

SAEON Grasslands-Forests- Wetlands Node Science Plan: 2016 – 2018

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“South Africa is committed to addressing climate change based on science and equity”

2015, COP21 SA's Intended Nationally Determined Contribution pledge

Introduction and context

The South African temperate grassland biome covers approximately one third of the land area of South Africa. It is arguably the most important biome for the country's economy. This is because of its size in combination with essential services we get from healthy grasslands. Water is one of the most potentially limiting factors for economic growth in South Africa. Grasslands are the major vegetation cover of the primary water-producing mountain catchment areas in summer rainfall regions. While not restricted to them, wetlands occur in high association with these grasslands, providing additional service benefits. Wetlands are often described as the “kidneys of the landscape”. They are known to regulate river flow, clean polluted water, mitigate against floods, provide base flow in dry times, recharge groundwater aquifers, trap sediments and provide habitat for various biota including a number of rare bird species. This highlights their importance linked to water resources management and their intrinsic value as ecological infrastructure assets in the landscape. There is consequently a significant degree of overlap in South Africa's strategic water production areas and the grassland-wetland mosaic. The grassland biome also provides natural forage, contributing significantly to dairy, beef and wool industries, as well as subsistence livestock production and game ranching activities. It is diverse and rich in natural resources traditionally used sustainably for subsistence. More recently their potential importance in carbon mitigation strategies has emerged. Healthy grasslands hold a significant proportion of the country's soil carbon pool, due to relatively high percentages of carbon within the soils in combination with the extent of the system. Wetlands are also very important for carbon storage. While not extensive in area, they are significantly more effective in carbon storage compared to adjacent “dryland” systems. Depending on how the wetland grassland mosaic is managed or transformed, these systems may potentially be either significant sinks for or sources of carbon.

*“Over 60% of the national terrestrial carbon stock is located in grassland and savanna ecosystems. Within these two ecosystems, more than 90% of the total carbon pool is located below ground mainly in the form of soil organic carbon”
(Synopsis Report: South African Carbon Sink Assessment, 2014)*

Extractive and transformative use activities within the biome also contribute to the economy. The majority of commercial forestry plantations, a significant proportion of the country's commercial and subsistence crop production as well as close to half the mining activities in the country take place within the biome. These activities as well as urbanization have resulted in over 30% of the Grassland biome being

permanently transformed and over 7% badly degraded. Only 2% of the grassland biome is formally protected. The expansion of mining, forestry, cultivation and urbanisation are considered immediate threats to grasslands and consequently the ecosystem services they provide to society. In addition, the direct and indirect impacts of climate change on this biome are predicted to be significant.

Indigenous forest is the smallest biome in South Africa, occupying approximately 0.3 % of the land area. South African forests are naturally patchy, having a discontinuous distribution, scattered across the eastern and southern margins of the country, with a high diversity of vegetation units. South African indigenous forests play a minimal role as carbon sinks due to their limited extent. Climate models that exclude fire, predict a much larger extent of forests in South Africa, including within the grassland biome, reflecting a potential alternate state to grasslands. There is a northern hemisphere-driven emphasis on the importance of reforestation programs for carbon sequestration. Some of these incorrectly classify South African grasslands as “degraded”, and promote afforestation of these systems. However, the relative impacts of albedo changes linked to land use change and carbon sequestration in African systems are unknown. Studies elsewhere indicate that albedo feedbacks can be more influential than carbon sequestration gains in influencing global warming. Furthermore using forests for carbon sequestration in African systems may be misplaced, given the high frequency of fires in these systems and the potential for increased fire storms to burn forest patches. This points to the need of assessing the “net effect” implications of climate and land use change on interactions between biological feedbacks and local, regional and global energy, carbon and water dynamics. Local effects may be differentially detrimental or positive compared to regional and global effects.

Notably, South African temperate grasslands are considered relatively old (i.e. they are not “degraded” secondary grasslands). The biome is dominated by C4 grasses which expanded globally in the Miocene. Pollen records show that open grasslands in the moist regions of southern Africa were well established early in the Holocene. Levels of diversity and endemism in grasslands are high, (second only to the fynbos biome) with several plant centres of endemism, including endemic-rich C3 dominated grasslands at higher altitudes. The biome also has relatively high faunal endemism and hosts 55 of 122 important bird areas recognised in the country. Unlike savannas, temperate grasslands are rare elsewhere in Africa.

The distribution of temperate grasslands can be largely explained by a combination of summer rainfall, minimum temperatures in winter and fire. Lightning strikes are common in grassland areas and considered the natural agent for starting fires. Fire is the key agent attributed to keeping forests out of grasslands at high altitudes. Grasslands and savannas share a large portion of their boundary with each other. Fire and summer rainfall are characteristic of both systems. Grasslands are thought to become distinct from savannas as a result of cooler winter temperatures (and fire)

and more mesic summers at higher elevation. Changes in CO₂ concentration, temperature, precipitation and fire regimes are predicted to have a dramatic effect on the grassland biome. Increases in temperature, for example, will make it possible for frost sensitive species to encroach into grasslands. A combination of land use impacts and increased CO₂ may further facilitate the rate and extent of this expansion of trees into the grassland biome. However, because of uncertainty around changes in precipitation and poorly understood ecological and earth system feedbacks, there is still uncertainty about how changes may manifest and what the net impacts will be on the services grasslands have traditionally provided. It is of major importance to understand how global change may impact these systems. Information is needed to guide the appropriate protection of critical water sources, while concurrently guiding sustainable development coupled with appropriate land care programs.

