that address gaps	Clear articulation of drivers or rehabilitation that needs to be addressed.	Municipality Lead
				If possible, development of implementation model that leverages existing capacity and employs local residents in an efficient manner.	Municipality Lead
				Development of business plan that articulates all operational, financial, risk, HR, governance and reporting elements.	Municipality Lead
				Assistance with raising funds and finance – see 'Implementation support' section.	
		Urban Medium-term implementation and testing	Continued facilitation of VRK process	Establishment of Urban Working Group to drive and continually develop the VRK process.	Municipality Lead
				Hosting Urban Working Group meetings to report on progress and develop new targeted scopes of work.	Municipality Lead
				Host informal events to provide a better understanding of certain elements or an emerging topic.	Municipality Lead
				Compile annual report to record progress, costs, emerging constraints and opportunities.	Municipality Lead

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
			Operational support	Establishment of Municipality Office, including premises, equipment and vehicles. The intention is to leverage existing capacity as far as possible.	DEFF National Office. Municipality Lead
				Based on clear needs identified in initial facilitation process, provide targeted support on necessary elements.	DEFF National Office, Municipality Lead
				Potential operational support to implementers on necessary elements, especially to address barriers to entry for community participation.	Municipality Lead
			Operational support: Field monitoring	Daily management of field monitoring operations.	Municipality Lead
				Establishment of local office and purchase and management of equipment.	Municipality Lead
				Recruitment, employment and hosting of field monitoring teams.	Municipality Lead
				Deployment and maintenance of fixed monitoring hardware.	Municipality Lead
				Management of data entry and transfer process.	Municipality Lead
			Facilitation of applied research	Support research personnel while in the field: Operations, hosting, access and introductions.	Municipality Lead
			Enhancement of law and regulatory enforcement	Continued engagement with provincial, local municipality, DALRRD and DEFF officials in particular landscape to address particular drivers based on monitoring.	Municipality Lead

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
Pilot implementa-tion support	**Supporting elements developed and tested based on pilot areas**	**Creation of pilot programme working group**	Establishment of Pilot Working Group to drive and continually develop the VRK process	Host inter-landscape meetings to report on progress and develop new targeted scopes of work.	DEFF National Office
			Continued facilitation of VRK process	Host inter-landscape meetings to report on progress and develop new targeted scopes of work.	DEFF National Office
				Host informal events to provide a better understanding of certain elements or an emerging topic.	DEFF National Office
				Compile annual report to record progress, costs, emerging constraints and opportunities.	DEFF National Office
		Creation of a landscape facilitation team	Early preparatory and development work in each pilot landscape and urban area	Lead the early preparatory work in each pilot landscape and urban area. Including identification of implementing entity, appointment of landscape manager and facilitation of VRK process.	DEFF National Office
		Development of MRV System	Review of metrics, capacity and programmes	Commission an entity to undertake a full review of MRV requirements and current capacity and programmes across the country.	DEFF National Office, monitoring lead
			Develop sampling design, including logistics, capacity and equipment considerations	Commission an entity to develop the MRV system. It would include each of the five outputs here, including field training. It makes logistical and financial sense for a single entity to undertake this scope of work.	DEFF National Office, monitoring lead
			Develop standard manual, data dictionaries and guidance documentation		

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
			Develop standardised data entry templates		
			Develop national monitoring framework and capacity, including institutional considerations		
			Train field monitoring staff and validate processes		
		Development of Incentive System	Review grant, finance, tax incentive as well as results-based payment options	Assess the scope and applicability of each option to EbA implementation in South Africa.	DEFF National Office
				For results-based payments, review of feasibility, reporting, permanence, tenure and legal elements.	DEFF National Office
			Develop an incentive system that addresses barriers to entry and decreases risk	Evaluate an appropriate instructional home for executing entity and required capacity.	DEFF National Office
				Create the legal foundation for carbon and water payments.	DEFF National Office
				Create national portfolio approach with associated tools to reduce costs and barriers to entry.	DEFF National Office
				Co-creation of grant and finance applications to bilateral funders.	DEFF National Office
			Pilot tax incentives and carbon and water payments	Based on early assessment, it would be pertinent to effect at least one payment to demonstrate process in first five years	DEFF National Office

Strategic Objective	Indicator	Strategic Workstreams	Outputs	Main Tasks	Responsible Lead Entity
		Development of EbA Atlas	Develop a web-portal that illustrates the spatial distribution and extent of EbA activities across the country	Work with the National Climate Change Response Database to finalise an initial list of projects.	DEFF National Office
				Obtain information on the spatial extent of each activities (a shape (SHP) file).	DEFF National Office
				Assess an appropriate long-term home institution for the web-portal.	DEFF National Office
				Commission the development of a user-friendly portal that can be readily updated with new projects in a clearly governed manner.	DEFF National Office
		Enhancement of EbA in spatial planning		Already included in Strategic framework and overarching implementation plan for ecosystem-based adaptation in South Africa 2016-2021	DEFF National Office
		Applied research on pilots	Improved understanding of management and capacity requirements Improved understanding of the costs of implementation Improved understanding of how to map and track land degradation over time	Improved understanding of management and capacity requirements Improved understanding of the costs of implementation Improved understanding of how to map and track land degradation over time	DEFF National Office

References

Abel, N., Wise, R. M., Colloff, M. J., Walker, B. H., Butler, J. R. A., Ryan, P., Norman, C., Langston, A., Anderies, JM, Gorddard, R, Dunlop, M, O'Connell, D. (2016). Building resilient pathways to transformation when "no one is in charge": Insights from Australia's Murray-Darling Basin. *Ecology and Society, 21*(2): 23. Retrieved from http://doi.org/10.5751/ES-08422-210223

Burkett V. R., Suarez A. G., Bindi M., Conde C., Mukerji R., Prather M.J., St. Clair A.L., and Yohe G.W. (2014). Point of departure. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. *Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field C.B., Barros, V.R., Dokken, D.J., Mach K.J., Mastrandrea M.D., Bilir T.E., Chatterjee M., Ebi K.L., Estrada Y.O, Genova R.C., Girma B., Kissel E.S., Levy A.N., MacCracken S., Mastrandrea P.R., and White L.L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 169–194. Accessed 12 March 2020 at: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap1_FINAL.pdf

Colloff, M. J., Martín-López, B., Lavorel, S., Locatelli, B., Gorddard, R., Longaretti, P. Y., Walters, G., van Kerkhoff, L., Wyborn, C., Coreau, A., Wise, R.M., Dunlop, M., Degeorges, P., Grantham, H., Overton, I. C., Williams, R.D., Doherty, M.D., Capon, T., Sanderson, T., Murphy, H. T. (2017). An integrative research framework for enabling transformative adaptation. *Environmental Science and Policy, 68*(February), 87–96. Retrieved from http://doi.org/10.1016/j.envsci.2016.11.007

Department of Environmental Affairs (DEA) (2011). *National Climate Change Response White Paper.* Pretoria: Department of Environmental Affairs. Accessed 12 March 2020 at: https://www.environment.gov.za/sites/default/files/legislations/national_climatechange_response_whitepaper.pdf

DEA (2013). Long Term Adaptation Scenarios: Together developing adaptation responses for future climates: Summary for Policy makers. Pretoria Department of Environmental Affairs. Accessed 31 March 2020 at: https://www.environment.gov.za/sites/default/files/docs/summary_policymakers_bookV3.pdf

DEA. (2015a). *The South African National Terrestrial Carbon Sink Assessment.* Pretoria, South Africa: Department of Environmental Affairs. Accessed 18 March 2020 at: https://www.environment.gov.za/sites/default/files/reports/nationalterrestrial_carbonsinks:_Synopsis report.pdf

Department of Environmental Affairs. 2015b. *Climate Change Adaptation Plans for South African Biomes* (eds. Kharika J.R.M., Mkhize N.C.S., Munyai T., Khavhagali V.P., Davis C., Dziba D., Scholes R., van Garderen E., von Maltitz G., Le Maitre D., Archibald S., Lotter D. van Deventer H., Midgely G. and Hoffman T). Pretoria Department of Environmental Affairs. Accessed 12 March 2020 at: https://www.environment.gov.za/sites/default/files/reports/climatechangeadaptation_plansforsouthafricanbiomes_report.pdf

DEA. (2017). *Unlocking barriers and opportunities for land-use based climate change mitigation activities in South Africa.* Pretoria, South Africa: Department of Environmental Affairs. Accessed 16 March 2020 at: https://www.environment.gov.za/sites/default/files/reports/unlockingbarriers_land-usebasedclimatechangemitigation.pdf

DEA. (2019). *Draft National Climate Change Adaptation Strategy, Republic of South Africa.* Pretoria, South Africa: Department of Environmental Affairs. Accessed 12 March 2020 at: https://cer.org.za/wp-content/uploads/2019/05/DEA-Draft-climate-change-adaptation-strategy.pdf

DEA, & SANBI. (2016). *Strategic Framework and Overarching Implementation Plan for Ecosystem-Based Adaptation (EbA) in South Africa: 2016-2021.* Pretoria, South Africa: Department of Environmental Affairs. Accessed 12 March 2020 at: https://www.sanbi.org/wp-content/uploads/2018/09/Strategic-Framework-and-Overarching-Implementation-Plan-for-EbA-in-SA.pdf

DEA & SANBI (2017). *Guidelines for ecosystem-based adaptation (EbA) in South Africa.* Pretoria, South Africa: Department of Environmental Affairs. Retrieved from http://www.sanbi.org/sites/default/files/documents/documents/final-guidelines-ecosystem-based-adaptation-eba-south-africa.pdf

Ellis, E. C., and Ramankutty, N. (2008). Putting people in the map: Anthropogenic biomes of the world. *Frontiers in Ecology and the Environment, 6*(8), 439–447. Retrieved from https://doi.org/10.1890/070062 pdf available at: https://esajournals.onlinelibrary.wiley.com/doi/pdf/10.1890/070062

Gorddard, R., Colloff, M. J., Wise, R. M., Ware, D. and Dunlop, M. (2016). Values, rules and knowledge: Adaptation as change in the decision context. *Environmental Science and Policy, 57,* 60–69. Retrieved from: http://doi.org/10.1016/j.envsci.2015.12.004

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (2018): *Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* R. Scholes, L. Montanarella, A. Brainich, N. Barger, B. ten Brink, M. Cantele, B. Erasmus, J. Fisher, T. Gardner, T. G. Holland, F. Kohler, J. S. Kotiaho, G. Von Maltitz, G. Nangendo, R. Pandit, J. Parrotta, M. D. Potts, S. Prince, M. Sankaran, and L. Willemen (eds.). IPBES secretariat, Bonn, Germany. 44 pages. Retrieved from https://ipbes.net/sites/default/files/2018_ldr_full_report_book_v4_pages.pdf

National Planning Commission (NPC) (2012). National Development Plan 2030: *Our future make it work.* Pretoria: Department: The Presidency. Accessed 18 March 2020 at: http://www.dac.gov.za/sites/default/files/NDP%202030%20-%20Our%20future%20-%20make%20it%20work_0.pdf

Ostrom, E. (1990). *Governing the Commons: The evolution of institutions for collective actions.* Cambridge: Cambridge University Press. Accessed 16 March 2020 at: https://wtf.tw/ref/ostrom_1990.pdf

Republic of South Africa (RSA) (2014). *Medium-term Strategic Framework (MTSF_ 2014–2019)* Pretoria: government of South Africa. Accessed 16 March 2020 at: https://www.gov.za/sites/default/files/gcis_document/201409/mtsf2014-2019.pdf

Wyborn, C., van Kerkhoff, L., Dunlop, M., Dudley, N., & Guevara, O. (2016). Future oriented conservation: knowledge governance, uncertainty and learning. *Biodiversity and Conservation, 25*(7), 1401–1408. Retrieved from http://doi.org/10.1007/s10531-016-1130-x

This assessment was conducted by Philip Desmet with assistance from:

- Tony Knowles and James Blignaut (project team members)
- Zander Venter (ZSV Consulting)
- Thomas G. King
- Lungile Moyo and Mark Thompson (GeoTerraImage)

The individuals on the Project Steering Committee are thanked for their contributions to the conceptual development of the project, review of outputs, and comments on products and draft reports:

- From Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: Alexa Brown
- From the Department of Environment Forestry and Fisheries (DEFF): Barney Kgope, Ntando Mkhize, Sibonelo Mbanjwa, Alinah Mthembu, Tshifhiwa Munyai, Nozipho Sibiya
- From the South African National Biodiversity Institute (SANBI): Mahlodi Tau, Kennedy Nemutamvuni

In addition, the following groups and individuals are thanked for their contributions:

- The SANBI Ecological Infrastructure Steering Committee
- The Provincial and Metro Biodiversity Planning Working Group
- Mandy Driver
- Mandy Barnett
- Fahiema Daniels
- Jeffery Manuel
- Genevieve Pence
- Emily Botts and Dick Cloete for proof editing

PRIORITY MAPPING

Table of Contents

Abbreviations **52**

Summary **53**

Introduction **58**

Mapping Objectives 58

What is Ecosystem-based Adaptation (EbA)? 58

Model Logic 61

STEP 1: Model Conceptual Development **62**

STEP 2: Data Gathering **70**

STEP 3: Spatial Modelling **72**

Ecological Infrastructure: Water 72

Ecological Infrastructure: Nature-based Tourism 72

Ecological Infrastructure: Rangelands 73

Ecological Infrastructure: Biodiversity Resilience 73

Ecological Infrastructure: Carbon 73

Social Demand 74

Risk 75

Biodiversity importance 75

Climate Change Risk 75

Uexisting EbA Project 76

Data Aggregation Unit 76

STEP 4: Priority Analysis 94

Conclusion and Recommendations 104

Annex A: Summary of Biome Climate Change Adaptation 106

Annex B: Model Parameters 111

Annex C: Municipalities Ranked Based on EbA Action Potential and Additional Variables 121

Annex D: Model Descriptions 134

Annex E: Project Outputs Metadata 158

References 161

Abbreviations

AOI	Automated Optical Inspection
ALOS	Advanced Land Observation Satellite
ARC	Agricultural Research Council
BGIS	Biodiversity Geographical Information
CBA	Critical Biodiversity Area
CCWR	Computer Centre for Water Research
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
DEM	Digital Elevation Model
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
EbA	Ecosystem-based Adaptation
EGIS	Environmental Geographical Information System
EI	Ecological Infrastructure
EV	Environmental Vulnerability
FEPA	Freshwater Ecosystem Priority Area
GEE	Google Earth Engine
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GTHF	Global Terrestrial Human Footprint
IBA	Important Bird Area
JAXA	Japan Aerospace Exploration Agency
JDEM	Japan Aerospace Exploration Agency Digital Elevation Model
LM	Local municipality
LSU	Large stock unit
MODIS	Moderate Resolution Imagining Spectroradiometer
MPI-ESM-MR	Max Planck Institute Earth System Model, medium resolution
NBA	National Biodiversity Assessment
NDVI	Normalised Difference Vegetation Index
NFEPA	National Freshwater Ecosystem Priority Area
NPAES	National Protected Area Expansion Strategy
PES	Present Ecological State
RCP	Representative Concentration Pathway
SAEON	South African Environmental Observation Network
SANBI	South African National Biodiversity Institute
SBC	ESKOM spot building count
SBC x SURPI	Population weighted SURPI using ESKOM's spot building count (SBC) to weight the SURPI index based on population per grid unit
SDF	Spatial Development Framework
Stats SA	Statistics South Africa
SURPI	Subsistence use resource and poverty index
SWSA	Strategic Water Source Areas
TDI	Topographic depression identification
TPI	Topographic Index
UNDP	United Nations Development Programme

Priority areas for implementation of Ecosystem-based Adaptation (EbA) projects are identified at the national and biome-levels, and the results summarised to local municipalities. EbA priorities are identified based on three primary criteria: extent of ecological infrastructure (EI); the condition of this EI; and the social demand for this EI. Four additional priority ranking criteria are also considered in the analysis: the risk of EI or ecosystems being lost to human development; the presence of important biodiversity; the vulnerability of ecosystems to climate change; and, the presence of existing EbA projects.

A conceptual model for mapping EbA priorities was developed based on the existing concept applied in South Africa and modified to reflect current stakeholder opinion (Figure 1). In this model the spatial overlap of EI extent and social demand determines EI importance to provide the primary dimension necessary to identify EbA opportunities. The condition of EI in the landscape provides a second dimension in the priority analysis. The combination of these two dimensions creates a basic framework for EbA implementation strategies, or an EbA response matrix (Figure 2). The response matrix can help rank spatial priorities for action as well as inform the type of EbA action to be implemented (for example, keeping EI in good condition or restoring EI). Opportunities within this matrix can be modified or further ranked using the additional implementation context criteria considered.

Spatial models for each criterion were developed from existing and available national datasets. A database of existing EbA projects was developed by this project from stakeholder inputs. Models were developed as raster models in a geographic information system (GIS) with a resolution of 1ha at a standardised extent and projection. This resolution is suitable for application at the cadastral-level or above.

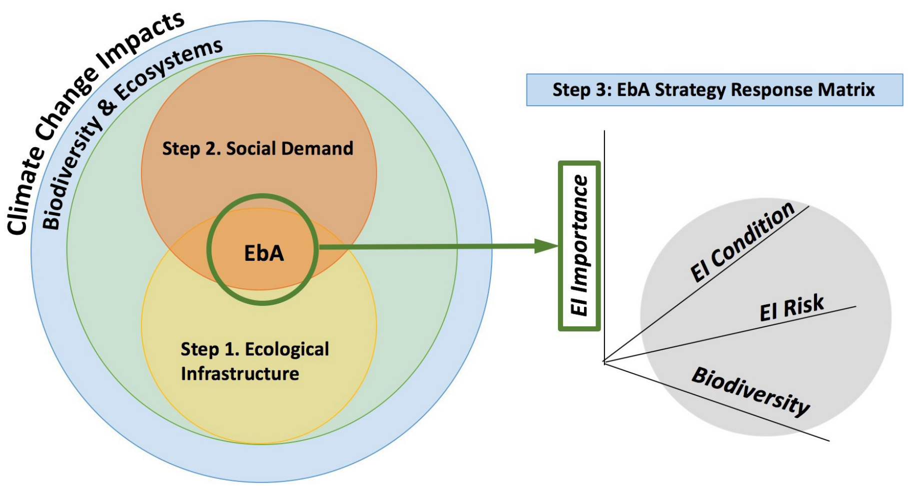


Figure 1: The EbA conceptual model developed and applied in this project.

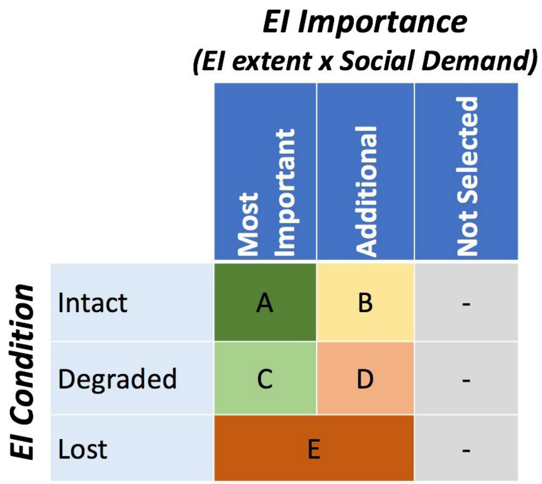


Figure 2: The response matrix for ranking spatial opportunities for EbA action.

The basic steps in the prioritisation process included:

1. Develop conceptual models for each component in the conceptual framework.
2. Gather relevant spatial datasets and compile a GIS database.
3. Implement GIS models to develop maps of each model component.
4. Assign priority ranks to areas by selecting areas that meet the EbA response matrix criteria.

In steps 1 and 3, modelling processes were implemented representing the major variables identified in the EbA conceptual model. These include:

1. The extent and relative value of water, nature-based tourism, rangeland, biodiversity resilience and carbon EI.
2. EI condition for each EI model.
3. Social demand for EI.
4. Risk of EI or ecosystems being lost – derived from historic land cover change (1990 to 2014).
5. Biodiversity importance based on bioregional plans and other spatial biodiversity planning informants.
6. Vulnerability of ecosystems to climate change based on an existing analysis of biome response to climate change.
7. Existing EbA projects were not modelled but based on stakeholder inputs on the location of actual EbA projects.

An integrated model for all ***Water EI*** (production, quality and flow regulation) was developed based on wetlands ranked according to their relative EI value; wetlands buffered by 100m; National Freshwater Ecosystem Priority Areas (NFEPA) river buffers (1km); and Strategic Water Source Areas (SWSAs) for surface water and groundwater. ***Water EI*** condition is based on neighbourhood land cover (non-natural, plantation, settlement and mining) and sub-quaternary catchment Present Ecological State (DWS 2014).

Nature-based Tourism EI attempts to capture the current potential of landscapes to support nature-based tourism of all kinds. Model inputs include positive factors supporting nature-based tourism (natural vegetation, scenic views, proximity to protected areas and water bodies, ease of access); and negative factors detracting from the resource (population density, distance to roads and industry/mining). EI extent (positive factors) and condition (negative factors) are combined in this model therefore there are no separate models for these factors.

Rangeland EI extent is based on natural land cover classes in the national land cover, weighted by livestock carrying capacity and slope to give a relative rangeland EI value. The rangeland EI condition model was developed specifically for this project based on a trend analysis of rangeland primary productivity (Normalised Difference Vegetation Index [NDVI]) over the past 33 years.

Biodiversity Resilience EI is mapped as the combination of areas identified as being important for biodiversity through various spatial biodiversity planning initiatives that have been conducted in South Africa. These include protected areas and conservation areas; Critical Biodiversity Area (CBA) maps; SWSAs; Important Bird Areas; National Biodiversity Assessment (NBA) 2011 (Driver *et al.* 2012) climate change resilience areas; and National Protected Areas Expansion Strategy (NPAES) for South Africa 2016 (DEA 2016) focus areas.

For ***Carbon EI***, soil carbon stocks are used as a proxy for ecosystem carbon EI. Only for soil carbon are there two independent assessments of the resource available for South Africa (Terrestrial Carbon Sink Assessment (DEA 2015b) and Identification and mapping of soils rich in organic carbon in South Africa as a climate change mitigation option (DEA 2019)). The baseline extent of the stock (a proxy for carbon EI) and the current condition is provided by each study as the resultant soil carbon stock under agricultural land use relative to natural vegetation. In most cases this is a negative relationship (i.e. soil carbon is less under agriculture than under natural vegetation). The extent of bare soils and soil erosion is used to represent the condition of the EI in natural ecosystems.

Population density, levels of poverty and household reliance on natural resources are used as proxies for Social Demand for EI. Social demand is considered at three spatial scales – global, national and local. Two versions of social demand are developed – social demand based only on the extent of subsistence natural resource use and poverty (subsistence use resource and poverty index [SURPI]) derived from the 2011 census data; and a population weighted SURPI that uses ESKOM's spot building count (SBC) to weight the SURPI index based on point population density.

Priority areas for EbA are determined based on the combination of EI extent, EI condition and social demand. In addition to this, implementation context variables are used to refine EbA priorities at the local municipality level. These variables include the risk of ecosystems being lost due to human development, biodiversity importance and climate change vulnerability of ecosystems.

The risk of ecosystems or EI being lost is mapped here as the likelihood of a natural land cover class being converted to a non-natural land cover based on historic neighbourhood land cover change 1990–2014. Also, the local municipality level environmental vulnerability index from the Council for Scientific and Industrial Research (CSIR) Green Book (Van Niekerk *et al.* 2019) is used here as an alternative ecosystem risk variable.

The Biodiversity Resilience EI model is also interpreted here as being synonymous with biodiversity importance. Although it is already incorporated into the EbA model, it is also used separately to refine spatial priorities for EbA action. This map is also synonymous with areas important for adaptation of biodiversity to climate change. Implicit in the conceptual development and implementation of all the spatial biodiversity planning tools informing the Biodiversity Resilience EI map is the consideration of climate change and the spatial requirements for adaptation of biodiversity to climate change.

The future predicted change in biomes in response to climate change is used as a local municipality level indicator (% of local municipality where a biome is expected to change in response to climate change) of vulnerability of ecosystems to climate change.

The database of existing EbA projects compiled here is used as a final mask to indicate potential priority areas where no EbA projects are currently occurring.

The EI model information is aggregated to two higher-order spatial scales – a standardised 10x10km grid unit and the local municipality – for the purpose of the spatial prioritisation. The final list of priority areas for EbA action are defined at the local municipality scale and are based on the potential for local municipalities to support EbA (aggregated EI extent, condition and social demand to the local municipality level) plus the overlay of the additional context.

A final set of 54 priority local municipalities are identified (the top quartile or 25% of local municipalities) based on the biome-level EbA analysis. This group of local municipalities are further subdivided into seven priority scenarios by overlaying the additional prioritisation variables (Figure 3).

The scenarios are:

Scenario 6

Baseline plus high environmental risk, biodiversity importance and climate change vulnerability

Scenario 5

Baseline plus high environmental risk and climate change vulnerability

Scenario 4

Baseline plus high biodiversity importance and climate change vulnerability of ecosystems

Scenario 3

Baseline plus high environmental risk and biodiversity importance

Scenario 2

Baseline plus high biodiversity importance

Scenario 1

Baseline plus high environmental risk of EI being lost to human development

Scenario 0

High EbA potential (baseline)

Scenarios 3 – 6 are possibly the most urgent scenarios for implementation as they represent local municipalities with high potential for EbA action plus high combination of two or more of the additional variables. Fourteen local municipalities fall into these scenario groups (Table 1). These results are relevant only for setting national or biome-level planning priorities, and only for the EI components considered in the model (water, nature-based tourism, rangeland, biodiversity resilience and carbon). The underlying EI models developed here are highly relevant for local-scale EbA analysis where priorities can be assessed relative to the assessment area (for example, within a district or local municipality). Also, the analysis does not adequately consider the EI needs of urban landscapes where there is mostly a spatial disassociation between social demand and EI extent. SWSAs incorporated into the water EI model capture water supply EI for urban areas, but no other EI components necessary for urban areas are captured in the models developed here. These aspects of EbA assessment should be addressed in future work.

Table 1: The set of highest priority local municipalities for EbA action based on their potential for EbA, plus the risk of ecosystems being lost to human development; biodiversity importance; and climate change vulnerability of ecosystems.

Scenario	Local Municipality	District Municipality
6	Okhahlamba	Uthukela
5	Mthonjaneni	Uthungulu
4	Ndlambe	Cacadu
	Laingsburg	Central Karoo
3	Thulamela	Vhembe
	Greater Tubatse/Fetakgomo	Sekhukhune
	uMngeni	Umgungundlovu
	Dr Nkosazana Dlamini Zuma	Sisonke
	Elundini	Joe Gqabi
	Impendle	Umgungundlovu
	Kou-Kamma	Cacadu
	Lepele-Nkumpi	Capricorn
	Senqu	Joe Gqabi
	Matatiele	Alfred Nzo

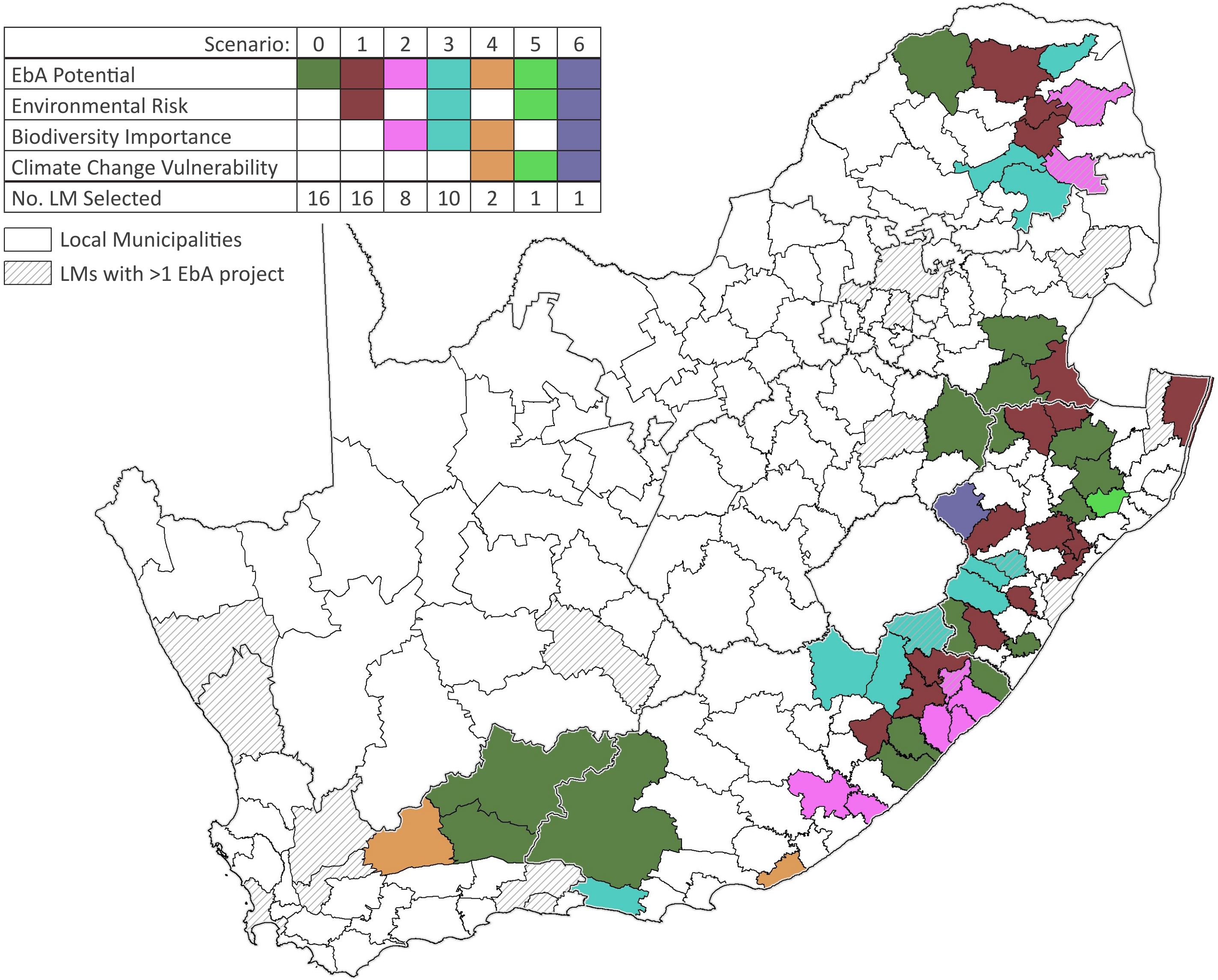


Figure 1: The final prioritisation of local municipalities based on the biome-level EbA score for local municipalities. The selected local municipalities represent the top quartile of EbA scores (namely, local municipalities with high EbA potential). Local municipalities are classified into seven implementation scenarios based on high values (top quartile) for risk of ecosystems being lost to human development, biodiversity importance, and vulnerability of ecosystems to climate change.

This report summarises the process of identifying priority areas for Ecosystem-based Adaptation (EbA) implementation in South Africa. The prioritisation approach employs a multiple criterion methodology to integrate the core determinants of EbA – ecological infrastructure (EI) extent and condition, and social demand – with contextual implementation information on the risk of ecosystems being lost to human development. biodiversity importance, and climate change vulnerability of ecosystems. A set of local municipalities is identified that have high EbA potential as well as being high in terms of the context variables.

Mapping Objectives

Objectives of this mapping process are to identify priority areas in each biome that are important for:

- Adaptation of biodiversity to climate change
- Implementation of EbA

This analysis focuses primarily on identifying priority areas for EbA implementation as this is a completely novel exercise at the national scale. The areas for adaptation of biodiversity to climate change are well considered in the country's Critical Biodiversity Area (CBA) maps (landscape corridors, core areas, climate change refuges, and so on). So, the analyses conducted here focus mainly on integrating existing spatial planning products rather than generating novel datasets. This is captured in the Biodiversity Resilience ecological infrastructure map discussed in the following sections.

What is Ecosystem-based Adaptation (EbA)?

EbA is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change.

EbA interventions integrate services from biodiversity and ecosystems, benefits for people, and climate change adaptation responses in the context of sustainable development.

EbA interventions include four components:

- Adaptation responses to current and future impacts of climate change
- Involve the use of biodiversity and ecosystem services
- Benefits include people being more resilient to climate change
- Contextualised in a paradigm of sustainable development

Therefore, in order to determine spatial priorities for EbA implementation it is necessary to identify ecosystem services important for society and then the EI from which these ecosystem services are derived. The areas suitable for EbA are those where the location of EI and social demand for ecosystem services/EI overlap.

Figure 4 represents the current conceptual framework that defines what EbA is. This is the starting point for how we have gone about identifying priority areas for EbA implementation. This framework defines what the basic components of the model should be and hence what we should be mapping. This basic conceptual model was reviewed and revised during this project to develop a more pragmatic model from an implementation perspective.

Stephen Holness is the only person to have attempted the mapping of EbA priority action areas in South Africa (for example, Bourne *et al.* 2015 and Holness 2017). His approach modifies the baseline conceptual model to the model presented in Figure 5. This forms the conceptual starting point for the model development undertaken in this project. In this model, there are four main input areas that together define where EbA priorities are located. These are the four overlapping circles in Step 1 in Figure 5. Step 2 divides the landscape into five possible EbA action response areas or strategies based on EI importance and condition of this EI.

The baseline conceptual model has been debated extensively with relevant stakeholders to arrive at the revised conceptual model presented in Figure 6. In the revised model the biodiversity and ecosystems, and the climate change circles are removed from the core model. These variables, as well as others not represented in the figure (e.g. presence of existing EbA projects or risk of ecosystems being lost) provide important context to EbA implementation but are not core to defining potential EbA areas.

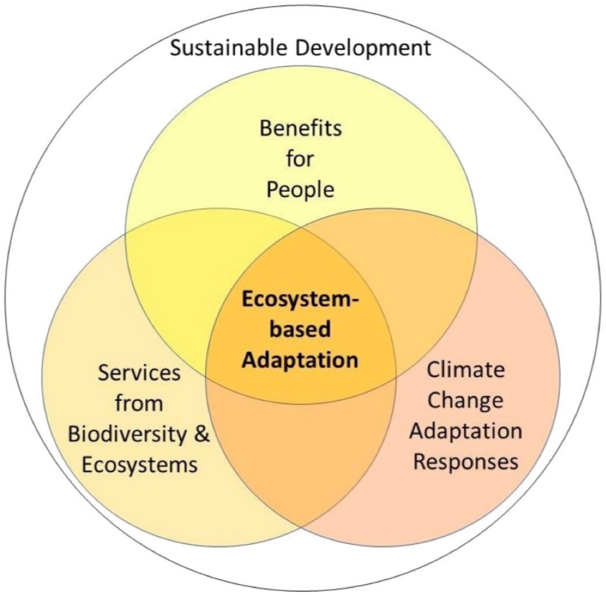


Figure 4: The EbA conceptual model (DEA 2017, 9).

Biodiversity is removed from the core model because it is about identifying areas for EbA implementation and not biodiversity conservation. It is important not to create the impression that EbA is a surrogate for biodiversity conservation. At implementation there are obvious synergies between EbA and biodiversity conservation, but for this process we need to keep them separate. Biodiversity is none-the-less considered in mapping biodiversity resilience of EI, and the latter is an important component of EbA. Also, biodiversity importance is brought in as an implementation context variable later on in the analysis.

