Nature Supporting People

The Southern African Millennium Ecosystem Assessment

Integrated Report

Millennium Ecosystem Assessment

STRENGTHENING CAPACITY TO MANAGE ECOSYSTEMS SUSTAINABLY FOR HUMAN WELL-BEING

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NATURE SUPPORTING PEOPLE
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Integrated report

R. Biggs, E. Bohensky, P.V. Desanker, C. Fabricius, T. Lynam, A.A. Misselhorn, C. Musvoto, M. Mutale, B. Reyers, R.J. Scholes, S. Shikongo, A.S. van Jaarsveld

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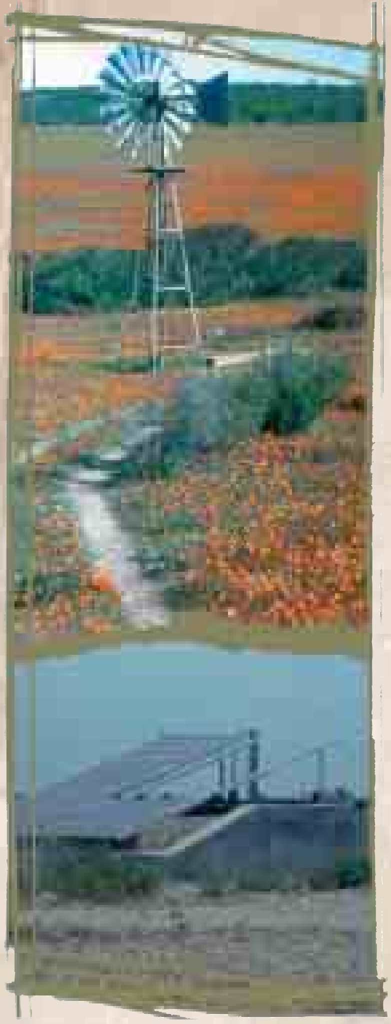


PREFACE: WHY WAS THIS ASSESSMENT DONE?

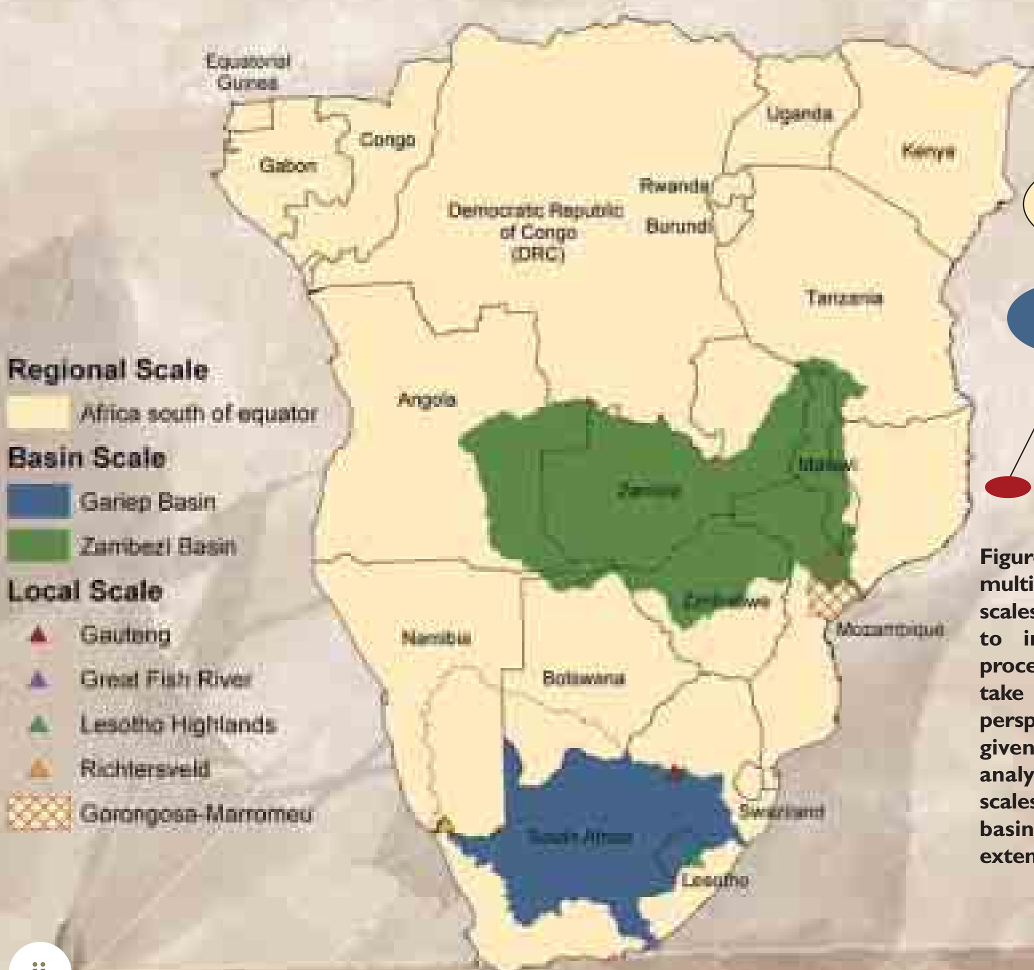
Ecosystems provide people with a variety of benefits, ranging from 'goods' such as food, water, fuel and timber, through services such as flood mitigation, climate regulation, and maintenance of soil fertility, to less tangible things such as spiritual and aesthetic well-being. The supply of these benefits, collectively called 'ecosystem services', is affected by policies, decisions and actions at all scales, from the local to the global. Decision-makers often face challenging decisions about trade-offs between ecosystem services and other aspects of human welfare, as well as among different ecosystem services, without having access to the best available information.