Studying mosaics of C3-C4 grasslands, wetlands and forests, provides an opportunity to understand past and future drivers of vegetation change with respect to grasslands. The boundary zone between the grassland and savanna biomes offers further opportunity in this regard with respect to broader scale biome changes within the country. Multiple land use impacts within such areas would allow for an assessment of the relative impacts of global change on the services these systems provide. Outputs would provide a basis for informing sustainable development strategies and building resilience for the country. Given its size, it is also important to understand the potential contribution of the grassland biome for mitigating global change impacts under different land use/climate change scenarios. There is a growing need to understand the feedbacks between land use, vegetation, biological processes and soils on carbon, water and earth system processes. A key question is to understand under what circumstance do these interactions moderate or amplify net global change impacts.

In summary, grasslands and the embedded mosaic of forests and wetlands within them, provide vital services to society. Change drivers include land use change, land cover change, climate change, changes in disturbance regime (fire and grazing) and possible CO₂ impacts. Long term observation and research is required to determine the magnitudes of anthropogenic and environmental changes in these systems and the key mechanisms by which they are induced. In addition the implications of different land use and land cover for climate change trajectories need to be determined. Research outputs may be used to inform optimal land use for sustainable development. A guiding question here is what is the optimal development strategy for land use in South Africa that will reduce regional and global temperature increases.

Themes and approach

Global change is likely to impact on the services provided by grasslands, wetlands and forests, and consequently the communities reliant on them and the economy of the country. SAEON's mandate is to detect change resulting from anthropogenic forcing. The science activities we undertake are guided by SAEON's Core Science Framework. The approach adopted is to measure responses to a specific set of drivers linked to human activity. Within this context, science activities at the Grasslands-Forest-Wetlands Node aim to be policy relevant, and need to address how global change is impacting on key services provided by these ecosystems.

The GFW node has thus structured its science activities for the next five years centered on the following four themes representing key services of ecological and economic value;

1. Water delivery
2. Carbon dynamics
3. Biodiversity
4. Land use-biological feedbacks with earth system processes.

South Africa is a water scarce country. There is concern about both the quantity and quality of water resources across the country. Pressure on water resources is increasing and demand is likely to outstrip supply. Managing carbon in landscapes is considered a priority field of investigation by government with respect to climate change mitigation and adaptation strategies, yet little information is available regarding the carbon cycle in these systems. Biodiversity provides resilience and services to society. The relative impacts of land use as well as direct and indirect impacts of climate change on biodiversity patterns are uncertain. Leading on from this, very little is known about the potential role of landuse-landcover change and biological feedbacks on earth system processes (e.g. changes in carbon cycling or radiative forcing with changes in landuse, climate and vegetation). The aim is thus to understand how global change will impact on the ecosystem and the consequences of this for society, by determining the moderating or amplifying interactions under different land-use, land-cover and climate change scenarios.

The four themes are interlinked and our platforms are specifically structured to enable understanding them in an integrated manner. This is achieved by co-locating the long term observation activities of each theme. A consistent research approach is applied that includes detailed long term observation and process level research at benchmark sites, complemented by work at satellite sites that represent contrasting land use and land cover situations. These include degraded sites relative to the benchmark, alternative land use states as well as restored sites. The intention is to understand the patterns, processes and services of benchmark sites, what services

might be lost (or gained) under global change, or land degradation, and whether or not vital ecosystem services that have been lost can be regained through restoration. Two systems, representing opposite extremes of the elevation gradient, have been selected on which to develop co-located long term monitoring and research activities to support the four themes. Both are classified as “Strategically Important Water Source areas” for South Africa. They are:

- 1) The uKhahlamba Drakensberg, the “water tower” of the country. The core benchmark site is centered at the Cathedral Peak research catchments. The area is predominantly grassland, interspersed with forest patches and wetlands. The site represents mid to high altitude headwater catchments. Despite their importance for water delivery, active monitoring and research in such high altitude areas is scarce. The value of the site lies in the fact that historically it was a forestry research station. As a result, it has a rich data legacy including long term streamflow, weather and rainfall records. Monitoring, however, ceased in the mid 1990’s and was resumed by SAEON in 2012/13. The core site is within a protected area enabling researchers to look at change detections specifically with respect to climate. Treatments (pristine grassland, degraded and fire protected catchments) within the site as well as in the surrounding landscape provide opportunities for assessing multiple land use impacts including rural farming and land degradation in the Upper Thukela catchment and restoration initiatives. Lower altitudinal sites within the area adjoin the savanna biome. Additional sites providing complimentary opportunities to look at the impacts of land-use/land-cover change include Baynesfield agricultural farm and the Two Streams forestry research site.
- 2) The Maputaland coastal plain from Mapelane to just south of Khozi Bay. This is a groundwater driven system adjacent to the sea (low altitude site). There are multiple land use impacts and cumulative impacts on water systems emanating from the contributing catchments. It is predominantly a wetland system within a grassland forest mosaic. Within the area there are high levels of poverty, with few opportunities for economic activity. It is currently a very water stressed area, with multiple demands on the groundwater resource. Parts of the system are protected in conservation areas, whereas others are undergoing rapid transformation. There is increasing pressure for expanding commercial forestry in the area. Good baseline groundwater data exist for various sites within the broader study area, including within the iSimangaliso Wetland Park. Detailed studies on the hydrodynamics and diversity have been undertaken by other researchers in sub-catchments in the area, for example Mgobozeleni, that SAEON can build on to assess longer term trends. While the focus in the next five years is understanding sub-catchment dynamics and fine scale processes, the ultimate long term vision for this area is to gain a

better understanding of the regional groundwater/surface water/land use/climate interaction.

For each theme the research process applied involves:

1. **Characterizing the key components** of each of the themes (survey and observation). This information will quantify parameters and their characteristics and provide the baseline for assessing trends over time and parameterising models (e.g. the ACRU hydrological model and Dynamic Global Vegetation Models (DGVM's)).
2. **Process level research** into how these key components interact. Building on the data from survey and monitoring, this level looks at more in-depth process level research into the linkages and feedbacks among the components in each theme. It is intended to stimulate integrative research that will be the basis for developing and improving integrated/coupled process based models, linking vegetation (biodiversity), hydrology and earth system processes E.g. Dynamic Soil Vegetation Atmosphere Transfer models (DSVAT's) through understanding system dynamics.
3. **Determining the current impacts** of global change on the key components of each theme (change detection). This level is aimed at stimulating research on change detection to provide the information required for modelling the impacts of global change on the four themes and refining our understanding of process interactions and dynamics among these in a changing world.

This approach is encapsulated in Figure 1 developed for the water theme. It also highlights the commitment and importance of capacity building in all activities that will be undertaken.

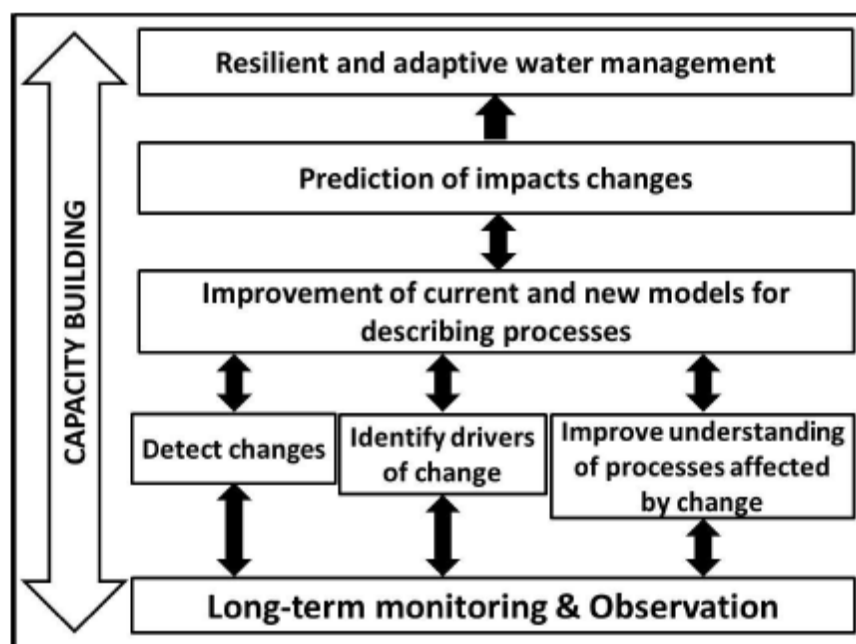


Figure 1 Long term monitoring as the foundation for improved understanding and the facilitation of resilient water management, from Warburton 2016, with permission.

An integrated model, encompassing outputs of all 4 themes, to determine the net effect of alternative scenarios of land use-land cover and climate change (scenario modeling) on earth system processes essentially forms a 5th theme. Here the intention is to explore the net consequences of anthropogenic forcing on earth system - ecosystem functioning and the associated services they provide under a range of alternative scenario trajectories. This will not be achieved conclusively within the next five years but it provides the guiding vision of the platform, from which to structure long term monitoring and research activities. This document outlines the science activities towards achieving this that will be undertaken over the next five years

Theme 1: Global change impacts on water delivery

Key question motivating theme: What are the relative impacts of climate and landuse changes on water delivery, with respect to quantity and quality of water?