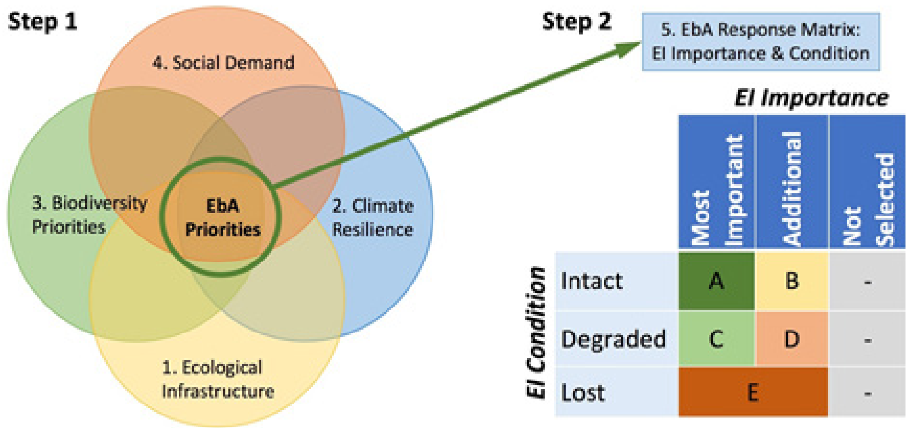


Figure 5: The EbA conceptual model currently applied in South Africa (from Bourne *et al.* 2015, 44).

Climate change impacts are not considered necessary to identify potential EbA areas. Irrespective of the magnitude and direction of climate change locally, any EbA response will always focus on the EI present locally as well as the social demand for and condition of this EI. Climate change impacts can be considered as an implementation context variable. Depending on the biome where EbA is being implemented and the climate change impact being targeted, the EbA response will target different components of EI. Examples of these biome-level responses are discussed in DEA (2015a) and summarised in *Annex A. Summary of biome climate change adaptation responses*.

Step 3 in the prioritisation analysis, developing the response strategy matrix, becomes multidimensional by considering more variables than Figure 5. Here we bring risk of ecosystems being lost, biodiversity importance and other context variables into prioritising areas in the response matrix (Figure 6).

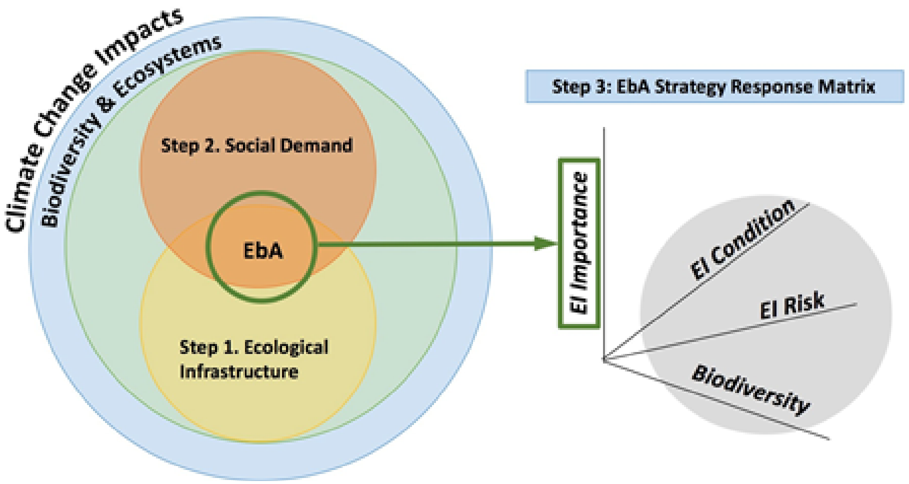


Figure 6: A modified Ecosystem-based Adaptation (EbA) conceptual model developed and applied in this project.

The derived conceptual model has three primary mapping outputs or variables that together define priorities for EbA action as depicted in the strategy response matrix in Figure 5 (EI extent, social demand and EI condition). In Figure 6, other variables are considered that could be used as implementation context criteria for defining EbA spatial priorities.

In summary, the prioritisation analysis attempts to map/model and integrate seven main variables:

1. EI importance (most important, additional or not selected) based on:
   - EI extent and value
   - Social demand for EI
2. EI condition (intact, degraded or lost)
3. Risk or vulnerability of ecosystems being lost based on historic land cover change
4. Biodiversity importance based on bioregional plans and other spatial biodiversity planning tools
5. Areas where EbA projects are being implemented
6. Vulnerability of ecosystems to climate change

Model Logic

The following logical steps were followed to arrive at a final map of EbA implementation priorities:

Step 1: Develop the conceptual model for mapping EbA priorities:

- What are the climate change impacts?
- What are the responses/interventions? (Table 2; Annex A. Summary of biome climate change adaptation responses)
- What ecosystem services support these interventions?
- What is the EI supporting these services? (Table 3; Annex B. Model parameters)

Step 2: Gather relevant spatial datasets (Table 4)

Step 3: Develop maps for:

- EI extent
- EI condition
- Social demand
- Risk or vulnerability to being lost
- Biodiversity importance
- Climate change vulnerability
- Presence of existing EbA projects

Step 4: Priority analysis – select areas to meet the response matrix criteria plus overlay implementation context variables

In order to determine what Ecological Infrastructure (EI) supports EbA, it is necessary to first understand the impacts of climate change on ecosystems and then work backwards from the impacts, linking these to ecosystem services and ultimately the underlying E

To get to what climate change-relevant EI is, we need to unpack first the impacts of climate change. The broad impacts of climate change on ecosystems that society need to grapple with include (UNDP 2010):

- Drought and floods: Increased temperature (extreme heat), erratic rainfall, increased storm intensity, shift in seasons
- Land degradation: desertification, deforestation, wildfires, invasive alien species, salinisation
- Loss of biodiversity
- Sea level rise/storm surge

It is important to note that climate change impacts are broadly the same everywhere. The EbA responses will differ depending on ecological and social context. Climate change impacts on ecosystems translate into increased societal risks to:

- Disasters
- Food security
- Health and well-being
- Economic enterprise
- Water security

The climate change impacts on ecosystems translate into increased risks for society in a number of socio-economic areas. Responding/adapting to the increased risks to society that come about due to climate change induced changes in the natural environment is foundational to any climate change

adaptation strategy. EbA is using natural ecosystems to respond/adapt to climate change. These areas of societal sustainability or risk categories can therefore be used as broad thematic areas for organising EbA interventions or strategies, as each sustainability theme depends on different components of natural ecosystems, ecosystem services and ultimately EI. We can use these thematic areas to identify (1) the components of EI that support these themes and (2) the social demand for ecological services derived from this EI.

South African biome climate change response themes identified in the *Climate Change Adaptation Plans for South African Biomes* (DEA 2015a) group responses into the following categories:

- Land management
- Monitoring
- Natural resource management
- Land-use planning
- Protected area development
- Restoration
- Social and economic investment
- Water resource management
- Disaster risk mitigation

These strategies can be unpacked and linked to ecosystem services that support them (Table 2). Note that some responses relate to the enabling/implementing environment and are not associated with a specific ecosystem service. These ecosystem services are derived from underlying EI. EI is the ecosystem features that support ecosystem services, such as a wetland or field of natural vegetation. These features can be mapped, and therefore it is necessary to unpack ecosystem services and identify the EIs that support these services in order to map EI in the landscape.

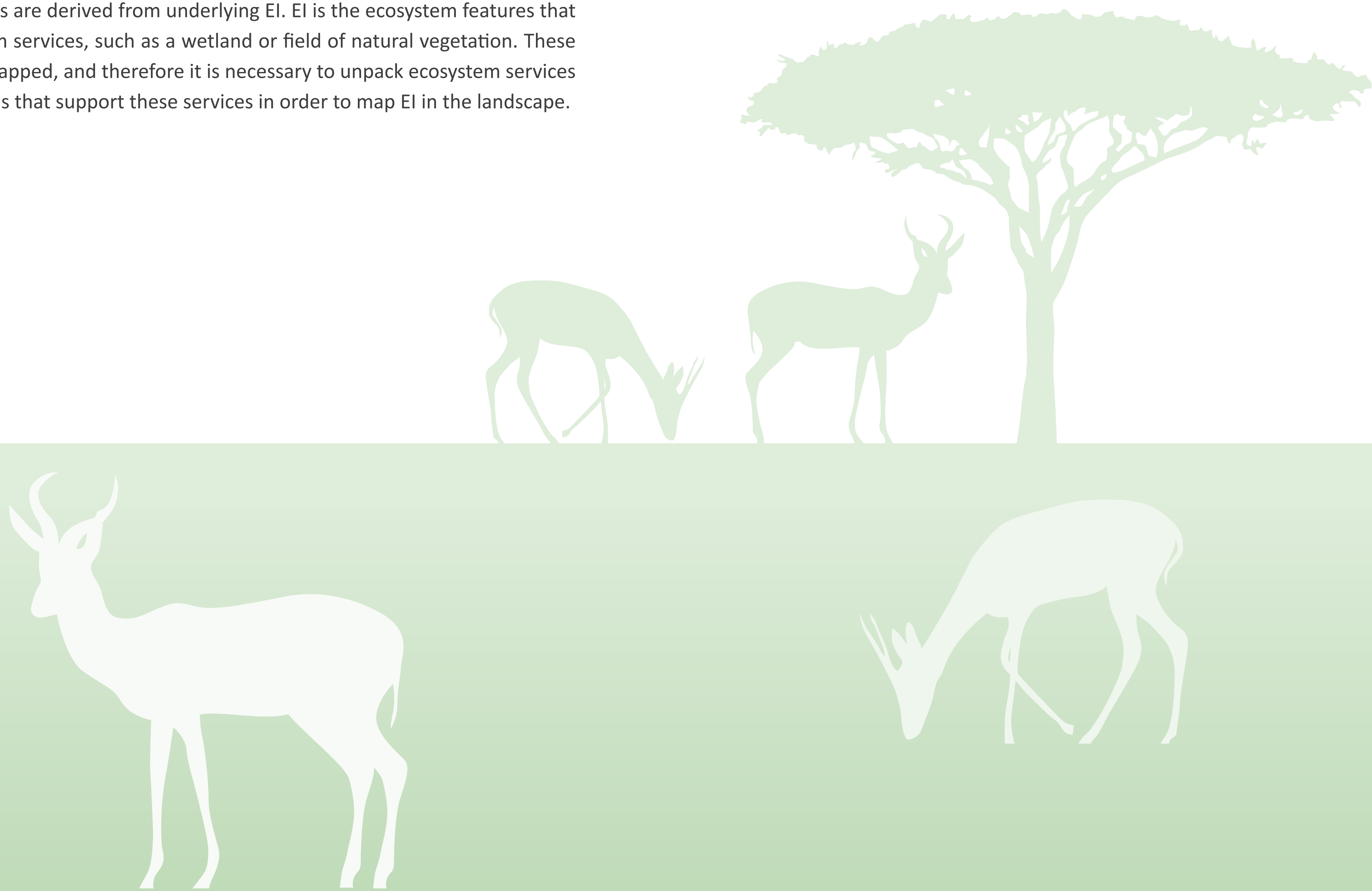


Table 2: Summary of ecosystem services associated with EbA options for South African biomes (adapted from DEA 2015a).

EbA options and associated ecosystem services	Albany Thicket	Desert & Nama Karoo	Forest	Fynbos	Grassland	Indian Ocean Coast	Savanna	Succulent Karoo
OPTIONS	**4**	**2**	**6**	**6**	**4**	**6**	**3**	**9**
Alien species management			2	1	1	1		
Biomass harvesting							1	
Capacity development								2
Fire management			1	1	1	1		
Land-use planning			1		1	1		
Monitoring				1				1
Natural resource management	1		1					2
Natural resource use management				1	1			
New economy						1	1	1
New economy development	1	1						
Protected area development				1			1	
Restoration	1	1	1					
Restoration (rangeland)						1		1
Water resource management	1							2
Water-use management						1		

EbA options and associated ecosystem services	Albany Thicket	Desert & Nama Karoo	Forest	Fynbos	Grassland	Indian Ocean Coast	Savanna	Succulent Karoo
SERVICES	**4**	**3**	**4**	**7**	**6**	**8**	**6**	**6**
Biodiversity			1	1				1
Carbon storage	1		1		1	1	1	
Dryland agriculture					1	1		
Erosion control				1				
Forestry						1		
Fuelwood			1			1	1	
Irrigation agriculture	1	1			1	1		
Medicinal plants				1	1	1		1
Horticultural plants				1				
Rangeland	1	1			1	1	1	2
Timber							1	
Tourism	1	1	1	1		1	1	1
Water provision				1	1		1	1
Wildflowers				1				
Water-use management						1		

Table 3 is a summary of the ecosystem services that have been identified as being important for supporting the sustainability themes discussed above. This information is derived from DEA 2015a, provincial conservation planners through the Biodiversity Planning Forum, other stakeholder engagement conducted as part of this project, and Turpie *et al.* 2017. The level-2 ecosystem services in Table 3 are further unpacked in *Annex B. Model Parameters* to identify potential mappable ecosystem features that can be considered as actual EI components or spatial surrogates. For each component of EI, features are identified to represent the current extent, condition and social demand for each EI component. These can be considered individual EI conceptual models.

Not all EI identified in *Annex B. Model Parameters* is mapped here due to data and time limitations. Ultimately, the number of models implemented was distilled into five individual EI models. This is because the input information for multiple components of EI within the same thematic area tends to be the same or similar therefore adding more models does not necessarily increase or improve the detail of information at hand. Also, crop agriculture EI components are not mapped, as in South Africa only natural EI is considered as contributing to ecosystem services, and ultimately EbA.

Table 3: Summary of ecosystem services that can be associated with EbA. Data source indicates the number of times an ecosystem service component is identified.

ECOSYSTEM SERVICE CATEGORIES			DATA SOURCE			
Ecosystem service level 1	**Ecosystem service level 2**	**EbA thematic area**	**DEA 2015a**	**Biodiversity Planning Forum**	**Turpie *et al.* 2017**	**Grand total**
Air quality	Amelioration of local air	HEALTH and WELLBEING		1	1	2
Biodiversity	Biological control	HEALTH and WELLBEING		3		3
	Control of pests and pathogens	FOOD SECURITY			1	1
	Future genetic potential	HEALTH and WELLBEING	2	2		4
	Medicinal/muthi plants	HEALTH and WELLBEING	5	2		7
	Pollination services	FOOD SECURITY		1	1	2
	Species harvested commercial	FOOD SECURITY		2		2
	Species harvested recreation	FOOD SECURITY		1		1
	Species harvested subsistence	FOOD SECURITY		1		1
Carbon stored in plants and soil	Carbon fixing	CARBON STORAGE		1		1
	Carbon retention	CARBON STORAGE	5		1	6
Coastal ecosystems	Control of erosion and sedimentation	DISASTER RISK REDUCTION			1	1
	Sea-level rise/Coastal storm protection	DISASTER RISK REDUCTION		1	1	2
Crop agriculture	Dryland agriculture	FOOD SECURITY	3			3
	Irrigation agriculture	FOOD SECURITY	2			2
	Niche agriculture	FOOD SECURITY	1			1
	Plantation forestry	FOOD SECURITY	1			1
Cultural and religious value	Amenity values	HEALTH and WELLBEING			1	1
	Existence and bequest values	HEALTH and WELLBEING			1	1
	Heritage	HEALTH and WELLBEING		1		1
	Nature/ndalo/ithlathi	HEALTH and WELLBEING	1		1	2

ECOSYSTEM SERVICE CATEGORIES			DATA SOURCE			
Ecosystem service level 1	**Ecosystem service level 2**	**EbA thematic area**	**DEA 2015a**	**Biodiversity Planning Forum**	**Turpie *et al.* 2017**	**Grand total**
Cultural and religious value	Quality of life	HEALTH and WELLBEING		1		1
	Scientific and educational value	HEALTH and WELLBEING			1	1
	Sense of place	HEALTH and WELLBEING		1		1
	Species used for culture	HEALTH and WELLBEING	1			1
Biodiversity resilience	Areas supporting climate change resilience	DISASTER RISK REDUCTION		1		1
	Critical habitats/refugia	DISASTER RISK REDUCTION			1	1
	Landscape connectivity	DISASTER RISK REDUCTION		1		1
Freshwater ecosystems	Flood attenuation	DISASTER RISK REDUCTION		1		1
	Flow regulation	DISASTER RISK REDUCTION			1	1
Nature-based tourism	Natural land/seascapes	NATURE-BASED ECONOMY	7	2		9
Non-tree products	Genetic resources	NATURE-BASED ECONOMY			1	1
	Harvested renewable resources	NATURE-BASED ECONOMY			1	1
	Honey	NATURE-BASED ECONOMY				
	Horticulture	NATURE-BASED ECONOMY	1	1		2
	Thatch	NATURE-BASED ECONOMY		1		1
	Wildflowers	NATURE-BASED ECONOMY	1			1
Rangeland resilience	Forage production	FOOD SECURITY	6	1	1	8
	Maintaining soil fertility	FOOD SECURITY		2	1	3
	Soil retention	FOOD SECURITY	1	1		2

ECOSYSTEM SERVICE CATEGORIES			DATA SOURCE			
Ecosystem service level 1	Ecosystem service level 2	EbA thematic area	DEA 2015a	Biodiversity Planning Forum	Turpie *et al.* 2017	Grand total
Terrestrial ecosystems	Fire management	DISASTER RISK REDUCTION		1		1
	Landslide reduction	DISASTER RISK REDUCTION		1		1
	Rangeland productivity	DISASTER RISK REDUCTION		1		1
	Regulation of local climate	DISASTER RISK REDUCTION		1	1	2
Tree products	Fuelwood	NATURE-BASED ECONOMY	4	1		5
	Harvested renewable resources	NATURE-BASED ECONOMY			1	1
	Timber	NATURE-BASED ECONOMY	2	1		3
Water provision and regulation	Water delivery	WATER SECURITY	3	2		5
	Water quality	WATER SECURITY		3	1	4
	Water source	WATER SECURITY	1	3		4
Wildlife economy	Game production	NATURE-BASED ECONOMY	1			1
	Genetic resources	NATURE-BASED ECONOMY		1		1
	Tourism and hunting	NATURE-BASED ECONOMY	3			3
Grand Total			**51**	**44**	**19**	**114**

Publicly available spatial datasets with potential to be used in the priority analysis were gathered from a variety of sources (Table 4). In addition to compiling existing datasets, this project also developed several novel datasets rom satellite imagery available through Google Earth Engine (GEE). These datasets as well as the derived model outputs are available as a product of this project.

Table 4: Summary of input datasets sourced or developed for this project.

	Name	Source	Date	Notes
1	Gullies	ARC	2011	Agricultural Research Council (ARC) mapped dongas and gullies (Mararakanye and Le Roux 2011)
2	National Invasive Alien Plant Survey	ARC	2010	
3	Predicted soil loss	ARC	2007	Modelled soil erosion (ARC-ISCW, 2004)
4	Water erosion	ARC	2008	
5	Wind erosion	ARC	2008	
6	Important Bird Areas	BirdLife	2015	
7	Rainfall (Mean Annual Precipitation)	CCWR	2007	Computer Centre for Water Research (CCWR) South African Climate Atlas (Schulze 2007)
8	Strategic Water Source Areas (SWSAs)	CSIR	2017	Le Maitre *et al.* (2018). Based on Mean Annual Precipitation data from Schulze (2007)
9	Long-term grazing capacity	DAFF	1993	Department of Agriculture, Forestry and Fisheries (DAFF) data released in 2018 based on 1993 large stock unit (LSU) estimates
10	National Protected Area Expansion Strategy (NPAES)	DEA	2016	Protected area expansion focus areas (DEA 2016)
11	South African national carbon stock surfaces	DEA	2015	Modelled carbon stocks (DEA 2015b)
12	Spot building count	ESKOM	2015	Point vector, 2006–2015 time series
13	Elevation	JAXA	2018	Japan Aerospace Exploration Agency (JAXA) Advanced Land Observing Satellite (ALOS) Global Digital Surface Model – 30m (AW3D30 Version 2.1)
14	Wetland probability	Nacelle Collins , DEA	2018	National Biodiversity Assessment (NBA) 2018 (SANBI 2019)

	Name	Source	Date	Notes
15	Bush encroachment	SAEON	2018	Derived from National Land Cover 2013/14 by the South African Environmental Observation Network (SAEON) (DEA 2015c)
16	Coastline	SANBI	2018	South African vegetation map used to set standard coastline
17	Land cover	SANBI	2018	NBA 2018: Landcover_SANBI_NBA
18	Land cover change	SANBI	2018	NBA 2018: HabModv51_AEA_withDocs
19	Protected areas	SANBI	2018	NBA 2018: NBA2018_PA_working
20	Provincial Critical Biodiversity Area (CBA) maps (11)	SANBI+	2018	BGIS (bgis.sanbi.org) as well as from provincial conservation planners
21	South African vegetation types	SANBI	2018	NBA 2018: Veg18_v6b_Coastal_ALS_20180820_ddw
22	Wetlands mapped	SANBI	2018	NBA 2018: Wetlands_NBA_SAIIAE_v2_20181106
23	Population census	Stats SA	2011	Statistics South Africa (Stats SA) Small place data
24	Air pollution NO_2	This project	2018	500m, Google Earth Engine (GEE) Sentinel5, July to December 2018
25	Bare ground	This project	2018	30m, from GEE Landsat and Moderate Resolution Spectroradiometer (MODIS)
26	Fire frequency	This project	2018	500m, from GEE Landsat and MODIS, 17-year timeseries
27	Normalised Difference Vegetation Index (NDVI) trend	Venter *et al.*	2018	30m, from GEE Landsat and MODIS, 33-year timeseries (Venter *et al.* in prep)
28	Woody cover	This project	2018	30m, from GEE Landsat and MODIS
29	Woody trend	This project	2018	30m, from GEE Landsat and MODIS, 33-year timeseries
30	Global Terrestrial Human Footprint (GTHF)	Venter *et al.*	2016	GTHF maps for 1993 and 2009 from the Dryad data repository (Venter *et al.* 2016)
31	Ecosystem-based Adaptation area	Stephen Holness	2011	Data layer as used in the NBA 2011 (SANBI 2011)
32	Humic soils	DEA	2018	Soil carbon (DEA. 2019)
33	CSIR Green Book	CSIR	2019	Socio-economic and physical vulnerabilities at the local municipality scale (CSIR 2019)

Seven modelling processes were implemented, representing the major variable classes identified in the EbA conceptual model. These include:

1. Ecological Infrastructure extent:
   - a. Water EI
   - b. Nature-based Tourism EI
   - c. Rangeland EI
   - d. Biodiversity Resilience EI
   - e. Carbon EI
2. EI condition for each EI model
3. Social demand for EI
4. Risk of EI being lost to human development
5. Biodiversity importance
6. Climate change vulnerability of ecosystems
7. Existing EbA projects

Spatial modelling was implemented for model groups 1, 2, 4 and 5 using raster analysis with cell size set to 1 ha (100x100 m, equal to 2x2 mm on a printed 1:50 000 scale topographical map). All model inputs and outputs are matched in terms of extent and raster cell size. For the EbA area prioritisation analysis, raster models were aggregated to two higher-order spatial units, namely a 10x10km grid and local municipalities. Spatial modelling for model groups 3, 6 and 7 was implemented using the higher-order spatial units that matched the spatial resolution of the input data.

The model flow is summarised in Figure 23. Inputs, parameters and outputs for each model are detailed in *Annex D. Model Descriptions*.

Ecological Infrastructure: Water

Inputs for mapping ***Water EI extent*** (Figure 7) included (1) wetlands ranked according to their relative EI value; (2) wetlands buffered by 100 m; (3) National Freshwater Ecosystem Priority Areas (NFEPA); (Nel *et al.* 2011) river buffers (1km); and, (4) SWSAs (Le Maitre *et al.* 2018, 15) (Figure 8).

The water production, water quality, and flow regulation sub-models in this analysis are combined into a single Water EI model. Each of the sub-models uses the same input variables (see spreadsheet summarising potential EI models *Annex B. Model Parameters*) with different weighting values. For the purposes of this analysis a single Water EI model is considered adequate.

Water EI condition (Figure 9) inputs include (1) sub-quaternary catchment Present Ecological State (PES 2013) and extent of neighbourhood in the following land-use classes (2) non-natural; (3) plantation; (4) settlement; and (5) mining. Inputs were scaled and summed to give a composite quantitative relative Water EI condition index.

Ecological Infrastructure: Nature-based Tourism

Nature-based Tourism EI (Figure 10) inputs included (1) landscape attractiveness (weighted distance to unsightly infrastructure (mines and industry); (2) scenic landscapes; (3) naturalness (neighbourhood population density); (4) distance to roads; (5) tourism economy/demand (proximity to protected areas, sea and dams, and travel time from cities).

Ecological Infrastructure: Rangelands

Rangeland EI extent (Figure 11) is based on the natural land-cover class in the national land cover map, weighted by livestock carrying capacity and slope to give a relative Rangeland EI value.

The ***Rangeland EI condition*** (Figure 17) model is based on an analysis of rangeland primary productivity (Normalised Difference Vegetation Index [NDVI]) trend over the past 30 years (Venter *et al.* in prep.). This is currently the best indicator of rangeland condition available for South Africa. Note that NDVI trend only captures how primary production has changed over time. This is only one dimension of degradation. This degradation map does not explicitly capture or represent other forms of degradation such as change in species composition.

Ecological Infrastructure: Biodiversity Resilience

Biodiversity Resilience EI (Figure 12) is the sum of areas identified as being important for biodiversity through various spatial biodiversity planning initiatives that have been conducted in South Africa. These include: (1) protected areas and conservation areas; (2) CBA maps; (3) SWSAs; (4) Important Bird Areas; (5) National Biodiversity Assessment (NBA) (Driver *et al.* 2011) climate change resilience areas; and (6) NPAES 2016 focus areas. Neighbourhood fragmentation is used as a proxy for Biodiversity Resilience EI condition (Figure 13).

Note that this map is also the map for ***biodiversity importance***. As this map depicts core biodiversity areas in the landscape as well as ecological corridors linking these areas, it also represents areas important for biodiversity climate change adaptation.

Ecological Infrastructure: Carbon

Soil carbon stocks are used as a proxy for ecosystem ***Carbon EI*** (Figure 14). Only for soil carbon are there two independent assessments of the resource (South African Carbon Stocks [DEA 2015b] and Department of Environmental Affairs humic soils study [DEA 2019]). The baseline extent of the stock (a proxy for carbon EI) and the current condition is provided by each study as the resultant soil carbon stock under agricultural land-use relative to natural vegetation. In most cases, this is a negative relationship (namely, soil carbon is less under agriculture than under natural vegetation). The extent of soil erosion is the variable used to represent the condition of the EI in natural ecosystems.

Social Demand

The spatial dimension of ***Social Demand*** for ecosystem services flowing from EI can be expressed at three spatial scales (Table 5). Global demand is considered equal across the country and is determined solely by the availability of the EI at a site. National demand characterises the debate around spatial disjunction of supply and demand for ecosystem services, where the demand for the service is located elsewhere relative to the location of the EI supplying the service.

Strategic Water Source Areas (SWSAs) are an example of this, and also the only example incorporated into this analysis. This spatial dimension of demand is not mapped as a separate demand surface, but is incorporated in the Water EI model via the delineation of SWSAs.

For other components of Water EI (for example, local water provision or flow regulation), as well as the remaining components of EI, the spatial association of demand and supply is assumed to be congruous. Here, social proxies for this demand, captured in statistics on population distribution, levels of poverty and reliance on natural sources for food, energy and water, are used to represent social demand at the local scale.

Only local demand is explicitly mapped in this assessment (Figure 15; Figure 18). Three key datasets were used in this regard:

- ESKOM spot building count (SBC) is a point count of dwellings in South Africa that has very high spatial resolution, giving an indication of distribution of population at the point level. This data is suitable for use at the baseline 100 m raster level.
- Census 2011 small place data contains data on household poverty and natural resource use (wood and water). This data is aggregated here into a subsistence use resource and poverty index (SURPI). The Census 2011 data is the most current and complete country-wide dataset on social and economic aspects of households. The downside of this dataset is that the data aggregation unit

(small place) is not spatially uniform therefore larger enumerator units distort spatial patterns. This data is only suitable for us here at the aggregated 10x10km grid or local municipality levels.

- Council for Scientific and Industrial Research (CSIR) Green Book 2019 (Van Niekerk *et al.* 2019) data on socio-economic and environmental vulnerability has useful aggregated statistics on communities at the local municipality level only. This data can only be used here for analysis at the local municipality level.

Table 5: Summary of the spatial components of social demand for Ecological Infrastructure (EI) applied in the model.

EI component	Global	National	Local
Carbon EI	Global demand for EI. Demand considered equal across South Africa and therefore not mapped.		
Water EI		National priorities for water production. SWSAs capture this demand.	Local demand for EI captured in population distribution, poverty and natural resource use statistics.
Nature-based Tourism EI			
Rangeland EI			
Biodiversity Resilience EI			

Risk

Risk of ecosystem loss is defined here as the likelihood of a natural landscape being converted to a non-natural landscape based on the land cover change trend of the neighbourhood since 1990 (Figure 19). This is a backward-looking statistic and is not necessarily the best indicator for predicting future land cover change. A product such as an integrated Spatial Development Framework (SDF) map of the country would be a good indicator of risk, but creating this map is beyond the scope of this project.

In the final priority analysis at the local municipality level, an additional risk variable is included from the CSIR Green Book dataset (CSIR 2019).

Environmental Vulnerability (EV) is an indicator representing the conflict between preserving the natural environment and accommodating the growth pressures associated with population growth, urbanisation and economic development. A high score reflects much conflict between preserving the environment and allowing land-use change to occur. The indicator measures air quality, environmental governance, and the competition between ecology and urban encroachment.

Biodiversity Importance

Biodiversity importance is the integration of CBA maps; protected areas and conservation areas; SWSAs; Important Bird Areas, and NPAES focus areas. This map is already considered in the EI extent map as it is synonymous with Biodiversity Resilience (Figure 12). A key question is how much this criterion is weighted in a final analysis.

Climate Change Risk

The predicted change in the extent of Southern African biomes is used as a surrogate for local municipality level ***climate change risk*** to ecosystems (Figure 20; Guo *et al.* 2017). This model integrates the full array of climate variables into a single map that represents the future predicted state of ecosystems, albeit at a coarse level. The degree to which biomes are expected to remain static or be replaced within local municipalities is indicative of where significant ecosystem changes in response to climate change may occur.

Social vulnerability to climate change is not considered here but should be considered in future refinements of this exercise. This could be considered as part of the social demand variable or kept separate as an implementation context variable.

Existing EbA Projects

The database of ***existing EbA projects*** compiled by this project[1] is used as a final mask to indicate potential priority areas where there are currently no EbA projects (Figure 21).

Data Aggregation Units

The stage 1 model outputs (at 100 m resolution, see Figure 16) were aggregated to a 10 x 10 km grid cell for the priority analysis (Figure 22). The reasons for aggregating this data were:

- Raster model outputs are difficult for non-GIS users to use for spatial analysis. Summarising all model outputs to a convenient and practical area unit means that information can be easily manipulated as a shapefile or in a spreadsheet. By using the summary unit, we can reduce the dataset from several million pixels to several thousand polygons that can be easily manipulated in a spreadsheet.
- Inherent in the analysis is a lot of noise or clutter in the outputs. Averaging information to a larger spatial unit will help dampen this noise and focus where real spatial national- and biome-level priorities are.
- Water catchments are a good ecological unit for analysis because they relate well to ecologically meaningful areas of EI and can therefore help focus implementation towards ecologically relevant areas. The downside of catchments is that they are not the same size. Therefore, larger catchments will always skew the analysis in favour of larger catchments because they act as 'attractors' in any numerical analysis simply because bigger areas tend to have more of any variable being measured. A uniform unit provides a more spatially balanced picture of patterns in the data being assessed. The 10 x 10 km square grid (area 100 km2) unit used here is spatially comparable to sub-quaternary catchments (mean area 130 km2). From an implementation perspective the ecological unit is more relevant, however, as this project is concerned with spatial prioritisation the spatially balanced or uniform grid unit is more relevant.
- Lastly, social demand is not well depicted at the 100 m grid cell resolution. Census data is linked to enumerator areas and these are variable in size, and can be the size of a local municipality. Therefore, the larger grid cell spatial unit is more suited to using this information in a national analysis.

In the final analysis, results were also aggregated to the local municipality level based on the feedback from stakeholders. Local municipalities are a practical unit with which to depict national priorities for EbA action as they are a spatial unit that many stakeholders are familiar with and are commonly used by government across sectors for defining implementation priorities nationally.

1 Stevens, L. and Knowles, T. (2019). Ecosystem-based Adaptation: Review of existing EbA activities. March 2019.

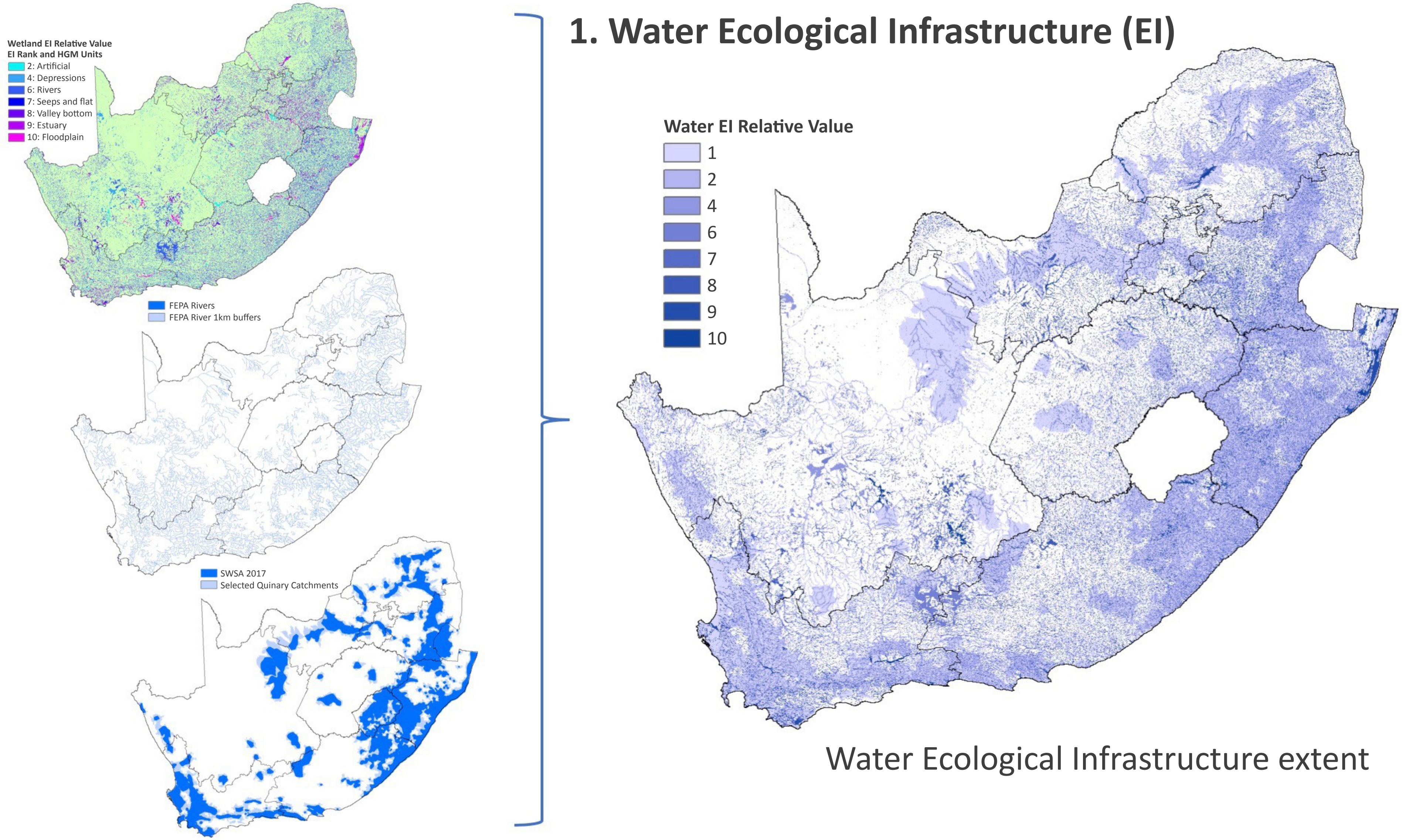


Figure 7: The extent of Water Ecological Infrastructure (EI) based on the extent of wetlands and wetland buffers, Freshwater Ecosystem Priority Areas (FEPA), rivers and river buffers, and Strategic Water Source Areas (SWSAs) for surface water and groundwater.

