



science  
& technology

Department:  
Science and Technology  
REPUBLIC OF SOUTH AFRICA



**SAEON**  
South African Environmental  
Observation Network



# SAEON Fynbos Node

## Science Plan: 2016 – 2018

Compiled by Nicky Allsopp

May 2016

## Introduction: the Node and its key environmental issues

The SAEON Fynbos Node's science plan is written in the context of SAEON's overarching mandate to detect and understand Global Change and the more detailed SAEON Core Science Framework focusing on drivers and responses to change. The exceptional biology of fynbos, the specific impacts shaped by the local socio-economic environment, as well as regional and global change pressures, predicate the need for a distinctive science plan for this unusual area.

The Fynbos node is situated in a unique mega-diverse region, the Cape Floristic Region, with high levels on endemism and high turnover of species, especially plants, over short spatial distances (see box 1). Unfortunately, this region is faced by unprecedented rates of anthropogenic change. Almost half the vegetation types in the Fynbos Biome (see box 2 on nomenclature of this region) are vulnerable, endangered or critically endangered, or irreversibly lost (SANBI 2013), while 71% of all threatened plant species in South Africa occur in the Western Cape (see boxes 1 and 2), 96% of which are endemic to the region (Raimondo *et al.* 2009).

The people of the Western Cape depend on these ecosystems for many services; particularly water. The mountains of the Fynbos Biome are major contributors of surface runoff, supplying water to agriculture, industry and people, as well as supporting other ecosystem services. The ecological infrastructure supporting water delivery is threatened by potential changes in ecological regime due to global change, excessive abstraction and poor management; especially of wetlands and rivers in production landscapes. Beyond the impact on water delivery, the reduced quality and quantity of freshwater reaching ocean ecosystems and estuaries impacts on physical processes, their productivity, and the breeding and feeding grounds for fish and other organisms.

The Fynbos region has international significance in that it is one of the five Mediterranean-Type Ecosystems (MTE) of the world, all of which are global biodiversity hotspots, with exceptionally high densities of endemic species (Myers *et al.* 2000). These regions face disproportionately high conservation threats with only 4.3% of the total land area encompassed within protected areas (Klausmeyer and Shaw 2009). Their favourable climates and abundant resources render them highly desirable for human habitation, and all are now highly populated. Both human populations and urban development are rising exponentially in the Western Cape (Allsopp *et al.* 2014). This has led to the transformation of natural ecosystems to other land cover types, high levels of resource extraction, altered fire regimes, the introduction of useful and damaging species that invade and degrade ecosystems, and water extraction impacts on the ecological integrity of freshwater systems. This confluence of circumstances has stimulated much collaboration among researchers across MTEs, providing clear benefits for research and management through transfer of knowledge, skills, tools, and lessons learnt about global change drivers and impacts. Given the size of its research community, South Africa has generally

punched above its weight in global MTE research, attracting much international attention and collaboration.

#### Box 1. Some indicators of the unique vascular flora of the Cape Floristic Region

20657 = number of vascular plants in South Africa (Germishuizen et al. 2006)  
11 423 = number of plant species in the Greater Cape Floristic Region (GCFR)  
77.9% = plant species in GCFR that are endemic to this area

9383 = number of plant species in the Core Cape flora  
76.2% = plant species in Cape Core that are endemic to this area

High plant diversity is restricted to certain families and genera. The top ten families in the Core Cape flora with their biggest genus are:

Asteraceae 1077 spp., 669 endemic, *Senecio* 114 spp., 54 endemic  
Fabaceae 754 spp., 594 endemic, *Aspalathus* 273 spp. 254 endemic  
Iridaceae\* 758 spp., 594 endemic, *Moraea* 122 spp., 54 endemic  
Ericaceae\* 680 spp., 659 endemic, *Erica* 680 spp., 659 endemic  
Aizoaceae 624 spp., 454 endemic, *Ruschia* 87 spp. 75 endemic  
Scrophulariaceae 410 spp., 294 endemic, *Selago* 100 spp., 77 endemic  
Restionaceae\* 342 spp., 313 endemic, *Restio* 163 spp., 146 endemic  
Proteaceae\* 333 spp., 321 endemic, *Leucadendron* 84 spp., 80 endemic  
Rutaceae\* 295 spp. 280 endemic, *Agathosma* 163 spp., 159 endemic  
Orchidaceae 234 spp., 146 endemic, *Disa* 100 spp., 82 endemic

\* indicates families threatened in the Cape Floristic Region which are among the top twenty threatened large families in South Africa (Raimondo et al. 2009). Penaeaceae, Stilbaceae, Bruniaceae are other large threatened Cape families in this group. Insufficient data exists to classify the threat status of Aizoaceae.