While there is relative confidence around predictions relating to increased temperature, there is still significant uncertainty around the impact of global change on South Africa's water delivery potential. This is partly due the fact that a large number of processes interact, often in complex ways, influencing rainfall and the translation of this into water reserves. Understanding the patterns, processes and functional linkages governing hydrology in strategic water source areas is crucial for the country. Determining the relative land use impacts and climate change impacts and how these interact remains a key challenge. To achieve this understanding, long-term monitoring combined with process level research is essential to detect changes and reduce uncertainty. It is also important to assess what positive impacts can be detected. Recognizing the importance of ecological infrastructure and ecosystem services, restoration programs are a key feature of government's adaptation and mitigation strategy as a means of enhancing resilience for the country. Significant investment is being made into these programs. How effective are these interventions in winning back lost services and what interventions work best?

In Cathedral Peak we aim to address the following in the next five years.

- a. "What's up with the weather?" ***Is it getting hotter? Is rainfall changing? Are our seasons changing?*** Long-term data will be used to address these change detection questions for our high altitude catchments: The aims are: to extend the historic weather and rainfall records; investigate rainfall pattern in relation to topography; use this to in-fill data gaps (there was a hiatus in

monitoring from 1990-2012) and analyse infilled rainfall records for change detection. Historical versus current temperature records will also be analysed for directional trends and changes with respect to seasonal patterns. Detailed climatological analysis are beyond the capacity of the node, however data collected will be of value to experts interested in climatological analysis. Additional benefits of this work will include calibration studies between historic and current instruments.

- b. “Where has all the water gone?” **Can we detect changes in the hydrology of the catchments since the 1940’s? If so, what can these be attributed to? What are the implications for changes in hydrological processes for water delivery?** Activities will be centered on: extending the historical streamflow record; in-filling data gaps for the period when no monitoring took place and undertaking analysis to detect changes in streamflow. Process-level research will be undertaken to determine the mechanisms moderating or amplifying changes in hydrological cycle. This will include investigating the different components of the water balance and how these interact with soils, vegetation communities, land use and weather. Such information will lead to the improvement of existing and new process-based models both in the description of processes and parameterization of the models.
- c. “Can I drink that?” **What are the human induced global change impacts on water quality?**
 - i. Can we detect atmospheric pollutants (Sulphur and nitrogen deposition) as well as DOC fluxes in pristine catchments? This acts as a benchmark for other sites impacted additionally by land use. (collaborative project with WITS)
 - ii. How does land use and land cover impact on erosion and sediment loads. This will be assessed in different treatments within the catchments as well as satellite sites reflecting different land uses and levels of degradation (collaborative project with UKZN)
- d. “Putting it together”. **What are the impacts of land use on water flow?** Here the hydrology of various land use/land cover systems will be assessed holistically. The relative impact of land use to any changes detected in weather patterns will be analysed. A component of this includes redefining the baseline reference for all vegetation units with respect to streamflow reduction activities. This project forms the basis of the PDP postdoctoral work undertaken by Dr Michelle Warburton. The work will extend well beyond the Cathedral Peak area. Drawing on advances made on the process-based models, the impacts of change can be further explored thereby providing improved information and understanding to ensure resilient and adaptive management of water resources.
- e. “Should we invest?” **How effective is restoration in improving hydrological processes in previously degraded areas?** In addition, areas where restoration work has taken place (Okhombe) will be compared with benchmark and non-restored degraded areas. Outputs will be used to

determine the returns on investment of restoration projects on water flow and water quality.

It should be noted that while we may produce trends within the next five years, as the current record is extended, outputs addressing change detection will become more robust.

In the Maputaland study area we will investigate the relative impact of rainfall versus land use on the groundwater level of the system. Specifically:

- a. **What is the relationship between rainfall and recharge rate in the sandy aquifer?** Fine scale data is required to understand the recharge dynamics in relation to rainfall within this system. This may vary depending on land use and position in landscape. This question will be explored in restored (eastern shores) , pristine and plantation scenarios (western shores and Vazi).
- b. **What are the transpiration rates of indigenous versus alien plantation species?** The relative impact of different land uses on the ground water dynamics within this system is a contentious and politically sensitive issue. Forestry plantations are considered by some to have a significant impact on the groundwater resource. However, there is insufficient data to adequately inform water user licence processes regarding this. The aim is to provide evidence based data regarding the relative impact of different vegetation communities, on groundwater dynamics.
- c. **What is the relative impact of climate versus land use on groundwater level?** Ground water levels in the Maputaland areas have been dropping over the last decade. Attributing the cause of this to the relative contribution of changes in land use, prevailing climate (extended drought) and possible climatic changes is not well understood.
- d. **Where are the wetlands?** This study will focus on understanding soil moisture dynamics and using this to delineate wetlands and margins for commercial forestry planting using the Cosmic Ray Rover System. Good wetland delineation is important for informing spatial planning with respect to where plantations boundary limits should be in relation to wetlands as per legislation.
- e. **What should we “plant”?** Here we investigate whether we optimize commercial and indigenous systems to secure the groundwater resource without compromising economic and ecological benefits. The aim is to explore the optimum agroforestry- forestry production system within the mosaic of grasslands, wetland, forest that does not irreversibly compromise the groundwater resource.
- f. **What is the interaction between surface water and groundwater?** Using all the information above, ultimately we would like to advance regional models that interlink surface and groundwater systems, to understand their influence on each other at the regional scale, and under different land use- climate

trajectories. This work will be initiated towards the latter part of the next five years.