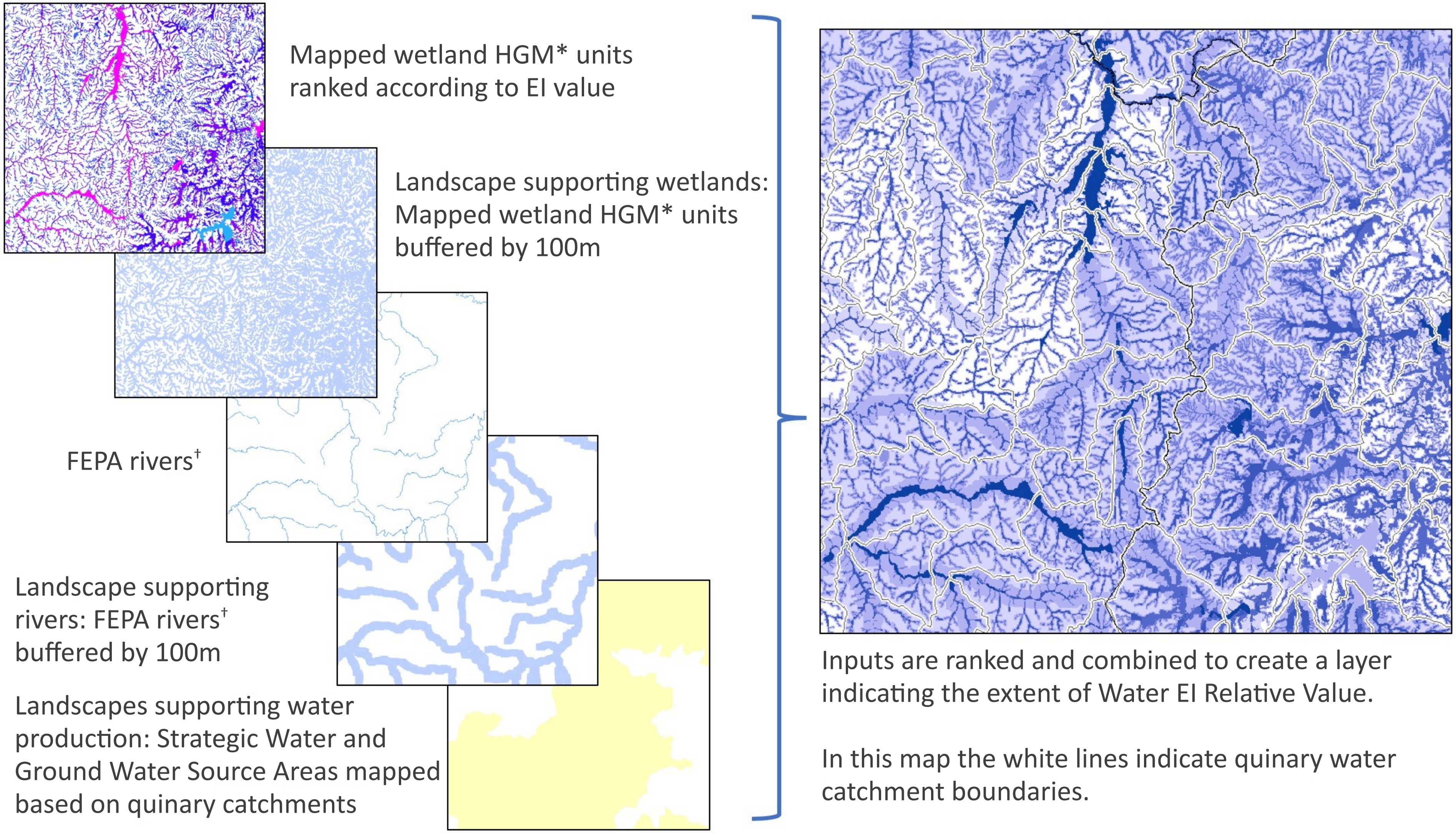


Figure 8: A close-up example of what the Water Ecological Infrastructure (EI) map looks like in terms of the raw input datasets and final EI model. (*Hydrogeomorphic, †Freshwater Ecosystem Priority Area)

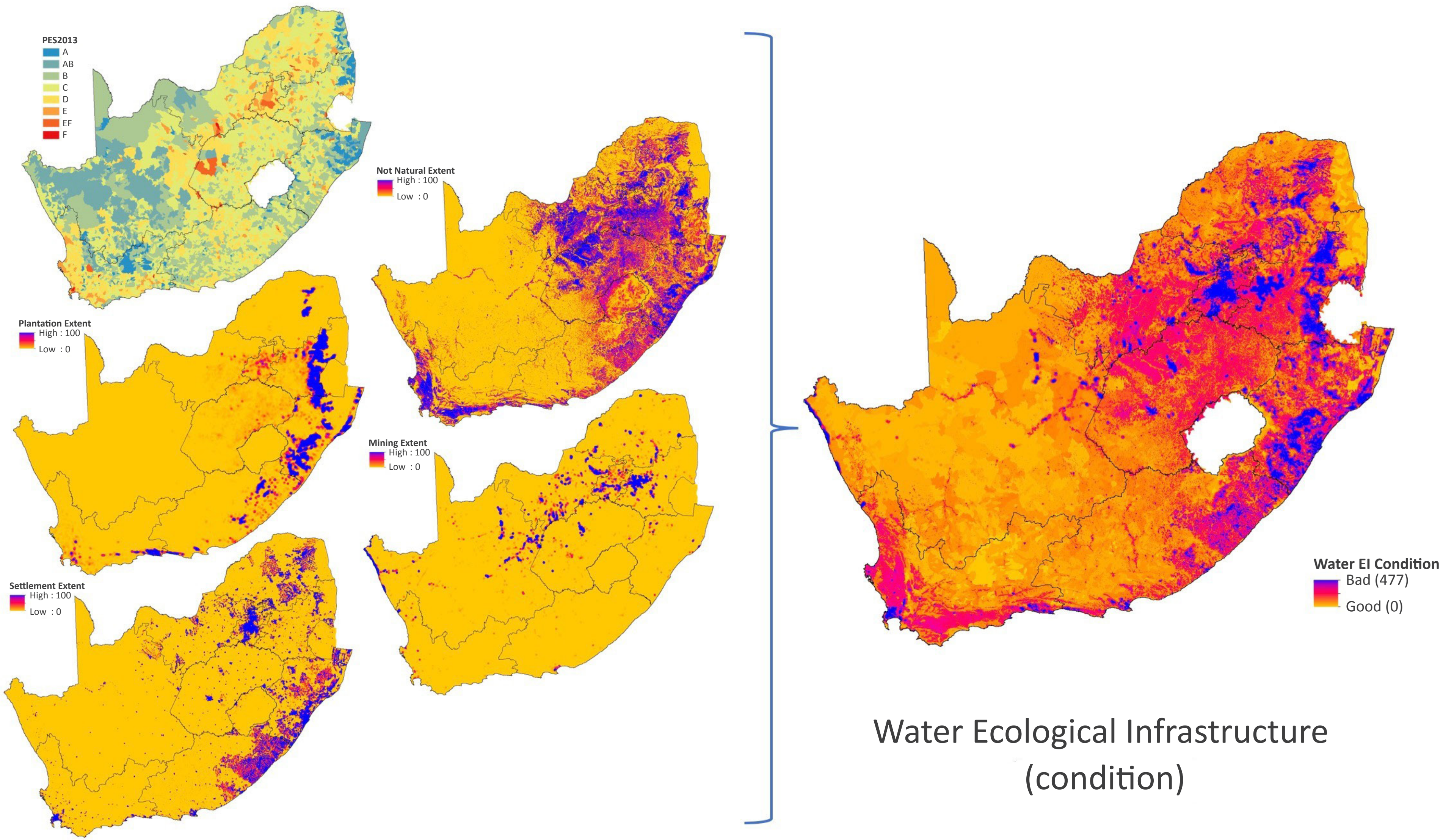


Figure 9: The map of Water Ecological Infrastructure (EI) condition based on sub-quaternary catchment Present Ecological State (PES) 2013 scores and neighbourhood extent of natural vegetation, plantations, mining and settlements.

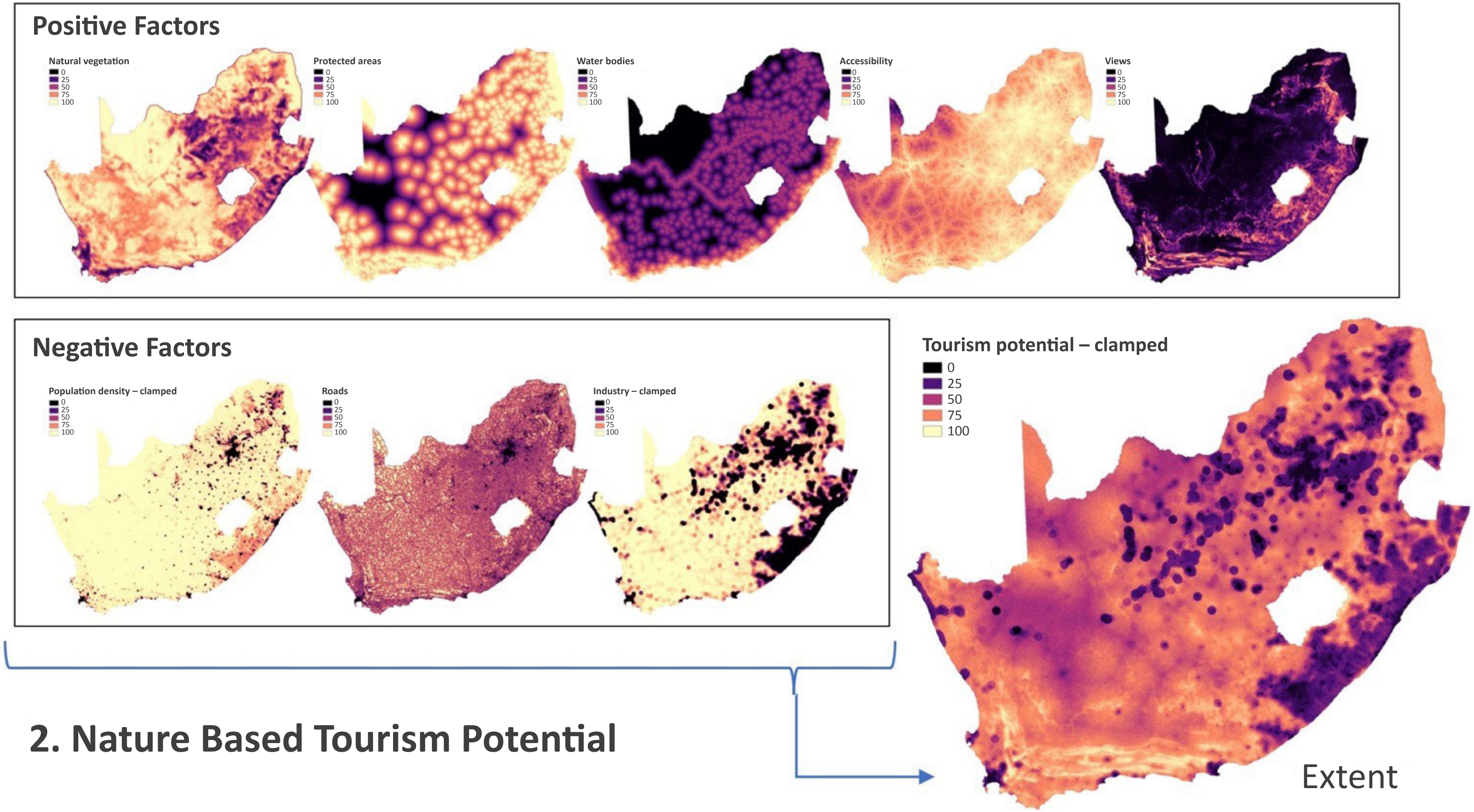


Figure 10: The extent of Nature-based Tourism Ecological Infrastructure (EI) based on a combination of positive factors (natural vegetation, protected areas, water bodies, accessibility and views) and negative factors (population density, roads and land use). No model was produced for Nature-based Tourism EI condition.

3. Rangeland Ecological Infrastructure

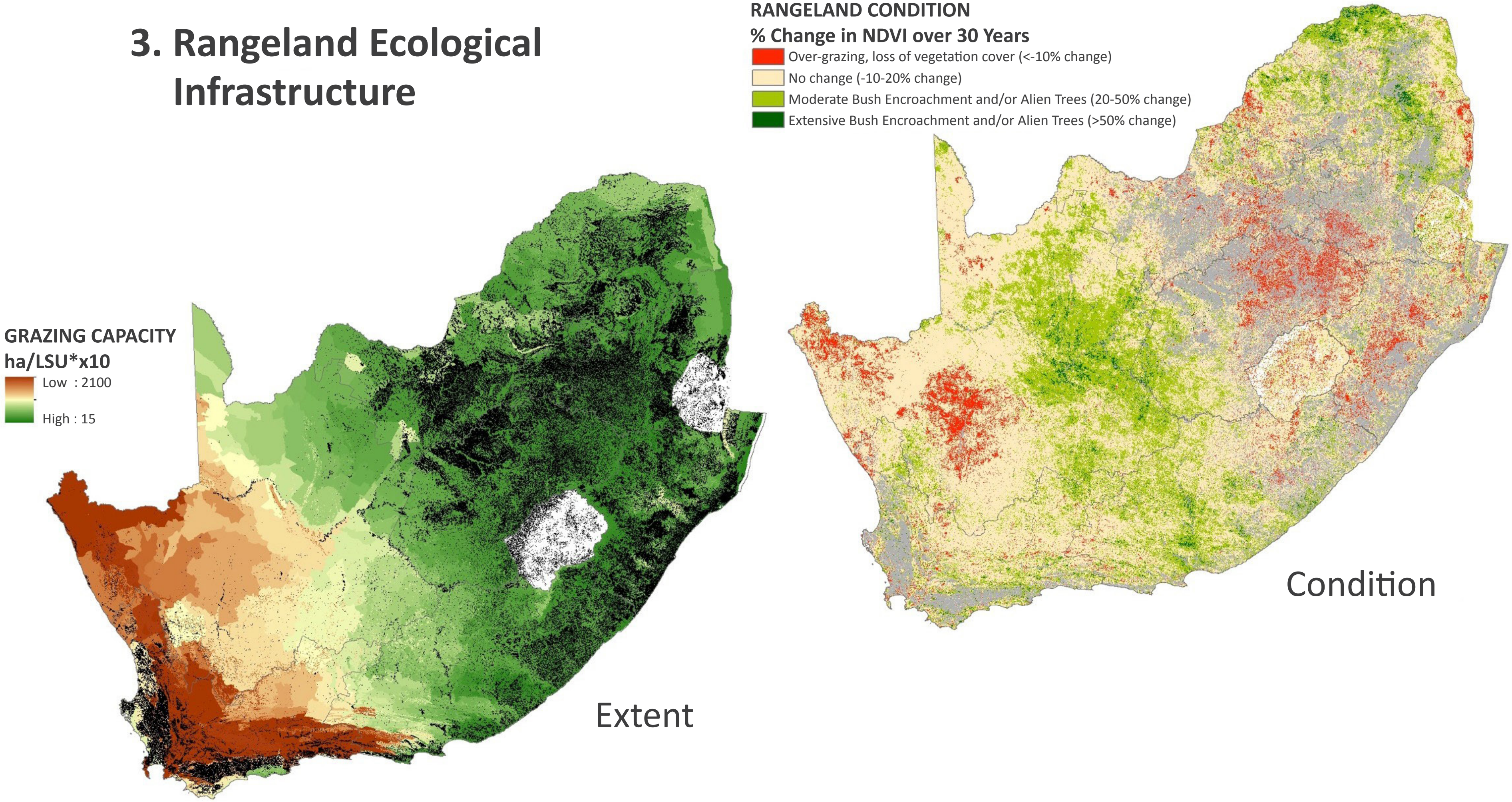


Figure 11: The extent of Rangeland Ecological Infrastructure (EI) based on livestock carrying capacity maps less not-natural areas, and Rangeland EI condition based on the trend in rangeland Normalised Difference Vegetation Index (NDVI) over the last 30 years. (*Large stock unit)

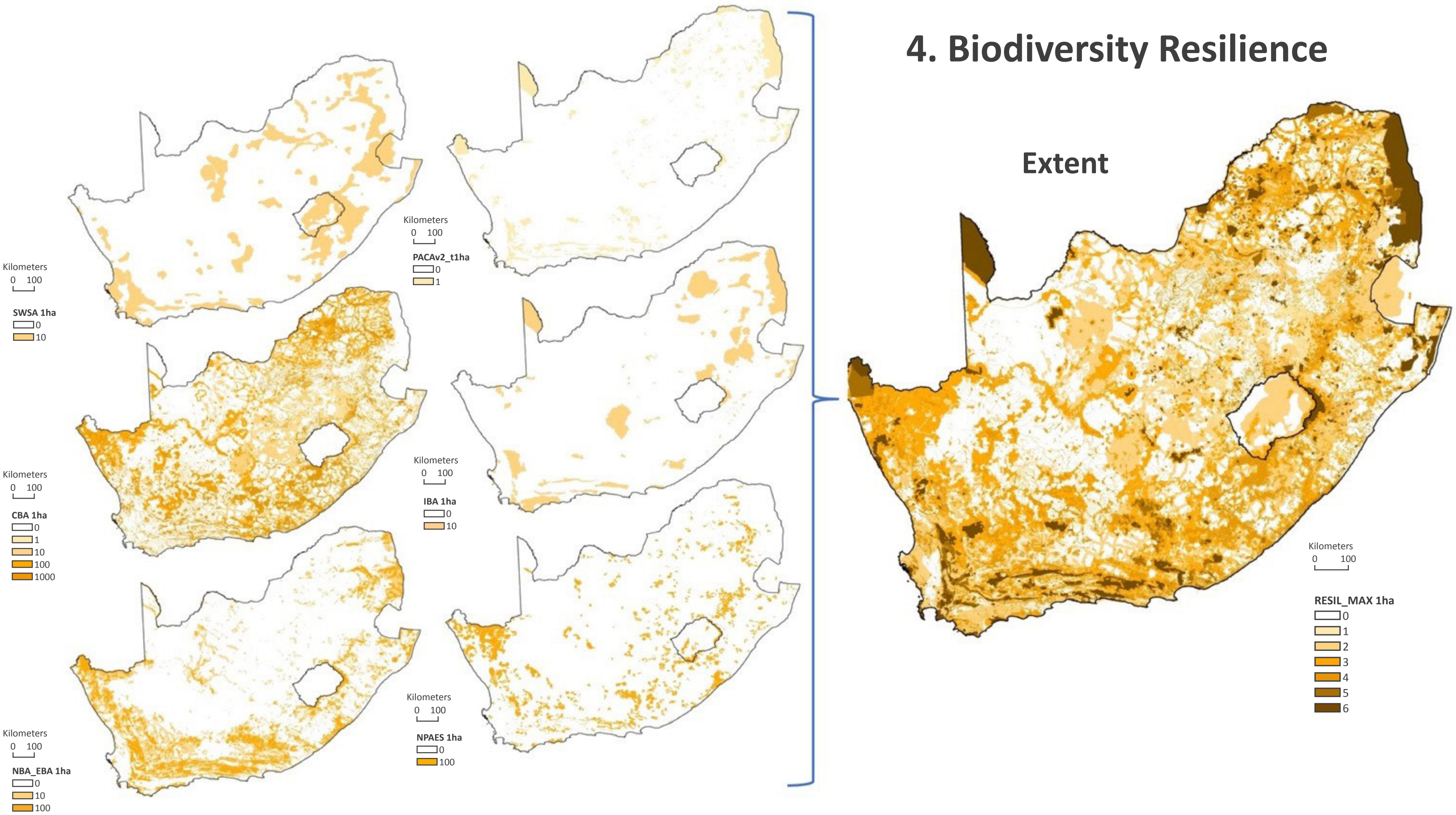


Figure 12: Extent of Biodiversity Resilience Ecological Infrastructure (EI) (right) based on the sum of spatial biodiversity planning tools. This represents the minimum amount of landscape required to maintain biodiversity patterns and processes. The inputs (left) include Strategic Water Supply Areas, (SWSAs), protected areas, Critical Biodiversity Area (CBA) maps, Important Bird Areas, climate change resilience areas, and National Protected Areas Expansion Strategy (NPAES) areas. The categories in the final map (right hand side)represent CBA map equivalents: 6=Protected Areas (high resilience), 5 = Conservation Areas, 4 = CBA1, 3 = CBA2, 2 = Ecological Support Areas 1, 1 = Ecological Support Areas 2 and 0 = No Natural Habitat Remaining (low resilience). This map also represents areas important for biodiversity climate change adaptation.

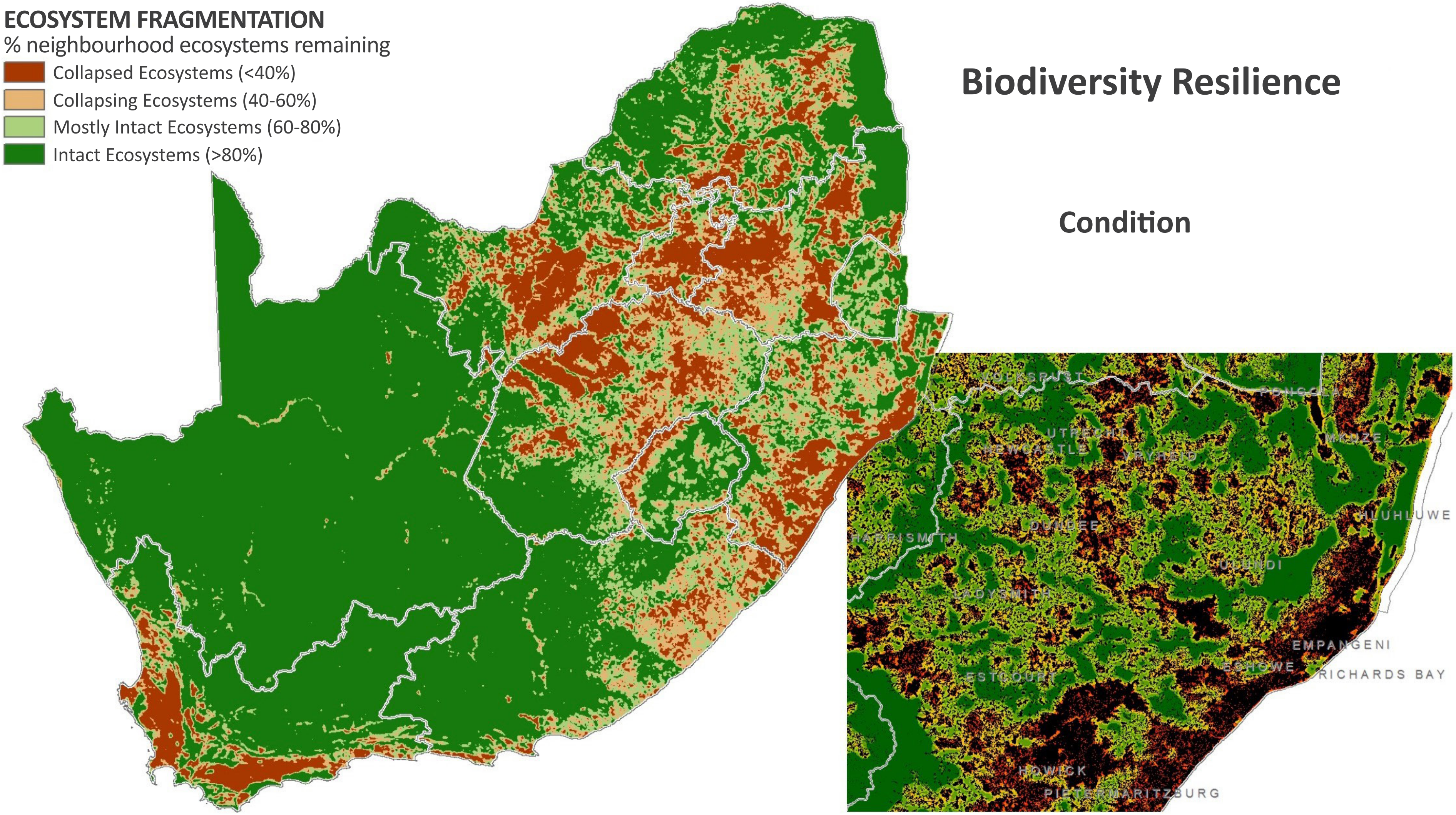


Figure 13: Neighbourhood fragmentation is used as a proxy for Biodiversity Resilience Ecological Infrastructure (EI) condition. The landscape fragmentation index is the percentage of a cell's neighbourhood that is in a non-natural land cover state. Collapsed ecosystems indicate areas where landscape ecological connectivity is below the critical threshold to maintain ecologically functional landscapes.

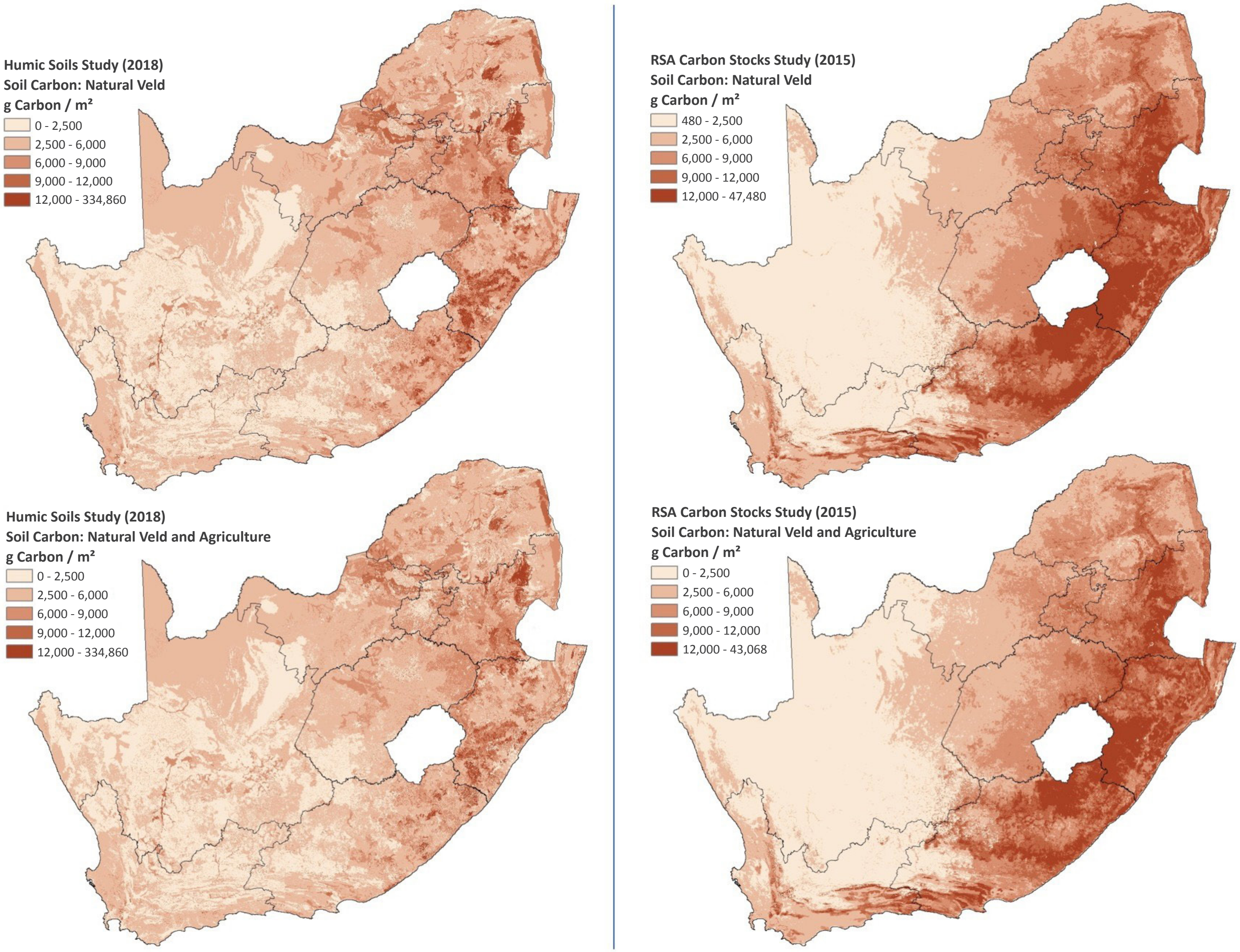


Figure 14: Comparison of different potential soil carbon datasets – Humic soils study (DEA 2019, left) and the South African carbon stocks study (DEA 2015b, right) under baseline conditions (top) and considering agriculture (bottom).

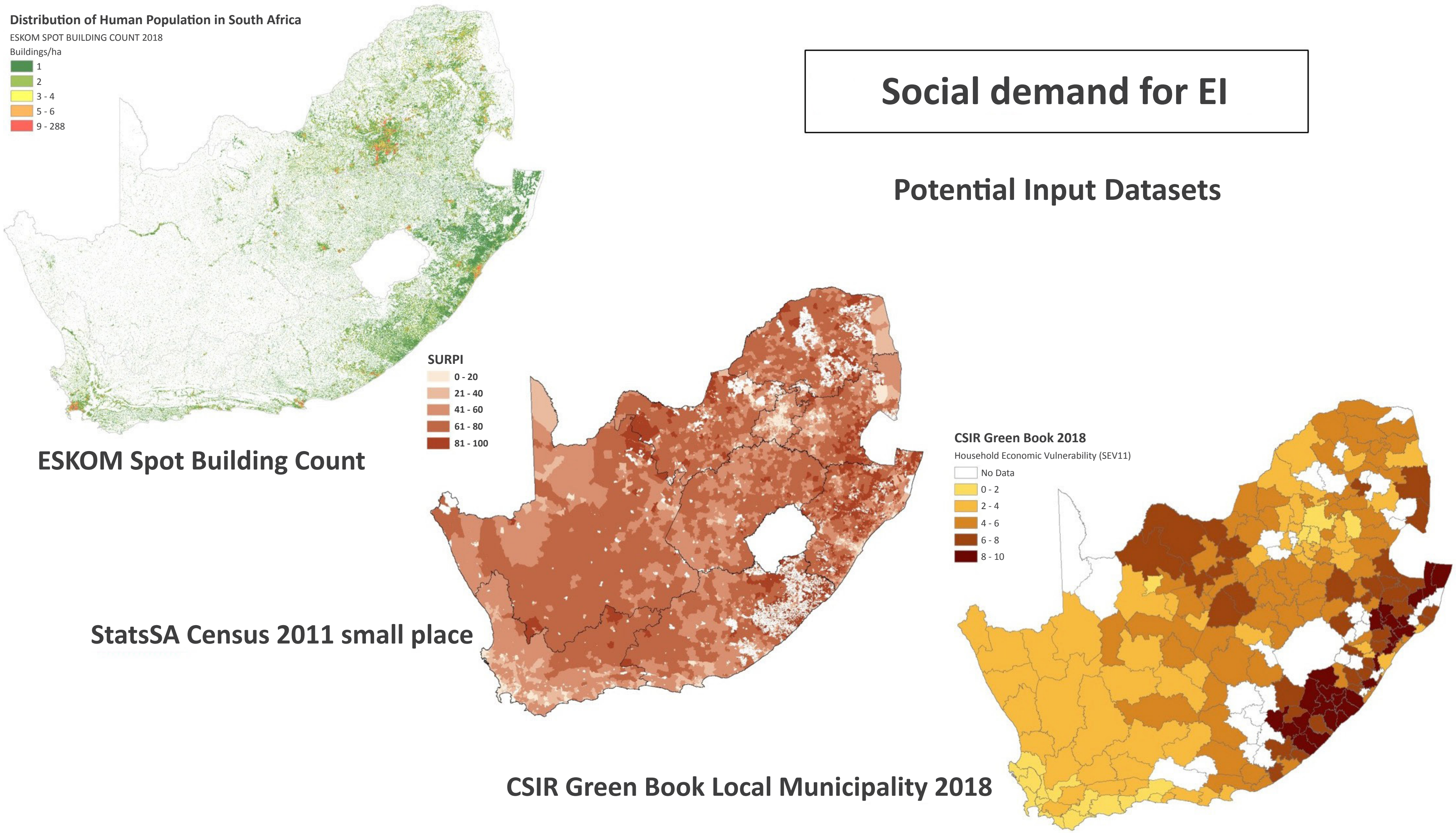


Figure 15: The raw data inputs to the Social Demand model illustrating the different spatial resolution of available input data: point (ESKOM spot building count), small place (Census 2011) and local municipality (CSIR Green Book 2019).