Data from Manning and Goldblatt 2012; Snyman 2012 (note the Cape Core area is almost equivalent to the Cape Floristic Region)

#### What is unique, interesting and important about the Fynbos region?

There are several factors common to MTEs and many specific to the Fynbos region that highlight the need for the observation and study of global change, and provide unique challenges and opportunities (Ackerly et al. 2014). There are also several interesting linkages between the ecosystems in the region and other terrestrial ecosystems in South Africa and the marine environment. Fynbos is located at the southern tip of Africa, surrounded by three ocean current systems which control local and global climate systems, and which drive the **summer-arid system** (characteristic of MTEs, and rare worldwide) that gave rise to the dominance of the current vegetation and prevalent fire regime (Bradshaw and Cowling 2014). The interaction of the ocean currents create a **spatial gradient in rainfall seasonality** from strongly winter dominated in south-western portion of South Africa, through a region of “dual-peak” rainfall in the eastern portion of the Fynbos region, continuing to summer rainfall in eastern South Africa. Within the Fynbos region, there is a decrease in mean annual rainfall and increase in maximum temperatures as one

moves North or inland, tempered by the mountain ranges which run in an L-shape parallel to the western and southern coastlines.

The “Mediterranean-Type” climate, whereby the season of low rainfall coincides with periods of high heat stress and evaporative demand, poses significant challenges for **water** resource management and the biota alike. Unfortunately, most water management solutions typically have negative impacts on biodiversity, although there are some win-win management options like the clearing of invasive woody alien species, which pose a direct threat to biodiversity and reduce catchment runoff. As expanding industry, agriculture and human populations demand more water, there is mounting pressure on ecological infrastructure and greater threat to biodiversity (Allsopp *et al.* 2014, Rouget *et al.* 2014). For example, recent trends towards tapping aquifers to enhance municipal water supply potentially threaten narrow endemic species that depend on seep areas fed by these aquifers (February *et al.* 2004). There is increasing need to improve water resource management to reduce both the threat to biodiversity and the threat of irreparably damaging ecological infrastructure and compromising its ability to provide sufficient potable water into the future. This need is all the more urgent given the threat and increasing impacts of **invasive alien species** (Wilson *et al.* 2014) and **climate change** (Altwegg *et al.* 2014).

A second major challenge common to MTEs is that the summer arid conditions make them highly susceptible to **fire**. Fire is natural and played a major role in the evolution of the biota of these regions (although this is not clear for Chile), and most MTEs contain vegetation types that are dependent on fire for their persistence, but it poses a major challenge for human health and infrastructure (Kraaij and van Wilgen 2014). Fire interacts with most global change drivers, creating complex responses and potential for non-linear feedbacks, impacting on biodiversity, ecosystem function and human endeavours. Direct global change impacts on fire include changes in the seasonal timing, frequency, intensity and extent of fires, which impact on species that are not adapted to cope with these new regimes, and challenge human efforts to manage and control fire. An area of increasing concern in MTEs is the **recovery of ecosystems after fire**. The first few years after fire are thought to be when they are most susceptible to climate extremes, alien species invasion, and other impacts, with potential to alter ecosystem-level functions like carbon uptake and hydrology. In Fynbos, plant adaptations to fire include resprouting, serotiny, seed burial by animals, post-fire flowering and seed germination triggered by smoke. Fynbos differs from grasslands and savannas in that fires occur at much lower and irregular frequencies (5-50 years), and while generally restricted to the drier months, natural fires have been recorded in every month. There is increasing concern that climate change, elevated CO<sub>2</sub>, repeated introductions and land use may facilitate invasion of the Fynbos region by **fast-growing flammable grasses (e.g. C<sub>4</sub> species)**, driving a shift to grassier ecosystems that facilitate more frequent fires, impacting on biodiversity and altering ecosystem properties.

The Fynbos region is home to an **incredible diversity** of fascinating plant and animal species (Colville *et al.* 2014). The Core Cape Flora contains upwards of 9000 species, three quarters of which are endemic (Box 1). The plant lineages have their origins in three distinct regions: Gondwana, Tropical Africa and Northern Temperate and some elements of the vegetation are thought to be very ancient while many diversified during the late cenozoic (Verboom *et al.* 2014). In contrast to the Northern Hemisphere, the region has not been glaciated since before the evolution of land plants and extinction rates are thought to have been negligible. The relatively stable environment, combined with high edaphic diversity, complex topography, steep climatic gradients, fire, and intricate biotic interactions like specialized pollination or seed dispersal mechanisms, have allowed for the accumulation of the region's spectacular diversity (Ellis *et al.* 2014). The bulk of this diversity is made up of relatively few highly speciose lineages that have diversified such that most are represented in almost all major communities, resulting in relatively homogenous vegetation physiognomy and function across the region. Consequently, perhaps more so than anywhere else in the world, **understanding the current ecology and future prospects of Fynbos requires developing a good understanding of the evolutionary history of the major lineages and accounting for their idiosyncrasies** (Slingsby *et al.* 2014). Furthermore, many of the Cape lineages have close relatives in neighbouring biomes and one can learn much about the relative histories and dominant ecological process of the biomes by exploring the similarities, differences and timing of the divergence among these lineages.

