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SAEON NDLOVU NODE

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THE NODE AND ITS KEY ENVIRONMENTAL ISSUES

The SAEON Core Science Framework outlines the environmental changes of relevance to SAEON. This plan details which of these various drivers of, and responders to, change are relevant to a particular part of the country. A subset of these is then selected as priorities for research over the next five years.

Geographical focus of the Node

The scientific focus of the SAEON Ndlovu Node is to determine the causes of the major environmental changes occurring in the north-eastern part of South Africa, and elucidating or predicting the consequences of these changes for society. Pristine, degraded and novel ecosystems are included as study systems, while urban and cultivated ecosystems are considered beyond the scope. North-eastern South Africa refers, for these purposes, to the Lowveld of the Limpopo and Mpumalanga Provinces, the adjacent mountains of the Transvaal Escarpment, the Soutpansberg and the area north of that to the Limpopo River. This focal area contains a diversity of ecosystems, all experiencing environmental changes that are also occurring throughout much of southern Africa, and in some cases globally. This geographic focus thus allows for study of a significant portion of South African environments and ecosystems, and a substantial range of environmental issues that are relevant nationally, regionally and in some cases globally.

Most of the focal area comprises savanna ecosystems, and the dominant land uses are nature conservation, game farming and communal rangeland. A significant proportion has been transformed for settlements, agriculture and mining, while much of the untransformed land is considered degraded. A small proportion consists of land previously transformed but now abandoned or rehabilitated, and novel ecosystems now exist in these areas. However almost half the area consists of formally protected areas, containing extensive ecosystems that have suffered little human modification over the past century. These include one of the largest and least modified tracts of savanna (the Kruger National Park) and one of the largest private conservation areas (the APNR-Timbavati-Sabi Sands block) in the world.

The various savanna ecosystems of the focal area provide a range of services to society, which are the basis of: 1) A large **eco-tourism** industry, centred on the aesthetic appeal of rare and iconic species and the wilderness landscapes that are found in the extensive conservation areas; 2) A large **game farming** and hunting industry, which makes a substantial contribution to the national sector; 3) A significant contribution of **natural resources** to the livelihoods of millions of rural people (particularly fuelwood, forage for domestic livestock, food plants and insects, and medicinal plants). Furthermore, the full extent of the main savanna type (semi-arid savannas) may make a globally-significant contribution to the regulation of the carbon and water cycles, and hence the global climate.

In terms of size or services provided, the next most important ecosystems in the focal area are montane grasslands and forests, and perennial rivers systems. Although small, these are sufficient in extent and diversity to allow for the study of environmental issues that affect these systems in many other parts of the world. These areas support a smaller amount of eco-tourism, but are critical for the **provision of freshwater.** The rivers which rise in the catchments of the Escarpment and Soutpansberg sustain extensive irrigated agriculture downstream, and make a significant contribution to eco-tourism.

Changes and their consequences

Drivers of change. Of the many anthropogenic impacts that have driven changes in the natural environment over the past century, the following are considered most important for the focal area:

1) Alteration of herbivore populations, initially through a massive reduction in numbers of indigenous species in the 19th and early 20th centuries. Following this natural herbivores were widely replaced by, or co-existed with, domestic livestock (particularly cattle). Over the latter half of the 20th century, numbers of both natural and domestic herbivores increased to levels far higher than historical densities, through the creation of artificial water points and supplemental feeding in rangelands, game farms and nature reserves. The spatial distribution of herbivory has also been altered by these factors, as well as extensive fencing and habitat fragmentation. Mega-herbivores which have the potential to alter ecosystem processes over significant areas (viz. elephant, rhinoceros and hippopotamus) have been absent from much of their former range for over 50 years, although in the larger conservation areas these species have recovered to densities similar to historical levels.

2) Land transformation, with extensive and on-going development of villages, towns, irrigated agriculture, small-scale dryland cropping and mines since the 1950s {Coetzer, 2010 #1548}. This has fragmented previously extensive ecosystems, introduced many pollutants and alien species into the region, and may have disrupted regional migration by larger herbivores. The semi-arid and arid parts of the focal area have been less affected, while the majority of mesic savannas and grasslands of the higher-lying areas have been replaced by forestry plantations, tea plantations and fruit orchards.