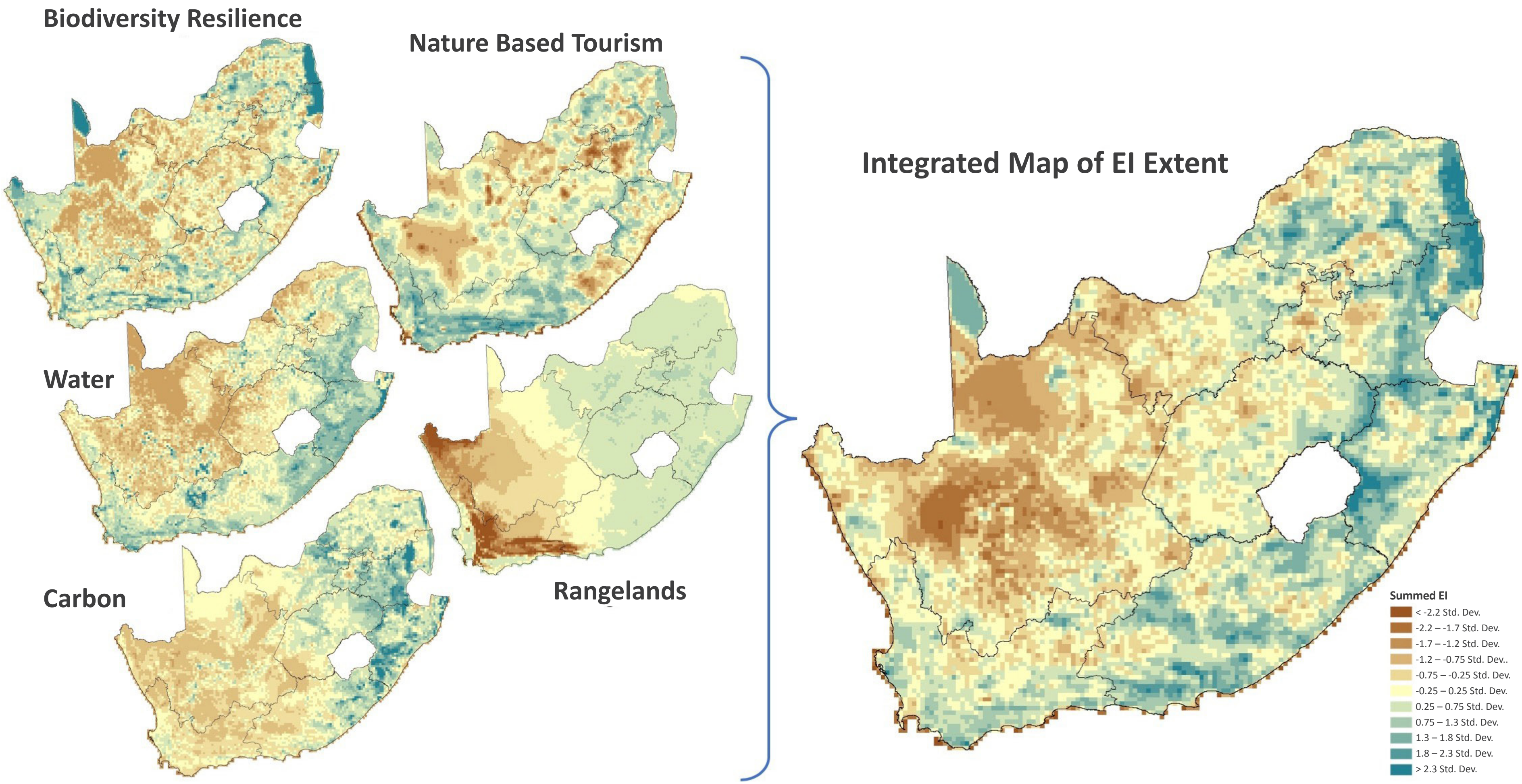


Figure 16: The integrated map of Ecological Infrastructure (EI) extent based on the sum of the five individual EI extent models. Values in the EI extent maps are relative and have no units.

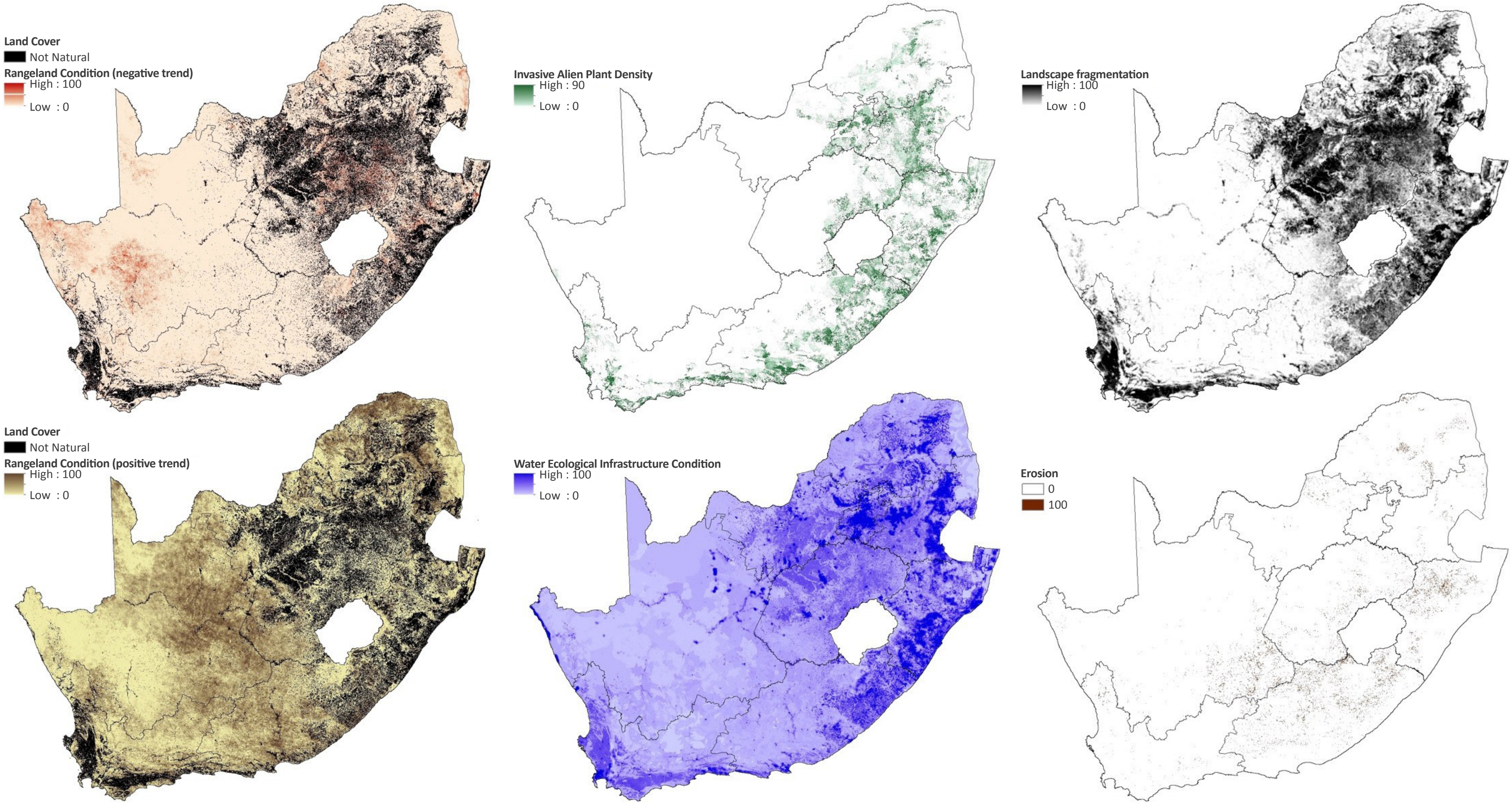
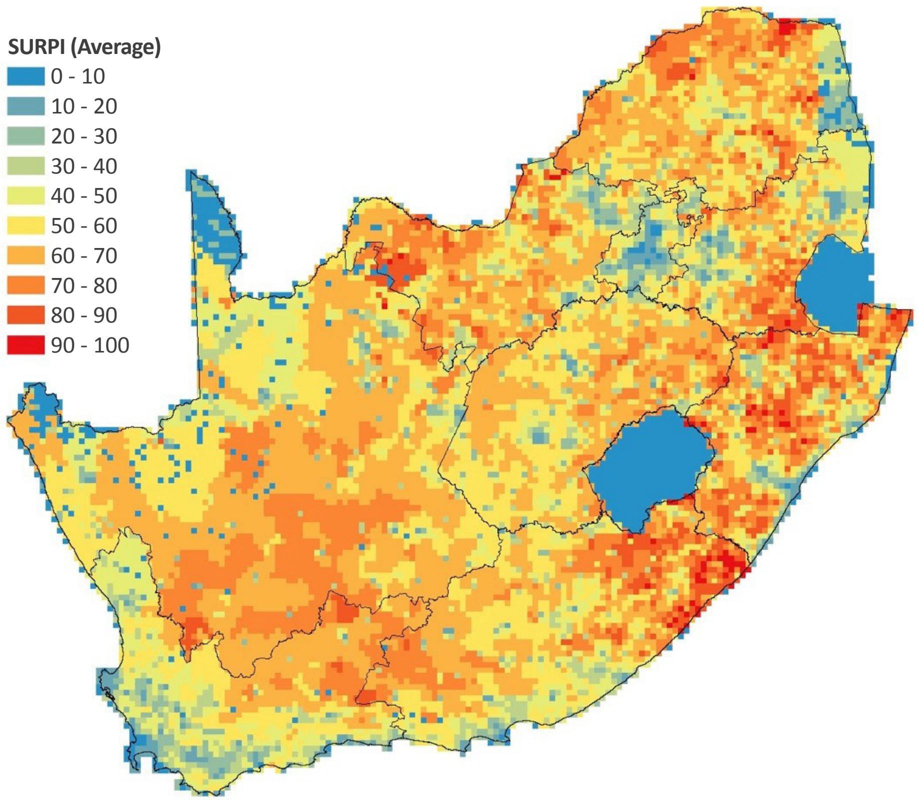


Figure 17: Rangeland Ecological Infrastructure (EI) condition models, including positive Normalised Difference Vegetation Index (NDVI) trend (namely, bush encroachment) and negative NDVI trend (loss of plant cover), invasive alien plants, water, landscape fragmentation and erosion.

Subsistence use resource and poverty index



Population density

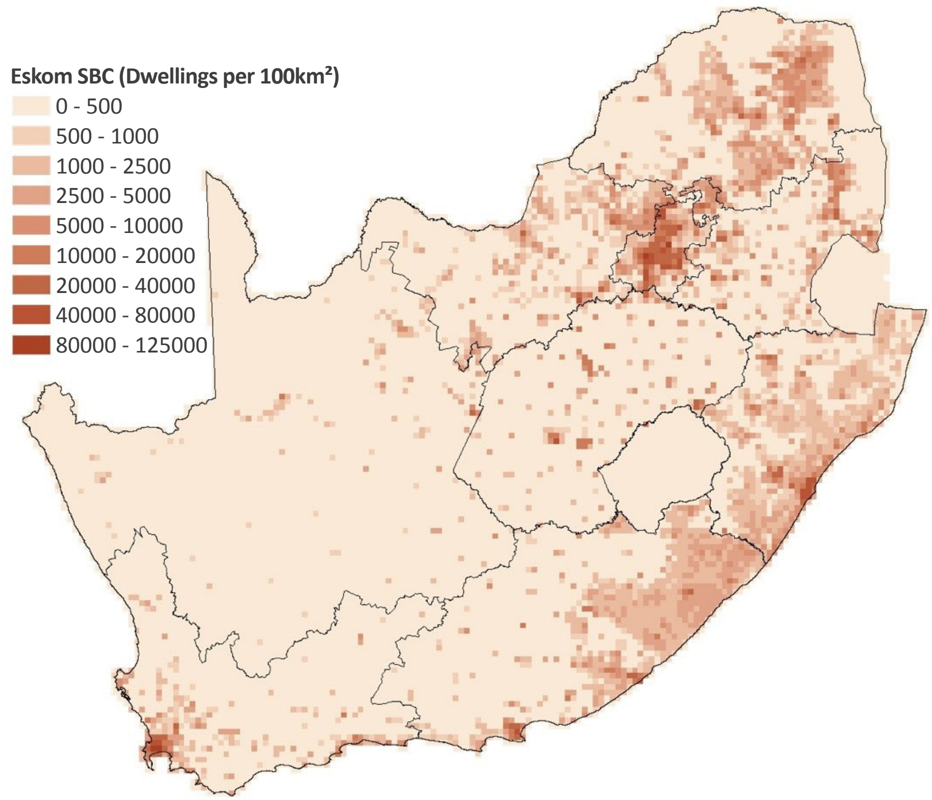


Figure 18: Inputs to the Social Demand model aggregated to the prioritisation analysis grid cell unit. Social demand is based on a subsistence use resource and poverty index (SURPI) derived from the Census 2011 and the ESKOM spot building count used as a proxy for point-based population density.

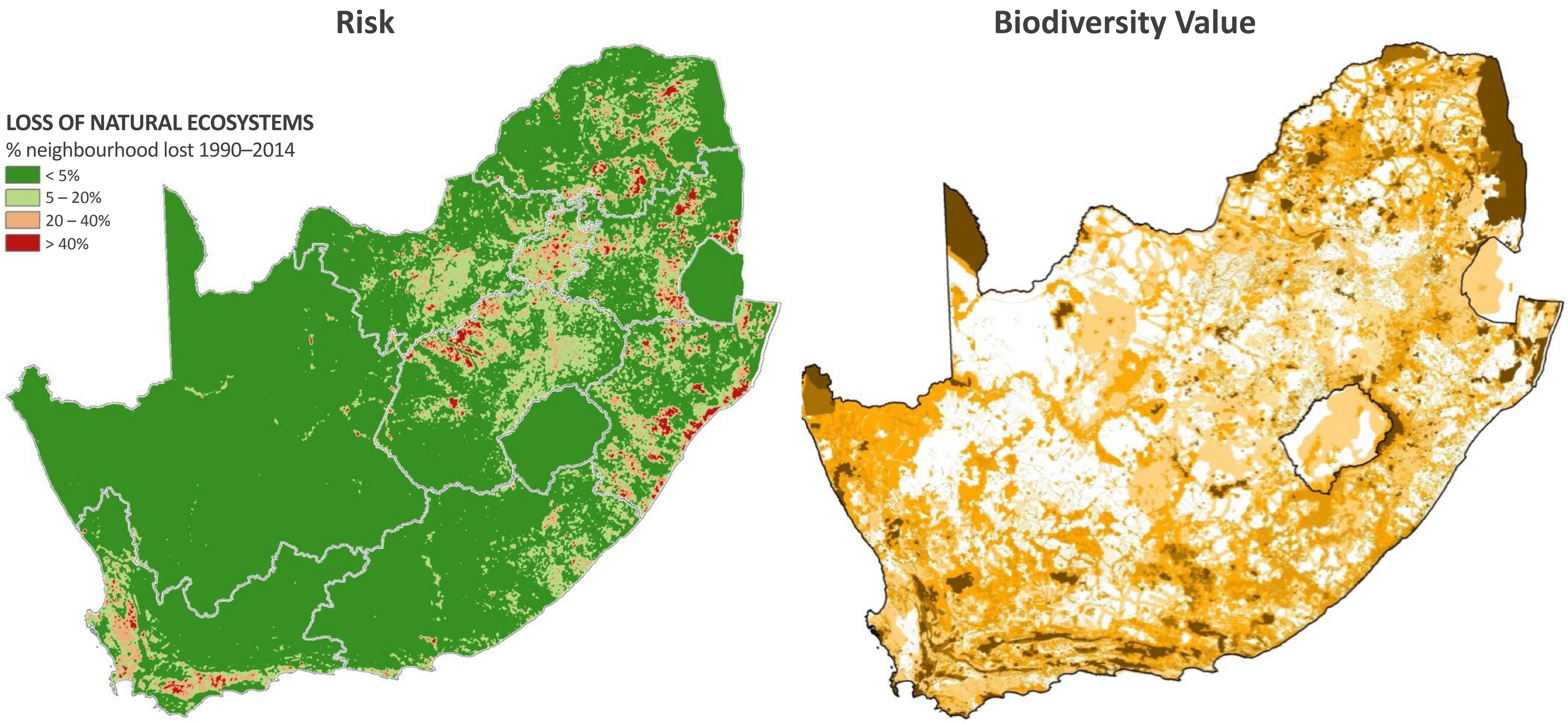


Figure 19: Additional criteria used to identify EbA priorities. Risk of Ecosystem Loss is based on the historic loss of ecosystems in the neighbourhood surrounding a focal cell. Biodiversity Value is the same as the biodiversity resilience map (Figure 16) and is expressed in terms of Critical Biodiversity Area (CBA) map category equivalents (Figure 12).

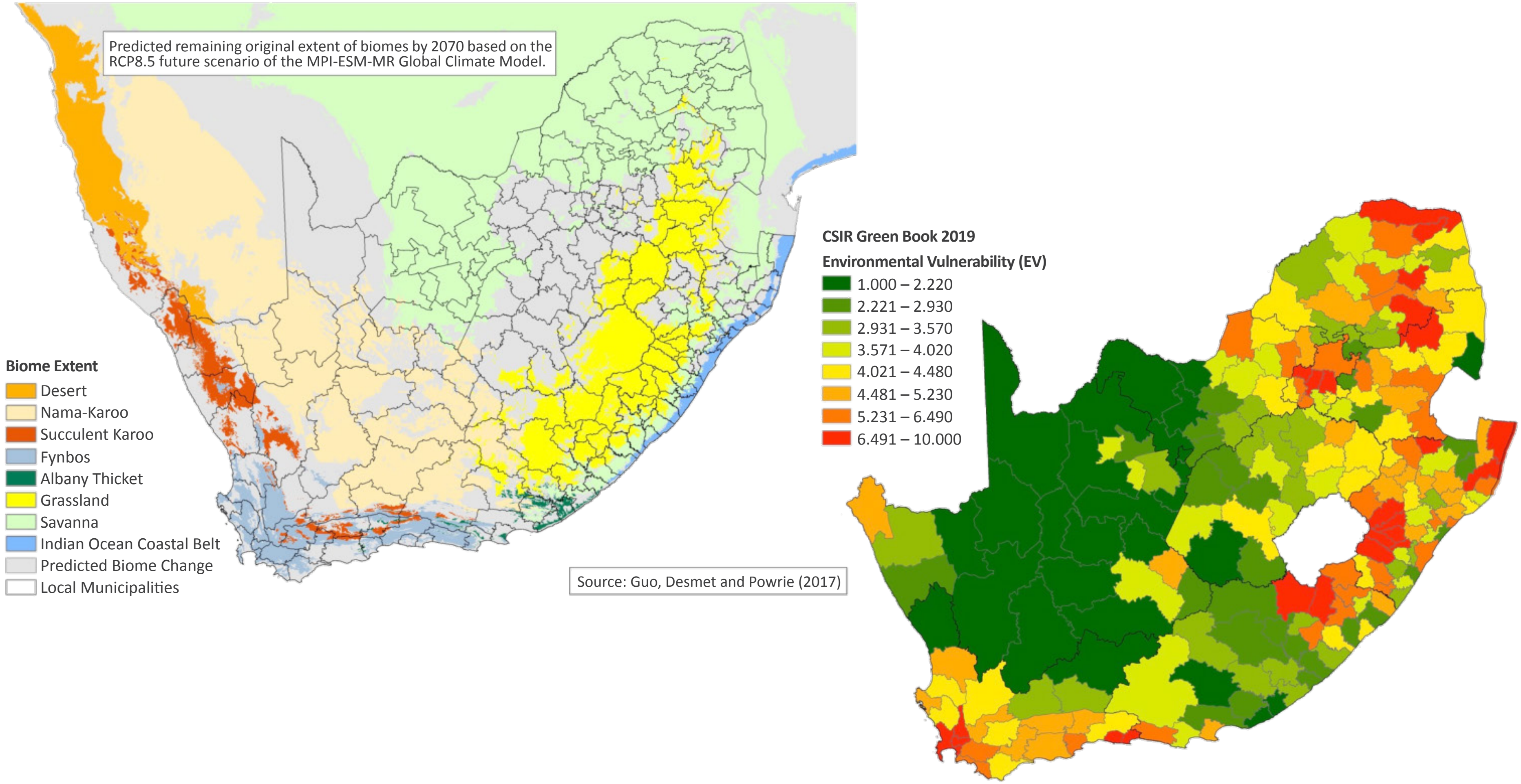


Figure 20: Additional criteria used to identify EbA priorities. Climate change risk (left) is based on the 2070 predicted change in the extent of biomes based on the Max Planck Institute Earth System Model, medium resolution (MPI-ESM-MR) climate change model. Local municipalities are ranked in terms of the percentage area where biomes are predicted to change from their current state. The CSIR Green Book (2019) local municipality environmental vulnerability index (right) is used as an additional variable for risk of ecosystem loss.

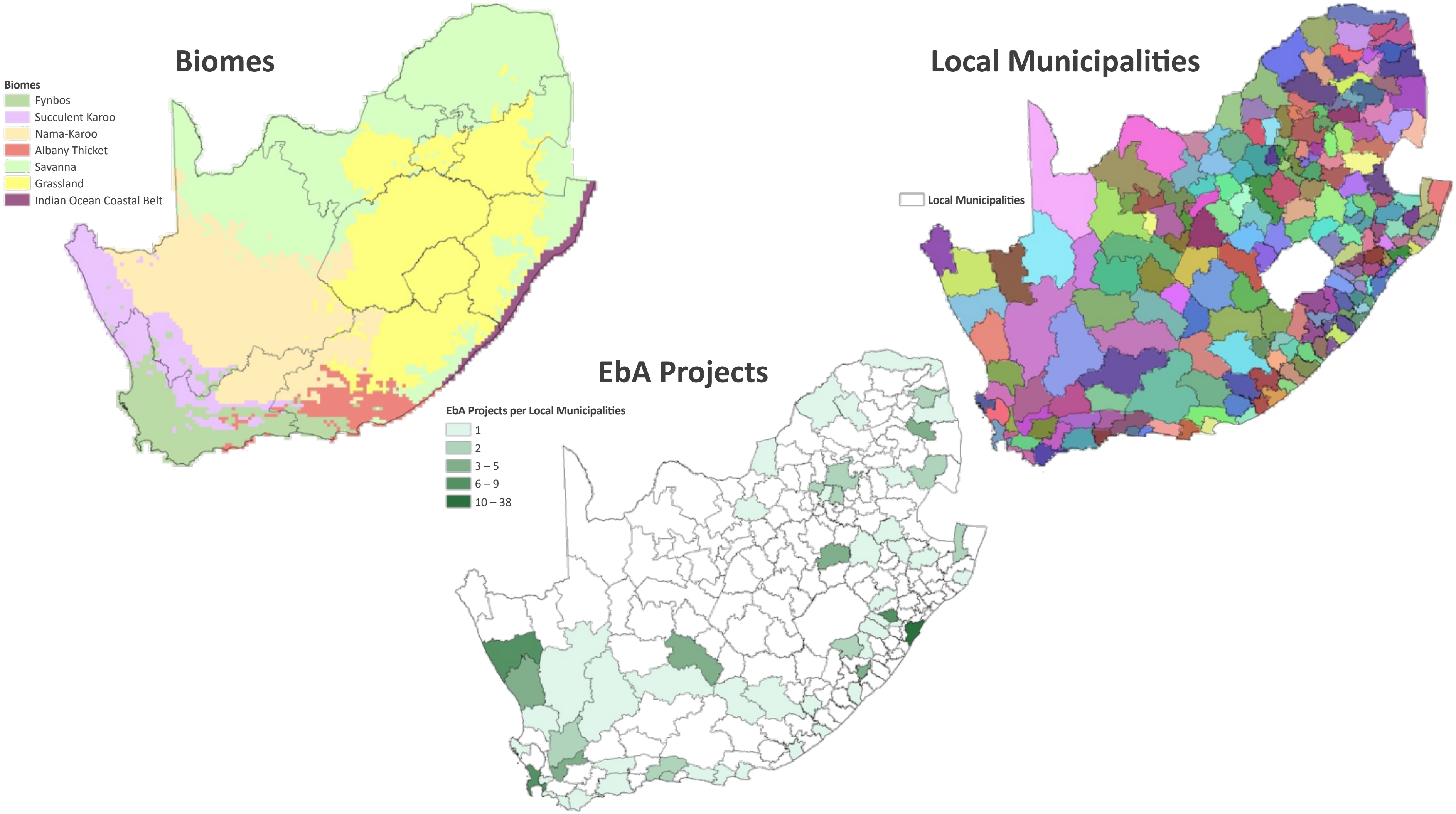


Figure 21: Additional criteria used to identify EbA priorities. Each integration grid cell is classified in terms of a single biome or local municipality based on majority area. Biomes with small extent – Forest, Desert and Azonal – are incorporated into neighbouring biomes. EbA projects (centre) are the number of existing EbA projects per local municipality.

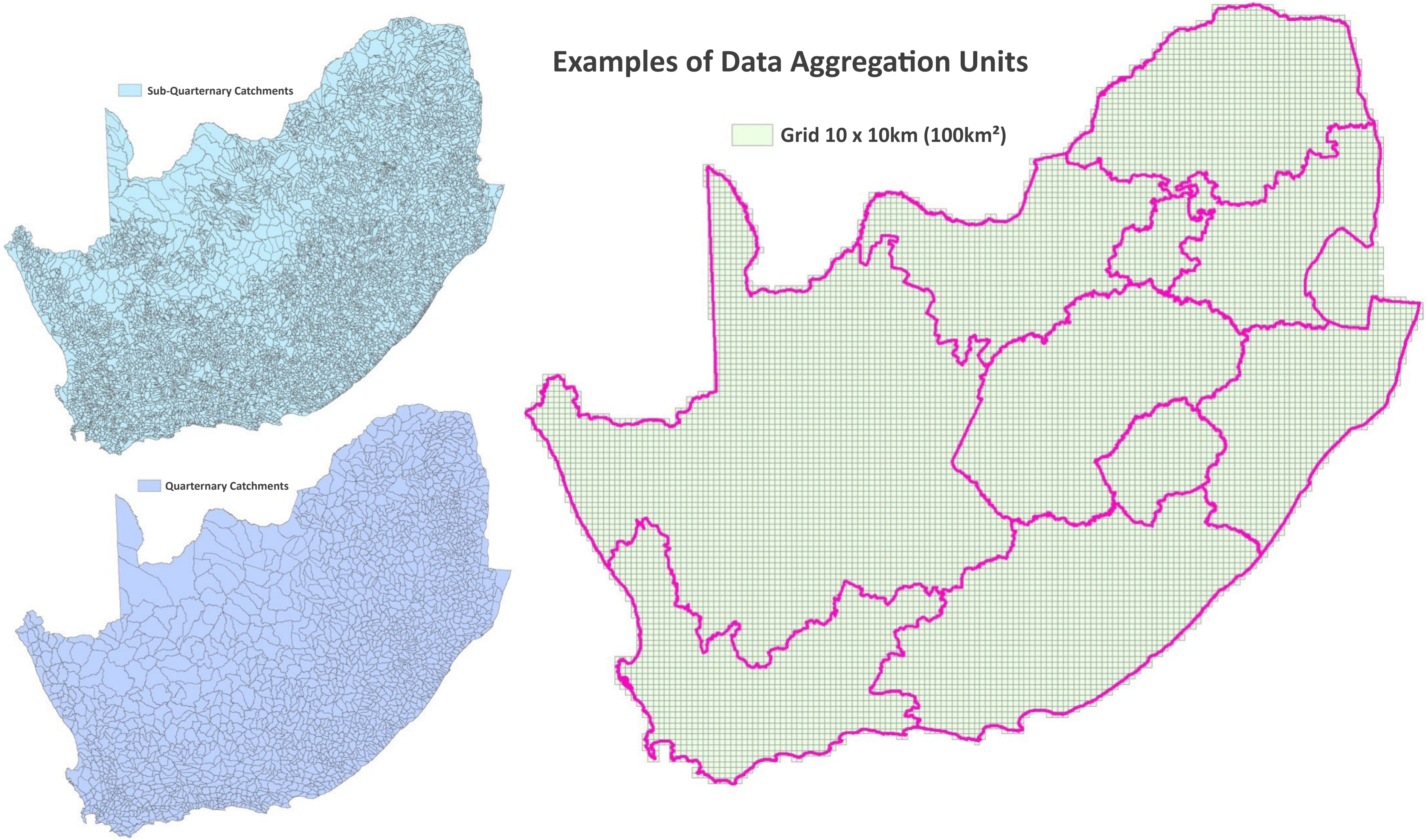


Figure 22: The standardised 10 x 10km grid unit (right) used to summarise and aggregate all model outputs to create the inputs for the priority analysis. Catchments (left), although a better ecological unit, were not used due to the unequal area of catchments biasing the analysis towards larger catchments.

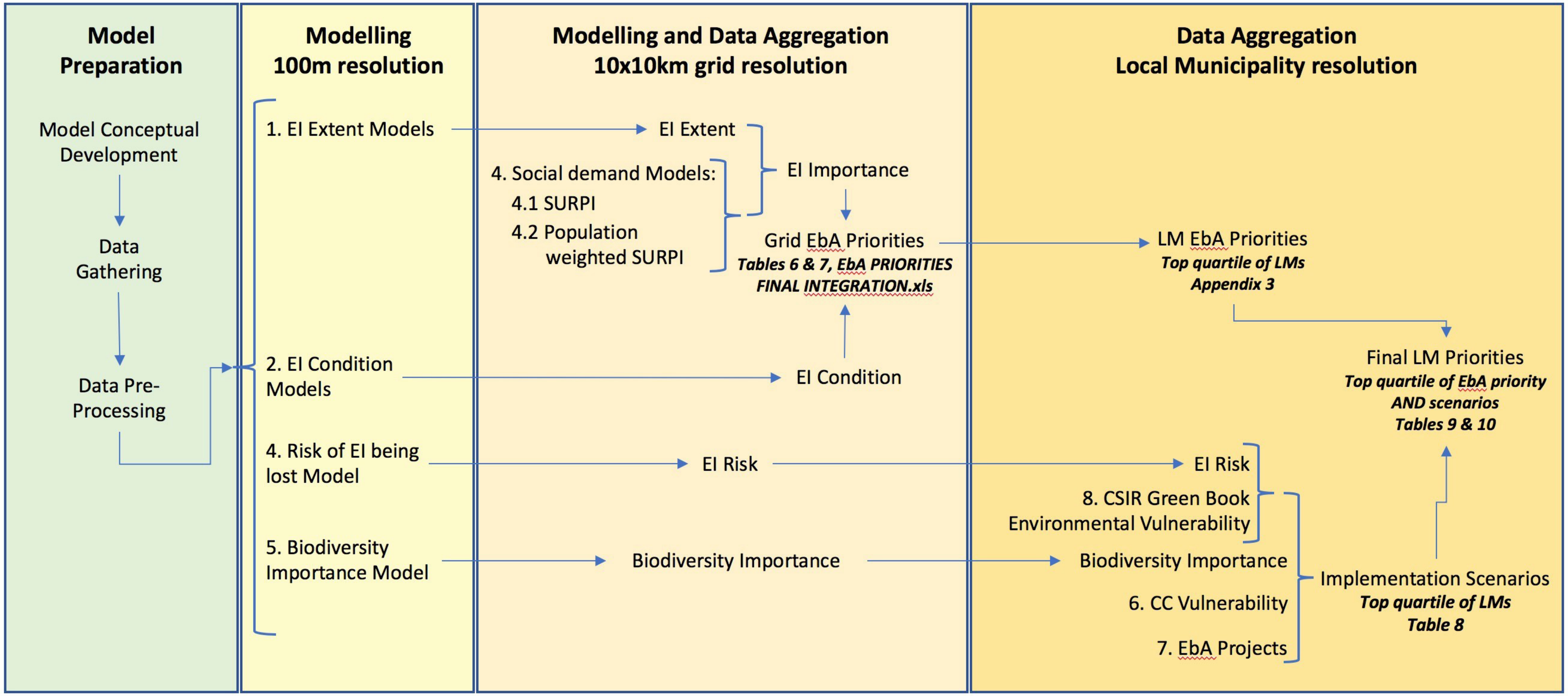


Figure 23: A summary of the EbA priority modelling work flow.
(EI Ecological Infrastructure, EbA Ecosystem-based Adaptation, SURPI Subsistence use resource and poverty index, LM Local municipality, CC Climate change)

For the priority analysis, all model outputs generated at the 100 m raster resolution (EI extent, EI condition, EI risk and biodiversity importance) were summarised to a standardised spatial unit (10 x 10 km grid, Figure 22). Social demand models (SURPI and population weighted SURPI) were generated only at the 10 x 10 km grid resolution. All grid-level data were relativised by dividing into percentile ranks from 0 to 100. Climate change vulnerability, EbA projects and CSIR Green Book (2019) environmental vulnerability variables were only available at the local municipality resolution and therefore are only summarised at this resolution. In addition to data aggregation, each grid cell was assigned to a biome and local municipality based on majority area.

The grid divides South Africa into 13 046 equal area units that provide a convenient unit of analysis that can be manipulated in a spreadsheet (EbA PRIORITIES FINAL INTEGRATION v4). Beyond what is reported here, this spreadsheet can be used for further analysis of EbA potential and priorities without the need to engage the raster model data in a GIS.

Using the aggregated spreadsheet data, each grid unit was assigned an EbA priority value (namely a value in the response matrix – A, B, C or D, Figure 24) if the EI extent, social demand and EI condition percentile values satisfied the criteria for each response matrix condition defined in Table 6. Four combinations of EbA assessments were conducted:

- A national-level assessment selecting from all grid cells in the country
- A biome-level assessment selecting only from grid cells that fall within a biome (i.e. the EbA priorities are relative to the aggregated values of the biome not the country)

For each of the spatial scales, two social demand models were used:

- A subsistence use resource and poverty index (SURPI); and,
- A population weighted SURPI using ESKOM's spot building count (SBC) to weight the SURPI index based on population per grid unit (SBC x SURPI)

The number of grid cells meeting the criteria for each EbA response type for the national assessment only is summarised in Table 7. It is interesting to note that the type A EbA response (high EI importance and good condition) is rare, occupying only 1.2% of South Africa. Therefore, EbA implementation opportunities aimed at keeping important EI in a good condition, which are possibly the most important EbA priorities to focus on, are going to be hard to find. Table 7 suggests that the bulk of EbA activities are going to be focused on restoration activities.

Table 6: Criteria for combining the three primary determinants of EbA priorities into an EbA response matrix. Values refer to percentiles within the grid-level aggregated input values.

EbA response category	EI importance		EI condition
	EI extent	Social demand	
A	>=0.7	>=0.7	<=0.5
B	<0.7 & >=0.45	>=0.7	<=0.5
C	>=0.7	>=0.7	>0.5
D	<0.7 & >=0.45	>=0.7	>0.5

Table 7: Summary of the number of grid cells classified per EbA response category using the criteria in Table 6 for the national-level analysis, using both the SURPI and the population weighted SURPI social demand variables. The EbA response category column represents the combined social demand classifications, e.g. AA means that a grid was classified as EbA response category A for both the SURPI and the population weighted SURPI. 0A or A0 means it was classified as A by only one of the social demand variables and the same for categories B, C and D (Figure 27).

EbA response category	No. grid cells	%	%
AA	26	0.20	1.13
0A or A0	121	0.93	
BB	85	0.65	8.15
0B or B0	978	7.50	
CC	398	3.05	8.39
0C or C0	697	5.34	
DD	485	3.72	17.26
0D or D0	1767	13.54	
None	8489	65.07	65.07
Total number of cells	**13046**	**100**	**100**

Next, the grid-level EbA priority analyses were summarised to the local municipality level to provide a list of priority local municipalities for EbA action. The grid outputs were aggregated to the local municipality level using a weighted sum of the combined national and biome models (Figure 25, see Annex C. Municipalities ranked based on EbA action potential and additional variables for weights). The result is a ranking of local municipalities in terms of their potential to support EbA action at the national- or biome-level of prioritisation.

For the final prioritisation step, the top quartile of local municipalities (25% or 54 local municipalities) of the biome-level analysis were subdivided into implementation scenarios based on the additional implementation context variables of risk (both risk of ecosystem loss due to human development (this project) and environmental vulnerability (from the CSIR Green Book 2019)); biodiversity importance; and, climate change vulnerability of ecosystems (Figure 27 and Table 10). The criteria applied and the number of local municipalities that fall into each scenario group are summarised in Table 8.