Theme 2: Carbon dynamics in a changing world

Key question motivating theme: What are the consequences of global change on the regional carbon cycle?

The carbon cycle is a biogeochemical process interlinking biotic components with climate systems. Changes in the carbon cycle are therefore likely to impact on both climate systems and biological processes independently as well as the interaction between them. Indeed human induced carbon emissions are the primary cause attributed to contemporary climate change, however the impacts on biological processes are less clear.

At the regional scale the carbon cycle influences a number of biophysical processes. These differ across ecosystems. Characterising ecosystem specific carbon dynamics is valuable for a range of applications including improving regional hydrology and vegetation models as well as global carbon models. It also provides an indication of whether a system is a net source or sink of carbon and one can explore how land use or land cover change may affect this balance. The largest proportion of the carbon pool in grasslands is in the soils. Understanding soil carbon pools and processes governing these and how these translate to atmospheric fluxes is important in resolving the carbon balance as well as understanding the consequences of land use or land cover change on these stocks and fluxes. Within this theme we will be addressing the following questions within the next five years:

- a. **Are mesic fire climax grasslands a net source or sink of carbon?** Here soil carbon stocks will be evaluated and characterised (French-SA collaboration), the full carbon balance of catchment 6 (a pristine fire climax grassland) will be determined using a combination of eddy covariance and soil respiration data. This will be characterised in relation to time since burn, season and phenology over a two year period. The project is structured to measure net ecosystem exchange, based on *in situ* measurements, to determine if grasslands are a net source or sink of carbon over time in relation to average burning frequencies (SAEON PhD SJvR-CE). Outputs will help parameterise and validate models. Complimenting this, a study is planned to assess the effect of different burning regimes on soil carbon stocks and respiration using the 30 year old Brotherton Plots (SJVR, CE and GFW Interns).
- b. **What are the consequences of changes in temperature (and soil moisture?) on soil respiration?** Soil carbon pools in grasslands are significant. Changes in cycling rates of these stocks are therefore likely to have significant effects on the regional carbon balance. Warming chambers

will be used (over a moisture gradient) to determine how predicted increases in temperature may alter cycling rates of carbon in the system via soil respiration. This directly addresses potential shifts in seasonality and phenology that may result from changes in the temperature regime for these high altitude catchments. (SAEON PhD SJvR-CE with EMU MteB)

- c. **What are the consequences of potential future alternative vegetation states on the regional carbon balance?** Experimental treatments historically applied as well as the natural mosaic of vegetation units within the Cathedral Peak area will allow us to determine soil respiration in alternative vegetation states in the landscape (degraded catchments, fire protected, and forest systems). It is also planned to test the impact of warming on soil respiration in each of these vegetation units. (SAEON PhD SJvR, CE, with French collaborators)
- d. **What is the impact of land use change on the carbon balance?** Collaborative research with UKZN and French colleagues is underway assessing carbon dynamics in different land uses. We will contribute to this work by assessing respiration in degraded versus restored grasslands in community areas (OKhombe). Outputs will assist in determining the impact and value of restoration on carbon dynamics in the system.
- e. **Productivity of different land uses: GOEGLAM: RAPP.** Partnering with SANSA and RAPP, the aim is to use a combination of remote sensing and *in situ* measurements to understand rangeland productivity in a changing climate in the greater area.

In Maputaland

- f. **How does soil respiration differ between alien plantations, coastal grassland, indigenous coastal forest and encroaching indigenous thicket?** Point measurements will be taken to determine relative differences in summer and winter. As this project advances, we will develop it further to incorporate all the elements being addressed within the Cathedral Peak sites.

Theme 3: Global change impacts on biodiversity?

Key question motivating theme: What are the natural patterns of biodiversity and how are global change drivers influencing these patterns?

Grasslands are diverse and as outlined above, support and provide numerous ecosystem services that are of benefit to society. There are a number of changes predicted for grasslands in relation to global change. These include:

- a. Changes in the vegetation community assemblages, within as well as at the boundary of the grassland biome as a result of the ingress of C3 and savanna elements, and possibly the ingress of grassland into the Nama Karoo, mainly as a consequence of CO₂ loading, climate change, alteration of fire regimes, land use and management.