While the Fynbos region and its vegetation types are typically circumscribed by the Mediterranean-Type climate, this on its own this does not explain the current distribution and function of fynbos. Edaphic factors are a major determinant of fynbos distribution and diversity with distinct species assemblies in adjacent plant communities on different soils (Cramer *et al.* 2014). Despite the importance of **soils**, they are only coarsely mapped for most of the region, data on their physical and chemical properties are scarce, scattered and vary in method, and our understanding of the implications for the biota are poor. This and several other components of the Fynbos environment that are largely accepted as important require better quantification and their implications under global change examined. **Fog** inputs into coastal vegetation and mountainous areas that intercept south east stratus cloud have long been recognised as an important source of water during the arid summers (Marloth 1904, Linder 2003) and are believed to sustain many narrow-endemic species, but little is known about the quantity, timing and long-term trends of these inputs. Similarly, topographic complexity is commonly cited as having been a driver of diversification (Linder 2003) and maintaining high regional diversity (Cowling and Lombard 2002), but little is known about how topographic complexity affects **microclimates** or how these microclimates may be affected by climate change (*sensu* Ackerly *et al.* 2010, Hannah *et al.* 2014).

The Fynbos region has a long and rich history of human habitation and human interactions with the landscape and biota. Evidence suggests that **early modern**

**humans** may have developed complex behaviour in this area, which served as a refuge for early people during periods when climate conditions were extremely harsh in other parts of Africa (Marean *et al.* 2014). Whilst the significance of this for shaping the vegetation has yet to be explored, it can be assumed to be of some relevance, particularly in the context of fire. Hunter-gatherers are known to have hunted and used “fire-stick” farming in the region for many millennia, while seasonal pastoralists arrived and began to alter the natural herbivory regime 2000 years ago. Large-scale **land cover change**, manipulation of fire, and reduction of indigenous mammal populations began with the initiation of European settlements in the 17<sup>th</sup> century (Allsopp *et al.* 2014, Rouget *et al.* 2014).

**Detection and attribution of global change impacts in systems subject to stand-replacing crown fires are highly problematic.** Comparing sites when they are of different post-fire age or successional status can be misleading, but post-fire recovery trajectories are typically slow (decades to centuries), requiring very long-term observation records. Traditional trend analysis approaches are rarely informative, because mature vegetation may be less sensitive to climate stressors than young recruits in the post-fire environment, so that impacts (or evidence thereof) are often only observed as episodic events when fires occur. In addition, while post-fire succession generally follows a similar pattern in fynbos, site history, age and composition of vegetation prior to fire, fire characteristics (e.g. intensity) and season of burn make prediction of species composition following a fire uncertain. Further “noise” is introduced by size of burnt area (which may affect predation of seedlings by animals or recolonization of the area by locally extinct species) and different responses to fire by taxa with interacting dependencies (i.e. biotic interactions (Anderson *et al.* 2014) or ecophysiological specializations (Cramer *et al.* 2014)). When this variability in response to stochastic events is overlain on a system with high plant species diversity, high turnover along relatively short spatial scales, and relatively high climate variability, determining the impact of global change drivers becomes increasingly complex.

In the context of its unique biota, abiotic environment and ecosystem drivers, overlain by the history of human habitation and the existing body of research and research community, the Fynbos Node aims to produce reliable data and information about environmental change in fynbos to help society mitigate and adapt to global change, while improving mind-sets, management and policy to reduce our impact and manage our environment sustainably. To achieve this we have broken this down into several subsidiary aims that we (with many partners) have focussed our attention on:

1. Engaging with the community of researchers, managers, policy makers and other stakeholders to identify key research gaps, needs and goals.
2. Developing or continuing long-term observation datasets to aid in the detection and attribution of global change impacts.

3. Testing and improving methods for collecting, analysing and integrating data relating to global change impacts.
4. Benchmarking and testing the accepted wisdoms of fynbos ecology and exploring their implications under global change.
5. Exploring understudied aspects of fynbos ecology and abiotic phenomena that have potential to affect or interact with global change impacts.
6. Investigating interactions among natural ecosystem processes and the diverse set of global change drivers and their potential impacts on biodiversity and ecosystem function.
7. Ultimately, a major desired outcome of the goals outlined above is to develop or contribute to tools and other products for researchers, managers and policy makers.

### **Box 2 Nomenclature and scope of the Fynbos Node**

Nomenclature associated with the vegetation types of the South Western portion of Africa is somewhat confusing. Fynbos is a term used in various contexts. It exists as a clearly defined and different vegetation type. It is also used to delineate the Fynbos Biome, one of nine terrestrial Biomes in South Africa (Mucina and Rutherford 2006). The Fynbos Biome is made up of three vegetation types *viz.* fynbos (67%), renosterveld and western strandveld. Floristic analyses of these vegetation types suggests that the grouping of these vegetation types into one biome is biologically artificial (Bergh *et al.* 2014) and as a consequence they should be split into three units. Among other factors, these vegetation types may not respond uniformly to global change pressures. The Fynbos Biome is the preferred unit for much conservation management, policy and legislation because it forms a fairly contiguous area roughly equivalent to the Western Cape Province. From the perspective of application of data emanating from the node to management and policy issues it is useful to retain the perspective of the Fynbos Biome as a 'management unit' to many statutory bodies.