This assessment of ecosystem services in Africa south of the equator forms part of the Millennium Ecosystem Assessment (MA), a four-year global effort to provide decision-makers with information on the consequences of ecosystem change for human well-being. An assessment is not a research project. It is a social process whereby existing information is collected and evaluated, by scientists, for use by society. The MA

- Takes stock of the condition of ecosystems and their services around the year 2000;
- Helps understand trends in ecosystem services, using indicators;
- Identifies the underlying and immediate causes ('drivers') of ecosystem change;
- Explores scenarios of plausible future change;
- Highlights the importance of ecosystem services in people's lives;
- Creates awareness of the consequences of change for human well-being; and
- Suggests courses of action that can maintain and promote the capacity of ecosystems to continue providing services that support human well-being.

The Southern African Millennium Ecosystem Assessment

The Southern African Millennium Ecosystem Assessment (SA*f*MA) is one of approximately 30 sub-global assessments linked to the MA. The objectives of SA*f*MA were to provide reliable and useful information on the relationship between ecosystem services and human well-being in southern Africa; to enhance the capacity in the southern African region to conduct integrated assessments; and thereby to promote sustainable development at local to regional scales.



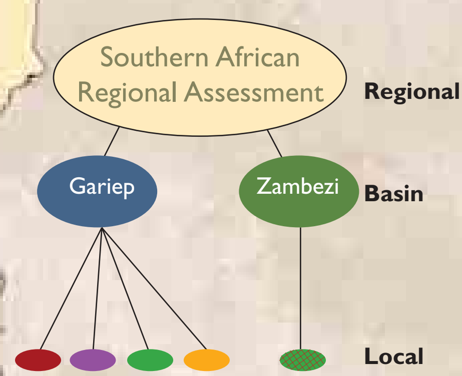


Figure A. The SA*f*MA study area and its multi-scale, nested design. The different scales were chosen to make it possible to investigate different ecological processes at the scales at which they take place, and to help ensure that perspectives of ecosystem users at any given scale were reflected in the analysis and conclusions at other scales. Note that the actual Gariep basin (indicated by a dashed line) extends beyond the area assessed.

Multi-scale structure

A unique feature of SA*f*MA is that it was undertaken at three spatial scales in a fully nested design (Fig A). All SA*f*MA studies assessed three core services (food, water, and services linked to biodiversity) as well as additional topics of interest to the stakeholders of each particular study. This document is the 'Integrated Report' of the five different studies that made up SA*f*MA. It deals with the major threads that run through all the studies, and that range across scales. For details on particular topics and locations, along with most of the data, referencing and scientific arguments, this report should be read in conjunction with the published reports of the component studies (ee back page for full details):

- **Gariep local livelihoods:** Shackleton et al. (2004)
- **Gariep Basin:** Bohensky et al. (2004)
- **Gorongosa-Marromeu:** Lynam et al. (2004)
- **Zambezi Basin:** Desanker et al. (in prep.)
- **Regional Assessment:** Scholes and Biggs (2004)