Table 8: Criteria for sub-dividing the top quartile of biome-level EbA priority local municipalities into implementation scenarios. The query for selecting a priority local municipality is EbA biome rank > = 75% percentile PLUS one of the additional scenarios that considers the additional variables of risk of ecosystems being lost, namely biodiversity importance and climate change vulnerability. High indicates that a value is in the top quartile for a variable. Environmental risk includes both the EI Risk variable developed here based on land cover change, as well as the local municipality Environmental Vulnerability variable from the CSIR Green Book (2019). The final column is the number of local municipalities (LM) selected for each scenario..

Scenario	Environmental risk	Biodiversity importance	Climate change vulnerability	No. LMs selected
0				16
1	High			16
2		High		8
3	High	High		10
4		High	High	2
5	High		High	1
6	High	High	High	1

Priority scenarios 3 – 6 are possibly the most urgent scenarios for implementation as they represent local municipalities with high potential for EbA action plus high combination of two or more of the additional variables. Fourteen local municipalities fall into these scenario groups (Table 9).

The presence of existing EbA projects was not considered in the results presented here. This data is however present in the analysis database (Annex C. Municipalities ranked based on EbA action potential and additional variables) and should be considered as an additional implementation context variable when refining the list of selected priority local municipalities for EbA action.

Table 9: The highest ranked EbA priority local municipalities based on high EbA potential and high combination of two or three implementation context variables.

Scenario	Local Municipality	District Municipality
6	Okhahlamba	Uthukela
5	Mthonjaneni	Uthungulu
4	Ndlambe	Cacadu
	Laingsburg	Central Karoo
3	Thulamela	Vhembe
	Greater Tubatse/Fetakgomo	Sekhukhune
	uMngeni	Umgungundlovu
	Dr Nkosazana Dlamini Zuma	Sisonke
	Elundini	Joe Gqabi
	Impendle	Umgungundlovu
	Kou-Kamma	Cacadu
	Lepele-Nkumpi	Capricorn
	Senqu	Joe Gqabi
	Matatiele	Alfred Nzo

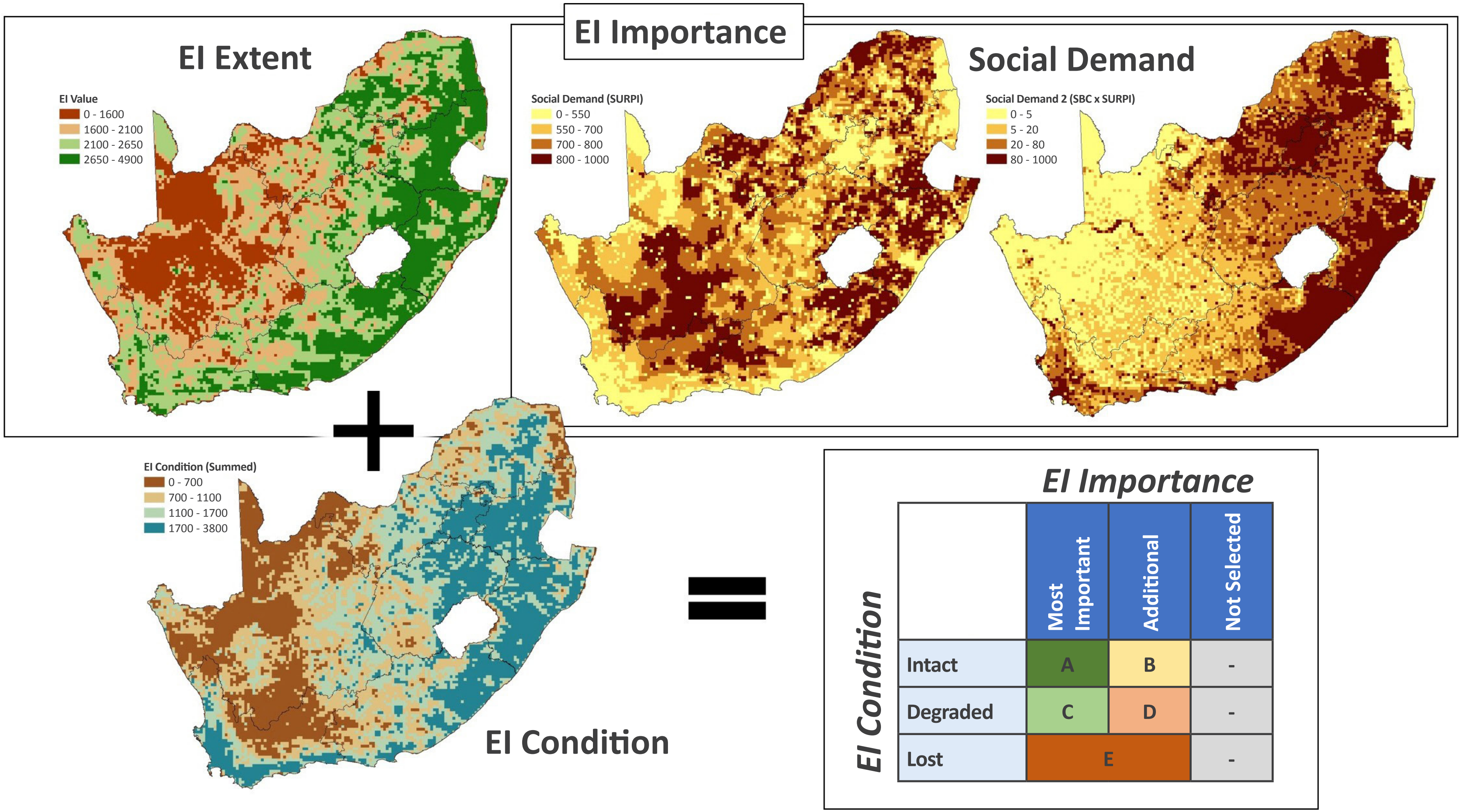


Figure 24: The final model outputs (EI importance, Social Demand and EI condition) and their integration to identify national-level and biome-level spatial priorities for the EbA action in terms of the four response categories (A, B, C and D). Two versions of social demand are considered (SURPI and population weighted SURPI). Figure 25 on the following page depicts the response matrix spatially.

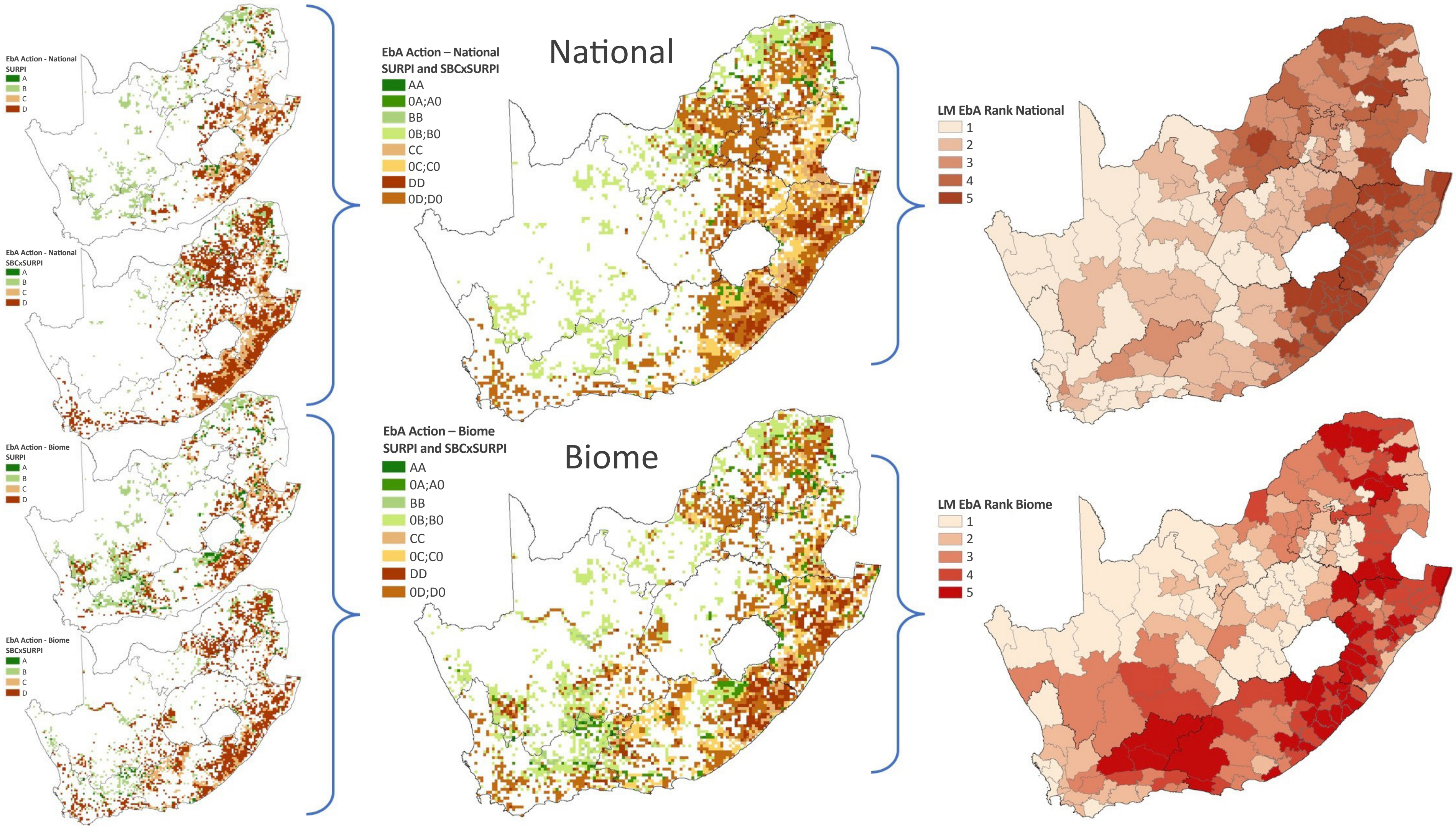


Figure 25: EbA priorities (response matrix categories) for the national-level and biome-level analyses, and for the two social demand models. On the right the EbA priorities are aggregated to the local municipality level to depict those local municipalities with the greatest EbA action potential. In Figure 26 on the following page the national and biome local municipality priority maps are integrated into a single map.

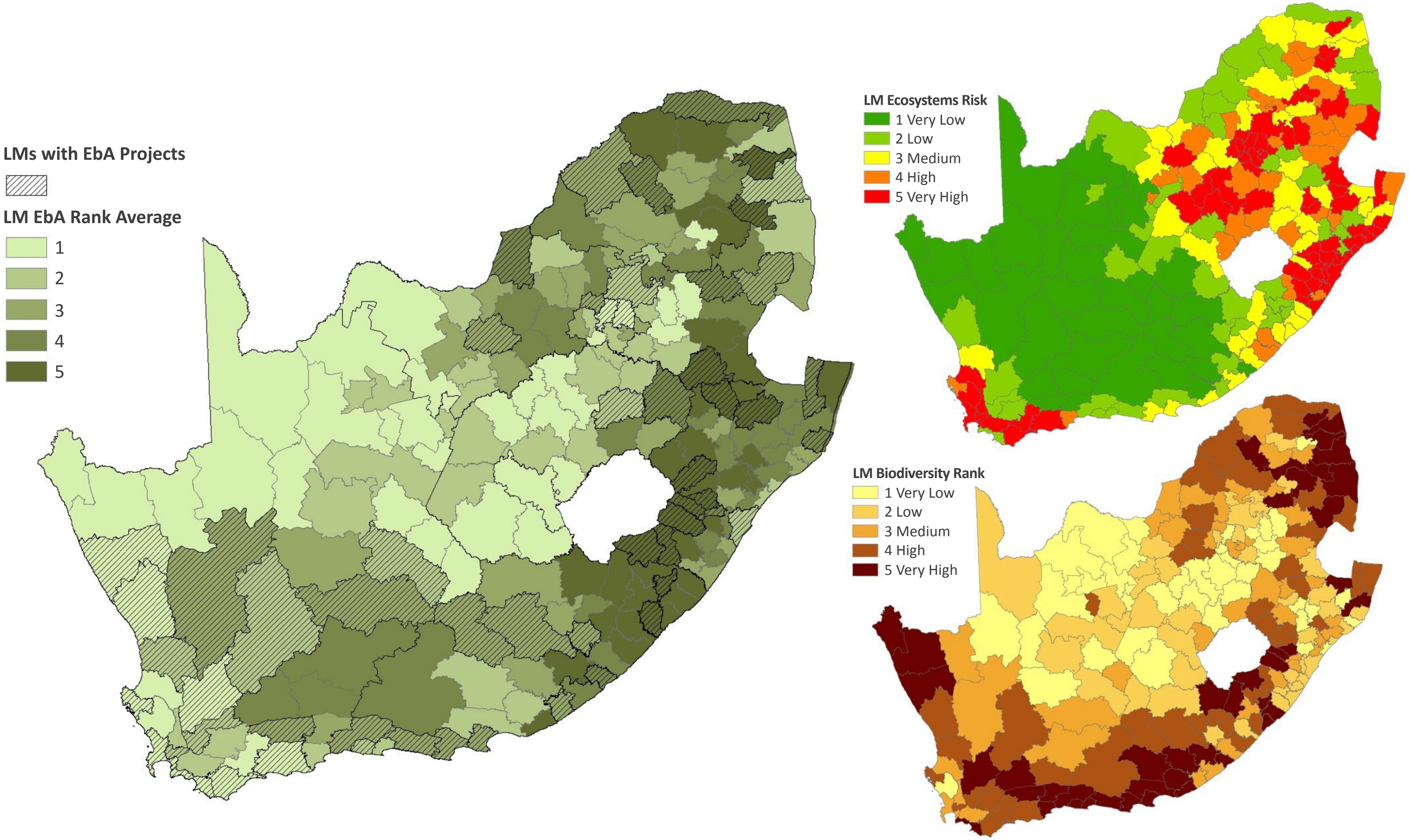


Figure 26: Combined national-level and biome-level EbA priority areas aggregated to the local municipality (left). Additional criteria that can be used to determine priorities are EI risk (top right) and biodiversity importance (bottom right). Analysis outputs for each municipality are summarised in Table 10.

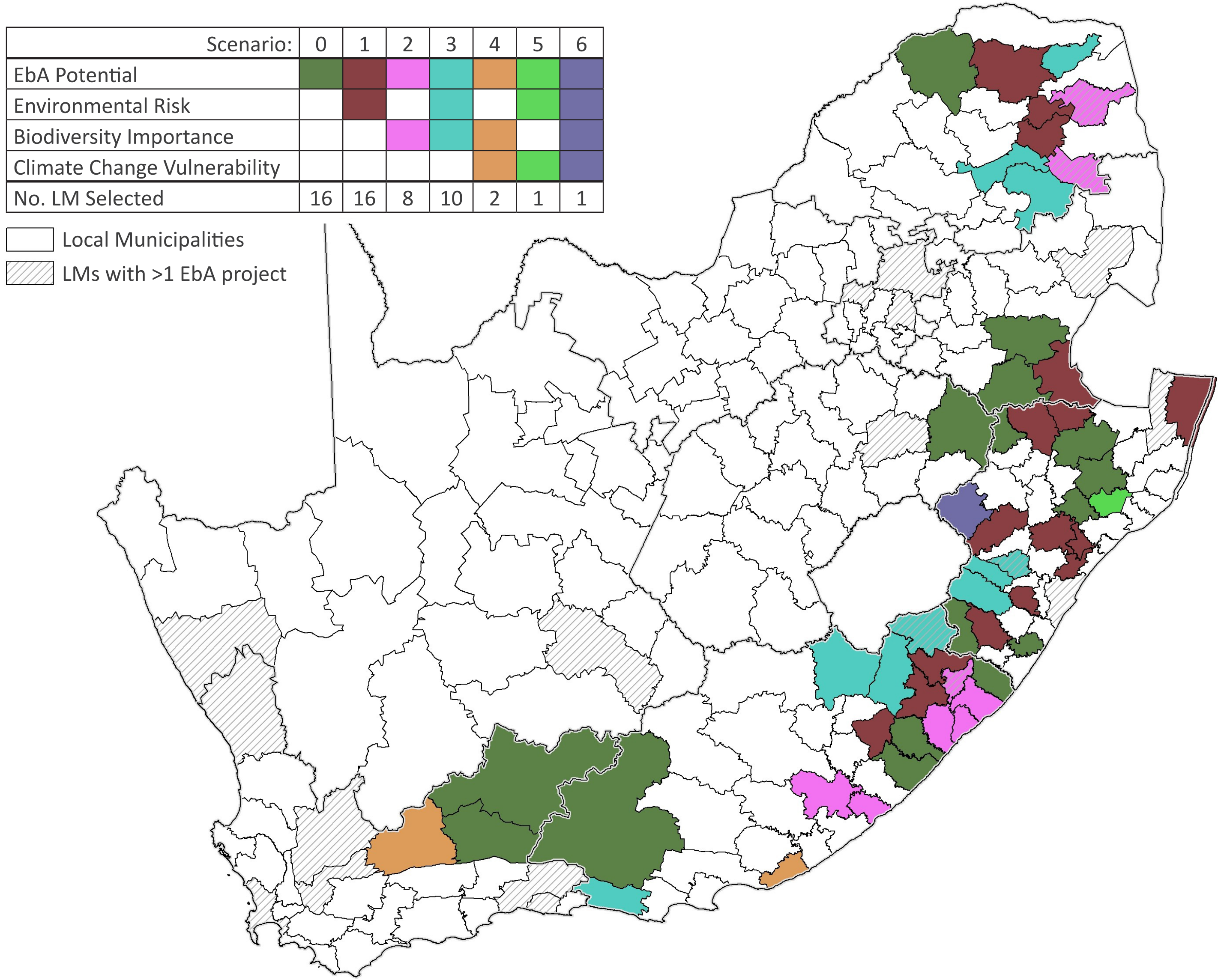


Figure 27: The final prioritisation of local municipalities based on the biome-level EbA score. The selected local municipalities represent the top quartile of EbA scores (i.e. local municipalities with high EbA potential). Local municipalities are classified into seven implementation scenarios based on high values (top quartile) for risk of ecosystems being lost to human development; biodiversity importance and vulnerability of ecosystems to climate change.

Table 10: The selected set of EbA priority local municipalities represented in Figure 27. The top quartile of biome-level EbA priorities is further subdivided into implementation priorities based on the additional variables of risk of ecosystems being lost; biodiversity importance; and, climate change risk (Average additional variable rank is the average of these ranks). The priority scenarios are described in Table 8.

Scenario	Province	LM code (CAT_B)	Local municipality	District municipality	EbA biome-level rank	Average additional variable rank
6	KwaZulu-Natal	KZN235	Okhahlamba	Uthukela	96	77
5	KwaZulu-Natal	KZN285	Mthonjaneni	Uthungulu	86	70
4	Eastern Cape	EC105	Ndlambe	Cacadu	95	55
	Western Cape	WC051	Laingsburg	Central Karoo	92	49
3	Limpopo	LIM343	Thulamela	Vhembe	77	77
	Limpopo	LIM476	Greater Tubatse/Fetakgomo	Sekhukhune	89	76
	KwaZulu-Natal	KZN222	uMngeni	Umgungundlovu	76	69
	KwaZulu-Natal	KZN436	Dr Nkosazana Dlamini Zuma	Sisonke	88	68
	Eastern Cape	EC141	Elundini	Joe Gqabi	94	66
	KwaZulu-Natal	KZN224	Impendle	Umgungundlovu	92	63
	Eastern Cape	EC109	Kou-Kamma	Cacadu	84	62
	Limpopo	LIM355	Lepele-Nkumpi	Capricorn	95	61
	Eastern Cape	EC142	Senqu	Joe Gqabi	96	57
	Eastern Cape	EC441	Matatiele	Alfred Nzo	75	55
2	Eastern Cape	EC154	Port St Johns	O.R.Tambo	100	57
	Limpopo	LIM335	Maruleng	Mopani	81	54
	Eastern Cape	EC153	Ngquza Hill	O.R.Tambo	91	47
	Eastern Cape	EC124	Amahlathi	Amathole	86	47
	Eastern Cape	EC123	Great Kei	Amathole	84	45
	Eastern Cape	EC444	Ntabankulu	Alfred Nzo	98	43
	Limpopo	LIM331	Greater Giyani	Mopani	93	43
	Eastern Cape	EC155	Nyandeni	O.R.Tambo	99	41
1	KwaZulu-Natal	KZN261	eDumbe	Zululand	94	77
	Mpumalanga	MP303	Mkhondo	Gert Sibande	99	69
	KwaZulu-Natal	KZN271	Umhlabuyalingana	Umkhanyakude	83	68
	KwaZulu-Natal	KZN253	Emadlangeni	Amajuba	88	66
	Limpopo	LIM333	Greater Tzaneen	Mopani	76	65

Scenario	Province	LM code (CAT_B)	Local municipality	District municipality	EbA biome-level rank	Average additional variable rank
1	KwaZulu-Natal	KZN237	Inkosi Langalibalele	Uthukela	87	64
	Eastern Cape	EC137	Engcobo	Chris Hani	82	58
	Eastern Cape	EC156	Mhlontlo	O.R.Tambo	79	57
	KwaZulu-Natal	KZN227	Richmond	Umgungundlovu	92	56
	KwaZulu-Natal	KZN435	Umzimkhulu	Sisonke	98	55
	KwaZulu-Natal	KZN245	Umvoti	Umzinyathi	82	54
	KwaZulu-Natal	KZN293	Ndwedwe	iLembe	78	54
	Limpopo	LIM344	Makhado	Vhembe	87	50
	KwaZulu-Natal	KZN294	Maphumulo	iLembe	84	50
	Eastern Cape	EC442	Umzimvubu	Alfred Nzo	97	48
	Limpopo	LIM332	Greater Letaba	Mopani	78	39
0	KwaZulu-Natal	KZN252	Newcastle	Amajuba	78	67
	KwaZulu-Natal	KZN263	Abaqulusi	Zululand	80	60
	Mpumalanga	MP302	Msukaligwa	Gert Sibande	75	51
	Eastern Cape	EC121	Mbhashe	Amathole	91	48
	KwaZulu-Natal	KZN433	Greater Kokstad	Sisonke	89	48
	KwaZulu-Natal	KZN266	Ulundi	Zululand	77	47
	KwaZulu-Natal	KZN286	Nkandla	Uthungulu	97	46
	Eastern Cape	EC157	King Sabata Dalindyebo	O.R.Tambo	84	46
	Eastern Cape	EC443	Mbizana	Alfred Nzo	80	46
	Eastern Cape	EC101	Dr Beyers Naude	Cacadu	82	43
	Free State	FS195	Phumelela	Thabo Mofutsanyane	81	43
	KwaZulu-Natal	KZN213	Umzumbe	Ugu	79	43
	Mpumalanga	MP304	Dr Pixley Ka Isaka Seme	Gert Sibande	83	39
	Western Cape	WC052	Prince Albert	Central Karoo	89	35
	Limpopo	LIM351	Blouberg	Capricorn	90	33
	Western Cape	WC053	Beaufort West	Central Karoo	92	18

- This project represents the first attempt in South Africa at mapping Ecosystem Infrastructure (EI) comprehensively at the national-level, and using this to determine national priorities for EbA implementation. South Africa is possibly the first country globally to have attempted this. This analysis has only been made possible by the extraordinarily rich source of national spatial datasets made available to this project and the funding made available through the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

- When interpreting this analysis, it is important to remember the purpose of Ecosystem-based Adaptation (EbA) and that priorities are driven by the relationship between EI extent, EI condition and social demand. This is not a biodiversity conservation prioritisation exercise, therefore there is no relationship implied, nor should there be, between priority areas identified here and biodiversity priorities identified by other spatial biodiversity planning tools. Arguably EbA can contribute to the conservation of biodiversity especially in areas with high EI importance, but as noted in Table 7 there are very few opportunities where high EbA potential overlaps with good condition EI. These few areas that are identified are ideal targets for synergies between EbA and biodiversity conservation.

- Biodiversity climate change adaptation: The primary mechanism whereby society can promote biodiversity adaptation to climate change is for government to implement and support the raft of policy and plans aimed at maintaining living landscapes, whereby biodiversity is able to persist in landscapes and adapt to climate change by utilising the network of ecological corridors. Whilst government does face implementation challenges, the development and periodic review of systematic plans that explicitly consider environment, society and economy are essential for supporting the achievement of this development vision. Initiatives like this EbA analysis present the opportunity to mainstream climate change resilience in a coherent and comprehensive manner into government planning and processes. Other key policy and systematic plans that support climate change adaptation include: Bioregional Plans that include CBA maps which designate areas for biodiversity retention and corridors for movement in production landscapes; protected areas and conservation areas that mandate areas for strict conservation; and, the National Protected Areas Expansion Strategy (NPAES) that lays the blueprint for the development of additional protected areas and conservation areas. These plans are all included in the *Biodiversity Resilience EI* model developed for this project. Therefore, implicit in identification of EbA priority areas is a consideration of biodiversity climate change adaptation. The Biodiversity Resilience EI map can be used in other assessments looking to include a map of areas important for biodiversity climate change adaptation.

- A large and rich source of spatial data has been generated by this project that can be used to identify and assess potential EbA projects from the national-level down to the local municipal-level and possibly even between cadastre-level. As the database currently stands (namely, individual maps or datasets) it is unlikely that the users of this information will be able to unlock the full value of the information available here. It would be beneficial to develop an interface or integrate into an existing online mapping portal (for example, the Environmental Geographical Information System (EGIS) [egis.environment.gov.za] or the Biodiversity Geographical Information System (BGIS) [bgis.sanbi.org]) whereby a user could query the datasets via a graphic user interface in order to identify potential EbA priority areas relevant to the user's spatial reference and EI focus.

- The EbA priorities identified here are relative to the national- or biome- scale of assessment. The resolution of the underlying EI models is such that EbA priorities can easily be re-assessed relative to the local-scale such as within a district municipality or local municipality to identify local-scale EbA priorities.

- Data challenges encountered here that could be addressed going forward include:
    - Mapping the EI-social demand relationship is possibly more a mapping conceptual issue rather than data issue but understanding the spatial parameters of these relationships is key to improving the understanding of EbA options in the landscape.
    - Estimating risk of EI being lost to human development is far more important than climate change vulnerability as this is a short-term risk and is most often associated with total loss of EI (e.g. ploughed field or urban development) whereas climate change risk is medium to long term and is a gradual rather than binary change. In this analysis, development risk was based solely on historic changes in land cover. It would be better to have a forward-looking estimate of risk and to that end the local municipality and district municipality Spatial Development Framework (SDF) maps present an excellent forward-looking land cover change perspective. Aggregating all 213 local municipality SDFs into a single wall-to-wall SDF map of South Africa would be an immensely valuable biodiversity spatial planning and assessment dataset.
    - Climate change impacts on environment and society are not considered in detail here, primarily due to the lack of suitable spatial data. What available data exists is not collated or easily accessible. Information repositories such as the South African Risk and Vulnerability Atlas (http://sarva2.dirisa.org) document a variety of climate change relevant data sources but there is no integration of information into a coherent climate change vulnerability map. The biome-shift model (Guo *et al.* 2017) used here integrates a diversity of climate variables into a single response map that is easily related to ecosystems. Attempting a similar approach with vegetation types or species (this is being widely implemented locally) at a fine resolution is the first step towards developing ecosystem vulnerability maps. Likewise integrating climate change predictions into climate change vulnerability maps for society is also required if we are to better integrate climate change into the social demand side of the EbA equation.

Table 11: Climate change adaptation options for biomes modified from DEA 2015a.

Biome	Category	Description	Ecosystem service
Albany Thicket	OPTIONS	Reduce stress from over-browsing of thickets	Natural resource management
		Switch to wildlife- and biodiversity-based land uses	New economy development
		Restore previously degraded areas	Restoration
		Improve irrigation efficiency	Water resource management
	SERVICES	Carbon storage	Carbon storage
		Irrigated horticulture	Irrigation agriculture
		Domestic small stock forage, especially angora goats and sheep	Rangeland
		Nature-based tourism, including hunting	Tourism
Desert and Nama Karoo	OPTIONS	Switch to ecotourism and wildlife management, using appropriately informed management, with sufficient advice and support	New economy development
		Restoration of degraded areas, preferably using a multiple benefits approach, with support for in situ conservation	Restoration
	SERVICES	Niche agriculture (e.g. organic, small-scale agriculture, incorporating an EbA approach, whether intended or not)	Irrigation agriculture
		Commercial and emerging agriculture large and small stock; range of species and production options	Rangeland
		Ecotourism, including a range of wildlife management options	Tourism
Forest	OPTIONS	Fire and alien plant management	Alien species management
		Fire and alien plant management	Fire management
		Spatial planning (often linked to the biomes in which forests are imbedded)	Land-use planning
		Remove stress from over-utilisation of forests	Natural resource management
		Restore forest margins and degraded forest areas, including the use of invasive alien species stands to allow for forest species recruitment	Restoration

Biome	Category	Description	Ecosystem service
Forest	SERVICES	Biodiversity	Biodiversity
		Carbon storage	Carbon storage
		Fuelwood and cultural values including traditional medicines	Fuelwood and medicinal plants
		Nature-based tourism	Tourism
Fynbos	OPTIONS	Partnerships between agricultural and conservation sectors to find more effective ways of managing landscapes for biodiversity and ecosystem services, including: controlling invasive alien species; public and private sector involvement in biodiversity conservation (partnerships, community-based conservation, citizen science, fire protection associations)	Alien species management
		Monitoring plant diversity and invasive species (in situ and satellite observations) to track whether ecosystems are responding as anticipated	Monitoring
		Maintaining effective land management on state land through water-supply based funding, especially for controlling invasive alien plant species and for managing fires; and support effective management of private land	Natural resource use management
		Implement the existing biome-wide and municipal conservation plans, including expanding existing reserve systems, and purchasing high biodiversity value land, especially in the lowlands	Protected area development
		In-situ management of biodiversity on private land through Biodiversity Stewardship Programmes	Biodiversity
	SERVICE	Biodiversity resources – endemic taxa offer unique gene pools, material for intellectual and scientific exploration, future options; diverse indigenous pollinators for crops	Biodiversity
		Soil stabilisation	Erosion control
		Medicinal plants	Medicinal plants
		Horticultural plants	Horticultural plants
		Nature-based tourism, non-consumptive use	Tourism
		Water flow and water quality regulation – sustained yield of high-quality water	Water provision
		Water flow and water quality regulation – sustained yield of high-quality water	Wildflowers

Biome	Category	Description	Ecosystem service
Grassland	OPTIONS	Alien plant management	Alien species management
		Fire management	Fire management
		Spatial planning to minimise fragmentation, to ensure strategic conservation and to conserve pathways	Land-use planning
		Protecting against overharvesting and over grazing	Natural resource use management
	SERVICES	Carbon storage – especially as soil carbon	Carbon storage
		Major area for crops, especially maize and forestry plantations	Dryland agriculture
		Irrigated horticulture	Irrigation agriculture
		Provision of medicinal plants	Medicinal plants
		Important for cattle (both beef and dairy) and sheep	Rangeland
		Major catchment areas for water provision	Water provision
Indian Ocean Coastal Belt	OPTIONS	Manage invasive alien plants	Alien species management
		Manage fire	Fire management
		Integrated spatial planning, including strategic conservation and protection of corridors. Reduce land transformation.	Land-use planning
		Switch to wildlife- and biodiversity-based land uses	New economy
		Restore previously degraded areas	Restoration (rangeland)
		Improve irrigation efficiency	Water-use management
	SERVICES	Carbon storage	Carbon storage
		Sugar cane and plantation forestry, both large-scale and as out growers	Dryland agriculture
		Sugar cane and plantation forestry, both large-scale and as out growers	Forestry
		Sugar cane and plantation forestry, both large-scale and as out growers	Irrigation agriculture
		Support for subsistence-based livelihoods, including fuelwood, medicinal plants, grazing and other natural products	Fuelwood

Biome	Category	Description	Ecosystem service
Indian Ocean Coastal Belt	SERVICES	Support for subsistence-based livelihoods, including fuelwood, medicinal plants, grazing and other natural products	Medicinal plants
		Support for subsistence-based livelihoods, including fuelwood, medicinal plants, grazing and other natural products	Rangeland
		Nature-based tourism	Tourism
Savanna	OPTIONS	Manage encroaching biomass (both indigenous and alien) for bioenergy generation/charcoal production	Biomass harvesting
		Switch to wildlife- and biodiversity-based land uses	New economy
		Identification of Critical Biodiversity Areas for expansion of protected area network	Protected area development
	SERVICES	Carbon storage	Carbon storage
		Fuel fire wood, timber, fencing posts	Fuelwood
		Livestock production, especially beef cattle farming	Rangeland
		Fuel fire wood, timber, fencing posts	Timber
		Nature-based tourism, including hunting	Tourism
		Water supply, some of South Africa's high yielding catchments occur in the savannah biome	Water provision
Succulent Karoo	OPTIONS	Ensure coordination between conservation and development projects and funding sources through the Succulent Karoo Ecosystem Programme (SKEP)	Capacity development
		Building of capacity within local government to manage both human and environmental issues	Capacity development
		Monitoring and evaluation of current initiatives and projects	Monitoring
		Mainstream biodiversity best practises into livestock grazing and ostrich farming	Natural resource management
		Implementation of integrated resource management plans aimed at ensuring the delivery of ecosystem services	Natural resource management
		Supporting emerging farmers through the development of economically viable Small Medium and Micro Enterprises (SMMEs)	New economy
		Restoration of previously degraded areas including mined areas	Restoration (rangeland)

Biome	Category	Description	Ecosystem service
Succulent Karoo	OPTIONS	Improved water-use efficiency and better coordination between water users	Water resource management
		Efficient water harvesting and water capture in aquifers	Water resource management
	SERVICES	Natural goods and services	Biodiversity
		Natural goods and services	Medicinal plants
		Grazing	Rangeland
		Game farming	Rangeland
		Tourism	Tourism
		Water	Water provision

Table 12: Summary of all model concepts developed for this project. Implemented models are described in detail in Annex D.