However, currently many scholars prefer to refer to the region where fynbos vegetation is dominant as the Cape Floristic Region (CFR). Fynbos makes up the major vegetation type in the Cape Floristic Region (CFR) (56% of the area), but the CFR also includes other non-fynbos-biome vegetation types such as succulent karoo, Albany thicket and afrotemperate forest as well as renosterveld and strandveld (falling into subtropical thicket). The CFR is recognised as a biodiversity hotspot by international conservation bodies (Myers *et al.* 2000).

For the time being, the focus of the node will be on fynbos vegetation systems (*sensu stricto*) and renosterveld (as a close fynbos ally) as delineated in Mucina and Rutherford (2006). However, where there are examples of vegetation shifts between fynbos vegetation types and the others in the CFR these others may receive attention.

Future developments may include extension beyond the fynbos vegetation to the Greater Cape Floristic Region so as to include the succulent karoo and allied arid vegetation. While fynbos and succulent karoo share a predominantly winter rainfall climate, the evolutionary trajectories and other drivers of the two systems are quite distinct. Expansion will require additional resources and may require a refocus of the scientific priorities

## Global change threats and impacts

In the current era the main threats or drivers of change of the Fynbos Biome have been identified as:

- **land use and management**, resulting in loss or fragmentation of natural vegetation and/or disturbance of processes (e.g. fire exclusion, too frequent fire, or changes in fire regime; altered herbivory; breakdown of pollination or dispersal mutualisms), affects by far the greatest area, especially in the lowlands that are more amenable to cultivation or development.
- **invasive alien species** are a major threat in both surviving lowlands and upland areas
- **water abstraction** threatens seeps and wetlands especially, but also some sandplain vegetation types
- **climate change**, potentially interacting with or exacerbated by other threats is of great concern
- **nutrient loading**, from atmospheric nitrogen and fertilizers, threatens vegetation adapted to extremely low soil nutrient levels
- **carbon dioxide fertilization**, has an unknown, but potentially deleterious impact on species composition and ecosystem processes.

These are examined as to their main impacts on the environment and where they may interact with other global change drivers (Table 1).



*TABLE 1: A consideration of the main drivers of global change in fynbos and their likely impacts. Linked to this is a list of institutions involved in monitoring and research activities*

	<b>Main impacts</b>	<b>Main interaction impacts</b>	<b>Main research and monitoring players</b>
Land use and management	<ul style="list-style-type: none"> <li>• Loss of habitat and destruction of biodiversity</li> <li>• Fragmentation of remaining ecosystems</li> <li>• Alteration of ecosystem processes (fire, herbivory, pollination, dispersal)</li> </ul>	<ul style="list-style-type: none"> <li>• Breakdown in connectivity</li> <li>• Re-engineering of natural processes (water and nutrient cycling, salinization of renosterveld)</li> <li>• Fire regime: Wildland-Urban Interface, ignition events</li> <li>• Herbivory</li> </ul>	<ul style="list-style-type: none"> <li>• Various SANBI programmes</li> <li>• Western Cape Department of Agriculture's land cover surveys</li> <li>• SAEON</li> <li>• SUN</li> <li>• UKZN</li> <li>• UCT</li> <li>• CapeNature</li> <li>• SANParks</li> </ul>
Invasive alien species	<ul style="list-style-type: none"> <li>• Threaten biodiversity</li> <li>• Reduce catchment water delivery</li> <li>• Change fire regime, primarily through increased intensity, although grasses have potential to increase frequency</li> <li>• Change soil physical and nutrient dynamics</li> </ul>	<ul style="list-style-type: none"> <li>• Fire and climate change</li> <li>• Land use</li> <li>• Societal responses</li> <li>• Carbon dioxide</li> </ul>	<ul style="list-style-type: none"> <li>• Centre for Invasion Biology and partners (SANBI, ARC, CSIR, SUN, UCT, City of Cape Town, CapeNature, SANParks)</li> <li>• SAEON</li> </ul>
Water abstraction	<ul style="list-style-type: none"> <li>• Alters flow regime of natural systems with downstream impacts</li> <li>• Threatens rare aquifer-dependent vegetation in seeps</li> <li>• Aridification of systems</li> </ul>	<ul style="list-style-type: none"> <li>• Associated with expanded agriculture and urbanizations</li> <li>• Exacerbated by climate change and invasive alien species</li> </ul>	<ul style="list-style-type: none"> <li>• City of Cape Town (Table Mountain Aquifer monitoring programme)</li> <li>• DWS</li> <li>• UWC Heuningnes</li> </ul>