3) Natural fire regimes have been altered, through land transformation, the construction of roads, increased ignitions, and a variety of fire management strategies ranging from complete fire suppression to rotational burning.

4) Cutting of trees and shrubs, for fuelwood and building material in rural areas, improved forage in game farms and improved game viewing in conservation areas.

5) The perennial rivers of the region, as well as most of the seasonal rivers, have experienced reductions in flows, a result of dam construction and direct abstraction. Many rivers have also suffered decades of contamination from agricultural, domestic and industrial pollution. While flow regimes have been reduced overall, floods may have become more severe in lower river reaches due to dam release management, the bursting of smaller dams, and possibly more extreme rainfall events recently.

6) Atmospheric concentration of CO_2 has increased, in-line with global trends.

The following additional drivers are likely to become important over the next 100 years:

7) Altered rainfall regimes, particularly increased intra- and inter-annual variability. This will lead to more intense floods, and more intense and frequent drought (mid-season and multiple year droughts).

8) Increased temperatures, particularly higher minimum temperatures in higher-lying areas. Associated increases in evapo-transpiration have the potential to increase aridity through much of the focal area, although increases in rainfall may offset this. An increased frequency of heat waves could have lethal effects for biota currently at the edge of their distributional ranges.

9) Increasing rates of land abandonment. The extent of dryland, cash-crop fields is likely to continue its rapid increase in the short-term, ultimately resulting in growth of the number of abandoned fields. In the medium term, migration to cities is likely to end the current growth of rural towns in the region, leading to less conversion of crop fields to settlements, and greater rates of abandonment of existing fields. Political processes may also result in additional abandonment of commercial agricultural land.

Responses to change. What effects have these various driving forces produced in the north-eastern part of the country, and what are the consequences of these changes for society? What additional changes are likely in the future?

1) Increased cover of shrubs and short trees in savanna ecosystems, known locally as bush encroachment. This phenomenon has occurred throughout the world over the past century, including South Africa and many parts of the focal area. This has occurred on rangelands, game farms and conservation areas, with substantial consequences for ecosystems services in each type of land use. The most direct and obvious impact is a reduction in forage for grazing livestock and wildlife, with obvious consequences for the livestock, game and ecotourism industries. In protected areas, increased predation, and avoidance of encroached areas for predator avoidance, may also play a role in reducing wildlife densities. The impacts of woody cover increase on biodiversity of other taxa are not well documented, but are likely to be significant for certain groups. There are also potential impacts to the hydrological cycle at region scales, such as reduced river flows and

larger convective storms. Finally, the extent of bush encroachment globally may be impacting the global carbon cycle.

2) The encroachment of woody plants into grasslands has not occurred over large areas within the focal area, due to the small extent of grassland and previous afforestation of much of this. While this change may be of more significance elsewhere (particularly the mountainous areas of KwaZulu-Natal and the Eastern Cape), the causes and consequences are the same. The latter include biodiversity losses (from the species to biome level), and reduced water supply (reduced yields from important river catchments).

3) A decreased density of tall trees is occurring rapidly in conservation areas where elephant are present. This is well documented in the focal area and throughout the current range of elephant in Africa, and may be causing a reduction in biodiversity over a significant proportion of the conservation areas of the continent. It is possible that an increase in tall trees preceded the current decline, due to the extirpation of elephants and disrupted fire regimes.

4) Decreased diversity and productivity of the herbaceous layer, particularly in semi-arid and arid areas. The herbaceous layer across much of the rangelands, game farms and nature reserves currently has lower basal cover and produces less biomass than is possible given the soils and climate. Areas where natural herbivore composition and movement has been little altered have a more diverse, resilient and productive herbaceous layer, with a higher cover of perennial species. Considering the overall increase in herbivory pressure of the past century, this indicates that the herbaceous layer is significantly degraded over much of the focal area. A related change is the erosion of much or all of the topsoil in some areas, particularly the most intensively grazed rural rangelands. The main consequence of this degradation is reduced forage, and it may be a driver of bush encroachment. Significant losses of organic material in soil are also likely to have occurred, although it is doubtful this is of significance to the carbon cycle at larger scales. Likewise, while soil infiltration and water storage must have been altered, this has probably not had significant implications for regional hydrological processes.