Thematic area	Ecosystem service 1	Ecosystem service 2	Model name (EI feature)	Model component	Input mapped features	Source dataset 1
Carbon Sequestration	Carbon stored in plants and soil	Soil carbon	Soil carbon natural vegetation	Extent		Humic soils (DEA 2019)
			New economy development	Condition		Humic soils (DEA 2019)
			Restoration	Condition		Humic soils (DEA 2019)
			Water resource management	Demand		None
Disaster Risk Reduction	Coastal ecosystems	Control of erosion and sedimentation				
		Sea level rise/ Coastal storm protection	Coastal protection	Extent	Elevation <5m smoothed	Japan Aerospace Exploration Agency (JAXA) Digital Elevation Model JDEM (JAXA 2015)
				Extent	Elevation <20m smoothed	JDEM
				Extent	Estuary functional zones	Integrated wetland layer
				Extent	Cross realm vegetation map features (excl. freshwater)	South African vegetation map
				Extent	Coastal Dune vegetation types	South African vegetation map
				Condition	Natural vegetation	Land cover
				Demand	Population density	ESKOM spot building count
				Demand	Distance to settlement	ESKOM spot building count
				Demand	Property value	Stats SA

Thematic area	Ecosystem service 1	Ecosystem service 2	Model name (EI feature)	Model component	Input mapped features	Source dataset 1
Disaster Risk Reduction	Biodiversity resilience	Areas supporting climate change resilience	Ecosystem resilience	Extent	Integrated CBA maps	Provincial CBA maps (11)
				Extent	National Protected Area Expansion Strategy (NPAES nodes	NPAES 2016 (DEA 2016)
				Extent	Climate change resilience areas	Climate change resilience (Stephen Holness)
				Extent	Important Bird Areas	Important Bird Areas
				Extent	Protected areas and conservation areas	SANBI National Biodiversity Assessment (protected areas and conservation areas) (SANBI 2019)
				Condition	Landscape connectivity: % of neighbourhood natural	Land cover (DEA 2019b)
				Demand		
				Demand		
		Critical habitats/ refugia	Critical habitats		See ecosystem resilience model	
		Landscape connectivity	Landscape fragmentation		Used as condition layer in ecosystem resilience model	
	Freshwater ecosystems	Flow regulation	Flow regulation	Extent	Wetlands and rivers	Integrated wetland layer
				Extent	Wetlands and rivers buffer 100m	Integrated wetland layer
				Extent	Natural vegetation	Land cover (DEA 2019b)
				Condition	Bare ground	Land cover (DEA 2019b)
				Condition	Bare ground	Agricultural Research Council (ARC) gullies (Mararakanye and Le Roux 2011))

Thematic area	Ecosystem service 1	Ecosystem service 2	Model name (EI feature)	Model component	Input mapped features	Source dataset 1
Disaster Risk Reduction	Freshwater ecosystems	Flow regulation	Flow regulation	Condition	Bare ground	South African vegetation index change dataset
				Demand	Population density	ESKOM spot building count
				Demand	Neighbourhood not-natural	Land cover (DEA 2019b)
				Demand	Flow accumulation	Japan Aerospace Exploration Agency (JAXA) Digital Elevation Model JDEM (JAXA 2015)
	Terrestrial ecosystems	Fire management	Fire risk	Extent	Natural vegetation	Land cover (DEA 2019b)
				Extent	Biomass	National Carbon Atlas
				Extent	Fire frequency	South African vegetation index change dataset
				Condition	Natural vegetation and plantations	Land cover (DEA 2019b)
				Condition	Alien density	Alien Survey 2010 (Kotze *et al.* 2010)
				Condition	Above ground biomass	National Carbon Atlas (DEA 2017)
				Demand	Density of plantations	Land cover (DEA 2019b)
				Demand	Distance to settlement	ESKOM spot building count
				Demand	Population density	ESKOM spot building count
		Landslide reduction	Landslide risk	Extent	Slope	JDEM (JAXA 2015)
				Condition	Not-natural land cover	Land cover (DEA 2019b)
				Demand	Population density	ESKOM spot building count
		Rangeland productivity	Rangeland		See Rangeland model below	

Thematic area	Ecosystem service 1	Ecosystem service 2	Model name (EI feature)	Model component	Input mapped features	Source dataset 1
Disaster Risk Reduction	Terrestrial ecosystems	Regulation of local climate	Natural vegetation: urban landscapes			
Food Security	Biodiversity	Control of pests and pathogens	Natural vegetation: agricultural landscapes			
		Pollination services	Crop pollination	Extent	Natural vegetation	Land cover (DEA 2019b)
				Extent	Distance (exponential decay) to orchard (all)	Land cover (DEA 2019b)
				Condition		
				Demand	Within cropland neighbourhood availability of natural habitat	Land cover (DEA 2019b)
		Species harvested commercial				
		Species harvested recreation				
		Species harvested subsistence				
	Crop agriculture	Dryland agriculture				
		Irrigation agriculture				
		Niche agriculture				
		Plantation forestry				
Food Security	Rangeland resilience	Forage production	**Rangeland**	**Extent**	Natural vegetation	Land cover (DEA 2019b)

Thematic area	Ecosystem service 1	Ecosystem service 2	Model name (EI feature)	Model component	Input mapped features	Source dataset 1
Food Security	Rangeland resilience	Forage production	**Rangeland**	**Extent**	Carrying capacity	South African vegetation index change dataset
				Extent	Grazing capacity	DAFF Long Term Grazing Capacity for South Africa 2018
				Extent	Slope	JDEM (JAXA 2015)
				Condition	NDVI trend	South Africa vegetation index change dataset
				Demand		
		Soil retention	Soil retention	Extent	Erosion potential	ARC erosion potential
				Extent	Natural vegetation	Land cover (DEA 2019b)
				Extent		
				Condition	Bare ground	Land cover (DEA 2019b)
				Condition	Bare ground	South African vegetation index change dataset
				Condition	Bare ground	ARC gullies (Mararakanye and Le Roux 2011)
				Demand	None (demand considered equal across the country)	
		Maintaining soil fertility				
Health and Wellbeing	Air quality	Amelioration of local air	Air quality	Extent	Natural vegetation	Land cover (DEA 2019b)
				Condition	Pollution extent	Sentinel5 NO_2 timeseries
				Demand	Population density	ESKOM spot building count

Thematic area	Ecosystem service 1	Ecosystem service 2	Model name (EI feature)	Model component	Input mapped features	Source dataset 1
Health and Wellbeing	Biodiversity	Biological control				
		Future genetic potential	Centres of endemism	Extent		
		Medicinal/muthi plants				
	Cultural and religious value	Amenity values				
		Existence and bequest values				
		Heritage				
		Nature/ndalo/ ithlathi	Nature	Extent	Thicket and forest vegetation types	South African vegetation map
				Condition	None	
				Demand	Distance to African settlement	ESKOM spot building count
				Demand	Presence of African settlement	
		Quality of life	Quality of life	Extent	Natural vegetation	Land cover (DEA 2019b)
				Condition	Neighbourhood not-natural	Land cover (DEA 2019b)
				Condition	Neighbourhood industrial/ mining weight	Land cover (DEA 2019b)
				Demand	Population density	ESKOM spot building count
				Demand	Natural vegetation	Land cover (DEA 2019b)
		Scientific and educational value				
		Sense of place	See tourism model			

Thematic area	Ecosystem service 1	Ecosystem service 2	Model name (EI feature)	Model component	Input mapped features	Source dataset 1
Health and Wellbeing	Cultural and religious value	Species used for culture				
Nature-based Economy	Nature-based tourism	Natural land/ seascapes	Nature tourism potential	Extent	Landscape attractiveness: unsightly infrastructure (mine and industry)	Land cover (DEA 2019b)
				Extent	Landscape attractiveness: views (topographic diversity index)	JDEM (JAXA 2915)
				Extent	Landscape attractiveness: wide-open spaces (uninterrupted plains)	JDEM (JAXA 2015)
				Extent	Landscape attractiveness: proximity to sea	Coastline
				Extent	Landscape attractiveness: neighbourhood % natural	Land cover (DEA 2019b)
				Extent	Proximity to existing protected areas (Distance2PA)	SANBI National Biodiversity Assessment protected areas and conservation areas (SANBI 2019)
				Condition	Naturalness: neighbourhood population density	ESKOM spot building count
				Condition	Naturalness: distance to population	ESKOM spot building count
				Condition	Naturalness: development density (settlement and industry [weighted])	Land cover (DEA (2019b)
				Demand	Tourism economy/demand/ density/use	

Thematic area	Ecosystem service 1	Ecosystem service 2	Model name (EI feature)	Model component	Input mapped features	Source dataset 1
Nature-based Economy	Non-tree products	Genetic resources	See ecosystem resilience model			
		Harvested renewable resources	See horticultural, thatch, wildflower, honey models			
		Horticultural				
		Thatch	Thatch	Extent	Agulhas Restio and Sourveld grassland vegetation types	South African vegetation map
				Condition		
				Demand		
		Wildflowers	Wildflowers	Extent	Agulhas and Overberg fynbos vegetation types	South African vegetation map
		Honey	Honey	Extent		
	Tree products	Fuelwood	Fuelwood	Extent	Savanna and bushveld vegetation types	South African vegetation map
				Extent	Extent/biomass of trees	
		Harvested renewable resources	See fuelwood and timber models			
		Timber	Timber	Extent	Broadleaf woodlands	South African vegetation map
				Extent	Forests	South African vegetation map
	Wildlife economy	Game production	See rangeland model			
		Genetic resources	See ecosystem resilience model			

Thematic area	Ecosystem service 1	Ecosystem service 2	Model name (EI feature)	Model component	Input mapped features	Source dataset 1
Nature-based Economy	Wildlife economy	Tourism and hunting	See tourism model			
Water Security	Water provision and regulation	Flow regulation	Flow regulation		See flow regulation (disaster risk reduction)	
		Water quality	All water EI	Extent	Wetlands ranked into EI relative value categories based on Kotze *et al*. (2009)	Wetlands_NBA_SAIIAE_ v2_20181106
				Extent	Strategic Water Source Areas (SWSAs) for surface water and groundwater	Strategic Water Source Areas (SWSAs) (Le Maitre *et al.* 2018)
				Extent	National Freshwater Ecosystem Priority Areas (NFEPA) rivers	NFEPA 2008 (Nel *et al.* 2011)
				Condition	Present Ecological State	Department of Water and Sanitation (DWS) River Quality Services (RQS) River Health Program dataset
				Condition	Not-natural areas	Land cover
				Condition	Plantations	Land cover (DEA 2019b)
				Condition	Settlement	Land cover (DEA 2019b)
				Condition	Mining	Land cover (DEA 2019b)
				Condition	Land cover (local and neighbourhood)	Land cover (DEA 2019b)
Water Security	Water provision and regulation	Water quality	Water quality	Condition	Inverse of soil retention model	
				Condition	Land cover (per catchment or within 1km distance of wetland)	

Thematic area	Ecosystem service 1	Ecosystem service 2	Model name (EI feature)	Model component	Input mapped features	Source dataset 1
Water Security	Water provision and regulation	Water quality	Water quality	Condition	Population density	
				Demand	Strategic Water Source Areas	SWSAs (Le Maitre *et al.* 2018)
		Water source	Water production	Extent	Natural vegetation	Land cover (DEA 2019b)
				Extent	Mean Annual Precipitation	SWSAs (Le Maitre *et al.* 2018)
				Extent	Strategic Water Source Areas	SWSAs (Le Maitre *et al.* 2018)
				Extent	Ground water areas	SWSAs (Le Maitre *et al.* 2018)
				Extent	Wetlands and rivers	Integrated wetland layer
				Extent	Wetlands and rivers buffer 100m	Integrated wetland layer
				Condition	Neighbourhood not natural	Land cover (DEA 2019b)
				Condition	Erosion and dongas	
				Demand	None, Mean Annual Precipitation defines demand	
Reporting Unit			Sub-quaternary catchments	Reporting	DWA sub-quaternary catchments	Department of Water Affairs (DWA) sub- quaternary catchments
			Biomes of South Africa	Reporting	Derived from Zonal Stats summary of dwellings per $50km^2$	
			Demographic landscapes	Reporting	Spot building count	ESKOM spot building count

Table 13: National- and biome-level EbA priority assessments aggregated to the level of local municipalities:

- Ecosystem-based Adaptation (EbA) national score and EbA biome score are the weighted sum of grid cell EbA responses (A, B, C, D or none) per local municipality adjusted for local municipality area (see weighting below). Risk score is the mean risk of ecosystem loss per local municipality. Risk rank is the percentile rank of these scores (1 = lowest risk, 100 = highest).
- *Biodiversity score* is the weighted sum of biodiversity resilience (Critical Biodiversity Area (CBA) map category equivalents) per local municipality adjusted for local municipality area.
- *Biodiversity rank* is the percentile rank of these scores (1 = lowest biodiversity, 100 = highest).
- *EbA projects* is a count of the number of projects recorded per local municipality (LM).
- *Climate change risk* is the percentage area of a local municipality where a biome is expected to change.
- *Climate change rank* is the percentile rank of these scores (1 = lowest biodiversity, 100 = highest).
- *SEV11* is the CSIR Green Book (2019) vulnerability of households living in the municipality index. *EVI11* is the economic vulnerability of the municipality.
- *PV* is the physical vulnerability, which addresses the physical fabric and connectedness of the settlements in the local municipality.
- *EV* is an indicator representing the conflict between preserving the natural environment and accommodating the growth pressures associated with population growth, urbanisation and economic development.
- *Average rank* is the average of the *Risk, Biodiversity, Climate Change* and *EV* ranks for local municipalities.
- Coloured cells indicate values in the top quartile (i.e. top 25% of values) for a variable.
- Local municipalities are sorted according to EbA biome score.

	Combined EbA action category Subsistence use resource and poverty index (SURPI) & population weighted SURPI using ESKOM'S spot building count (SBCxSURPI)	**Weight**
1	AA	10
2	0A or A0	5
3	BB	6
4	OB or B0	3
5	CC	6
6	0C or C0	3
7	DD	2
8	0D or D0	1
9	00	0

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
EC154	Port St Johns	O.R.Tambo	450	99	408	100	4.132	39	7.345	98	0	1	14	38	9.21	97	5.52	6.15	4.15	53	57	2
EC155	Nyandeni	O.R.Tambo	354	97	333	99	4.893	45	5.086	75	1	1	5	22	8.65	93	4.03	6.52	2.85	22	41	2
MP303	Mkhondo	Gert Sibande	376	98	335	99	20.94	96	3.408	37	0	1	37	60	6.46	73	9.4	5.51	5.83	82	69	1
EC444	Ntabankulu	Alfred Nzo	346	96	300	98	3.02	29	5.574	83	3		3	18	10	100	3	6.04	3.68	41	43	2
KZN435		Sisonke	428	98	292	98	11.26	74	3.851	48	0	1	2	14	7.95	87	4.34	6.58	6.12	84	55	1
EC442		Alfred Nzo	319	94	288	97	2.559	26	4.631	64	0	1	4	21	8.32	90	4.63	7.07	5.61	80	48	1
KZN286		Uthungulu	441	99	288	97	3.849	35	4.937	71	0	1	15	40	8.89	96	3.13	7.16	3.56	37	46	0
KZN235		Uthukela	330	95	286	96	7.57	58	5.246	77	0	1	71	83	7.89	86	3.33	5.74	6.49	88	77	6
EC142		Joe Gqabi	263	86	286	96	1.513	19	6.167	88	0	1	10	31	7.43	80	6.12	6.74	6.53	89	57	3
EC105		Cacadu	167	66	283	95	4.058	38	6.84	93	0	1	64	80	5.18	54	7.57	7.5	1.72	7	55	4
LIM355		Capricorn	270	88	278	95	5.589	50	6.166	88	0	1	9	29	5.04	52	8.78	5.87	5.33	78	61	3
EC141		Joe Gqabi	353	97	267	94	6.094	54	6.048	86	0	1	9	29	8.35	91	4.06	6.26	7.91	96	66	3
KZN261		Zululand	453	100	263	94	20.609	95	3.9	50	0	1	52	71	7.58	82	6.15	4.75	6.61	90	77	1
LIM331		Mopani	278	91	260	93	5.267	48	5.949	86	2		1	10	5.95	67	6.46	6.09	3.03	27	43	2
WC051		Central Karoo	107	50	257	92	0.023	2	6.078	87	0	1	58	75	2.56	16	2.96	4.73	3.26	30	49	4
KZN224		Umgungundlovu	278	91	250	92	4.45	42	7.836	99	1	1	1	10	7.6	83	4.38	4.83	9.44	99	63	3
KZN227		Umgungundlovu	307	93	257	92	16.904	91	3.62	42	0	1	26	47	6.79	75	4.47	5.18	3.7	42	56	1
WC053		Central Karoo	85	43	257	92	0.022	2	3.799	46	0	1	2	14	2.9	20	3.77	5.83	2	10	18	0
EC153		O.R.Tambo	350	96	246	91	4.574	43	6.18	89	0	1	10	31	8.85	95	3.48	7.61	2.9	24	47	2
EC121		Amathole	272	90	239	91	8.308	62	4.486	59	0	1	16	42	9.56	99	3.36	7.97	3.09	28	48	0
LIM351		Capricorn	257	85	234	90	4.142	40	4.189	54	0	1	0	0	5.93	66	5.35	6.63	3.64	39	33	0

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
LIM476	Greater Tubatse/ Fetakgomo	Sekhukhune	264	87	227	89	9.233	68	5.889	85	0	1	32	55	5.38	57	9.44	8.44	7.41	96	76	3
KZN433	Greater Kokstad	Sisonke	311	93	233	89	9.019	67	4.621	64	1	1	0	0	4.42	41	5.44	6.52	4.39	59	48	0
WC052	Prince Albert	Central Karoo	59	31	233	89	0.031	3	4.795	70	0	1	14	38	3.39	29	3.71	4.52	3.26	30	35	0
KZN436	Dr Nkosazana Dlamini Zuma	Sisonke	292	92	222	88	12.389	79	5.752	83	1	1	1	10	7.78	85	2.94	6.27	9.34	98	68	3
KZN253	Emadlangeni	Amajuba	303	92	225	88	5.84	52	4.675	66	1	1	37	60	7.8	86	4.02	3.87	6.12	84	66	1
KZN237	Inkosi Langalibalele	Uthukela	240	81	220	87	6.187	55	4.559	62	1	1	19	44	7.31	80	4.88	5.17	7.04	94	64	1
LIM344	Makhado	Vhembe	274	90	220	87	5.734	50	4.973	72	0	1	0	0	4.79	47	6.19	6.91	5.36	79	50	1
KZN285	Mthonjaneni	Uthungulu	188	72	206	86	13.231	82	3.695	44	0	1	66	81	8.26	89	5.09	6.25	5.1	74	70	5
EC124	Amahlathi	Amathole	234	81	217	86	2.327	25	6.614	91	0	1	13	36	7.24	79	4.5	4.88	3.41	34	47	2
EC109	Kou-Kamma	Cacadu	50	29	200	84	2.868	28	7.825	99	1	1	15	40	3.64	29	1.3	6.47	5.69	81	62	3
EC123	Great Kei	Amathole	183	71	200	84	0.929	16	7.208	96	1	1	26	47	7.56	82	4.54	5.27	2.83	21	45	2
KZN294	Maphumulo	iLembe	240	81	200	84	2.88	29	4.006	52	0	1	15	40	9.03	97	3.44	5.66	5.54	79	50	1
EC157	King Sabata Dalindyebo	O.R.Tambo	226	79	200	84	9.776	70	3.079	30	0	1	8	26	6.89	76	6.31	7.23	4.33	57	46	0
KZN271	Umhlabuyal-ingana	Umkhanyakude	254	84	198	83	8.965	66	4.734	68	0	1	21	46	8.69	94	4.88	10	6.98	93	68	1
MP304	Dr Pixley Ka Isaka Seme	Gert Sibande	224	79	198	83	2.775	27	4.644	64	1	1	2	14	5.74	62	8.17	5.49	4.06	51	39	0
EC137	Engcobo	Chris Hani	267	87	196	82	5.36	48	4.797	70	0	1	10	31	9.48	98	4.7	6.49	5.62	81	58	1

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
KZN245	Umvoti	Umzinyathi	270	88	196	82	17.459	92	3.259	34	0	1	14	38	7.65	84	4.56	6.43	3.97	50	54	1
EC101	Dr Beyers Naude	Cacadu	78	39	194	82	0.049	5	4.79	69	0	1	35	57	3.8	32	4.74	5.82	3.65	40	43	0
LIM335	Maruleng	Mopani	257	85	189	81	4.495	43	6.226	89	5		1	10	5.54	58	9.89	4.79	4.97	72	54	2
FS195	Phumelela	Thabo Mofutsanyane	180	70	191	81	5.085	46	4.375	57	1	1	3	18	6.05	69	8	6.06	4.11	52	43	0
KZN263	Abaqulusi	Zululand	337	95	188	80	11.056	73	3.511	39	1	1	72	84	6.43	72	5.25	4.77	3.77	44	60	0
EC443	Mbizana	Alfred Nzo	308	93	188	80	6.675	56	3.382	36	0	1	8	26	8.8	94	3.43	8.71	4.52	64	46	0
EC156	Mhlontlo	O.R.Tambo	267	87	187	79	3.932	36	4.485	59	0	1	20	45	8.67	93	3.91	6.31	6.49	88	57	1
KZN213	Umzumbe	Ugu	193	73	186	79	9.817	70	2.983	27	0	1	11	34	8.58	93	5.05	6.16	3.6	39	43	0
KZN293	Ndwedwe	iLembe	200	75	180	78	13.351	83	3.64	42	0	1	22	46	8.8	94	5.77	5.77	3.86	45	54	1
LIM332	Greater Letaba	Mopani	183	71	178	78	11.972	77	2.456	18	0	1	1	10	5.78	64	7.06	5.6	3.96	49	39	1
KZN252	Newcastle	Amajuba	240	81	180	78	10.69	72	4.202	55	0	1	72	84	4.94	50	7.06	4.76	4.34	57	67	0
LIM343	Thulamela	Vhembe	208	76	173	77	13.928	84	6.989	95	0	1	14	38	4.89	48	6.22	6.19	6.87	92	77	3
KZN266	Ulundi	Zululand	215	77	173	77	3.008	29	3.111	31	0	1	37	60	7.61	84	4.67	6.37	4.67	66	47	0
KZN222	uMngeni	Umgungundlovu	231	80	169	76	15.911	89	5.477	81	8		1	10	3.63	29	6.17	5.02	7.1	94	69	3
LIM333	Greater Tzaneen	Mopani	216	78	169	76	15.205	88	4.281	56	0	1	7	24	5.04	52	8.14	6.19	6.64	90	65	1
EC441	Matatiele	Alfred Nzo	261	86	161	75	3.373	33	6.436	91	2		4	21	8.02	88	3.55	7.17	5.27	76	55	3
MP302	Msukaligwa	Gert Sibande	271	89	163	75	8.846	64	4.073	53	0	1	2	14	4.26	39	6.31	4.88	4.96	71	51	0
MP321	Thaba Chweu	Ehlanzeni	207	76	157	74	12.497	79	4.717	67	0	1	36	58	3.18	24	5.43	6.3	6.54	89	73	
EC122	Mnquma	Amathole	220	78	160	74	6.806	56	4	51	0	1	13	36	8.01	88	4.13	6.64	2.89	23	42	
KZN238	Alfred Duma	Uthukela	245	84	153	73	5.205	47	3.693	44	0	1	66	81	6.34	71	5.59	7.33	4.99	72	61	

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
NC074	Kareeberg	Pixley ka Seme	45	25	155	73	0.01	1	1.217	2	0	1	42	64	3.76	31	4.53	6.83	1.19	1	17	
KZN276	Big Five Hlabisa	Umkhanyakude	174	68	151	72	4.168	40	6.691	92	0	1	49	69	7.99	87	4.12	6.74	7.19	95	74	
LIM367	Mogalakwena	Waterberg	184	71	152	72	3.932	36	5.406	80	1	1	6	23	4.65	45	7.57	5.93	3.89	47	47	
KZN223	Mpofana	Umgungundlovu	319	94	150	71	10.93	73	5.127	76	0	1	2	14	5.75	62	4.55	4.22	6.76	91	64	
KZN265	Nongoma	Zululand	164	65	145	71	4.493	43	0.82	1	0	1	32	55	8.56	92	2.56	6.74	2.75	20	30	
LIM341	Musina	Vhembe	169	66	143	71	1.775	21	5.158	76	1	1	12	35	4.73	46	7.19	6.27	6.83	91	56	
KZN434	Ubuhlebezwe	Sisonke	240	81	140	70	13.949	85	3.025	29	0	1	4	21	7.81	86	5.43	7.07	3.28	31	42	
MP315	Thembisile	Nkangala	133	56	142	70	5.147	46	3.166	33	0	1	10	31	5.45	57	5.04	4.55	2.67	18	32	
EC131	Inxuba Yethemba	Chris Hani	21	12	137	69	0.741	15	5.013	73	1	1	10	31	4.23	37	5.34	5.39	3.31	32	38	
WC041	Kannaland	Eden	35	19	135	68	0.233	9	6.135	87	1	1	45	66	2.9	20	1.24	4.66	4.72	67	57	
WC044	George	Eden	35	19	135	68	3.043	30	5.865	85	2		13	36	1.6	6	3.38	6.03	4.36	58	52	
KZN226	Mkhambathini	Umgungundlovu	144	60	133	67	14.059	85	3.174	33	0	1	67	82	9.38	98	4.68	4.35	3.17	29	57	
KZN225	The Msunduzi	Umgungundlovu	133	56	133	67	13.071	81	3.644	43	1	1	7	24	3.87	35	6.28	4.9	6.97	93	60	
NC071	Ubuntu	Pixley ka Seme	57	29	133	67	0.009	0	3.745	46	1	1	28	50	4.32	40	7.23	6.63	1.66	5	25	
LIM472	Elias Motsoaledi	Sekhukhune	171	67	132	66	5.388	49	5.525	82	0	1	19	44	5.63	60	4.73	5.61	3.49	35	53	
EC145	Walter Sisulu	Joe Gqabi	49	28	132	66	0.738	14	3.274	35	0	1	44	65	5.19	55	4.61	6.04	2.37	14	32	
BUF	Buffalo City	Buffalo City	150	62	130	65	4.598	44	3.806	47	0	1	53	72	4.52	43	7.52	6.62	3.32	32	49	
MP314	Emakhazeni	Nkangala	191	73	130	65	7.245	57	4.278	56	1	1	8	26	4.24	38	7.05	5.36	4.44	60	50	
MP301	Chief Albert Luthuli	Gert Sibande	215	77	128	64	9.674	69	4.532	60	0	1	26	47	5.94	67	7.01	5.88	5.27	76	63	

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
KZN272	Jozini	Umkhanyakude	178	69	127	63	11.706	75	4.556	61	2		15	40	8.47	91	4.66	8.22	4.76	68	61	
KZN262	uPhongolo	Zululand	173	68	127	63	5.758	51	5.855	84	0	1	27	49	7.43	80	6.13	5.96	2.68	18	51	
NW385	Ramotshere Moiloa	Ngaka Modiri Molema	140	58	127	63	2.645	26	3.893	49	1	1	6	23	5.75	62	6.86	6.74	5.57	79	44	
EC108	Kouga	Cacadu	125	55	125	63	5.476	49	6.876	94	1	1	61	77	3.2	25	3.92	6.03	3.64	39	65	
KZN284	uMlalazi	Uthungulu	195	74	124	62	14.542	86	3.863	48	0	1	32	55	8.04	89	5.64	7.14	4.53	65	64	
EC135	Intsika Yethu	Chris Hani	135	57	123	62	4.192	41	3.41	37	1	1	8	26	8.88	96	4.04	5.56	2.71	19	31	
EC138	Sakhisizwe	Chris Hani	221	79	121	61	3.601	34	4.845	71	0	1	3	18	7.51	81	7.25	6.42	3.1	29	38	
KZN254	Dannhauser	Amajuba	144	60	119	60	11.734	76	3.022	28	0	1	89	91	7.15	79	7.05	4.98	4.9	70	66	
NW374	Kgetlengrivier	Bojanala	137	57	120	60	3.268	31	4.54	60	0	1	29	52	4.45	42	8.46	6.57	3.71	43	47	
WC045	Oudtshoorn	Eden	31	17	120	60	0.862	16	5.983	86	0	1	28	50	2.68	18	2.63	4.57	5	73	56	
GT481	Mogale City	West Rand	142	59	117	59	10.802	72	3.914	50	2		51	71	2.28	13	5.67	5.84	7.03	93	72	
NW405	Ventersdorp/ Tlokwe	Dr Kenneth Kaunda	206	75	118	59	5.239	47	5.024	74	0	1	88	90	3.17	23	5.98	6	4.16	54	66	
KZN242	Nqutu	Umzinyathi	181	70	114	58	7.836	59	1.789	8	0	1	27	49	8.33	90	2.71	6.16	4.56	65	45	
NW372	Madibeng	Bojanala	159	63	114	58	6.334	55	4.188	54	0	1	1	10	3.73	31	8.04	8.17	4.85	69	47	
KZN214	uMuziwa-bantu	Ugu	144	60	111	57	19.307	94	3.055	30	0	1	1	10	7.7	85	3.45	5.79	5.86	82	54	
NC066	Karoo Hoogland	Namakwa	26	14	111	57	0.017	1	4.679	66	1	1	36	58	3.31	27	4.77	6.2	1.87	7	33	
EC139	Enoch Mgijima	Chris Hani	74	37	110	56	0.578	13	4.706	67	1	1	8	26	5.78	64	6.75	5.6	2.57	15	30	
LIM361	Thabazimbi	Waterberg	157	63	109	56	2.261	25	4.67	65	0	1	2	14	2.3	14	6.76	7.39	4.4	60	41	
NC065	Hantam	Namakwa	66	35	110	56	0.249	9	4.007	52	1	1	39	62	2.69	18	1.89	5.97	1.68	5	32	

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
KZN244	Msinga	Umzinyathi	243	83	104	55	3.046	30	2.009	11	0	1	20	45	9.94	99	3.65	7.36	4.48	62	37	
EC129	Raymond Mhlaba	Amathole	112	52	108	55	0.939	17	6.296	90	0	1	40	62	6.64	73	8.16	6.03	2.94	26	49	
LIM353	Molemole	Capricorn	121	54	103	54	9.162	67	3.293	35	0	1	0	0	5.01	51	7.47	6.67	3.82	44	37	
NC077	Siyathemba	Pixley ka Seme	6	6	103	54	0.298	10	2.618	20	0	1	52	71	3.69	30	4.25	6.69	1.46	3	26	
LIM354	Polokwane	Capricorn	122	54	102	53	8.896	65	3.651	43	0	1	1	10	3.19	24	6.8	7.22	6.17	86	51	
KZN221	uMshwathi	Umgungundlovu	161	64	100	52	26.263	98	2.477	19	0	1	36	58	6.92	77	4.83	5.32	4.81	69	61	
KZN281	Mfolozi	Uthungulu	133	56	100	52	36.268	99	1.698	7	0	1	62	78	6.89	76	4.68	5.4	3.66	41	56	
EC126	Ngqushwa	Amathole	143	59	100	52	1.177	18	3.891	49	1	1	40	62	6.71	75	5.92	5.17	2.22	13	36	
FS194	Maluti a Phofung	Thabo Mofutsanyane	162	64	98	51	4.198	41	5.297	78	0	1	0	0	5.58	59	7.45	4.88	4.26	55	44	
WC048	Knysna	Eden	42	23	92	50	3.311	32	6.885	94	2		58	75	1.92	8	5.66	5.93	8.13	97	75	
FS161	Letsemeng	Xhariep	6	6	93	50	3.908	36	1.66	5	0	1	71	83	4.89	48	5.05	5.45	3.74	43	42	
EC106	Sundays River Valley	Cacadu	45	25	93	50	2.655	27	6.872	93	0	1	86	88	5.07	53	1.56	6.28	2.78	21	57	
WC026	Langeberg	Cape Winelands	34	18	93	50	3.367	33	5.265	77	0	1	8	26	2.1	10	2.01	5.8	4.14	53	47	
WC047	Bitou	Eden	36	20	91	49	2.132	24	7.297	97	0	1	62	78	2.32	14	6.5	7.17	6.84	92	73	
NMA	Nelson Mandela Bay	Nelson Mandela Bay	95	47	90	47	5.734	50	7.52	98	1	1	86	88	3.3	27	6.7	3.92	4.67	66	76	
KZN212	Umdoni	Ugu	130	55	90	47	15.424	89	3.004	28	0	1	3	18	6.66	74	6.76	5.7	2.65	16	38	
LIM471	Ephraim Mogale	Sekhukhune	110	51	90	47	13.261	82	3.941	50	0	1	0	0	5.64	61	6.72	4.73	3.36	33	41	

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
LIM368	Modimolle/ Mookgoph-ong	Waterberg	144	60	90	47	6.941	57	5.067	75	0	1	3	18	3.8	32	2.52	6.09	4.56	65	54	
NC073	Emthanjeni	Pixley ka Seme	46	26	90	47	0.201	8	2.627	21	3		30	53	3.05	22	3.45	5.71	3.88	46	32	
KZN275	Mtubatuba	Umkhanyakude	184	71	89	46	18.403	93	3.395	36	1	1	54	73	7.05	78	3.59	5.62	5.6	80	71	
NW371	Moretele	Bojanala	100	48	87	46	5.961	53	2.809	25	0	1	0	0	5.48	58	6.39	6.24	3.56	37	29	
MP324	Nkomazi	Ehlanzeni	116	52	86	45	13.779	84	4.772	69	0	1	17	42	6.34	71	6.51	6.94	2.04	11	52	
MP326	Mbombela	Ehlanzeni	147	62	86	45	8.009	60	5.408	80	2		22	46	3.92	35	6	6.78	4.39	59	61	
EC136	Emalahleni	Chris Hani	109	51	85	44	2.005	22	4.989	73	0	1	17	42	8.47	91	6.27	5.54	2.93	25	41	
NC064	Kamiesberg	Namakwa	2	3	85	44	0.174	7	5.811	84	9		46	68	3.84	34	8.65	7.85	2.33	13	43	
NW373	Rustenburg	Bojanala	119	53	83	43	7.836	59	4.549	61	0	1	13	36	2.32	14	8.49	6.8	6.19	86	61	
FS192	Dihlabeng	Thabo Mofutsanyane	198	74	84	43	9.346	68	4.452	58	0	1	17	42	4.3	40	5.36	5.19	3.69	42	53	
GT484	Merafong City	West Rand	106	50	82	41	10.164	71	3.733	45	0	1	76	86	2.83	19	6.65	5.6	4.48	62	66	
NW383	Mafikeng	Ngaka Modiri Molema	176	69	82	41	4.791	45	3.66	43	0	1	67	82	4.55	44	7.84	5.81	4.02	50	55	
WC025	Breede Valley	Cape Winelands	39	21	82	41	3.11	31	4.657	65	3		17	42	1.81	8	3.43	5.4	5.11	74	53	
EC102	Blue Crane Route	Cacadu	37	21	80	41	0.509	12	5.422	81	0	1	45	66	4.9	49	4.47	5.36	1.9	8	42	
LIM362	Lephalale	Waterberg	99	48	82	41	2.064	23	4.565	62	1	1	0	0	3.03	21	9.18	7.1	3.44	35	30	
KZN282	uMhlathuze	Uthungulu	162	64	77	40	18.152	93	3.119	32	0	1	58	75	3.92	35	5.6	6.23	4.44	60	65	
NW392	Naledi	Dr Ruth Segomotsi Mompati	90	46	79	40	4.058	38	2.015	12	0	1	7	24	4.5	43	6.65	7.41	1.68	5	20	