			<ul style="list-style-type: none"> <li>• WFW</li> </ul>
Climate change	<ul style="list-style-type: none"> <li>• Temperature rise-specifically duration of warmer spells</li> <li>• Increased evapotranspiration</li> <li>• Change in rainfall amount and seasonality</li> <li>• Change in fog precipitation</li> <li>• Change in wind velocities (global stilling)</li> </ul>	<ul style="list-style-type: none"> <li>• Heat and water stress for animal species (germination and survival of seedlings for plant species)</li> <li>• Fire regime influenced by interactions between climate, vegetation and invasives</li> <li>• Climate and land use impacting water cycles</li> <li>• Societal responses</li> </ul>	<ul style="list-style-type: none"> <li>• UCT</li> <li>• SUN</li> <li>• SANBI</li> <li>• SAEON</li> <li>• CSIR</li> </ul>
Nutrient loading	<ul style="list-style-type: none"> <li>• Exacerbates extinction debt of rare vegetation surviving in islands</li> <li>• Promotes alien grass and forb invasion and expansion of grass species from other South African biomes</li> </ul>	<ul style="list-style-type: none"> <li>• Leads to changed fire regimes in association with other drivers of change</li> <li>• With land use leads to pollution of Cape Flats aquifer</li> </ul>	<ul style="list-style-type: none"> <li>• SAEON, UCT, ASU</li> <li>• Princeton</li> </ul>
Carbon dioxide fertilisation	<ul style="list-style-type: none"> <li>• Promotes, as yet unidentified, growth forms through altered transpiration/photosynthesis or nutrient uptake efficiencies</li> <li>• Alters energy/CO<sub>2</sub>/water fluxes in system</li> <li>• Alters nutrient cycling directly (higher C:N ratios) or through vegetation impacts on fire or through changes in plant nutrient uptake efficiencies</li> </ul>	<ul style="list-style-type: none"> <li>• Fire and invasives</li> <li>• Streamflow may respond if transpiration is reduced at high CO<sub>2</sub>.</li> </ul>	<ul style="list-style-type: none"> <li>• SUN</li> <li>• Rhodes</li> </ul>

It is clear that there are strong interactions between drivers (Table 1) and that many of the drivers tend to impact certain core features of “what makes fynbos, fynbos”. These interactions are likely to differ from other terrestrial biomes in South Africa, justifying the existence of a SAEON Fynbos Node.

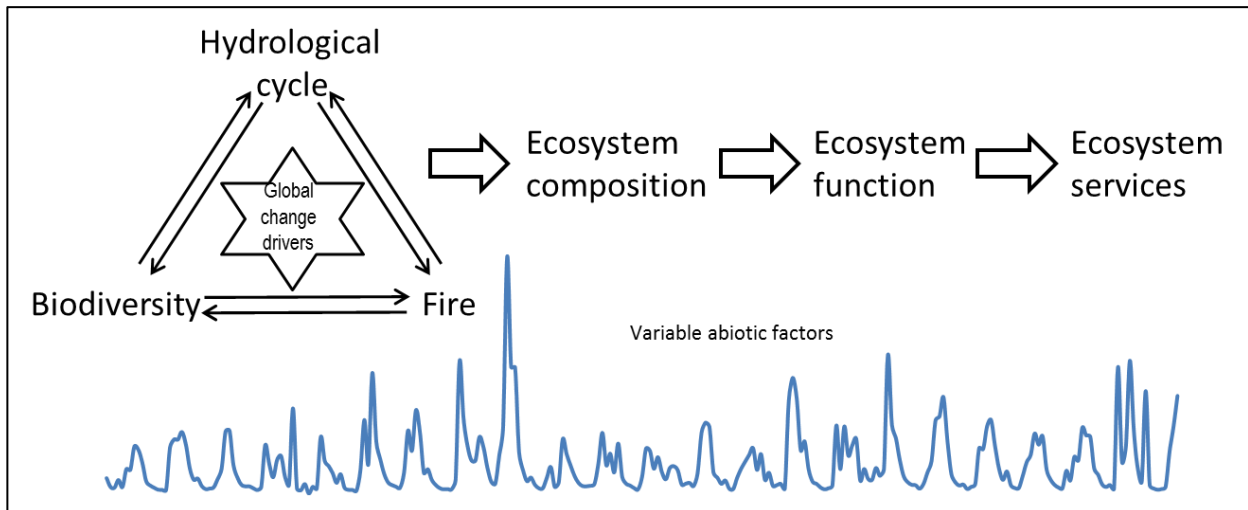
The SAEON Fynbos Node has already built on its mandate for long-term observation and research in reviving the monitoring of the Jonkershoek Catchment experiments and resurveying several established vegetation surveys. These datasets allow testing for evidence of trends/impacts and can be used to test the broader relevance of findings from experimental studies (e.g. seed germination or seedling survival trials).

## **Global change in fynbos: a conceptual framework**

The main response variables to global change drivers in fynbos are biodiversity<sup>1</sup>, hydrological function and disturbance regime, especially fire. These are anticipated to interact and create further agents of change. For example, increased aridity and invasive alien plants are likely to alter the fire regime which may drive further change in biodiversity and hydrological function. Impacts on biodiversity and hydrological processes are likely to interact and negatively affect critical ecosystem services such as water delivery. The schematic (Figure 1) illustrates a simplified way of conceptualizing the interactions between drivers of global change and the main response variables. An important component of the fynbos system is its dynamic nature through time, which is a product of stochastic disturbance, through fire, and the subsequent reassembly of species influenced by previous vegetation history, natural environmental variability, species specific responses and various drivers of global change. The composition and structure of ecosystems will influence ecosystem function, with implications for the ecosystem services on which people depend, both inside the fynbos region and more distant. Global change drivers which alter intrinsic features of fynbos ecosystems will thus have subsequent repercussions down the line for people’s welfare.