5) Reduced distributions of species at the upper trophic levels. Consistent with changes throughout the world, the ranges of large predators and specialized herbivores has been greatly reduced and population densities are generally lower than in pre-industrial times. A range of taxonomic groups have been affected, from raptors, to large mammals to fish. While many species from the higher trophic levels have been extirpated from many parts of the world, their decline within the focal area has been comparatively slow and has even been reversed for some species as a result of game farming and ecotourism in the late 20th century. However, the loss or reduction of these species may have, and may still be having, a negative effect on biodiversity in many areas. Furthermore reduced genetic diversity, novel diseases and climate change have the potential to renew declines in many of these species.

6) Distributional shifts of a much broader range of species in response to climate change may have already started. These are likely to become significant in the future, and may even culminate in biome shifts. However, the geographic re-arrangement of species, required for them to persist under an altered climate, will be constrained by the rapid rate of climate change and habitat fragmentation, and many range reductions and local extinctions are likely, leading to reduced ecosystem integrity, and even the emergence of novel ecosystems and biomes. The negative

consequences for society range from aesthetically-related ones (losses of iconic and rare species, and degraded landscapes) to regional-scale alteration of freshwater supplies and weather.

7) Freshwater ecosystems in the large rivers have probably experienced the greatest change, with highly altered flow regimes, altered water temperatures, high levels of contamination, and greatly reduced ranges or even local extinctions of freshwater species. Significant reductions in aquatic biodiversity are likely to have already resulted, as in the case for rivers globally. This is also the case for a high proportion of riparian ecosystems. Reduced flows already constrain irrigated agriculture in many parts of the focal area, and will soon affect domestic water supplies. Past and current conversion of perennial rivers to seasonal rivers has probably reduced eco-tourism potential in some areas. Biodiversity losses may have some localized direct impacts, where fishing or eco-tourism makes a significant contribution to rural livelihoods. A potentially much greater consequence is a reduction in the ability of rivers to ameliorate pollution, resulting in reductions of water quality to critical levels for down-stream users.

8) The creation of novel ecosystems following the abandonment of croplands, the creation of artificial substrates from mining (i.e. dumps and pits), intensive grazing and fuelwood harvesting that produces irreversible changes (through the loss of topsoil and dominant species), and invasions by alien plants. These ecosystems are distinct from those of the pre-transformed lands, and are unlikely to ever revert to that state. While novel ecosystems are relatively small in the focal area, or anywhere in South Africa, they will continue to grow steadily in the foreseeable future, and will eventually reach a similar extent as in the developed world. Additional ones may be created in untransformed areas as a result of global climate change (much of the savanna biome within the focal area is predicted to change to a climate regime for which there is currently no analogous biome). Thus in the long-term they are likely to have significant impacts on biodiversity and ecosystem services at a regional scale. More importantly these systems already have a negative influence on ecological and hydrology processes well beyond their boundaries: they often contain high densities of alien plants and act as a dispersal source of invasive species; they can be a source of dust and sediment into neighbouring lands and rivers; many produce a continuous input of accumulated contaminants into downstream groundwater and freshwater systems.

THEMES

The SAEON Core Science Framework outlines specific driver and response variables relevant to the savanna biome (Table 3, pg38-39). Only a subset of these have been incorporated into the following themes. These themes are not meant to address each of the changes described above, as this is not currently feasible. Instead four have been selected which encompass the environmental issues considered to be of the most significance in the focal area. Note that:

- The key research questions listed under each theme are broad, and encapsulate a number of more specific questions that would form the basis of specific research projects.
- The selection of themes is scale dependent. Those included here are most relevant to the focal area, and do not include themes relevant only at the national, sub-continental or global scales, which would be best addressed with standardized methods applied at sites across a larger area.

• In most cases, there is little quantitative data to support the changes described above, or validate the selection of the themes and key research questions. Ideally such justification would be provided by regional and national monitoring schemes (such as the SANBI Biodiversity Assessments, the Rivers Health Program, the National Land Cover maps). Neither time nor resources are available to acquire such data before addressing the research questions below. Consequently, much of the planned research addresses causes and consequences of changes that are not necessarily definitively known. In many cases, monitoring trends in the ecosystems under study can be incorporated into research designs, to simultaneously address pattern, cause and consequence of change.