Variety of data sources and methods

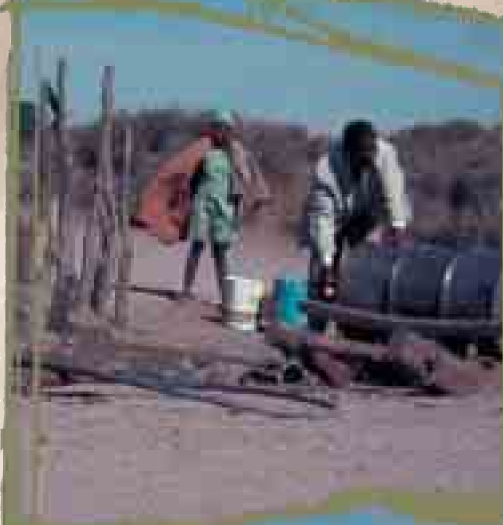
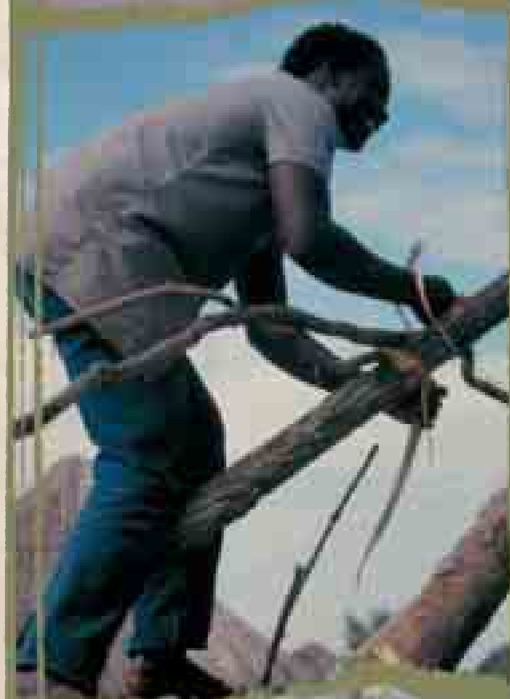
Since a multi-scale assessment had never been conducted in the southern African region, SA*f*MA adopted an experimental approach. Each assessment selected methods that were capable of answering the questions relevant at its particular scale while trying to retain multi-scale comparability. Much of the local level data was collected using participatory methods, while the basin and regional scale studies primarily made use of published studies, national and international databases and modelling approaches. Our experience was that, as the scale of assessment moved from regional to local, so the balance of information availability shifted from formal, documented data, typically regarded as being in the 'scientific domain', towards informal, tacit information contained in the life experience of local residents and in folklore transmitted by oral tradition. Nevertheless, there are elements of both sorts of knowledge at all scales. The distinction between 'formal' and 'informal' knowledge is not as absolute as is often thought, and at the level of broad principles, similar rules of use and validation apply, although the procedures may differ.

Target audience and stakeholders

SA*f*MA engaged a broad target audience and key decision makers at various scales to ensure that the results of the assessment were as directly relevant to management and policy development as possible. Representatives of user groups were invited to contribute to SA*f*MA as members of the User Advisory Group (UAG) of each component study. These groups guided the assessors regarding what information user communities needed, and provided linkages to decision-making processes. At the regional level, stakeholders include the Southern African Development Community (SADC), national government structures, regional non-governmental organisations, the media and the public. The basin scale assessments were designed to contribute primarily to the needs of national and district government bodies, conservation, agriculture and development agencies, and catchment management authorities in the respective basins. For local assessments, the stakeholders and users were local communities, municipalities, common property associations as well as local teachers and scholars.

Funding

Funding for SA*f*MA came via UNEP and the MA from the government of Norway, with in-kind contributions from various agencies (governmental, non-governmental and private donors). Partnerships were formed with a range of different agencies in southern Africa and this facilitated the exchange of data, information and expertise.


SUMMARY FOR DECISION MAKERS

ECOSYSTEMS AND HUMAN WELL-BEING

The MA defines ecosystem services as the benefits people obtain from ecosystems. These include physical products, such as food, timber and water (sometimes referred to as 'goods') as well as less tangible, but nevertheless essential services such as soil fertility, climate regulation and cultural values. Underpinning many ecosystem services is the biological diversity that allows ecosystems to work reliably and efficiently.

Human well-being includes access to the things which we need to live well, including an income, bodily health, a society free from conflict, protection from natural hazards, and the freedom to make choices. Human well-being in the SA*f*MA region is low relative to the rest of the world when measured in terms of longevity, per capita income or education levels.

Human well-being depends on ecosystem services

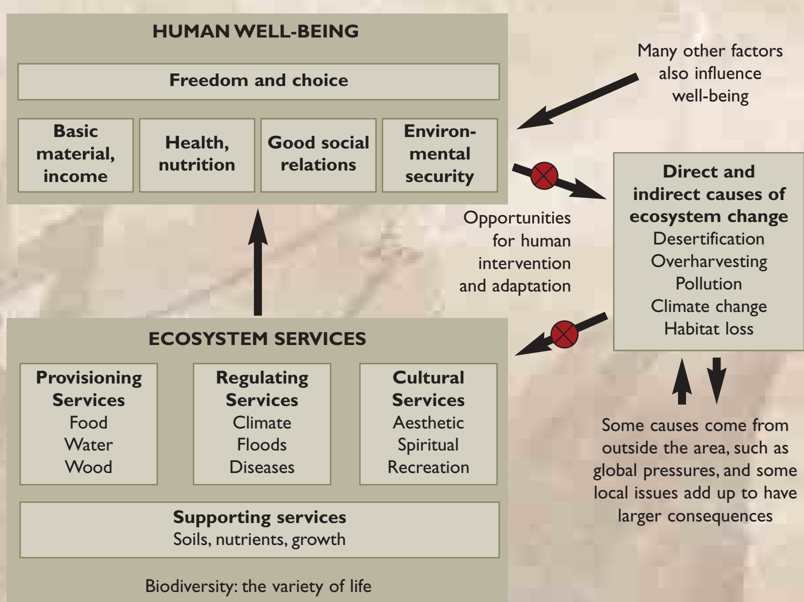
All people, everywhere, are absolutely dependent on ecosystem services, although well-being is also affected by many other factors. People who live a modern lifestyle in a city often forget that their food, water and air mostly come from ecosystems elsewhere. Poor people and rural people usually supply their needs for health, nutrition and income directly from ecosystems in which they live.