---

<sup>1</sup> Note in this context biodiversity refers to the wider conceptualisation of this term as described by Noss 1990 to include processes, composition and structure.



*FIGURE 1. A conceptual model for global change in fynbos. The main response variables to global change in fynbos are the hydrological cycle, biodiversity and fire (a disturbance). Interactions between these variables in response to global change drivers affect ecosystem composition, structure and function which ultimately impact on ecosystem services and, hence, society. Responses are also governed by various abiotic factors, which are both predictable and unpredictable (variable) at different scales (Illustrated here is streamflow over several decades showing inter-annual variability as a consequence of climate and vegetation variability).*

Specific research opportunities and challenges for studying the impacts of Global Change on fynbos are presented by the prevalence of stochastic disturbance events (fire) and high levels of species turnover in time and across space, which hinder the detection of impacts of global change by conventional analysis of repeat-survey vegetation monitoring approaches. The challenges include developing methodological approaches to monitoring that will encompass such variability while allowing for detection of change. The interactions between biodiversity and the hydrological cycle in this dynamic fire driven environment are as yet not well defined and require elucidation if we are to understand their impact on the functioning of ecosystems and their capacity to deliver services to people.

From this reasoning, overarching questions include:

- What do we need to understand about fynbos biology and ecosystem functioning in order to understand, project or mitigate impacts of global change?
- How does global change manifest itself in fynbos?
- How can we best collect, analyse and integrate data relating to global change impacts?

- What are the consequences of global change for fynbos composition, ecosystem functioning (including the hydrological cycle) and disturbance regime (fire)?
- What are the consequences of these changes in the natural environment to ecosystem services and, hence, to society?

## Fynbos node science Themes

In order to answer the above questions, the Fynbos Node science plan takes an approach starting with themes elucidating fundamental knowledge and ending in delivery of knowledge to society to inform responses. The framework (figure 1) defines the scope within which the themes are elaborated on. While we have defined five main themes, we recognise that there is considerable overlap between them in terms of the actual projects and interdependencies for data. Questions or projects under each theme typically address one or more of our aims outlined above.

### Theme 1: Biodiversity and biogeography

In a system as diverse and complex as Fynbos it is incredibly difficult to ascertain global change driven directional change as opposed to natural variability, or to project the change expected under future scenarios. The complex abiotic template overlain by a rich biota with diverse adaptations and ecological strategies creates great scope for ecological contingency (i.e. “surprises”) in the effects of global change. Rugged topography, differences in underlying geology, soil type and depth interact with climate and hydrology to produce a high diversity of microhabitats that support different arrays of plant species and vary in their resilience or vulnerability to global change impacts. For example, mountains in the region harbour a variety of localized seeps and wetlands of different hydrologic origin that support unique flora and fauna. While there is much evidence that the biota of these microhabitats are highly sensitive to changes in hydrology, e.g. through water abstraction or altered rainfall (February *et al.* 2004, Araya *et al.* 2010, Aston unpublished MSc, City of Cape Town unpublished), where access to water is maintained they may well be more resilient to elevated temperatures than species in other microhabitats (although this remains to be tested). Similarly, species traits mediate their response to the environment (e.g. the ability to resprout after fire), and are highly likely to effect varied responses to global change drivers. Given that traits are morphological or ecophysiological manifestations of adaptations to habitat requirements, they may hold the key to understanding vegetation responses to global change.

A main focus of this theme is detecting and attributing global change impacts on the biodiversity of the region over and above natural variability. Sub-themes include developing a better understanding of microhabitats and the determinants of species

occurrence, and exploring traits, their variability and role in determining species responses to environmental gradients and global change impacts.

Questions that arise from this are:

- Are fynbos and related communities showing directional change in response to global change and what are the most important drivers?
- How resilient are fynbos and allied systems to fragmentation in the face of multiple change drivers?
- Can functional traits or evolutionary relatedness be used to simplify and observe change in complex community datasets?
- Are sprouter species less resilient to climate change than seeder species? i.e. Do they have worse dispersal abilities and cooler, wetter habitat preferences than seeder species?
- Can we observe intraspecific shifts in traits in response to global change drivers?
- To what extent does topographic variability reduce the likely impacts of climate change on species distributions?
- Where are we likely to observe climate change impacts in mountainous landscapes first and how can we best monitor for these impacts?
- Are measures of fire regime derived from satellite imagery useful for predicting the distributions of species and vegetation types and does this vary according to species fire response strategies?
- Can we use remotely sensed measures of changing vegetation state to predict population trends and distribution changes in animal species? (e.g. Rose's Mountain toadlet, *Capensibufo rosea*, a Cape Peninsula endemic).

## **Theme 2: Global change and water yield from fynbos catchments**

The longest continuously recorded streamflow monitoring of experimental catchments globally takes place at Jonkershoek in the Fynbos Biome. These experiments were critical in providing the evidence for the deleterious impact of plantation forestry and invasive woody species on water delivery by fynbos mountain catchments. This knowledge was used to launch the largest poverty-relief-based biodiversity conservation programme in the world, the Working on Water programme of the South African Government. The meticulous long-term records arising from the catchment experiments has enabled SAEON to take over the Jonkershoek monitoring in order to answer questions pertaining to current global change research.