Theme 1. Structural changes in savannas

Relevance

Major changes in ecosystem structure coincide with changes in ecological processes (forage production, fluxes of energy, carbon, water and nutrients etc…) whether through cause or effect. Changes in structure are thus intertwined with changes in the many ecosystem services, with wide-ranging consequences for society. Therefore while "structure" was been chosen as the description for this theme, it is intended to guide research across a wide range of ecological levels.

Changes to three major components of savanna structure – the woody layer, the herbaceous layer and the herbivores – are included concurrently. These three are closely linked in terms of patterns of change and causes of change, and changes in one may drive changes in the other.

The Node is well located to explore this theme, with a range of land-use types, management strategies and some long-term research infrastructure in close proximity. These provide natural experiments that can be used to disentangle multiple and interacting drivers.

Key questions

1.1. What is the cause of bush encroachment in semi-arid savannas?

• Various theories have been proposed to explain bush encroachment, involving increased atmospheric **CO_2, over-grazing**, reduced **fire** and reduced **browsing**. Long-term research is required to determine the relative importance of these putative causes, and whether different causes apply in different ecosystems and different land uses.

• Determining **past and current rates of bush encroachment** in a variety of savanna types and land-use types will help to address this question.

• Changes in the **herbaceous layer** are a critical aspect, and addressing this question will provide insights into the consequences of the degradation of the herbaceous layer.

• Addressing this question will contribute to answering related questions of **how is woody cover likely to change in the future** and **what management actions can be used to halt or reverse bush encroachment**?

1.2. What are the consequences of bush encroachment?

• Despite widespread acknowledgement of the problem of bush encroachment, there is little evidence of the consequences of it, particularly for biodiversity and hydrological processes.
• The potentially positive effect of increased density and growth rates of woody plants on the **supply of fuelwood** in rural areas is an important component of this question.

1.3. What are the causes and consequences of declining densities of tall trees?

• Particularly for **biodiversity**, although local impacts to ecosystem functioning (via processes such as hydraulic lift and nutrient hotspots) may also be relevant.
• Impacts are likely to be greatest in **riparian zones**, where the sizes and densities of tall trees are greatest.
• This question requires investigation of both mortality/felling of tall trees, and causes for low **recruitment** into the tallest height classes.

1.4. What are current densities and population trends of large herbivores?

• For both domestic livestock and indigenous species.
• Results from this question would assist with questions 1.1 and 1.3 above.

Key beneficiaries
• Savanna ecologists. Results will inform the broader question of what determines tree-grass co-existence, which has been a popular topic of ecology for decades. Research infrastructure and long-term data created under this theme will provide new opportunities for academic pursuit this topic.
• Managers of rangelands, game farms and conservation areas, including livestock owners in communal rural lands. Large amounts of resources have been expended on combating bush encroachment, often with limited success. Results regarding the consequences of bush encroachment, and projections of future rates, will inform how many resources should be allocated to try to halt or reverse bush encroachment, while results relating to causes will lead to new or improved methods for achieving this.
• Rural communities which are dependent on fuelwood, provided results can be used to improve management of this resource.

Relevance to legislation
NEMA (NEMBA), National Veld and Forest Fire Act (and Fire Protection Agency rules and guidelines).

Science collaborations
<u>Actual</u>
Stefan Grab and two of his MSc students (Amy Trent & Nicky Maraschin; WITS), Frances Siebert (North-West University), Corli Coetsee (Scientific Services, SANParks), Emma Gray (PhD student, University of McQuarrie), Deron Burkepile (University of California, Santa Barbara),
<u>Potential</u>

Numerous research groups working within the broad topic of tree-grass interactions, including), Sally Archibald (WITS), Dave Ward (Stellenbosch University), Mahesh Sankaran (University of Leeds), Ricardo Holdo (Missouri University), Jesse Nippert (Kansas State University, Sally Koerner (Duke University), Alan Knapp (Colorado State University),

Competitors

Numerous research groups working on similar topics, in the focal area as well as in other savanna areas around the world.

Opportunities for attracting more collaborators

While these topics are being studied around the world, many sites where the Node is currently active, or could become active, have the advantage of working in relatively pristine savanna ecosystems containing the full suite of large mammals, as well as some sites where destructive sampling is possible. Access to existing long-term experiments, such as the Experimental Burn Plots and large herbivore exclosures in the Kruger National Park is another draw-card.