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
GT423	Lesedi	Sedibeng	119	53	69	38	14.936	86	4.475	58	0	1	80	87	3.13	22	6.72	4.41	4.3	57	72	
NW403	City of Matlosana	Dr Kenneth Kaunda	226	79	69	38	5.589	50	4.595	63	0	1	97	97	3.35	28	8.48	5.06	3.14	29	60	
EC104	Makana	Cacadu	44	24	67	38	0.791	15	6.389	90	0	1	44	65	4.35	41	5.9	5.62	2.9	24	49	
NC078	Siyancuma	Pixley ka Seme	40	22	69	38	0.647	13	3.123	32	0	1	35	57	4.75	46	6.44	6.88	2.09	11	28	
WC012	Cederberg	West Coast	29	16	66	37	5.821	52	5.323	78	1	1	55	74	2.29	13	2.82	5.75	4.75	68	68	
KZN241	Endumeni	Umzinyathi	94	46	63	36	7.638	58	2.42	17	0	1	76	86	4.11	36	5.24	4.83	5.21	75	59	
FS181	Masilonyana	Lejweleputswa	79	40	63	36	3.98	37	2.894	25	0	1	100	99	5.82	66	8.73	5.33	2.55	14	44	
WC031	Theewaters-kloof	Overberg	48	27	61	36	13.222	81	4.405	57	0	1	2	14	2.83	19	3.34	5.56	6.23	86	60	
NW396	Lekwa-Teemane	Dr Ruth Segomotsi Mompati	89	45	61	36	3.8	35	2.756	23	0	1	3	18	4.76	47	7.58	6.21	2.37	14	23	
NW384	Ditsobotla	Ngaka Modiri Molema	255	85	58	33	8.359	63	3.58	40	0	1	95	95	5.35	56	5.14	6.45	3.92	47	61	
FS193	Nketoana	Thabo Mofutsanyane	89	45	60	33	12.489	79	1.665	6	3		32	55	5.66	61	6.67	5.69	4.27	56	49	
LIM345	New	Vhembe	60	32	60	33	4.579	44	7.103	96	0	1	5	22	6.11	69	7.14	6.52	4.05	51	53	
WC032	Overstrand	Overberg	30	17	60	33	1.621	20	6.637	92	1	1	55	74	1.54	5	4.07	6.39	5.3	78	66	
NC452	Ga-Segonyana	John Taolo Gaetsewe	70	36	60	33	0.738	14	1.994	10	0	1	0	0	4.6	44	6.82	6.58	2.72	19	11	
NC453	Gamagara	John Taolo Gaetsewe	72	37	60	33	1.869	21	2.378	17	0	1	0	0	1.45	4	4.82	6.84	3.7	42	20	
MP325	Bushbuck-ridge	Ehlanzeni	66	35	57	32	2.096	24	7.32	97	0	1	5	22	6.65	74	9.05	8.25	4.17	54	49	

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
LIM366	Bela-Bela	Waterberg	95	47	57	32	8.57	64	4.077	53	0	1	0	0	3.19	24	3.97	6.02	3.57	38	39	
KZN216	Ray Nkonyeni	Ugu	138	58	56	31	16.195	90	3.509	38	0	1	12	35	5.26	56	5.56	6	3.01	27	48	
NW375	Moses Kotane	Bojanala	87	44	56	31	3.311	32	3.61	41	0	1	2	14	4.49	42	8.18	7.92	4.38	58	36	
ETH	eThekwini	eThekwini	81	42	54	30	11.745	76	2.905	26	38		31	54	3.67	30	4.02	6.35	6.26	87	61	
WC022	Witzenberg	Cape Winelands	13	9	55	30	1.992	22	5.402	79	2		50	70	2.07	9	1.79	5.94	4.44	60	58	
WC043	Mossel Bay	Eden	42	23	53	29	8.2	61	5.485	82	0	1	48	68	1.26	3	2.82	5.4	6.1	84	74	
NW381	Ratlou	Ngaka Modiri Molema	80	41	53	29	6.119	54	2.561	19	0	1	10	31	7.58	82	7.34	6.13	2.12	12	29	
LIM334	Ba-Phalaborwa	Mopani	62	32	53	29	1.583	19	7.981	100	1	1	0	0	3.83	33	10	4.52	4.48	62	45	
TSH	City of Tshwane	City of Tshwane	80	41	52	28	13.716	83	3.561	39	2		36	58	1.07	1	2.52	4.48	6.13	85	66	
GT485	Rand West City	West Rand	83	43	50	25	15.983	90	2.958	27	0	1	91	92	3.22	26	9.32	5.94	6.05	83	73	
WC023	Drakenstein	Cape Winelands	81	42	50	25	14.238	86	4.336	57	0	1	33	57	1.24	2	3.25	4.43	7.26	95	74	
WC034	Swellendam	Overberg	21	12	50	25	12.255	78	4.742	68	0	1	50	70	1.71	7	1.02	5.57	5.09	73	72	
MP311	Victor Khanye	Nkangala	100	48	50	25	9.947	71	0.933	1	0	1	92	93	4.49	42	6.91	5.1	2.58	15	45	
WC024	Stellenbosch	Cape Winelands	75	38	50	25	12.713	80	5.365	79	1	1	8	26	1.77	7	3.91	5.17	9.21	97	71	
NW393	Mamusa	Dr Ruth Segomotsi Mompati	49	28	49	25	8.51	64	2.634	21	0	1	32	55	6.04	68	7.96	6.87	2.72	19	40	
FS182	Tokologo	Lejweleputswa	48	27	50	25	4.224	42	2.673	21	0	1	49	69	6.42	72	4.79	5.5	2.89	23	39	
NC075	Renosterberg	Pixley ka Seme	15	10	45	24	0.375	11	3.612	41	0	1	26	47	3.78	32	5.66	5.28	4.52	64	41	

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
FS205	Mafube	Fezile Dabi	74	37	41	23	8.141	61	1.614	5	0	1	75	86	5.6	59	5.78	6.71	4.92	70	56	
KZN291	Mandeni	iLembe	71	36	43	23	28.83	99	3.49	38	0	1	10	31	5.76	63	4.31	5.35	5.29	77	61	
NC094	Phokwane	Frances Baard	43	24	43	23	8.904	65	1.141	2	0	1	0	0	5.11	53	9.17	5.05	1.17	1	17	
WC013	Bergrivier	West Coast	27	15	40	22	17.563	93	3.725	45	0	1	45	66	1.23	2	1.3	4.33	4.48	62	67	
NC093	Magareng	Frances Baard	100	48	40	22	2.824	28	1.958	10	0	1	0	0	5.18	54	6.15	5.56	1.4	3	10	
WC042	Hessequa	Eden	15	10	39	21	11.769	77	4.975	72	1	1	74	85	1.6	6	2.96	5.28	5.12	75	77	
MP306	Dipaleseng	Gert Sibande	85	43	38	21	3.792	34	2.736	23	0	1	87	89	5	50	6.27	7.24	3.99	50	49	
KZN292	KwaDukuza	iLembe	63	33	38	21	40.909	100	1.572	4	0	1	7	24	4.65	45	7.03	4.14	2.61	16	36	
NC451	Joe Morolong	John Taolo Gaetsewe	40	22	36	20	0.079	6	2.06	13	0	1	28	50	7.12	79	9.37	7.57	1.69	6	19	
NC085	Tsantsabane	Z F Mgcawu	36	20	36	20	0.132	7	1.714	7	0	1	50	70	3.13	22	6.17	6.9	2.03	10	24	
GT422	Midvaal	Sedibeng	76	39	35	19	15.078	87	3.825	47	0	1	77	87	2.21	12	5.06	5.11	3.86	45	67	
MP305	Lekwa	Gert Sibande	79	40	35	19	4.011	38	2.018	12	0	1	43	64	3.83	33	7.65	5.83	2.76	21	34	
CPT	City of Cape Town	City of Cape Town	22	13	33	18	14.942	87	3.949	51	7		40	62	1.18	1	1.22	3.12	10	100	75	
MP316	Dr JS Moroka	Nkangala	108	50	33	18	7.834	59	2.782	24	0	1	0	0	5.78	64	5.18	4.93	2.98	26	27	
FS184	Matjhabeng	Lejweleputswa	49	28	32	17	12.207	78	2.146	14	0	1	100	99	4.23	37	9.87	5.26	3.92	47	60	
NW404	Maquassi Hills	Dr Kenneth Kaunda	162	64	32	17	8.412	63	3.309	36	0	1	93	94	5.63	60	7.02	5.15	3.29	31	56	
LIM473	Makhuduth-amaga	Sekhukhune	35	19	30	16	24.565	97	3.05	29	0	1	30	53	6.11	69	6.92	6.45	3.96	49	57	
FS204	Metsimaholo	Fezile Dabi	65	34	29	16	15.123	88	0.697	0	0	1	91	92	2.65	17	7.26	5.61	3.95	48	57	
FS203	Ngwathe	Fezile Dabi	64	34	27	15	8.215	62	1.759	7	0	1	97	97	4.97	50	7.83	5.7	3.38	33	50	
NC082	Kai !Garib	Z F Mgcawu	12	8	28	15	0.288	10	2.307	15	0	1	12	35	3.36	28	4.65	5.11	1.19	1	15	

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
EKU	Ekurhuleni	Ekurhuleni	58	31	26	14	24.09	96	3.099	31	2		95	95	1.94	9	4.46	2.62	9.74	99	80	
NW382	Tswaing	Ngaka Modiri Molema	172	67	26	14	12.747	80	2.801	24	1	1	97	97	6.29	71	6.45	7.01	2.85	22	56	
NC072	Umsobomvu	Pixley ka Seme	0	0	23	14	0.118	6	2.72	22	0	1	27	49	4.26	39	6.56	7.03	2.66	17	24	
MAN	Mangaung	Mangaung	45	25	20	12	6.063	53	3.026	29	0	1	99	98	3.23	26	5.08	5.46	4.23	55	59	
MP313	Steve Tshwete	Nkangala	57	29	19	12	10.162	71	2.087	13	0	1	62	78	1.69	7	5.21	4.58	4.96	71	58	
MP307	Govan Mbeki	Gert Sibande	70	36	20	12	3.939	37	2.435	18	0	1	62	78	2.55	15	7.04	5.97	4.48	62	49	
NW397	Kagisano/ Molopo	Dr Ruth Segomotsi Mompati	25	14	20	12	1.255	18	1.947	9	0	1	0	0	6.96	77	7.92	7.43	1.55	4	8	
FS196	Mantsopa	Thabo Mofutsanyane	57	29	17	10	7.229	57	3.568	40	0	1	90	92	5	50	4.3	5.54	3.88	46	59	
NC076	Thembelihle	Pixley ka Seme	4	4	17	10	1.011	17	1.792	8	0	1	59	77	4.17	36	5.56	7.01	1.91	8	28	
NC062	Nama Khoi	Namakwa	0	0	17	10	0.057	5	6.865	93	0	1	43	64	2.19	12	5.25	6.85	3.08	28	48	
FS163	Mohokare	Xhariep	26	14	16	9	1.589	20	2.723	22	0	1	65	80	5.81	65	5.96	6.11	2.89	23	36	
WC011	Matzikama	West Coast	4	4	16	9	1.882	21	5.014	74	3		72	84	2.17	11	4.26	7.19	1.91	8	47	
NW394	Greater Taung	Dr Ruth Segomotsi Mompati	16	11	16	9	0.708	14	2	11	0	1	0	0	7.01	78	8.52	7.43	1.92	9	9	
FS191	Setsoto	Thabo Mofutsanyane	79	40	15	8	9.529	69	2.373	16	0	1	92	93	5.77	64	7.04	6.42	3.39	34	53	
NC086	Kgatelopele	Z F Mgcawu	13	9	13	8	0.215	8	4.569	63	0	1	0	0	2.18	11	5.99	5.29	3.58	38	27	
FS201	Moqhaka	Fezile Dabi	62	32	12	7	11.265	74	2.247	15	0	1	96	96	4.18	37	7.16	4.68	3.51	36	55	
WC033	Cape Agulhas	Overberg	9	7	11	7	11.66	75	4.867	71	1	1	55	74	1.44	4	1	5.97	4.27	56	69	

LM Code (CAT_B)	Local municipality name	District municipality name	EbA national score	EbA national rank	EbA biome score	EbA biome rank	Risk score	Risk score	Biodiversity score	Biodiversity rank	EbA projects per LM	<2 EbA projects	Climate change risk	Climate change rank	SEV11	SEV11 rank	EVI11	PV	EV	EV rank	AVERAGE RANK	SCENARIO
NC084	!Kheis	Z F Mgcawu	3	3	12	7	0.043	4	1.42	4	0	1	29	52	5.19	55	5.78	7.57	1	0	15	
NC092	Dikgatlong	Frances Baard	5	5	10	6	0.485	11	3.256	34	0	1	0	0	5.44	57	7.98	6.99	3.53	36	20	
FS183	Tswelopele	Lejweleputswa	23	14	9	5	16.996	92	1.83	9	0	1	61	77	6.13	70	6.9	5.86	2.66	17	49	
FS162	Kopanong	Xhariep	5	5	9	5	0.52	12	2.373	16	0	1	82	88	4.79	47	5.27	5.82	2.11	12	32	
NC061	Richtersveld	Namakwa	0	0	9	5	0.164	7	7.047	95	0	1	43	64	2.09	10	5.73	8.18	4.96	71	59	
WC014	Saldanha Bay	West Coast	11	7	5	4	8.966	66	5.346	79	1	1	54	73	1	0	3.67	5.22	5.23	76	74	
WC015	Swartland	West Coast	22	13	8	4	18.851	94	2.116	14	0	1	29	52	1.45	4	2.32	5.15	4.1	52	53	
NC087	Dawid Kruiper	Z F Mgcawu	1	2	4	3	0.042	3	2.916	26	0	1	94	94	2.58	17	3.41	7.66	1.29	2	31	
NC091	Sol Plaatjie	Frances Baard	9	7	3	3	2.074	23	2.591	20	0	1	0	0	2.99	21	5.07	5.6	1.79	7	13	
GT421	Emfuleni	Sedibeng	18	11	0	0	20.434	95	1.671	6	0	1	99	98	2.82	19	7.96	4.2	5.95	83	71	
FS185	Nala	Lejweleputswa	12	8	0	0	24.995	97	1.262	3	0	1	88	90	6	68	6.06	5.28	3.52	36	57	
MP312	Emalahleni	Nkangala	33	18	0	0	16.765	91	1.231	3	0	1	96	96	2.55	15	6.09	5.13	6.36	87	69	
JHB	City of Johannesburg	City of Johannesburg	27	15	0	0	25.066	98	2.199	14	1	1	88	90	1.26	3	2.51	1	9.32	98	75	
NC067	Khâi-Ma	Namakwa	0	0	0	0	0.042	3	4.211	55	0	1	9	29	2.56	16	5.22	5.85	1.62	4	23	

Summary of the input parameters and protocols for each model developed.

Dataset Name:	**Water Ecological Infrastructure Extent**
Purpose:	Map indicating the extent and relative value of water-related ecological infrastructure (EI) in South Africa. The extent and relative value of water EI is based on the combination of: (1) Wetlands; (2) Wetlands and rivers buffered by 100m; (3) River Freshwater Ecosystem Priority Area (FEPA) buffers (1km); (4) Strategic Water Source Areas (SWSAs) for surface water and groundwater. All water EI features are ranked according to their relative EI value. This is a single integrated model for water EI rather than potentially separate models for water production, water quality and flow regulation. Each of these EI components would use the same input variables just with different weighting values. For the purposes of this analysis, a single Water EI model is adequate.
Supplemental Information:	

Input Datasets:

1. National Wetland Map (NWM) 5_20181105_v12_AEA
2. National_Wetland_Map_5_2
3. Wetland Probability Nacelle Collins
4. National Freshwater Ecosystem Priority Area (NFEPA) Rivers
5. Strategic Water Source Areas (SWSAs) for surface water and groundwater (Le Maitre *et al.* 2018)

Method:

1. Create an integrated wetland layer – convert all input layers to raster, snap to automated optical inspection (AOI) resolution and extent, and re-classify input feature classes to common wetland classification (rivers and wetlands class conversion 20181121.xls (see below) and merge all inputs into a single raster:

   NWM5_20181105_v12_AEA: Use class NWM52_L4A National_Wetland_Map_5_2: Use class CS_L4A Wetland Probability Nacelle Collins: Use class HGM

   NFEPA Rivers: Convert river lines to raster and reclass all rivers as 5

2. Include terrestrial areas supporting water EI. Select land surrounding wetland features that supply water to and support the wetland. Extent of land included dependent on the broader EI value of the system:

   SWSA include all catchment (Selected Q5 catchments that intersect) NFEPA rivers include 1km buffer

   All other wetlands/rivers include 100m buffer

3. Assign a relative EI value rank to all wetland, river and buffer classes. Ranking follows Kotze *et al.* (2009).

Final Class	Final Class Name	Final EI Rank
1	Valley bottom	8
2	Depression wetland	4
3	Estuary	9
4	Floodplain wetland	10
5	River	6
6	Seep wetland	7
7	Wetland flat	7
8	Artificial	2
	SWSA	1
	FEPA rivers 1km buffer	2
	Other rivers and wetlands 100m buffer	2

4. Combine all re-classified input layers into a single raster using a maximum value function to determine the pixel EI value.

Output: Water EI Relative Value.tif

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
Cell value	Cell value	8-bit integer	Water EI relative value Values range from 0 (= no value assigned) to 10 (= maximum EI value)	5

Dataset Name:	Water Ecological Infrastructure Extent
Purpose:	Map of relative water EI condition based on measured water condition values (Present Ecological State) and indicators of water condition (neighbourhood land cover attributes). Water EI condition inputs: (1) Sub-quaternary catchment Present Ecological State (PES 2013); and, relative extent of neighbourhood in the following land-use classes (2) non-natural; (3) plantation, (4) settlement and (5) mining.

Supplemental Information:

Input Datasets:

1. Department of Water and Sanitation (DWS) RQS SQ4hash Present Ecological Status (PES) 2013 category
2. SANBI NBA land cover

Method:

1. Calculate focal and neighbourhood statistics for land cover categories and scale values 0 – 100:

   Mining radius = distance weighted (Euclidean distance to) neighbourhood extent (focal stat) value where: Distance window = 10 x 10 km (at mine = 100, 10 km from mine = 1); and,

   Neighbourhood extent = sum mine area in 5 km radius (Cell radius = 50 cells)

   For settlement, plantation and not-natural only a neighbourhood extent (focal stat) value: Settlement radius = 13

   Plantation radius = 57 (114 x 114)

   Not-natural radius = 6 (12 x 12)

2. Scale inputs (0–70 for PES [PES values only have a 7-point scale] and 0–100 for neighbourhood stats) and add to give a composite quantitative relative water EI condition using the following weighted sum equation:

   'PES2013' + 'Not natural extent' + 'Plantation extent' + 'Settlement extent' + 2* 'Mining extent' Min value = 0 = very good condition

   Max value = 570 = very bad condition (this is because PES values only have a 7-point scale)

   Assign a relative EI value rank to all wetland, river and buffer classes. Ranking follows Kotze *et al.* (2009).

Notes:

SQ4_ALBERS PES 2013 catchments with PES = Z (i.e. unclassified) were ELIMINATED based on neighbours with greatest shared border length. Output SQ4_ALBERS PES 2013_filled

Output: Water EI Relative Value.tif

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
Cell value	Cell value	16-bit integer	Water EI condition Actual values range from 0 (= very good condition) to 477 (= very bad condition).	50

Identification

Dataset Name:	**Nature-based Tourism Ecological Infrastructure Extent**
Purpose:	Map of Nature-based Tourism ecological infrastructure extent based on landscape tourism potential as a proxy. Tourism potential based on positive tourism attractors (naturalness, proximity to interesting tourism features [protected areas, seaside and dams], and accessibility to the resource) and negative detractors (densely populated and industrial landscapes); agrarian landscapes are considered neutral in this model (e.g. fields and plantations have no influence here). Tourism attractors and detractors are combined to calculate overall tourism potential using a weighted averaging model. Low to high tourism potential is quantified on a scale from 0 to 100. No map of Nature-based Tourism EI condition is produced as the factors that influence the condition of this EI, namely land non-natural landscapes, are included in the EI extent model.

Supplemental Information:

	Mapped features	Input data	Processing steps	Model weighting
Tourism attractors:				
	Topographic diversity		**Bicubic resampling of 270m Advanced Land Observation Satellite**	
Views	Index	Japan Aerospace Exploration Agency Digital Elevation Model JDEM 30m <- Advanced Land Observation Satellite (ALOS) Topographic Depression Identification (TDI)	(ALOS) Topographic Index (TPI) to 100m. Median TPI in 5km circular neighbourhood of 5km radius. Scale from 0 to 100. Euclidean distance to nearest protected area pixel. Cut-off threshold of 100km beyond which no influence. Scale from 0 to 100.	2
Protected areas	Distance to protected area			3
		SANBI Protected areas and conservation areas		
Water bodies	Distance to waterbodies > 25ha in size (including coastline)	Land cover	Isolate all permanent water landcover. Define connected pixels in circular kernel of 500m radius (ca. 25ha). Euclidean distance from selected water objects. Cut-off threshold of 100 km for sea, and 50 km for dams beyond which no influence. Scale from 0 to 100.	1
Natural vegetation	Neighbourhood % natural	Land cover	Isolate natural vegetation pixels from landcover - those covered by Indigenous Forest (4), Thicket (5), Woodland (6), Grassland (7), or Shrubland (9), Bare non vegetated (41). Calculate the percentage of circular neighbourhood (10km radius) covered by natural vegetation. Scale from 0 to 100.	1
Access	Travel time to cities	Accessibility (https://www.nature.com/articles/nature25181)	Bicubic resampling to 100m. Scale from 0 to 100.	

	Mapped features	Input data	Processing steps	Model weighting
Tourism attractors:				
Population density	Neighbourhood population density	ESKOM spot building count	Sum of buildings in a 5km radius neighbourhood using circular kernel. Scale from 0 to 100. [for '_clamped' raster I clamped the pixel values to 5th and 100th percentile and then rescaled from 0 to 100]	2
Roads	Distance to roads	Roads	Rasterise all roads. Euclidean distance to nearest road pixel as well as density of road pixels in 10km radius circular neighbourhood. Re-projected to automated optical inspection (AOI). Cut-off threshold of 10km beyond which no influence. Weight distance to road by road density and scale from 0 to 100. Log transform and then rescale from 0 to 100.	1
Industry	Distance to mines/ urban industrial	Land cover	Isolate land cover pixels of Urban industrial (43), Mine buildings (39), Mine bare (35, 36), Mine water (37, 38). Euclidean distance from nearest industrial pixel as well as density of industrial pixels in circular neighbourhood of 25km radius. Cut-off threshold of 100km beyond which no influence. Weight distance to industry by density of industry and scale from 0 to 100. [for '_clamped' raster I clamped the pixel values to 5th and 100th percentile and then rescaled to 0–100]	5

Output: tourm_INT.tif

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
Cell value	Cell value	16-bit integer	Nature-based Tourism potential Values range from 0 (= low potential) to 100 (= high potential).	50

Dataset Name:	Rangeland Ecological Infrastructure Condition
Purpose:	Rangeland ecological infrastructure extent is a measure of the current relative value of natural rangelands in South Africa available for livestock grazing. The extent is derived from natural land cover classes in the national land cover. The relative value of areas is based on the estimated livestock carrying capacity modified by the slope (livestock accessibility) of an area.

Supplemental Information:

Input datasets used in the model:

1. SANBI NBA 2018 Land cover LC14L1 – modified natural (used as mask)
2. DAFF Long Term Grazing Capacity for South Africa 2018 (ha/large stock unit [LSU], grazing capacity 10102016)
3. Japan Aerospace Exploration Agency (JAXA) Digital Elevation Model (DEM) April 2018 (slope)

Method:

1. Convert grazing capacity shape file (shp) to raster (100m, snap to automated optical inspection (AOI)).
2. From digital elevation model (DEM) generate slope and reclass the slope into the following classes:
   a. <= 10 = 1 (i.e. carrying capacity unchanged)
   b. 10 – 20 = 0.5 (carrying capacity reduced by 50%)
   c. 20 – 40 = 0.25 (carrying capacity reduced by 75%)
   d. > 40 = 0 (carrying capacity = 0, slope too steep to support livestock)
3. Adjust grazing capacity to take into account slope (grazing capacity x slope).
4. Mask out not-natural areas (If land cover = not natural, 0, else grazing capacity).
5. Convert grazing capacity ha per large stock unit (LSU) to LSU per ha value.

Output: g_v2_lsuperha

Value: above grid inverted top produce LSU per ha to allow one to sum cells for an area to determine the number of LSU recommended for an area.

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
Cell value	Cell value	32-bit floating point	Large Stock Unit (LSU) per hectare	0.090909

Dataset Name:	Rangeland Ecological Infrastructure Condition
Purpose:	Represent the current condition of rangeland ecological infrastructure in South Africa using change in net primary productivity (Normalised Difference Vegetation Index [NDVI]) as a proxy for rangeland condition The rangeland condition model is based on an analysis of rangeland primary productivity (NDVI) trend over the past 33 years (Venter *et al.* in prep.). It is currently the best indicator of rangeland condition available for South Africa. Note that NDVI trend only captures how primary production has changed over time and so captures both overgrazing (loss of net primary productivity) and bush encroachment (increases in net primary productivity). This is only one dimension of degradation. This degradation map does not explicitly capture or represent other forms of degradation such as change in species composition. Also, this layer does not separate change in NDVI due to land use versus climate change. Note that the NDVI trend analysis is a BETA product and updates will be available from the authors.

Supplemental Information:

Input Datasets:

1. SANBI NBA 2018 Land cover LC14L1 – modified natural (used as mask)
2. NDVI trend 1984 to 2018 (ndvi_trend_raw_100m)

Method:

1. Convert NDVI trend to % change over time period (annual rate * 33).
2. Mask out not-natural areas (If land cover = not natural, 0, else grazing capacity).

Output: g_cond2

Value: Percentage (%) change in baseline NDVI from 1984 to 2018

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
Cell value	Cell value	16-bit integer	Percentage (%) change in baseline NDVI from 1984 to 2018 Values range from -330 to +330. Values greater than or less than 100 indicate 100% change in underlying land cover class not reflected in the land cover mask. These can be considered as NoData areas.	10

Dataset Name:	Biodiversity Resilience Ecological Infrastructure Extent
Purpose:	Map of biodiversity resilience ecological infrastructure (EI) extent. Biodiversity Resilience EI is interpreted as being the sum of areas identified as being important for biodiversity through various spatial biodiversity plans that have been conducted in South Africa. These include: (1) protected areas and conservation areas database, (2) Critical Biodiversity Area (CBA) maps, (3) Strategic Water Source Areas (SWSAs) for surface water and groundwater, (4) Important Bird Areas, (5) National Biodiversity Assessment 2011 climate change resilience areas, and (6) National Protected Areas Expansion Strategy 2016 focus areas. This is also a map depicting areas important for biodiversity climate change adaptation. Implicit in the development of all the informants of this map is the identification of areas required for biodiversity climate change adaptation.

Supplemental Information:

Input datasets:

Dataset Name	Year	File Name
Eastern Cape CBA Map	2018	EC_MARXAN_draft4_CBA_ESA
Free State CBA Map	2016	PUs_FINAL_for_distribution
Gauteng CBA Map	2011	CPlanV33_1110_ge
KwaZulu-Natal CBA Map	2014	Draft_whs_udp_rsa_buffer_20160505_v3_wdd
KwaZulu-Natal CBA Map	2014	KZN_CBA_Irreplaceable_wll_01022016
KwaZulu-Natal CBA Map	2014	KZN_CBA_Optimal_wll_03032016
KwaZulu-Natal CBA Map	2014	KZN_ESA_Species_wll_01022016
KwaZulu-Natal CBA Map	2014	KZN_ESA_wll_01022016
Limpopo CBA Map	2017	LCPv2_CBA_Layer_VHEMBE
Limpopo CBA Map	2016	Mopani CBA Map v3
Limpopo CBA Map	2018	Sekhu_Capri_CBA_Map2018_poly_U35s
Limpopo CBA Map	2015	Waterberg_Terrestrial_CBA_2015_FINAL_u35s
Mpumalanga CBA Map	2014	Mpumalanga Biodiversity Sector Plan (MBSP)_terrestrial.shp
Northern Cape CBA Map	2016	Northern_Cape_CBA_Map
North West CBA Map	2015	NWBSP2015_Terrestrial_CBA_v1_u35s
Western Cape CBA Map	2016	WCape_CBA_Map_vBeta
Important Bird Areas	2015	IBA Shapefile September 2015

Dataset Name	Year	File Name
Climate Change Resilience Areas	2011	eba_30m0
National Protected Area Expansion Strategy (NPAES) focus areas	2016	npaes_focus_areas_completetable
Strategic Water Source Areas (SWSAs) for surface water and groundwater	2016	swsa_poly_kern_014_gwsa_v2
Protected Areas	2018	NBA2018_PA_working
Conservation Areas	2018	SACAD_OR_2018_Q2

Method:

1. Re-classify all inputs to a common numerical scale based on CBA map categories. Where inputs did not define CBA map categories these were assigned using the look-up table below.
2. Convert re-classified inputs to raster.
3. Combine inputs using a max value function (i.e. cell value is assigned based on the maximum of the input values).

Output: RESIL_MAX1ha.tif

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
Value	Value	8-bit integer	Biodiversity Resilience EI extent Values range: 0: No classification 1: ESA2 2: ESA1 3: CBA2 4: CBA1 5: CA 6: PA	1

Input data look-up table:

Proj. No.	Proj. Acronym	Year	Relevant .shp file or grid	Field Name	Type of Data	Category 1	Category 2	New Category
1	NBA_EBA	2011	eba_30m0	Value	Quantitative	0 to 2		0
1	NBA_EBA	2011	eba_30m0	Value	Quantitative	3 and 4		10
1	NBA_EBA	2011	eba_30m0	Value	Quantitative	5 to 10		100
2	NPAES_2016	2016	npaes_focus_areas_complete table		Single Value			100
3	NC_CBA16	2016	Northern_Cape_CBA_Map	CBA_Cat	Categories	Critical Biodiversity Area One		1000
3	NC_CBA16	2016	Northern_Cape_CBA_Map	CBA_Cat	Categories	Critical Biodiversity Area Two		100
3	NC_CBA16	2016	Northern_Cape_CBA_Map	CBA_Cat	Categories	Ecological Support Area		10
3	NC_CBA16	2016	Northern_Cape_CBA_Map	CBA_Cat	Categories	Other Natural Areas		0
3	NC_CBA16	2016	Northern_Cape_CBA_Map	CBA_Cat	Categories	Protected Area		0
4	KZN_CBA14	2014	KZN_CBA_Irreplaceable_wll_01022016	LEGEND	Categories	CBA: Irreplaceable		1000
4	KZN_CBA14	2014	KZN_CBA_Optimal_wll_03032016	LEGEND	Categories	CBA:Optimal		100
4	KZN_CBA14	2014	KZN_ESA_wll_01022016	LEGEND	Categories	ESA		10
4	KZN_CBA14	2014	KZN_ESA_Species_wll_01022016	LEGEND	Categories	ESA Species Specific		10
4	KZN_CBA14	2014	Draft_whs_udp_rsa_buffer_20160505_ v3_wdd	Descrip	Categories	Legend 1		100
4	KZN_CBA14	2014	Draft_whs_udp_rsa_buffer_20160505_ v3_wdd	Descrip	Categories	Legend 2		100
5	WC_CBA16	2016	WCape_CBA_Map_vBeta	Quick_Ref	Categories	PA		0
5	WC_CBA16	2016	WCape_CBA_Map_vBeta	Quick_Ref	Categories	CBA1		1000
5	WC_CBA16	2016	WCape_CBA_Map_vBeta	Quick_Ref	Categories	CBA2		100
5	WC_CBA16	2016	WCape_CBA_Map_vBeta	Quick_Ref	Categories	ESA1		10
5	WC_CBA16	2016	WCape_CBA_Map_vBeta	Quick_Ref	Categories	ESA2		1
5	WC_CBA16	2016	WCape_CBA_Map_vBeta	Quick_Ref	Categories	ESA2b		1
5	WC_CBA16	2016	WCape_CBA_Map_vBeta	Quick_Ref	Categories	ESA2c		1
5	WC_CBA16	2016	WCape_CBA_Map_vBeta	Quick_Ref	Categories	ONA		0
6	FS_CBA16	2016	PUs_FINAL_for_distribution	FINAL	Categories	Protected		0

Proj. No.	Proj. Acronym	Year	Relevant .shp file or grid	Field Name	Type of Data	Category 1	Category 2	New Category
6	FS_CBA16	2016	PUs_FINAL_for_distribution	FINAL	Categories	CBA1		1000
6	FS_CBA16	2016	PUs_FINAL_for_distribution	FINAL	Categories	CBA2		100
6	FS_CBA16	2016	PUs_FINAL_for_distribution	FINAL	Categories	ESA1		10
6	FS_CBA16	2016	PUs_FINAL_for_distribution	FINAL	Categories	ESA2		1
6	FS_CBA16	2016	PUs_FINAL_for_distribution	FINAL	Categories	Other		0
6	FS_CBA16	2016	PUs_FINAL_for_distribution	FINAL	Categories	Degraded		0
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Critical Biodiversity Area	CBA Irreplaceable	1000
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Critical Biodiversity Area	CBA Optimal	100
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Ecological Support Area	ESA Landscape corridor	10
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Ecological Support Area	ESA Local corridor	10
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Ecological Support Area	ESA Protected Area buffer	10
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Ecological Support Area	ESA Species Specific	10
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Heavily or moderately modified	Heavily modified	0
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Heavily or moderately modified	Moderately modified- Old lands	0
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Other Natural Areas	Other natural areas	0
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Protected areas	Protected area: National Parks & Nature Reserves	0
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Protected areas	Protected area: Pro-tected Environment: Modified	0

Proj. No.	Proj. Acronym	Year	Relevant .shp file or grid	Field Name	Type of Data	Category 1	Category 2	New Category
7	MBSP14	2014	MBSP_terrestrial.shp	Category & Subcategor	Categories	Protected areas	Protected area: Protected Environment: Natural	0
8	NWBSP2015	2015	NWBSP2015_Terrestrial_CBA_v1_u35s	CBA_Disp	Categories	CBA1		1000
8	NWBSP2015	2015	NWBSP2015_Terrestrial_CBA_v1_u35s	CBA_Disp	Categories	CBA2		100
8	NWBSP2015	2015	NWBSP2015_Terrestrial_CBA_v1_u35s	CBA_Disp	Categories	ESA1		10
8	NWBSP2015	2015	NWBSP2015_Terrestrial_CBA_v1_u35s	CBA_Disp	Categories	ESA2		1
9	LIMP2018	2015-18	Sekhu_Capri_CBA_Map2018_poly_U35s	CBA	Categories	CBA1		1000
9	LIMP2018	2015-18	Sekhu_Capri_CBA_Map2018_poly_U35s	CBA	Categories	CBA2		100
9	LIMP2018	2015-18	Sekhu_Capri_CBA_Map2018_poly_U35s	CBA	Categories	ESA1		10
9	LIMP2018	2015-18	Sekhu_Capri_CBA_Map2018_poly_U35s	CBA	Categories	ESA2		1
9	LIMP2018	2015-18	Sekhu_Capri_CBA_Map2018_poly_U35s	CBA	Categories	NNR		0
9	LIMP2018	2015-18	Sekhu_Capri_CBA_Map2018_poly_U35s	CBA	Categories	ONA		0
9	LIMP2018	2015-18	Sekhu_Capri_CBA_Map2018_poly_U35s	CBA	Categories	PA		0
9	LIMP2018	2015-18	LCPv2_CBA_Layer_VHEMBE	CBA	Categories	CBA1		1000
9	LIMP2018	2015-18	LCPv2_CBA_Layer_VHEMBE	CBA	Categories	CBA2		100
9	LIMP2018	2015-18	LCPv2_CBA_Layer_VHEMBE	CBA	Categories	ESA1		10
9	LIMP2018	2015-18	LCPv2_CBA_Layer_VHEMBE	CBA	Categories	ESA2		1
9	LIMP2018	2015-18	LCPv2_CBA_Layer_VHEMBE	CBA	Categories	NNR		0
9	LIMP2018	2015-18	LCPv2_CBA_Layer_VHEMBE	CBA	Categories	ONA		0
9	LIMP2018	2015-18	LCPv2_CBA_Layer_VHEMBE	CBA	Categories	PA		0
9	LIMP2018	2015-18	Mopani CBA Map v3	MBRP2_CBA	Categories	CBA1		1000
9	LIMP2018	2015-18	Mopani CBA Map v4	MBRP2_CBA	Categories	CBA2		100
9	LIMP2018	2015-18	Mopani CBA Map v5	MBRP2_CBA	Categories	ESA1		10
9	LIMP2018	2015-18	Mopani CBA Map v6	MBRP2_CBA	Categories	ESA2		1
9	LIMP2018	2015-18	Mopani CBA Map v7	MBRP2_CBA	Categories	NNR		0
9	LIMP2018	2015-18	Mopani CBA Map v8	MBRP2_CBA	Categories	ONA		0

Proj. No.	Proj. Acronym	Year	Relevant .shp file or grid	Field Name	Type of Data	Category 1	Category 2	New Category
9	LIMP2018	2015-18	Mopani CBA Map v9	MBRP2_CBA	Categories	PA		0
9	LIMP2018	2015-18	Waterberg_Terrestrial_CBA_2015_FINAL_u35s	CBA_T	Categories	CBA1		1000
9	LIMP2018	2015-18	Waterberg_Terrestrial_CBA_2015_FINAL_u35s	CBA_T	Categories	CBA2		100
9	LIMP2018	2015-18	Waterberg_Terrestrial_CBA_2015_FINAL_u35s	CBA_T	Categories	ESA1		10
9	LIMP2018	2015-18	Waterberg_Terrestrial_CBA_2015_FINAL_u35s	CBA_T	Categories	ESA2		1
9	LIMP2018	2015-18	Waterberg_Terrestrial_CBA_2015_FINAL_u35s	CBA_T	Categories	NNHR		0
9	LIMP2018	2015-18	Waterberg_Terrestrial_CBA_2015_FINAL_u35s	CBA_T	Categories	ONA		0
9	LIMP2018	2015-18	Waterberg_Terrestrial_CBA_2015_FINAL_u35s	CBA_T	Categories	PA		0
10	GAUT2011	2011	CPlanV33_1110_ge	CATEGORY	Categories	CBA		1000
10	GAUT2011	2011	CPlanV33_1110_ge	CATEGORY	Categories	ESA		10
11	EC2018	2018	EC_MARXAN_draft4_CBA_ESA	T_CBA10	Categories	0 (No CBA/ESA classification)		0
11	EC2018	2018	EC_MARXAN_draft4_CBA_ESA	T_CBA10	Categories	2 (ESA 2)		1
11	EC2018	2018	EC_MARXAN_draft4_CBA_ESA	T_CBA10	Categories	3 (ESA 1)		10
11	EC2018	2018	EC_MARXAN_draft4_CBA_ESA	T_CBA10	Categories	4 (CBA 2)		100
11	EC2018	2018	EC_MARXAN_draft4_CBA_ESA	T_CBA10	Categories	5 (CBA 1)		1000
11	EC2018	2018	EC_MARXAN_draft4_CBA_ESA	T_CBA10	Categories	6 (Protected area)		0
12	SWSA2016	2016	swsa_poly_kern_014_gwsa_v2	Value	Single Value			10
30	IBA2015	2015	IBA Shapefile September 2015	Name	Single Value			10

Dataset Name:	Biodiversity Resilience Ecological Infrastructure Condition
Purpose:	Map of biodiversity resilience ecological infrastructure condition. Neighbourhood landscape fragmentation (natural vs not natural) is used as a proxy for the biodiversity resilience ecological infrastructure condition. The amount of natural landscape remaining and type of land uses within the neighbourhood of a site is directly related to the condition of biodiversity present at the site (e.g. biodiversity intactness index, (Scholes & Biggs 2005) and the ecological functionality of this landscape (e.g. ecological process conservation target threshold, (Desmet 2018). This layer can be combined with the water ecological infrastructure condition layer to produce a condition layer that is weighted by neighbourhood land use types and density.