If we allow the capacity of ecosystems to deliver services to deteriorate, our well-being suffers sooner or later. Many examples of such degradation already exist in southern Africa. Failure to pay attention to ecosystem services will limit our human development possibilities.

Low levels of well-being can make it difficult to focus resources on protecting ecosystem services. This can lead to a downward spiral of ecosystem degradation and declining well-being through the creation of a 'poverty trap'. On the other hand, if appropriate interventions are made, it can drive an upward spiral of healthy ecosystems and rising well-being.

Understanding processes is essential

The underlying biological and physical processes that deliver services from ecosystems work at various scales in space and time: some are regional (e.g. climate) while others are local (e.g. groundwater recharge); some are slow (e.g. soil formation), and others fast (e.g. plant growth). Similarly, the human systems that use and manage ecosystem services (e.g. national and local government authorities) also have characteristic areas of authority and response times. Getting the linked human-ecological system to work together well often requires the human system and ecosystem scales to be matched, for instance by managing shared river basins through multi-national institutions.



Ecologists no longer believe that nature always remains in balance if left to its own devices. Once ecosystems pass a certain threshold as a result of disturbance, they may not return to their previous level of service provision within a reasonable period of time. Accelerated soil erosion, salinised irrigated croplands, destructive logging and over-fishing are examples of disturbances that may lead to downward-spiralling degradation that is difficult to reverse. Policy-makers face the challenge of increasing human well-being without reducing the resilience of the coupled human-ecological system to withstand such natural and human-induced disturbances.

KEY ECOSYSTEM SERVICES IN SOUTHERN AFRICA

SA*f*MA assessed three ecosystem services at all scales: freshwater, food and biodiversity. In addition, woodfuel and less-tangible cultural services were assessed by multiple SA*f*MA studies. Variability in the supply of and demand for ecosystem services showed up at all scales of the assessment, implying that at all levels management effort is most effective if applied in a targeted manner. In southern Africa, access to ecosystem services, determined by factors such as poverty and land entitlements, is often more limiting than physical shortages in the supply of services.

Freshwater

An adequate supply of freshwater of acceptable quality is vital to life, ecosystem processes, human well-being and economic activity. All the major river systems in southern Africa are shared by several countries, and the region has some of the most advanced international river basin organisations and agreements in the world. Most of Africa south of 17°S (Namibia, Botswana and Zimbabwe southwards) is already water-scarce by international standards. This part of the region is becoming progressively more vulnerable to development-limiting water shortages as a result of increasing population, increasing water use per capita, and the anticipated effects of climate change. People in this part of the region are highly dependent on groundwater, which is used unsustainably in most areas and becoming increasingly polluted. The area north of 17°S has an abundant water supply, but it is often contaminated with debilitating human pathogens.

Lack of access to safe water is a leading cause of infant mortality in the region. Adequate access to safe water also means that women and children can spend less time collecting water and focus on other activities. Degradation of freshwater ecosystems through excessive water removal, erosion of the catchments and pollution from mining, industries, agricultural runoff and human waste leads to increased flood risk, reduced water storage capacity, loss of aquatic biodiversity, loss of recreational amenity and declines in freshwater and coastal fish stocks, which in turn affects food security.

Food

All food comes either from semi-natural ecosystems (e.g. fish, range-fed livestock, wild fruits) or from agro-ecosystems (e.g. crops). The supply of food depends on both the biological capacity of ecosystems, as well as economic, political and technological factors. The SA*f*MA study region is one of the most food insecure parts of the world, despite the fact that the region has the potential to produce enough food for its population, now and in the future. Political, infrastructural and economic factors have prevented this potential from being realized. There is an alarming level of under-nutrition in the region. Without decisive intervention, tens of millions more people will be food insecure by 2020.

Insufficient protein is a serious and growing problem, especially in the nitrogen and phosphorus-poor areas north of the Zambezi, where diets are based on root crops rather than cereals. There is a large but poorly-documented reliance on wild plants and animals as food sources in the SA*f*MA region. Freshwater fisheries are overexploited and evidence suggests that the same holds for the east-coast marine fisheries. Domestic livestock (particularly cattle) are a central component of the livelihoods and identity of rural communities in many parts of southern Africa. Since excessive cattle densities can result in land degradation, important tradeoffs exist between the cultural and economic services delivered by livestock and other ecosystems services, such as water, crops and biodiversity.

Biodiversity

Biodiversity, the variety of life on earth, is a necessary condition for the delivery of many ecosystem services. The biodiversity of southern Africa is unusually high both in terms of species and ecosystem types. With certain notable exceptions, the region's biodiversity is in remarkably good condition. It forms the basis of the burgeoning nature-based tourism industry, as well as making important contributions to food supply and traditional medicines.