Opportunities for cross-nodal collaboration

The Nodes current activities are restricted to semi-arid sites. The GWF and Arid Lands Nodes are better located to address the above questions in mesic and arid systems respectively, which would increase the generality of the results.

Theme 2. Changing Distributions

Relevance

Significant changes in the distribution of species or biomes in response to global climate change have yet to be documented within the focal area, but there are signs that this is beginning. Thickening of the woody layer in high altitude savannas is evident, as has been reported on for similar environments. Range shifts of species towards higher altitudes and latitudes have been extensively documented elsewhere in the world.

Key questions

2.1. Which species are most likely to shift their distribution as a direct result of climatic change?

• Two types of species are of interest: 1) **Indicator species** – species which are particularly sensitive to changes in climate. The purpose of studying these species is simply to demonstrate a tangible impact of climate change in South Africa (which has been done for many species in the northern Hemisphere). Species restricted to the summits of the Escarpment and Soutpansberg and to the upper reaches of the rivers, as well as species at the edge of their latitudinal range are natural candidates. 2) **Keystone species** – species which have significant effects on biodiversity and / or ecosystem functioning, and for which range shifts would have the greatest impacts on society. Species which currently dominate their communities, such as Mopane trees and Bracken Fern, are potential candidates.

• **Freshwater** species are included, as climate-induced changes in water temperature or chemistry is likely to drive shifts in these up or down rivers.
• Establishing the **current distribution** for candidate species, and **determinants** thereof, is a first step, making the question of broader ecological interest.
• **Modelling** current and future distributions is then needed, together with **fine-scale monitoring** of actual distributions at suitable sites**.** Such sites would require adequate space for species to migrate into, and consistent land management.

2.2. Where are biome shifts occurring or likely to occur?

• Both retrospective (e.g. analysis of aerial photographs) and modelling approaches are needed to identify where shifts are starting to occur, or are likely to occur first. The conversion of grassland to forests, mesic savanna or thicket in the upper parts of the Escarpment is the most likely shift to occur first in the focus area.
• Again, long-term monitoring at appropriate sites would be needed, both for demonstration and testing of model predictions.
• A related question is **what will be the impacts of these shifts on ecosystem services**, such as freshwater production?

2.3. Could local-scale management actions prevent species or biomes shifts?

• Can local management actions mitigate some of the negative impacts of climate change, e.g **could more frequent or more intense fires prevent the conversion of grassland to thicket or forest?**

Key beneficiaries
• SANBI and conservation agencies (particularly MTPA and LEDET).
• Water resource managers
• Rural communities where species that currently contribute to livelihoods may become locally extinct.

Relevance to legislation
NEMA (NEMBA), National Veld and Forest Fire Act (and Fire Protection Agency rules and guidelines).

Science collaborations
<u>Actual</u>
Bob Scholes (WITS), Michele Greave (University of Pretoria), Martin Potgieter (University of Limpopo), Ed Witkowski (WITS) and Barend Erasmus (WITS), and six MSc students supervised by them.
<u>Potential</u>
Various research groups working in the Soutpansberg, including Stefan Foord and Peter Taylor (University of Venda).

The Avian Demography Unit of the University of Cape Town.

Competitors

While the effect of climate change on species ranges is being studied extensively throughout the world, there is little of this type of research done in Africa. A few research groups are studying altitudinal distribution limits in South Africa, including Mark Robertson (WITS) and Nigel Barker (Rhodes University).

SANBI has previously conducted research of this nature, although is not currently active in the geographical region of the node.

Opportunities for attracting more collaborators

Good base-line data for species that are expected to shift their distribution soon should attract academic researchers, who could use that data to model expected changes or even directly demonstrate distributional shifts in the near future. Similarly, the identification of species that would have large implications for society if their ranges shifted would attract researchers to conduct the required auto-ecological research on those species.

Opportunities for cross-nodal collaboration

Similar changes are expected, if not already occurring, in the mountains near the GWF and Fynbos Nodes. While some similar work is already underway there, assessment of species and predictions of where in the country changes will occur first, or where distributional shifts would have the greatest consequences, would allow for more efficient research (in terms of species and site selections). Thus an opportunity exists for a national assessment, and thereafter standardized base-line studies across relevant nodes.