While the earlier monitoring answered questions about water use over the duration of a plantation's life cycle, the current monitoring allows one to answer questions about the impact of several rotations of plantations on the long-term sustainability of water delivery by mountain catchments in a warming climate.

Further questions around catchment functioning arise in context of post-modern rehabilitation of degraded catchments. Rehabilitation experiments and the abandonment of farming in the Baviaanskloof allow us to test the success of restoring hydrological function in an altered system.

Questions that arise from this are:

- How do changes in climate, especially temperature, impact streamflow, and is this influenced by rising atmospheric CO<sub>2</sub>?
- Now that plantation forestry has been through several plantation and/or fire cycles can we determine the impact of alien trees on longer-term indicators of sustainability of these systems, especially in terms of water delivery?
- Can hydrological functioning be restored in abandoned or actively rehabilitated agricultural landscape?

### **Theme 3: Climate and atmospheric change**

While the fynbos region is generally regarded as a winter rainfall area, climate seasonality varies quite considerably across its range. Several major patterns are manifest. There is a steep rainfall gradient of decreasing rainfall up the west coast and also as one moves inland. The south western part of the fynbos region experiences the strongest winter rainfall seasonality and yet 25-40% of the rain in this area falls in summer. Northwards and eastwards the percentage of summer rainfall increases until this rain dominates at the extreme ends of the CFR. All-year rainfall is typical in the southern Cape. There are, hence, potential for changes in precipitation amount and seasonal shifts in climate across the range. A few species such as the Clanwilliam cedar tree (*Widdringtonia cedarbergensis*) of the Cederberg (NW CFR) appear to be in decline, potentially due to changing climate. Other species of similarly limited distribution have received less attention. In the far eastern portion of the CFR, several different biomes meet in the Baviaanskloof offering opportunities to study biome shifts in response to global change. Monitoring at these extremes has been initiated to serve as a comparison to change in the south western heart of the CFR.

Other atmospheric phenomena of interest are the impact of fog precipitation on biodiversity, in fynbos on the often cloud-enveloped tops of mountains as well as along the west coast lowlands where the cool Benguela current gives rise to advective fog.

A third atmospheric phenomenon which is directly caused by humans is the atmospheric deposition of nitrogen. This is centred around areas of high human density and is of concern because of the extremely low nutrient conditions under which fynbos evolved.

Questions that arise from this are:

- What are the characteristics of CO<sub>2</sub>, water and energy fluxes in fynbos?
- What is the potential contribution of fog precipitation to the water cycle of high elevation communities?
- How have patterns in rainfall and temperature changed over time? Are there differences in absolute values, seasonality, duration or intensity of events, and are these a consequence of natural variability or anthropogenic climate change?
- Can we determine how these shifts in climate may affect species distribution, specifically range restricted rare species? (In the longer term can we assess the contribution of fog to high elevation species?)
- What is the magnitude, distribution, and nature of atmospheric pollutants impacting on fynbos?

## Theme 4: Systems ecology

This theme brings us closer to an integration of components of the above three themes by taking a more systems-based approach to explore how fynbos is changing at a broader scale and how these changes feed back to influence other components of the system. Methodologically this requires approaches that allow scaling up e.g. remote sensing, and dealing with components around which there is still uncertainty or absence of data. The latter can be approached through modelling.

Activities under this theme are of an iterative nature. For example, models are developed, tested, modified with new knowledge and enter a new cycle of development. Whilst such models, e.g. Dynamic Vegetation Models (DVMs), may initially direct our attention to identifying the kinds of data required to build them (themes 1-3), in later developments they will provide projections for consideration in decision making (theme 5). Modelling can be envisaged as a tool that directs and focuses further global change research rather than producing absolute predictions. It may also help focus thinking for future observation priorities.

Questions that arise from this are:

- Can we detect the imprint of the various global change drivers on remotely sensed measures of the recovery of vegetation after fire and can we use this to develop a system to support decision makers and researchers? This requires ground truthing, collation of existing layers of spatially explicit data, and development of new layers e.g. a soil database.
- Can we refine Dynamic Vegetation Models for South African vegetation types to test various scenarios and provide projections for other models or assessments of future states (e.g. biome shifts or invasions by C<sub>4</sub> grasses)?



## Theme 5: In a wider world

This theme is an integrative theme which brings together knowledge generated in the other four themes and elsewhere in SAEON and beyond. It looks both at where efforts to manage fynbos ecosystems for continued delivery of ecosystem services and biodiversity conservation can follow approaches developed in other systems or where novel approaches are required, and how we can use the knowledge learnt locally or from others to develop databases, tools and platforms to support management and policy. Making the knowledge gained available for easy use is essentially the end goal for all our efforts. While most of our research is far from reaching this goal, it is important to invest effort into thinking about and soliciting input about what kinds of research, databases, tools and platforms are needed by society and how they would best be presented.