SAfMA developed several innovative ways to measure the condition of biodiversity. These analyses highlighted that the impacts of humans on biodiversity are selective, focusing on particular groups of species, usually large-bodied ones, and specific ecosystems, such as grasslands and wetlands. Urban spread, expansion of crop agriculture and plantations all lead to habitat loss, but ***the largest immediate threat to biodiversity is the expansion of degraded lands into areas currently under sustainable use.*** The mechanism of degradation can involve over-exploitation (of trees, fish, grass, soil or water), damaging logging, fishing or agricultural practices, the invasion of alien species and pollution from industries, mines, croplands or urban areas. In the longer term, climate change has the potential to endanger thousands of species in the region, and have serious impacts on people and the economy.

Woodfuel

Southern-hemisphere Africa will continue to be heavily dependent on wood and charcoal as an energy source in the coming decades. The woodfuel crisis predicted in the region two decades ago has not materialized as a general collapse, although there are many examples of local to district-scale shortages, which are a significant cause of woodland and forest degradation around urban areas. SAfMA found that at the regional scale, more wood is grown than is consumed, and that the places where shortages are likely to occur can be accurately predicted.

Cultural, spiritual, aesthetic and recreational services

SAfMA found that the ***cultural, spiritual, aesthetic and recreational use of ecosystems are highly valued by all communities, of all income levels,*** but in different ways. Traditional local communities recognise and protect sacred sites such as pools or groves, while affluent urban communities campaign for national parks. These forms of ecosystem use usually have a positive effect on ecosystem resilience and often focus on protecting key resource areas, protecting specific species and enhancing landscape diversity. Collectively, these ultimately reduce the vulnerability of ecosystems and people in the region.

KEY RESPONSES FOR MANAGING ECOSYSTEM SERVICES AND HUMAN WELL-BEING

At least four of the eight Millennium Development Goals (reducing hunger and child mortality, combating diseases and ensuring environmental sustainability) will not be met in the southern African region unless decisive action is taken to stabilise ecosystem services. Responses are the ways in which people adapt to ecosystem change or change ecosystems to suit their needs, for example drafting national policies or changing behaviour. Responses tend to be more effective if they are integrated rather than sectoral, match the scale of management to the scale of the underlying ecosystem processes, deal with trade-offs explicitly, and acknowledge and allow for uncertainty in making decisions.

Integrated management is essential

A sector-by-sector approach to the management of natural resources is being replaced by more integrated – as well as more sustainable and equitable – policies based on the ecosystem concept. Integrated management enables a single, coordinated response to satisfy multiple objectives. The multi-agency Working for Water Programme in South Africa, for example, creates a synergy between social development, through job creation, poverty relief and ecosystem rehabilitation. This model is being extended to the management of fire and coastal ecosystems.

Scales of management need to be matched to ecosystem processes

In southern Africa, institutions are being created to respond at scales that more closely match those of ecological and social processes, on the premise that ecosystem services will be most effectively managed by giving all affected parties a stake. Management of several southern African river basins is moving towards both devolution, where decision-making occurs at the local catchment scale, and evolution, where international river basin organisations are being formed to manage river basins shared by multiple countries. Transboundary Conservation Areas and Spatial Development Initiatives are other examples of responses that consider the spatial extent of ecosystem processes and their human well-being benefits.

Trade-offs have to be carefully considered

The most difficult decisions involve trade-offs, where promoting one benefit results in a decrease of other benefits. Because diverse actors with different values and objectives are involved, mediating trade-offs can be a contentious and conflict-ridden process. Decision-makers bear a special responsibility when the loss of benefits is borne by disadvantaged or unrepresented stakeholders, including the youth and future generations. Decisions need, as far as possible, to consider the full costs and benefits of the actions they promote, and pricing policies should reflect the full cost of the resource.

There is frequently a trade-off between biodiversity conservation and the need to earn a livelihood from the land. Granting use-rights to wildlife has been one solution to this dilemma in southern Africa. In Namibia and South Africa, private landowners have had the right to use and manage wildlife on their land for several decades, and the result has been a doubling of protected land as well as increased economic benefits. In Zimbabwe, the Campfire programme granted similar rights to communities on the periphery of national parks or hunting reserves. Transferring rights to own and manage ecosystem services to private individuals or communities gives them a stake in conserving those services, but these can backfire in the absence of adequate levels of institutional support. For example, the long-term viability of the Campfire programme has been severely challenged by the repossession of land given to communities.

Uncertainty requires flexible responses

Because we cannot accurately predict changes in ecosystem services, response strategies that maintain flexibility tend to be better able to deal with unexpected events. Scenario analysis has been increasingly used as a way to explore the consequences of uncertainties stemming from political, social, economic and environmental forces. SA*f*MA created scenarios that link these forces to ecosystem services and human well-being. Approaches varied from adaptation of existing scenarios to the use of participatory theatre.

Cultural practices represent an important long-term adaptive response to uncertainty at the local level, by regulating the use of the landscape and its resources. AmaXhosa communities in the Great Fish River basin in South Africa have strong beliefs about taboo areas such as sacred pools and forests, which serve as important sites of ecosystem renewal during times of crisis, such as severe droughts. Adaptive management, long practiced by local communities, is now being incorporated into formal institutional policies and governance arrangements.