- b. Faunal and floral species shifts in response to warming
- c. Radical habitat transformation to make way for development infrastructure and agriculture with a consequent loss in the services provided by these systems

Over the next five years activities will focus on determining the following:

- a. **What are the climatic envelopes of plant species and communities in the Drakensberg?** (SAEON PDP NH-TOC) All available vegetation data will be consolidated into one database. This will be used to analyse and assess distributions in relation to physical parameters. Outputs from this will be used to inform a long-term vegetation monitoring program across land uses and up the altitudinal gradient
- b. **Can directional change trends be detected in plant species in the Drakensberg, despite land use/treatment?** This work relies on follow up studies repeating various historical plant surveys (including Thomlinson, Granger, Everson and Everson and others). (SAEON PG PHD, TS MSc-TOC). Plot locations and activities are such that outputs will also necessitate and include analysis on the impact of land use on plant communities, as well as detect potential encroachment from the savanna boundary.
- c. **What are the impacts of different fire regimes on plant and microbial communities in the Drakensberg?** (SAEON PG PhD-TOC; SAEON SJvR and GM from RU)
- d. **What is the historic and current distribution of C3 and C4 grass species in the berg and how is this likely to change?** (local scale SJvR, regional scale: LB and TOC, CA (SANSA) and UM (UKZN)- remote sensing)
- e. **Are ant assemblages responding to changes in temperature with altitude?** Annual data is collected at three altitudes each year. Data from theme 1 will be used to assess temperature trends. Trends in the ant assemblages themselves may not be evident within the next five years but the work forms a component of what is being undertaken in the field to build a long-term dataset (SAEON SJvR- UP)
- f. **What changes occur in the vegetation on the Maputaland plains, and what drives these?** (AS, CE, TOC and others).

Theme 4: Land use-biological feedbacks to earth system processes

Key question motivating theme: What are the potential land use-biological feedbacks with earth system processes and how might these change with global change?

Earth system processes include interacting chemical, biological and physical components. Research into quantifying these parameters in different ecosystems and determining how they interact assists in improving regional and global models. Such models are aimed at understanding how climate change will impact on earth

system processes and vice versa. Determining the impact of changes in land use and land cover on these interactions is an important contribution to parameterizing and validating models to enable scenario projects under different land use/land cover climate scenarios. A big unknown is to what extent land use and land cover change will amplify or moderate regional and global climate change impacts, where tipping points in cycles such as the carbon cycle may occur, how strong relative feedbacks may be and what thresholds might be reached as systems change. Focus areas in this theme for the next five years will be on the following.

- a. **What is the energy-carbon-water balance in Cathedral Peak?** Drawing on work outlined above, as well as additional measurements on energy and soil moisture, a carbon energy water balance will be characterized for Cathedral peak for Catchment 6 which is representative of C4 grassland for this high altitude catchments. This data will provide a benchmark from which to compare the impact and interaction of alternative land use/land cover changes in grasslands and these physical parameters. (SAEON-CE). For example the impact of radiation on different mountain slopes and how this affects vegetation will be explored in pristine, degraded and fire protected catchments.
- b. **What would be the consequences of a shift in vegetation communities on the water –carbon-energy balance?** In particular we will be exploring:
 - i. The impacts of a change in dominance from C4 to C3 grasses, as well as the consequences of woody thickening on the water balance in Cathedral peak. This work necessitates determining key vegetation traits and Eco-physiological characteristics routinely used in dynamic vegetation and hydrological models (including transpiration of C3 and C4 plants growing together and also whole swards dominated by *Festuca/Merxmuellera* versus *Themeda*). Optimal use will be made of the warming chambers outlined in theme 2 to also assess eco-physiological responses of different plant functional types in a warmer world. (SAEON – SJvR CE, GM).
 - ii. The same questions will be addressed on the Maputaland site where the impact on indigenous versus commercial woody encroachment into the coastal grasslands and wetland sites on the ground water resource will be determined. The approach here will be explore differences in transpiration rates of different tree species and consequences for groundwater. This draws on the analysis of rainfall patterns and groundwater dynamics covered in theme 1 above.
- c. **What is the impact of landuse-landcover on albedo and consequently regional energy balance?** This will be done at high resolution at local scales within the two key study sites; Cathedral Peak and the Maputaland coastal plain, using *in situ* measurements. Different land uses and vegetation units will be assessed (SAEON-SjVR CE, and EMU- MtB). At the landscape scale, land cover change and remote sensing products will be used to determine

consequences of change at regional scales (EMU-MtB, EKZNW, UKZN with assistance from SAEON).

Collectively this work, in combination with outputs from themes 1, 2, and 3 will make a key contribution towards the long term vision of the node: determining the net effect on earth system processes of different land uses and land cover changes under different climate scenarios. There is a paucity of data from natural systems of many of the parameters that will be measured. Models often revert to using crop standards and proxies and this does not necessarily accurately represent non-crop systems. Outputs from this work will enable improved process-based models to be developed and parameterized. It will also allow hydrological, carbon and vegetation modeling, and ultimately facilitate the integration between these and climate models.

Of particular relevance is the role ecosystems can or may play in mitigating human impacts as well as understanding their relative resilience and adaptation characteristics under natural and modified scenarios. Contextualizing information on changes in ecosystem functioning in relation to ecosystem services, resilience, adaptation and mitigation potential provides a workable framework for influencing policy. Ideally outputs could be used to optimize land use and land management policies for resilience and mitigation.