Questions we are currently working on include:

- How similar are the issues facing conservation of Mediterranean systems worldwide and what can we learn from this?
- How do we develop cross-nodal approaches to common or complementary problems?
- How do we develop data pipelines that facilitate large synthesis projects?
- *What would we like to be doing:*
  - Support national water strategy or more local water focus groupings
  - Work with a transdisciplinary group around water/land use and management/restoration.

## In Context

This is a work in progress but aims to identify beneficiaries of this science, relevant legislation or policy that may use this science, collaborators or competitors, and cross-nodal collaboration (Table 2).

Most of the potential collaborators, partners or competitors are listed in Table 1. Approaches need to be developed to identify the most strategic ones, to attract them to work with us, and to dissipate potential competition. The high number of reputable and highly productive researchers and the high level of proactive responses to environmental issues and functionality in both the government and non-government sector in the Western Cape makes this a very busy field to establish oneself in. We need to be careful not to overstretch ourselves and promise more than we can deliver as SAEON, whilst also making sure we do provide a visible return on investment. Identifying and advertising our specific niche areas will be one approach, supported by delivery on these components.

This group is expanded to include a diverse group of international collaborators. From the USA : the University of California at Berkley, University of California at Davis, University of Connecticut, State University of New York at Buffalo, Pace University, NY. Germany: University of Hohenheim, Stuttgart, University of Frankfurt. New Zealand: University of Otago.

*TABLE 2: Situating our research and observation in a wider context*

<b>Theme</b>	<b>Beneficiaries</b>	<b>Legislation or policy</b>	<b>Cross Nodal</b>
<b>1) Biodiversity and biogeography</b>	<ul style="list-style-type: none"> <li>• Scientists</li> <li>• SANParks and CapeNature</li> <li>• DEA-NRM</li> <li>• SANBI</li> <li>• National databases</li> </ul>	NEMBA and SoE	Sharing best practice
<b>2) Global change and water yield from fynbos catchments</b>	<ul style="list-style-type: none"> <li>• Scientists</li> <li>• SANParks and CapeNature</li> <li>• DEA-NRM</li> <li>• DWS</li> <li>• National databases</li> </ul>	National Water Research Strategy	Cathedral Peak Elwandle
<b>3) Climate and atmospheric change</b>	<ul style="list-style-type: none"> <li>• SANParks and CapeNature</li> </ul>	NEMBA and SoE National Water Research Strategy	Sharing best practice National SAEON input
<b>4) Systems ecology</b>	<ul style="list-style-type: none"> <li>• SANParks, CapeNature, SANBI, CSIR, Scientists</li> <li>• W Cape Govt.</li> <li>• Society</li> </ul>	NEMBA and SoE, Western Cape Government's initiatives around climate change adaptation: SmartAgri and water policy	DVMs cover the regions of all terrestrial nodes
<b>5) In a wider world</b>	<ul style="list-style-type: none"> <li>• DWS, DEA, Western Cape Government, conservation agencies,</li> </ul>	NEMBA and SoE National Water Research Strategy	Sharing best practice re data pipelines and synthesis National SAEON input Supporting the Resource economics component of the DEA-NRM project

## Cross-nodal collaboration:

Two themes that can be developed further in SAEON to which our projects contribute are the Mountain to Coasts theme and a Climate gradient theme. The Baviaanskloof is the best developed of the former with Elwandle Node focusing on estuaries fed by this catchment while the Fynbos Node are working in the catchment.

Other areas where we are developing cross-nodally include:

- The Dynamic Vegetation Model is being refined and extended to vegetation formations for all of South Africa and, hence, can be applied in all terrestrial nodes.
- The Observations Database which archives sensor data from all nodes and outside organisations.
- Farmer's rainfall records-the fynbos node is responsible for collecting about 33 long term rainfall records, many from the more arid parts of the country.
- Methodological approaches, for example in scaling up using remote sensing data or developing microclimate networks.
- Synthesis projects. The Fynbos node has been central to initiating and brainstorming the idea of SAEON synthesis projects.
- Data pipelines. The node is trialling the idea of "data pipelines" whereby data generated are synthesized and made available to users/stakeholders in a useful format. The pilot project for this involves a collaboration with SANBI and SEEC developing a web-based platform for calculating ecosystem threat status based on land cover transformation and protection levels. The advantage of a system like this is that it could be expanded to include all manner of data including climate or DVM projections, species distributions, etc.

## List of acronyms and abbreviations

ARC	Agricultural Research Council
ASU	Arizona State University
CSIR	Council for Scientific and Industrial Research
DEA-NRM	Department of Environmental Affairs, Natural Resource Management
DVMs	Dynamic Vegetation Models
DWS	Department of Water and Sanitation
GCFR	Greater Cape Floristic Region
MTE	Mediterranean-Type Ecosystems
NEMBA	National Environmental Management: Biodiversity Act

SoE	State of the Environment
SANBI	South African National Biodiversity Institute
SUN	Stellenbosch University
UCT	University of Cape Town
UKZN	University of KwaZulu-Natal
UWC	University of the Western Cape
WFW	Working for Water