Supplemental Information:

Input datasets:

1. SANBI NBA 2018 land cover - HabModv51_AEA_withDocs

Method:

1. Calculate a landscape fragmentation index using a circular focal stat at two spatial scales:
   a. Local-area = 10km^2, radius = 18 cells, number of cells = 1009
   b. Broader neighbourhood-area = 50km^2, radius = 40 cells, number of cells = 5025
2. Weight combine the two focal stats to get an overall index:
   a. Local = 60% weighting
   b. Broader neighbourhood = 40% weighting
3. Combine the focal stat layers in Raster Calculator:
   a. Int(((Float('LC_foc10km') / 1009) * 100) * 0.6) + Int(((Float('LC_foc50km') / 5025) * 100) * 0.4)
   b. Values range from 0 (0% natural) to 100 (100% natural)

Output: Landfrag_v1.tif

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
Value	Value	8-bit integer	Biodiversity Resilience EI condition Values range from 0 (0% of neighbourhood natural) to 100 (100% of neighbourhood natural)	50

Dataset Name:	Carbon Ecological Infrastructure Extent
Purpose:	Map of carbon ecological infrastructure extent. Soil carbon stocks are used as a proxy for ecosystem carbon EI. Only for soil carbon are there two independent assessments of the resource (National terrestrial carbon sinks assessment [DEA 2015b], and DEA humic soils study [DEA 2019]). The baseline extent of the stock (a proxy for carbon EI) and the current condition is provided by each study as the resultant soil carbon stock under agricultural land use relative to natural vegetation. In most cases this is a negative relationship (namely, soil carbon is less under agriculture than under natural vegetation). For the soil carbon EI extent layer only values for natural veld are used. Non-natural areas (for example agriculture, plantation, settlement, and so on.) are masked out of the analysis as they are not considered part of EbA. The extent of soil erosion is used as a proxy for soil carbon EI condition of natural ecosystems.

Supplemental Information:

Input Datasets:

1. DEA (2019) Soils Rich in Organic Carbon dataset (humic soils).
2. Soil Carbon: Natural Vegetation and Agriculture (soilc_NV & Ag)

Method:

1. Fill missing values based on the average carbon values for land type values per topographic position unit in order to create a contiguous soil carbon layer for South Africa. Fill values include:
   a. NV_kgCperm² (Natural vegetation carbon stocks in top- and subsoil in kg/m^)
   b. Ag_kgCperm² (Agriculture carbon stocks in top- and subsoil in kg/m^2)
   c. Ag over NV kg perm² (Ratio carbon stocks in top- and subsoil, agriculture over natural vegetation)
2. Resample and snap to standard project raster extent and resolution (100m).

Output: soil carbon schulz2018 filled.tif

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
KEY1A		Text	Land type - topographic position unit unique code (n = 25969)	Aa1_3
NV_FILL		16-bit floating	NV_kgC perm2 (Natural vegetation carbon stocks in top- and subsoil in kg/m^2)	16.94
Ag_FILL		16-bit floating	Ag_kgC perm2 (Agriculture carbon stocks in top- and subsoil in kg/m^2)	16.32
AgNV_FILL		16-bit floating	AgoverNVkgperm2 (Ratio carbon stocks in top- and subsoil, agriculture over natural vegetation)	1

Dataset Name:	Carbon Ecological Infrastructure Condition
Purpose:	Map of carbon ecological infrastructure condition. The extent of soil erosion is used as a proxy for soil carbon EI condition of natural ecosystems. For the soil carbon EI extent layer only values for natural veld are used. Non-natural areas (e.g. agriculture, plantation, settlement, etc.) are masked out of the analysis as they are not considered part of EbA.

Supplemental Information:

Input datasets:

1. SANBI NBA 2018 land cover, HabMod_v51_AEA
2. ARC South African gullies 2011 (Mararakanye and Le Roux 2011)

Method:

1. Re-classify erosion class (LC14L3 = erosion) in the SANBI land cover to new raster (1 = erosion, 0 = no erosion).
2. Convert gullies to raster and re-classify (1 = erosion, 0 = no erosion).
3. Merge inputs using max function.

Output: erosngully.tif

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
Value	Value	8-bit integer	Is erosion (100) or not (0)	100

Dataset Name:	Risk of Ecosystems Being Lost
Purpose:	Map of carbon ecological infrastructure condition. The extent of soil erosion is used as a proxy for soil carbon EI condition of natural ecosystems. For the soil carbon EI extent layer values for natural veld only are used. Non-natural areas (e.g. agriculture, plantation, settlement, etc.) are masked out of the analysis as they are not considered part of EbA.

Supplemental Information:

Input datasets:

1. SANBI NBA 2018 land cover, HabMod_v51_AEA
2. ARC South African gullies 2011 (Mararakanye and Le Roux 2011)

Method:

1. Calculate % of neighbourhood that was converted from a natural to non-natural land cover class between 1990 and 2014. Calculated at two spatial scales – $10km^2$ and $50km^2$.
2. For each cell calculate a weighted sum of neighbourhood land cover change [(0.6 * $10km^2$) + (0.4 * $50km^2$)]. Express as percentage of total neighbourhood sampled.

Output: prob_comb1

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
Value	Value	8-bit integer	% of neighbourhood converted from natural to non- natural between 1990 and 2014 Value range: 0 (no change) to 100 (100% change)	54

Dataset Name:	Carbon Ecological Infrastructure Condition
Purpose:	Map of the extent of areas with a potential to contain climate change related sea-level rise. Coastal ecosystems within the zone of sea-level rise have the potential to buffer or protect human infrastructure from the effects of sea-level rise. This map identifies those areas and ranks them according to elevation above the sea and overlap of coastal ecosystems. Note that this is a potential EI extent map as this model is not masked by land cover to indicate where this coastal protection EI is lost or at risk of being lost. Coastal protection EI can be further ranked or classified based on its proximity to human infrastructure (social demand) to determine which is 'critical EI'.

Supplemental Information:

Input datasets:

1. South African vegetation types – SANBI South African vegetation map 2018
2. Wetlands – NWM5_20181105_v12_AEA
3. Elevation – JAXA DEM (April 2018)

Method:

1. Select all areas with coastal protection potential, convert to raster with 0/1 classification of selected features:
   a. JAXA DEM 100m (elevation < 20 m) (upper limit of sea level change influence)
   b. JAXA DEM 100m (elevation <6 m) (expected level of sea level change influence)
   c. Wetlands dataset – Estuary class 3
   d. Coastal veg all (buffered by 100 m)
   e. Coastal veg cross-realm (buffered by 100 m)

2. Add all input layers together and re-classify as follows:
    a. 0 – No coastal protection value (i.e. above 20m elevation or outside a coastal ecosystem type)
    b. 1 – Low protection value (i.e. below 20m elevation OR occurrence of a coastal ecosystem only)
    c. 2 – Medium protection value (i.e. below 20m elevation AND occurrence of a coastal ecosystem)
    d. 3 – High protection value (i.e. below 5m elevation)
3. Clean single cells from raster with a majority filter.

Output: coast_fnl_v2

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
Value	Value	8-bit integer	Coastal Protection EI extent Values range: 0 – No coastal protection value (i.e. above 20m elevation or outside a coastal ecosystem type) 1 – Low protection value (i.e. below 20m elevation OR occurrence of a coastal ecosystem only) 2 – Medium protection value (i.e. below 20m elevation AND occurrence of a coastal ecosystem) 3 – High protection value (i.e. below 5m elevation)	1

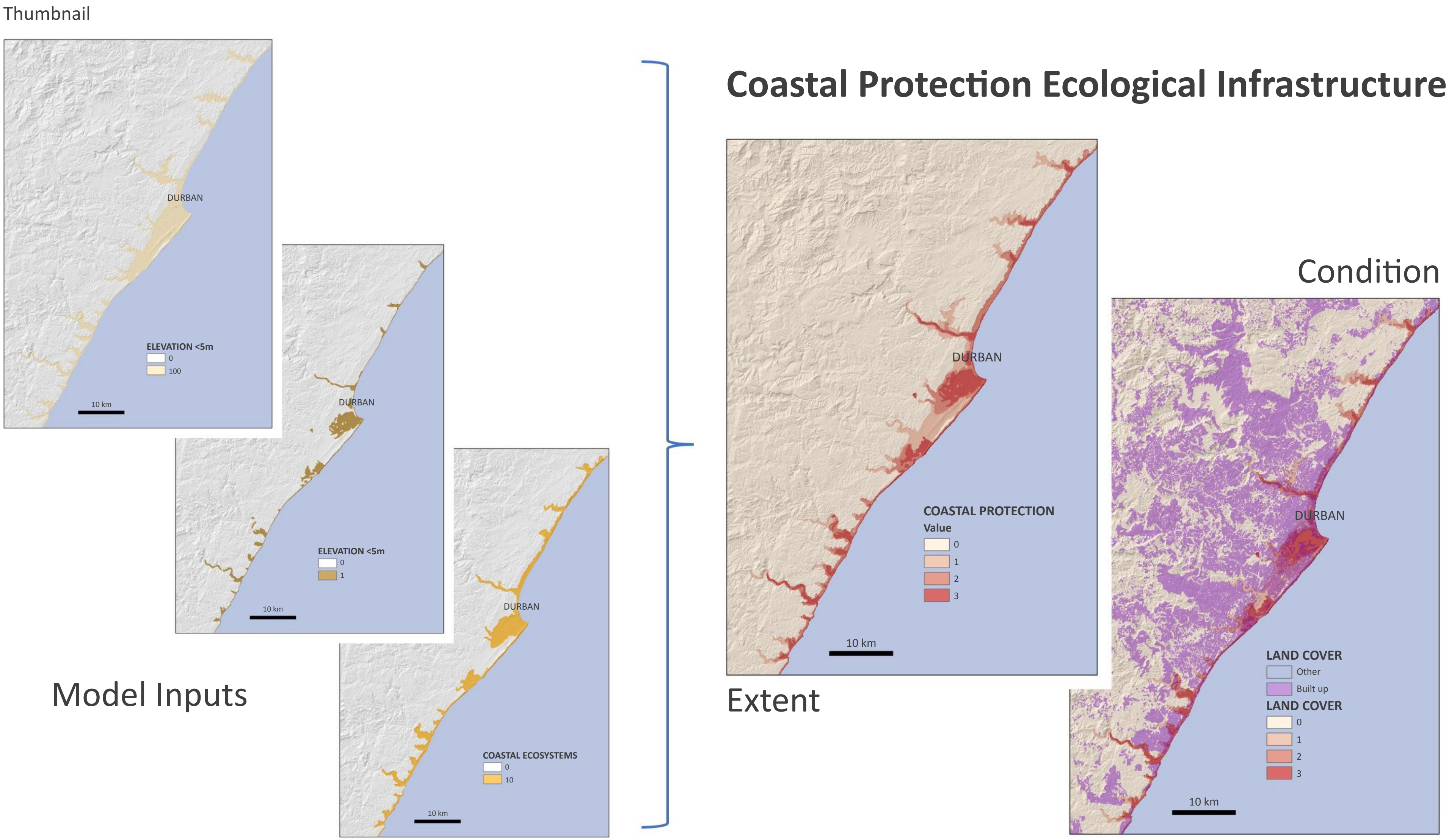


Figure A4.1: Coastal Protection Ecological Infrastructure Model inputs for extent and condition

Dataset Name:	Risk of Ecosystems Being Lost
Purpose:	Map of rural landscapes transitioning to urban and peri-urban landscapes in South Africa. Urban-rural is defined as any landscape with contiguous area equal to or greater than one dwelling per 1ha. The identified area covers 25% (305 000km2) of South African area and contains 86% of South African dwellings (namely, population).
Supplemental Information:	
Input datasets: 1. ESKOM spot building count 2018 2. ARC South African gullies 2011 (Mararakanye and Le Roux 2011) **Method:** 1. Convert input point dataset to raster 1ha (dwellings per ha). 2. Re-classify raster (1 = > = 1 dwelling per ha, 0 = not). 3. Buffer value = 1 by 2 km to aggregate zones and majority filter to reduce noise in the dataset. 4. Convert raster to polygon. Output: Rural_Urban_Areas_ALBERS.shp	
Attribute Description:	No attribute information. All polygons = urban rural landscape. Overlay metropolitan municipalities to indicate extensive urban areas.

Field name	Alias Name	Data Type	Description	Example

Thumbnail

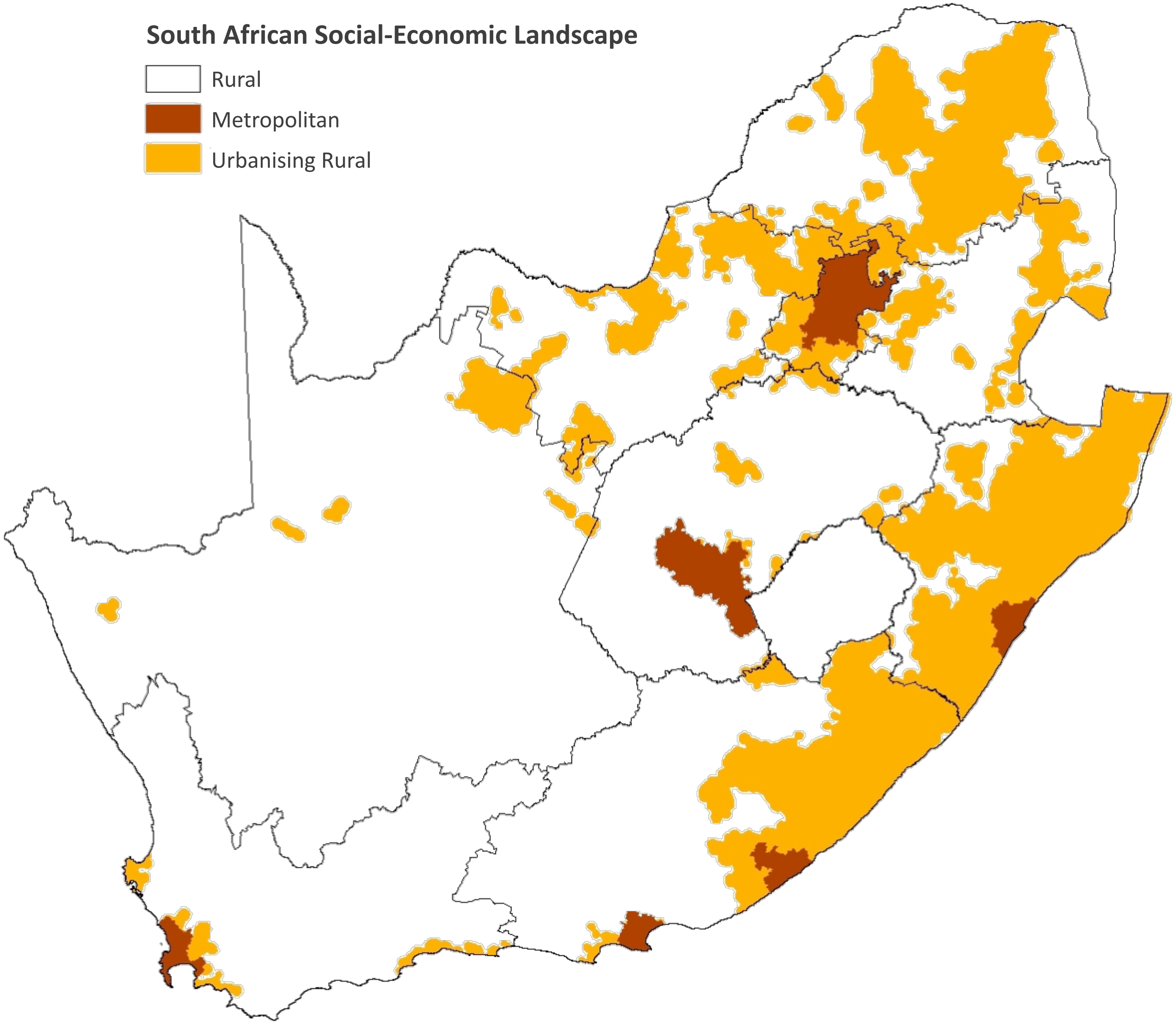


Figure A4.2: South African Social-Economic Landscape

Dataset Name:	Risk of Ecosystems Being Lost
Purpose:	Standard reporting unit used to aggregate finer-scale raster data for the purpose of EbA data integration, analysis and determination of EbA action priority areas.

Supplemental Information:

Input datasets:

1. None

Method:

1. Generate 10 x 10 km polygon grid snapped to project automated optical inspection (AOI) raster.
2. Determine if generated grid falls within South Africa based on majority area.

Output: GRID 10x10km ALBERS.shp

Attribute Description:

Field name	Alias Name	Data Type	Description	Example
GRID_ID		8-bit integer	Grid unit unique identifier. Used as the link field when joining table data to the vector data. Value range: 1 – 13 046	2456
RSA		8-bit integer	Grid unit is determined to occur in South Africa or not Value binary: 0 = not in South Africa, 1 = is in South Africa	1

ANNEX E: PROJECT OUTPUTS METADATA

The project data drive contains the following directories with spatial data:

01 Water EI Models\

02 Nature-based Tourism Model\

03 Rangeland EI Models\

04 Biodiversity Resilience Models\

05 Soil Carbon EI Models\

06 Social Demand\

07 Risk of biodiversity being lost\

08 Biodiversity importance\

09 Existing EbA projects\

10 Aggregation Units\

11 Additional\ METADATA docs\

And the following spreadsheet:

EbA PRIORITIES FINAL INTEGRATION v4 20180429 - Microsoft Excel spreadsheet with final integration of data to determine priority areas for EbA action at national, biome and local municipality levels.

Worksheets contained in spreadsheet:

Worksheet Number	Description
1	Raw data from EI 1 ha models summarised to the 10 km^2 aggregation grid units.
2	Raw data relativised nationally by dividing into percentiles at the NATIONAL SCALE.
3	Raw data relativised by biome by dividing values into percentiles within each BIOME.
4	Summary of grid units per EbA response categories nationally and per biome.
5	EbA response categories aggregated to local municipality level.
6	Local municipality data organised for export back to GIS using 'CAT_B' and the link field. This sheet contains the final prioritisation of local municipalities.
7	Summary of the criteria used for local municipality selection scenarios.

Description of field names used in spreadsheet:

Field Name	Description
GRID_ID	Unique grid unit identifier
RSA	Grid unit is within RSA
BIOME_18	Grid unit BIOME classification
PROVINCE	Grid unit PROVINCE classification
CATEGORY	Local municipality category
CAT2	Grid unit LOCAL MUNICIPALITY classification
CAT_B	Local municipality unique code
MUNICNAME	Local municipality name
DISTRICT	District municipality code
DISTRICT_N	District municipality name
COUNT	Count of input raster cells (1 ha) per grid unit
SBC_SUM	Sum of building per grid unit from ESKOM spot building count (SBC)
SURPI_AVG	SURPI average per grid unit
SBC_SURPI	Population weighted (SBC) SURPI per grid unit
GRAZING	Sum of Rangeland EI per grid unit
BIODIV	Sum of Biodiversity Resilience EI per grid unit
CARBON	Sum of Soil Carbon EI per grid unit
TOURISM	Sum of Tourism EI per grid unit
WATER	Sum of Water EI per grid unit
CON_GP_MSK	Sum of rangeland EI condition (positive change only) per grid unit with land cover mask
CON_GN_MSK	Sum of rangeland EI condition (negative change only) per grid unit with land cover mask
CON_GP	Sum of rangeland EI condition (positive change only) per grid unit
CON_GN	Sum of rangeland EI condition (negative change only) per grid unit
Con_Frag	Sum of biodiversity resilience EI condition (fragmentation) per grid unit
CON_Alien	Sum of alien density per grid unit
CON_Ero	Sum of erosion (soil carbon EI condition) per grid unit

Field Name	Description
CON_Water	Sum of water EI condition per grid unit
EI_CON_AVG	Average EI condition of each grid unit based on an average of the percentiles
RISK	Risk of losing ecosystems: Relative risk of site being lost based on land cover change 1994 to present
EbA1	EbA response categorised based on SURPI social demand
EbA2	EbA response categorised based on population weighted SBCxSURPI social demand
EbA_comb	Aggregation of SURPI and SBCxSURPI EbA response categories

Worksheet 6: LM EXPORT	
EbA_NAT	EbA_Score is an indication of a local municipality's potential to support EbA. This is a national ranking.
EbA_BIOME	EbA_Score is an indication of a local municipality's potential to support EbA. This is a biome-level ranking.
EbA_AVG	An average of the national and biome rankings
Risk_MEAN	Mean per local municipality of Risk of losing ecosystems: Relative risk of site being lost based on land cover change 1994 to present
RISK_P_RANK	Risk ranked into percentiles
BIO_W_SUM	Sum of Biodiversity Resilience EI per local municipality
BIO_P_RANK	Biodiversity importance ranked into percentiles
EbA_LM	Number of EbA projects per local municipality
CC_BIOME	Climate Change Risk: % of local municipality where current biome is expected to change (Guo *et al.* 2017)
SEV11	CSIR Green Book 2019: The vulnerability of households living in the municipality. A high vulnerability score indicates a high number of vulnerable households with regards to household composition, income composition, education and health, access to basic services, and safety and security.
EVI11	CSIR Green Book 2019: The economic vulnerability of the municipality. The higher the economic vulnerability the more susceptible the municipality is to external shocks based on the economic diversity, size of the economy, labour force, GDP growth rate and the inequality present in the municipality.
PV	CSIR Green Book 2019: PV – Physical vulnerability addresses the physical fabric and connectedness of the settlements in the local municipality. A high physical vulnerability score highlights areas of remoteness and/or areas with structural vulnerabilities
EV	CSIR Green Book 2019: An indicator representing the conflict between preserving the natural environment and accommodating the growth pressures associated with population growth, urbanisation and economic development. A high score reflects much conflict between preserving the environment and allowing land-use change to occur. The indicator measures air quality, environmental governance, and the competition between the ecology and urban encroachment.
Average Rank	Mean of the Risk, Biodiversity, Climate Change and EV ranks per local municipality
Scenario	Classification of local municipalities into one of 7 selection scenarios based on the criteria summarised in Worksheet 7

References

Bourne, A., de Abreu, P., Donatti, C., Holness, S., Scorgie, S. and Midgley, G.F. (2015). Climate Change: Vulnerability Assessment for the Namakwa District Municipality. Conservation South Africa. https://www.weadapt.org/sites/weadapt.org/files/legacy-new/knowledge-base/files/51c4c23ad02f8final-vulnerability-assessment-full-technical-report-ndm-with-cover.pdf

Council for Scientific and Industrial Research (CSIR). (2019). Green Book: Adapting South African settlements to climate change. Online tool to support municipal planning with development of climate resilient settlements. Website: www.greenbook.co.za

Department of Environmental Affairs (DEA). (2015a). Climate Change Adaptation Plans for South African Biomes. Kharika, J.R.M., Mkhize, N.C.S., Munyai, T., Khavhagali, V.P., Davis, C., Dziba, D., Scholes, R., van Garderen, E., von Maltitz, G., Le Maitre, D., Archibald, S., Lotter, D., van Deventer, H., Midgely, G. and Hoffman, T. (Eds.). Department of Environmental Affairs, Pretoria, South Africa. https://www.environment.gov.za/sites/default/files/reports/climatechangeadaptation_plansforsouthafricanbiomes_report.pdf

Department of Environmental Affairs (DEA). (2015b). National Terrestrial Carbon Sink Assessment. Department of Environmental Affairs, Pretoria, South Africa.

Department of Environmental Affairs (DEA) (2015c). 2013-14 National Land-Cover – 72 classes [Data set]. Department of Environmental Affairs (DEA). Accessed 4 March 2020 at: https://doi.org/10.15493/DEA.CARBON.10000028.

Department of Environmental Affairs (DEA). (2016) National Protected Areas Expansion Strategy for South Africa 2016. Draft for public comment. Department of Environmental Affairs, Pretoria, South Africa. Accessed 10 March 2020 at: https://www.environment.gov.za/sites/default/files/docs/national_protectedareas_expansionstrategy2016_ofsouthafrica.pdf

Department of Environmental Affairs (DEA). (2017a) Guidelines for Ecosystem-based Adaptation (EbA) in South Africa. Department of Environmental Affairs, Pretoria, South Africa. https://www.sanbi.org/wp-content/uploads/2018/03/final-guidelines-ecosystem-based-adaptation-eba-south-africa.pdf

Department of Environmental Affairs (DEA) (2017b) National Carbon Sinks Atlas. First edition. Department of Environmental Affairs Pretoria, South Africa. Accessed 7 March 2020 at: https://www.environment.gov.za/sites/default/files/docs/carbonsinks_southafricanatlas2017.pdf Online version available at version at: http://carbon-atlas.dirisa.org

Department of Environmental Affairs (DEA). (2019a). Identification and mapping of soils rich in organic carbon in South Africa as a climate change mitigation option. Department of Environmental Affairs, Pretoria, South Africa.

Department of Environmental Affairs (DEA) (2019b). South African National Land-Cover 2018 dataset. Available at: https://egis.environment.gov.za/gis_data_downloads

Department of Water and Sanitation. (2014). A Desktop Assessment of the Present Ecological State, Ecological Importance and Ecological Sensitivity per Sub Quaternary Reaches for Secondary Catchments in South Africa.

Desmet, P.G. (2018). Using landscape fragmentation thresholds to determine ecological process targets in systematic conservation plans. Biological Conservation 221: 257–260.

Driver, A., Sink, K.J., Nel, J.N., Holness, S., Van Niekerk, L., Daniels, F., Jonas, Z., Majiedt, P.A., Harris, L. & Maze, K. (2012). National Biodiversity Assessment 2011: An assessment of South Africa's biodiversity and ecosystems. Synthesis Report. South African National Biodiversity Institute and Department of Environmental Affairs, Pretoria.

Eskom's SPOT Building Count, 2014. www.ee.co.za/article/use-spatial-data-study-informal-settlement-growth.html

Guo, D., Desmet, P.G. and Powrie, L.W. (2017). Impact of the Future Changing Climate on the Southern Africa Biomes, and the Importance of Geology. Journal of Geoscience and Environment Protection 5: 1-9. https://doi.org/10.4236/gep.2017.57001

Holness, S. (2017). Priority Areas for Ecosystem-based Adaptation to Climate Change in the Kruger to Canyons Biosphere. Report for Conservation South Africa and Kruger to Canyons Biosphere.

Japan Aerospace Exploration Agency (JAXA) (2015). Webpage at: https://global.jaxa.jp/press/2015/05/20150518_daichi.html

Kotze, D., Marnewick, G., Batchelor, A., Lindley, D. and Collins, N. (2009). WET-EcoServices: A technique for rapidly assessing ecosystem services supplied by wetlands. Wetland Management Series. WRC Report TT 339/09, March 2009. Water Research Commission, Pretoria, South Africa. Accessed 9 March 2020 at http://www.wrc.org.za/wp-content/uploads/mdocs/TT%20339-09.pdf

Kotze I, Beukes H, van den Berg E, Newby T. (2010) National Invasive Alien Plant Survey. Report Number: GW/A/2010/21. Agricultural Research Council - Institute for Soil, Climate and WaterPrivate Bag X79, Pretoria, South Africa. Accessed 07 March 2020 at: https://pdfs.semanticscholar.org/f34e/fd52f169944531b0ab71e60da9a682326001.pdf

Le Maitre, D.C., Seyler, H., Holland, M., Smith-Adao, L., Nel, J.L., Maherry, A. and Witthüser, K. (2018) Identification, Delineation and Importance of the Strategic Water Source Areas of South Africa, Lesotho and Swaziland for Surface Water and Groundwater. Report No. TT 743/1/18. Water Research Commission, Pretoria, South Africa. Accessed 8 March 2020 at: http://www.wrc.org.za/wp-content/uploads/mdocs/TT%20754-1-18.pdf

Mararakanye, N. and Le Roux, J.J. (2011). Manual Digitizing of Gully Erosion in South Africa Using High Resolution SPOT 5 Satellite Imagery at 1:10 000 Scale. Directorate Land Use and Soil Management, Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa.

Nel, J.L., Murray, K.M., Maherry, A.M., Petersen, C.P., Roux, D.J., Driver, A., Hill, L., van Deventer, H., Funke, N., Swartz, E.R., Smith-Adao, L.B, Mbona, N., Downsborough, L. and Nienaber, S. (2011). Technical Report for the National Freshwater Ecosystem Priority Areas project. WRC Report No. 1801/2/11, Water Research Commission, Pretoria, South Africa. Accessed 8 March at: http://www.fewlbnexus.uct.ac.za/sites/default/files/image_tool/images/91/ NFEPA_Technical_Report.pdf

Ollis, D.J., Snaddon, C.D., Job, N.M. & Mbona, N. 2013. Classification System for Wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland Systems. SANBI Biodiversity Series 22. South African National Biodiversity Institute Pretoria. Accessed 4 March 2020 at: http://biodiversityadvisor.sanbi.org/wp-content/uploads/2016/07/Classification-system-for-wetlands-other-aquatic-ecosystems.pdf

South African National Biodiversity Institute (SANBI). 2019. National Biodiversity Assessment 2018: The status of South Africa's ecosystems and biodiversity. Synthesis Report. South African National Biodiversity Institute, an entity of the Department of Environment, Forestry and Fisheries, Pretoria. pp. 1–214. Accessed 4 March 2020 at: https://www.sanbi.org/wp-content/uploads/2019/10/NBA-Report-2019.pdf

Scholes, R.J. and Biggs, R. (2005). A biodiversity intactness index. Nature 434: 45-49. PDF accessed 11 March 2020 at: https://www.pik-potsdam.de/news/public-events/archiv/alter-net/former-ss/2007/09-09.2007/klok/literature/scholes_nature_2005.pdf

Schulze, R.E. (Ed.) (2007). South African Atlas of Climatology and Agrohydrology. WRC Report 1489/1/06. Water Research Commission, Pretoria, South Africa.

Turpie, J.K., Forsythe, K.J., Knowles, A., Blignaut, J. and Letley, G. (2017). Mapping and valuation of South Africa's ecosystem services: A local perspective. Ecosystem Services 27: 179– 192.

United Nations Development Programme (UNDP). (2010). Mapping Climate Change Vulnerability and Impact Scenarios. A Guidebook for Sub-National Planners. United Nations Development Programme Bureau for Development Policy Environment and Energy Group, New York, USA. https://www.adaptationcommunity.net/?wpfb_dl=58

Van Niekerk, W.; Le Roux, A.; Pieterse, A.; Mans, G.; Makhanya, S. and Van Huyssteen, E. 2019. Final Technical Report for the Green Book: Adapting South African settlements to climate change. CSIR: Pretoria. Accessed at 25 March 2020 at: https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/57701/IDL%20-%2057701.pdf

Venter, O., Sanderson, E.W., Magrach, A., Allan, J.R., Beher, J., Jones, K.R., Possingham, H.P., Laurance, W.F., Wood, P., Fekete, B.M., Levy, M.A. and Watson, J.E. (2016). Global Terrestrial Human Footprint maps for 1993 and 2009. Scientific Data 3: 160067. https://doi.org/10.1038/sdata.2016.67

Venter, ZS, Scott, SL, Desmet, PG and Hoffman, MT (2020) Application of Landsat-derived vegetation trends over South Africa: Potential for monitoring land degradation and restoration. Ecological Indicators, Volume 113 (106206). https://doi.org/10.1016/j.ecolind.2020.106206.