Making informed and effective choices

Increasingly, techniques and processes are being developed to help decision-makers understand trade-offs and make informed choices in managing coupled human-ecological systems. SA*f*MA aims to contribute to decision-making by highlighting the issues of ecosystem services, human well-being and their linked management that require urgent and concerted attention.

PART 1: ECOSYSTEMS AND HUMAN WELL-BEING

Ecosystems make irreplaceable contributions to human well-being, for everyone, everywhere. Because their contribution is so fundamental and ubiquitous, we tend to take it for granted. But the capacity of ecosystems to supply services such as clean water and air, fertile soils, food and fibre and habitat for other species can deteriorate abruptly and irreversibly, with negative consequences for human well-being. This part of the report provides the conceptual background used in SA*f*MA.

1.1 DEFINITIONS AND CONCEPTS

What are ecosystems?

An ecosystem consists of organisms, including humans, interacting with each other and their physical environment, which includes things such as soil, water, climate and atmosphere. Thus the vegetation, mammals, birds, insects and uncounted other organisms of any of our great southern African nature reserves is an ecosystem (e.g., the 'Serengeti ecosystem'); but so are the human-dominated, alien-plant covered urban areas of Nairobi, Lusaka or Gauteng. Things don't have to be 'natural' to be an ecosystem. Indeed, even the most remote ecosystems these days are altered to a degree by human activities. In Africa, this is nothing new. African ecosystems have co-evolved with human influence for several million years.

Many of the ecosystems most important to people are the ones that we have radically transformed. For example, complex human societies only arose once humans had domesticated wild plants and animals, beginning the expansion of agricultural ecosystems that now dominate large parts of the world. These are 'coupled socio-ecological systems', where the human-nature interactions are strong, and the human-human interactions take the form not only of material flows (such as food) but also flows of information or money.

Ecosystems can be big or small. The whole world, with all its landmasses, oceans and shared atmosphere is an ecosystem, and so is the collection of microbes that exist in the stomach of every healthy person. It is hard to put exact boundaries on most ecosystems, because some interactions and movement of organisms and material occurs between adjacent ecosystems. This fuzziness at the edges is not of great practical importance. We recognize that in some landscapes there are sharper boundaries than in others. For instance, we have no real difficulty in conceiving a 'coastal ecosystem', even though its landward and low ocean-ward boundaries are quite vague.