Opportunities for developing research platforms which could attract science collaborators

Effort should be focused within selected priority catchments (strategic water source areas), adopting a catchment-to-coast model, where, in transformed catchments, cumulative impacts on systems can be explored, and in relatively pristine catchments, consequences of change modeled. Criteria for selecting catchments include; economic importance linked to service provisioning, potential and actual demand pressure and/or potential for transformation, the representation of grasslands forests and wetlands mosaics within catchments, pre-existing data sets to build on and the potential for linking cross-nodal efforts dovetailing across terrestrial and marine systems (estuaries, nearshore and marine observation efforts). It thus follows that site selection should take cognisance of the national development goals and strategic research infrastructure proposals (e.g. SIPS). Once catchments have been selected, focal sites should be set up for detailed observation and process level research within natural/protected sites within the catchments. This provides a benchmark for ecosystem functioning. Linked to focal sites, complementary observations structured along altitudinal and land use gradients within the catchments, that are aimed at assessing ecosystem patterns, shifts and boundary dynamics as well as assessing the ecosystem services lost through degradation/ change and possibility of regaining these (restoration initiatives). Many other institutions are assessing land use transformation. We would not duplicate

effort here but rather, using their products, focus on consequences of land use change.

Recommendation 1: An integrated catchment observation program centered on understanding ecosystem services provided by natural areas and cumulative impacts of climate and land use on the St Lucia wetland system, incorporating all five inflowing catchments (Mfolozi, Nyalazi, Hluhluwe, Mkuze, Mphati). River systems flow through different land use types and protected areas before culminating within the St. Lucia estuary system

- Focal sites within protected areas assessing climate diversity, carbon energy water dynamics in natural systems combined with assessing the protected areas services e.g. cleaning water, carbon storage etc)
- Compliment focal site observations with discrete question driven research and observation when necessary, employing experimental techniques and manipulation were appropriate.
 - Extend critical components of the focal site observations to satellite sites within the catchment, along altitudinal, land use and environmental gradients. (e.g. simple rainfall wind stations as opposed to fully automated weather stations)
 - Add complementary data collection to enable assessments of the extent, dynamics (shifts) and integrity of communities, ecosystems and landscape-level relations (Exploring boundary patterns and processes between ecosystems across land use and environmental gradients).
- Cross-Boundary patterns and processes explored (across biomes and large scale biological-earth-system interfaces).

Relevant legislation, that the science will help serve

1 Legislation

1. SPLUMA: Spatial Planning and Land Use Management Act, August 2013 (potentially most effective insertion point)
2. National Climate Change Response White Paper, October 2011
3. Carbon Tax Policy Paper, May 2013/ Nov 2015- for comment
4. National Development plan 2030
5. RAMSAR convention (reporting on states of RAMSAR wetland sites)
6. Forestry 2030 Roadmap (Forestry Strategy 2009-2030) (monitoring threats).
7. National Environmental Management: Biodiversity Act 2004 (Act No. 10 Of 2004)
 - a. National list of ecosystems that are threatened and in need of protection Insertion point for policy and listed sites can guide site selection for future studies)
8. Department Of Environmental Affairs National Environmental Management: Protected Areas Act, 2003 (Act No. 57 Of 2003)

9. The South African National Infrastructure Plan, <http://www.gov.za/issues/national-infrastructure-plan>

2 Key initiatives and alignment opportunities to keep in mind that we could contribute to with respect to data and or reporting

1. COP21 Emissions reduction pledge
2. COP21 Water pledge (SA not signed but may consider doing so in future)?
3. South Africa's: National Climate Change Adaptation Strategy and Plan
4. South African carbon atlas (DEA, we will contribute data to improve model outputs)
5. Sustainable development goals (contribute to setting up indices and reports)
6. Millennium development goals Superseded by SDG's
 - a. Outcome 10: Protected and enhanced environmental assets and natural resources
 - b. Suboutput 4.4 • **Valuing ecosystem services** • 4.4.1 Environmental costs related to the provision of resource based services • (a)Number of tools developed for the economic valuing of ecosystem services
7. National Freshwater priority areas / strategic water source areas(site alignment)
8. National System of innovation (contribute and report to)
9. Carbon mitigation strategy (we can align and provide key data)
10. Bio-economy road map
11. WRC TOR project: A National Water R&D and Innovation Roadmap for South Africa
12. Valuing Natural Capital A Government Perspective Current Policy Approaches and Priorities, February 2014.
13. The South African Coal Roadmap, 2013 (Industry driven not government) (Monitor threats/ potential land use pressure shifts)
14. IPBES
15. IPCC
16. SIPS program linked to NDP (Monitor potential land use change, threats, and possibly provide data to guide)

Collaborations

1 Current collaborations

- WITS (Prof Chris Curtis)
- UKZN (T Hill, J Finch Alistair Clulow, Oni Matango)Jewitt?
- UP (M Robertson) + Plant Production and Soil Science (they own LAS, CRP through RISP and will manage the Vasi contract with WRC)
- UFS (E Sieben)
- DARD (C Botha)