In principle, the same questions could be applied to ocean species responding to changes in water temperature. Similar work is already being done by the Elwandle Node, for the southern and eastern coasts. Collaboration could be useful on modelling methods, and perhaps synthesis papers that investigate commonalities in the types of species that are sensitive to climate / ocean temperature changes across a very broad range of taxa.

Theme 3. The ecology and hydrology of savanna rivers

Relevance

Almost all the rivers of the focal area, and the country, have been highly modified by human activities. While the Department of Water Affairs has reasonable data indicating how flow rates have been reduced for perennial rivers, little is known regarding the seasonal and ephemeral rivers. Knowledge on the impacts on biodiversity is rudimentary and mostly anecdotal. Furthermore, little is known of how land cover in catchments affects flow rates, other than the effect of afforestation in the source areas of the Escarpment. Although very applied, these questions are relevant to most rivers around the world, and addressing them could produce novel results.

Key questions

3.1. What is the current state of biodiversity of the major rivers, and is it stable or changing?

• National scale monitoring programs were not designed to address this question. Consequently, their data are lacking in terms of number of sites, frequency of sampling and the range of taxa sampled
• A related, more applied question is: **how should rivers be sampled** in order to detect trends in aquatic biodiversity?
• Research might also capture the effects of more extreme **droughts and floods** – predicted with global climate change – on aquatic biodiversity.
• Both **aquatic and riparian** ecosystems are included.

3.2. What is the effect of altered river flows and water quality on aquatic biodiversity?

• This follows from question 3.1 - if biodiversity is changing, what are the **causes**?
• What are the relative impacts of current sources of altered flows and pollutions, specifically:
  - Dams, and dam release management.
  - Eutrophication, primarily from discharge of untreated sewerage and in some cases. from leaching of fertilizers from agricultural lands.
  - Contamination by heavy metals, primarily from mining activities.
  - Contamination by organic pollutants, from agriculture and urban areas.

3.3. What is the effect of aquatic biodiversity on water quality?

• This relates to the value of the ecosystem services provided by rivers that are lightly impacted. To what degree are relatively pristine rivers able to **ameliorate** the effects of pollution by assimilating or transforming contaminants?

3.4. How does land use affect the hydrology of rivers in areas downstream of source catchments?

• As rivers flow down from mountains and into the semi-arid and arid areas, do they continue to gain water from their environment, or **lose** water?
• Does **land use**, and the associated changes in vegetation structure and productivity, affect gains or losses? (this links to key question 1.2)

Key beneficiaries

- The Department of Water Affairs and Sanitation, and Catchment Management Authorities, as many of the results will inform strategies needed to sustain or improve the supply of clean water for society.
- SANBI
- Water users downstream of source catchments.
- NPOs working on river management issues.

Relevance to legislation

Legislation relating to the management of rivers (the Water Act) and biodiversity (NEMA: NEMBA)

Science collaborations

Actual

Abe Addo-Bediako, Kris Bal and Sean Marr (University of Limpopo), Stefan Grab (WITS) and 1 MSc student, Eddie Riddel, Hendrik Sithole and Robin Petersen (Scientific Services, SANParks), Jaco Nel and Caren Jarmain (consultants), Sharon Pollard (AWARD - an NPO)

Potential

Helen Barber-James (Albany Museum & Rhodes University), Olaf Weyl (SAIAB), other freshwater scientists, particularly at North-West University.

Competitors

Similar research is being done in the developed world and other parts of South Africa, although little is being done in the focal area.

Opportunities for attracting more collaborators

Due to the developing water crisis in South Africa, there is an abundance of interest in freshwater ecology, both within and outside of the country. Inventories of biota at established research sites, long-term data on their abundances and technical capacity to identify aquatic biota will attract academic researchers.

While this research would be of interest to the Department of Water Affairs and Sanitation, they are unlikely to collaborate or fund it, as it is not directly relevant to their mandate.

Opportunities for cross-nodal collaboration

The issues that underpin this theme occur throughout the country. Research designs needed to study these are simple, and a number of standardized methods exist, making the replication of this work at other Nodes relatively easy. While fairly scarce species-identification skills are required, the Ndlovu Node river technician could conduct sampling at additional sites for other Nodes, or train technicians based at other Nodes.

A more ambitious, broader project that aims to link changes in rivers to changes in estuaries and near-shore marine processes would be unique in South Africa (and perhaps in the world) and would produce novel results.