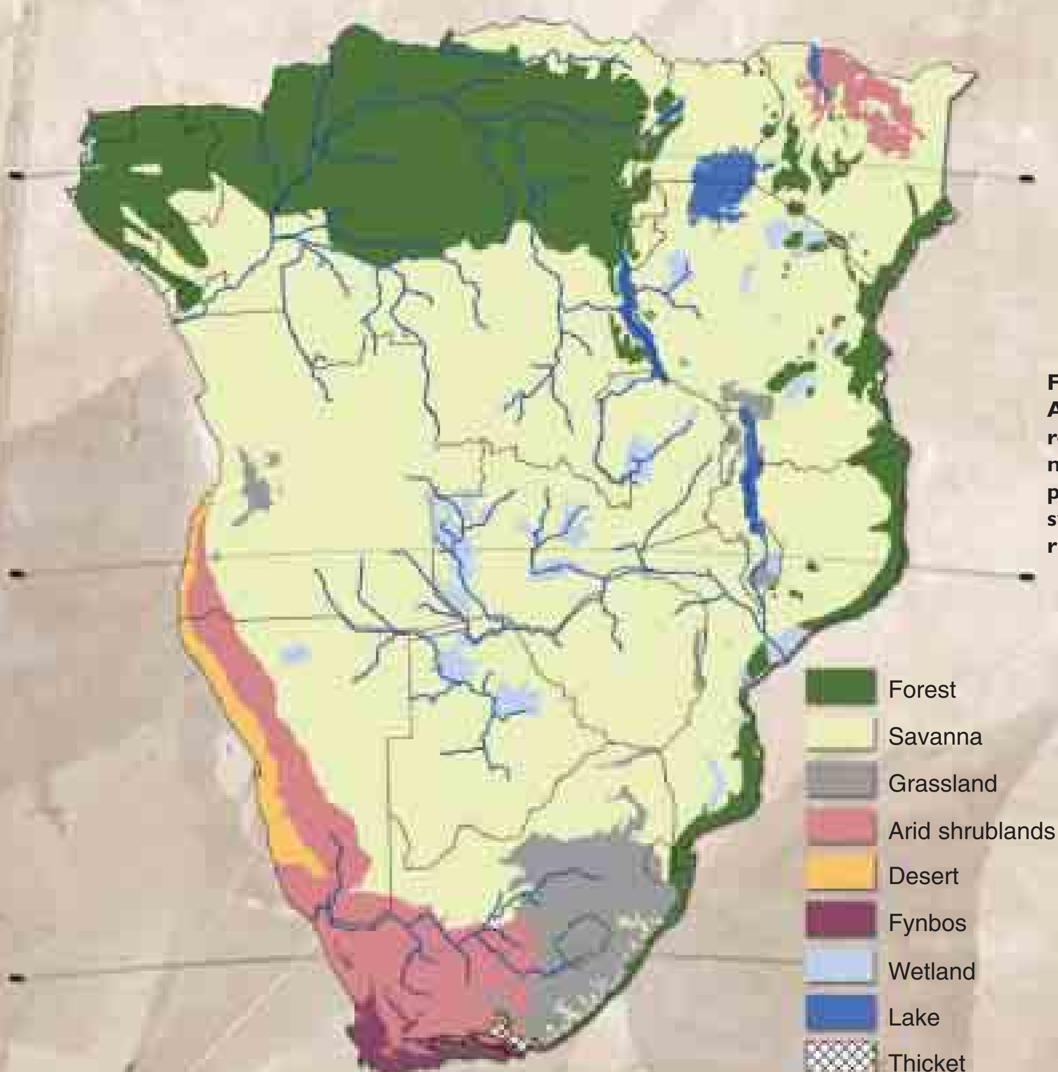


Figure 1.1 The biomes of southern Africa as classified in the SAfMA regional-scale study. Savannas cover more than half the region. The central plateau is drained by four major river systems, while numerous smaller rivers drain the coastal regions.

The highest level of ecosystem classification below that of the whole globe is known as a 'biome'. Examples of biomes are tropical forest, coniferous forest, grassland, savanna, desert, shrubland, coastal and marine. In most classifications there are about twenty such broad units worldwide, about ten of which are widespread in southern Africa. On land, they are mapped using vegetation as a guide. Exactly how to split them is a matter of judgement, and depends on the purpose of the study and the scale at which it is executed. For instance, the Eastern Cape of South Africa has a vegetation type that has some unique features, but also shares many features with the adjacent savannas, forests and shrublands. It is a bit too dense to be a typical savanna, too tall for a shrubland, and too low for a forest; so it is called a subtropical thicket. In South African national studies it is frequently raised to biome status but at the scale of southern hemisphere Africa, it is almost invisible. In the SA*f*MA regional study it is lumped with savannas (Fig 1.1).

Ecosystems can also be analysed using much more arbitrary 'reporting units' such as the political boundaries of countries. Because a lot of the movement of material in ecosystems is controlled by the flow of water, it is often convenient to define drainage basins (also known as 'catchments' or 'watersheds') as the unit of study. Similarly, in southern Africa the trapped air circulation over the continent follows a predictable pattern, making it possible to define an 'airshed', known as the southern African gyre.

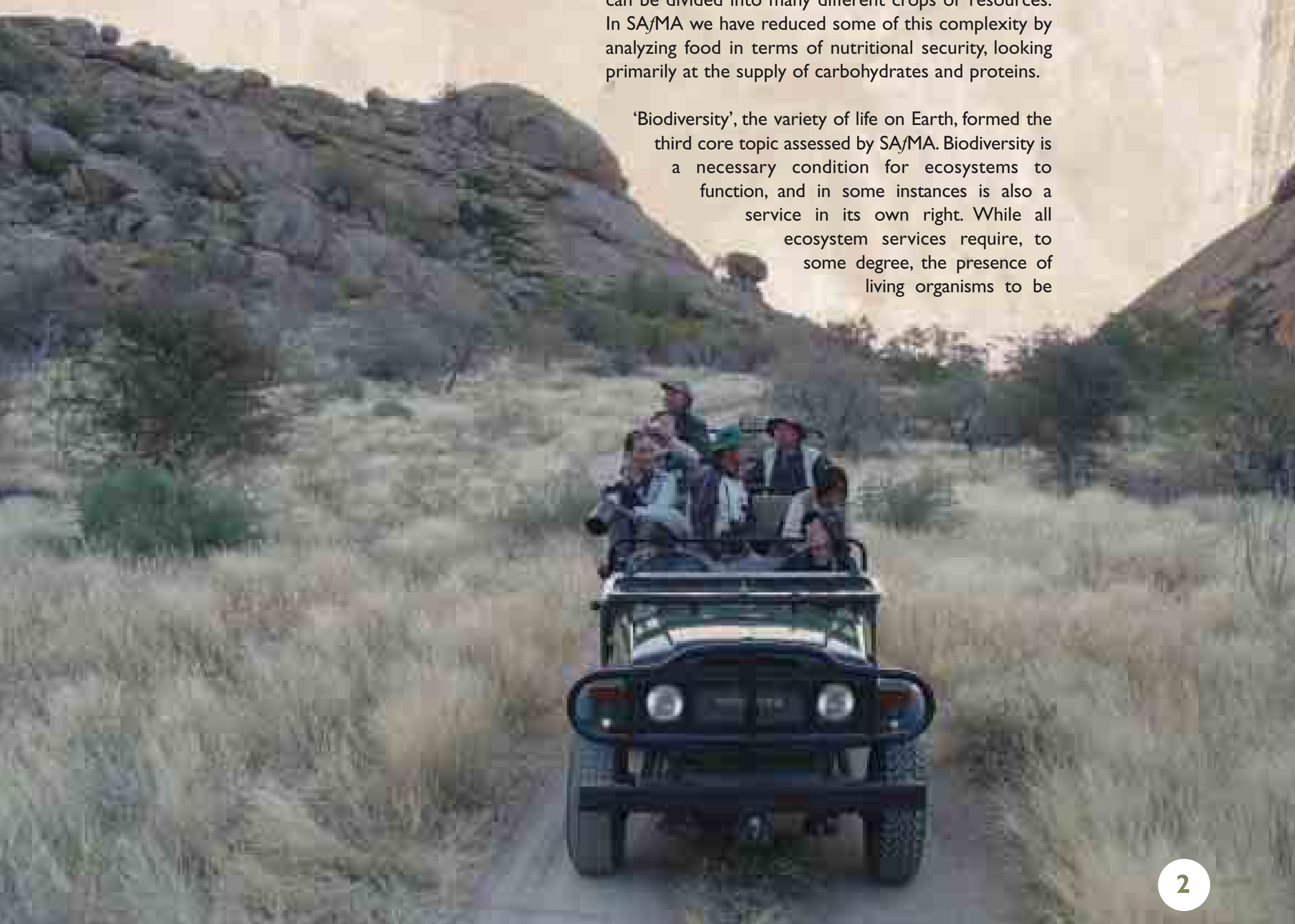
What is meant by 'ecosystem services'?