- IRD (V Chaplot)
- UMR CNRS BIOGEOSCIENCES, Université de Bourgogne, Dijon. (Olivier Mathieu, Jean Leveque, Mathieu Thevenot)
- UCT (PCU) (T. Hoffman)
- DEA: Natural Resource Management (NRM)
- Umea, Sweden (J Cromsigt, M te beest)
- (Water Research Commission)
- DWS, regional and national
- EKZNW (D Mabunda)
- Ground truth (M Graham)
- Mondi (B Cochren+P.Gardiner)
- Robert B. Daugherty Water for Food Institute at the University of Nebraska (Trenton Franz)

2 Potential Collaborations

- WRC- strengthen relationships to develop and support internal and external projects around focal sites and themes. Co theme and location investment model
- Africa Welcome Center if research catchment to estuary program in St Lucia is developed
- INR: science capacity but not sure of funding model to adopted
- MONDI: both contract as well as collaboration work
- CSAG in situ data mode output synergies
- SANS- remote in situ synergy for long term monitoring
 - a. GEOGLAM:RAPP initiative
- State vet services (looking at a project on parasite loads in cattle at focus sties (berg and Vazi)
- GNOMO & GLORIA

Opportunities for cross-nodal collaboration

All of the above themes could be common to all nodes. It would be of particular value to determine soil carbon pools, carbon balance and albedo in all sites along with all required weather variables, biological feedbacks and implications for water security under different land use/land cover/climate change trajectories.

Key beneficiaries of the science

There are a number of beneficiaries of the science, both direct and indirect. The primary intended recipient of knowledge generated through the South African Environmental Observation Network is government. The ultimate beneficiary of this information should be society. The obligation of the SAEON GFW node is to provide relevant and commanding enough science to exert sufficient stimulus to positively influence sustainable development within South Africa. In addition to national needs,

the science outputs should serve global change science efforts internationally. They should also position South Africa as a credible respected contributor to global change science.

Science outputs, data and product offerings will be of benefit to academics spanning several disciplines. Students aiming to further their studies are also intended beneficiaries of data provided by the platform that they can utilize for analysis and knowledge generation while at the same time advancing their qualifications. They should also use the platform and the sites to advance their knowledge, networks and skills in global change science. The aim is to use the platform to build a new generation of scientists that can talk across disciplines and advance cross discipline integrations.

Science products should be most relevant to municipal development planners and conservation agencies through the implementation of SPLUMA. Products to facilitate this would be made available through local collaborators making use of the data

- South Africa carbon atlas program,
- Risk and vulnerability atlas,
- SAWS,
- CSAG,
- Climate modelers,
- DWS,
- hydrologists,
- Systems ecologists.
- SAEON
- WRC
- WaterNet

Internationally data would potentially feed into any one or all of the following international initiatives:

- ILTER
- International Geosphere-Biosphere program IGBP (2006)
- GEWEX
- COSMOS
- Future earth
- FLuxnet
- Global carbon project
- World Climate Research Program (WCRP)
- Global water system project (GWSP)
 - o Themes and relevant activities from GWSP (water) from Earth system science partnership (ESSP)
 - a. **Theme 1.** What are the magnitudes of anthropogenic and environmental changes in the global water system and what are the key mechanisms by which they are induced?

- b. **Theme 2.** What are the main linkages and feedbacks within the earth system arising from changes in the global water system?
 - c. **Theme 3.** How resilient and adaptable is the global water system to change, and what are sustainable water management strategies?
- GEO networks through GEOBON,
 - The integrated global water cycle observations (IGWCO) community of practice

List of Acronyms

ACRU	Agriculture Catchments Research Unit (UKZN)
ARC	Agricultural Research Council
COSMOS	?
CRP	?
CSAG	Climate System Analysis Group
CSIR	Council for Scientific and Industrial Research
DARD	Department of Agriculture and Rural Development
DEA	Department of Environmental Affairs
DGVM	Dynamic Global Vegetation Models
DOC	Dissolved Organic Carbon
DSVAT's	Dynamics Soil Vegetation Atmosphere Transfer models
DWS	Department of Water and Sanitation
ESSP	Earth system science partnership
GEO	Group on Earth Observations
GEOBON	GEO Biodiversity Observations Network
GEWEX	Global Energy and water cycle Experiment
GNOMO	Global Network of Mountain Observatories
GLORIA	Global Observation Research Initiative In Alpine Environments
GEOGLAM	Group on Earth Observations Global Agricultural Monitoring
GWSP	Global water system project
IGBP	International Geosphere-Biosphere program
IGWCO	Integrated Global Water Cycle Observations
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel for Climate Change
IRD	Institut de recherche pour le développement
LAS	?
NDP	National Development Plan
NRM	Natural Resource Management
PDP	Professional Development Programme
RAPP	Rangelands and Pasture Productivity
RISP	Research Innovation Support Programme
SANSA	(The) South African National Space Agency

SAWS	South African Weather Service
SIPs	Strategic Infrastructure Projects
UCT	University of Cape Town
UFS	University of the Free State
UKZN	University of KwaZulu-Natal
WCRP	World Climate Research Program
WRC	Water Research Commission