Ecosystem services are the benefits that people obtain from ecosystems. In much of the literature, the phrase 'ecosystem goods and services' is used. The MA simply uses the term 'services', since 'goods' are a subcategory of service. The MA further subdivides services into provisioning services (most of which are 'goods'), regulating services that keep ecosystems functioning within bounds, cultural services that relate to the human need for beauty, spirituality, knowledge and a sense of belonging, and supporting services necessary for the delivery of all the other services (Fig 1.2).

Nature is not always kind. How can we consider a flood or a drought as a 'benefit'? The MA does not, but observes that human vulnerability to such 'disservices' is often mediated by ecosystems. For example, the severity of a flood is strongly affected by land uses in the catchment. Thus the service is flood regulation, which can be increased or decreased by human actions. Floods also deliver nutrients to floodplains, and maintain biodiversity in riparian ecosystems.

The key provisioning services that were chosen for analysis by SA*f*MA were water and food. Broad categories of service, such as 'food' or 'water' are in fact made up of many sub-categories. Water, for instance, can come in various qualities, which are fit for only certain uses, and be divided into 'beneficial flows' (the normal, steady flow in a river) and 'hazardous flows' (storm peaks, which can usually not be usefully captured, and can cause great damage and loss of life). Similarly, 'food' can be divided into many different crops or resources. In SA*f*MA we have reduced some of this complexity by analyzing food in terms of nutritional security, looking primarily at the supply of carbohydrates and proteins.

'Biodiversity', the variety of life on Earth, formed the third core topic assessed by SA*f*MA. Biodiversity is a necessary condition for ecosystems to function, and in some instances is also a service in its own right. While all ecosystem services require, to some degree, the presence of living organisms to be



Provisioning *Products obtained from ecosystems* • Food • Fresh water • Fuelwood • Fiber • Biochemicals • Genetic resources	**Regulating** *Benefits obtained from regulation of ecosystem processes* • Climate regulation • Disease regulation • Water regulation • Water purification • Pollination	**Cultural** *Nonmaterial benefits obtained from ecosystems* • Spiritual & religious • Recreation & ecotourism • Aesthetic • Inspirational • Educational • Sense of place • Cultural heritage
Supporting *Services necessary for the production of other ecosystem services* • Soil formation • Nutrient cycling • Primary production		

Figure 1.2 The Millennium Ecosystem Assessment classification of ecosystem services (MA 2003). Ecosystem services are the benefits people obtain from ecosystems, and include provisioning, regulating and cultural services that directly affect people, as well as supporting services needed to maintain the other services.

delivered, in most cases it is not the *variety* of the living organisms that matters, but only that particular organisms involved in the production of the specific services are present. Most human food and fibre comes from a rather small and non-diverse group of crop plants, and biodiversity is arguably not necessary in supporting the quantity of these services. Many experts counter that the reliability of these services is indeed dependent on biodiversity, since a more diverse range of food plants, grown in a more diverse environment, is less likely to fail in the event of a drought or an outbreak of pests. Thus biodiversity is a regulating service in this instance. In the area of cultural services, nature-based tourism (which is an important source of income in southern Africa) depends directly on the spectacular diversity of life on display. In this case biodiversity is a cultural service.

'Ecosystem services' is, by definition, a human-centred concept. There is a valid, and ongoing, moral and philosophical discussion whether nature has 'value' outside of a human context. Many people, from many different cultures, argue that nature has 'intrinsic value', independent of whether it is useful to humans or not. The MA is agnostic on this point. It has adopted the human-centred 'ecosystem services' approach because doing so makes it feasible to quantify the importance of ecosystems to human well-being. The MA does not set out to calculate the 'total value' of nature. Since all life depends on it, the total value is by definition infinite. Instead, the MA demonstrates that even taking a partial, conservative view, the value of nature is so immense that it warrants much more careful management.

Sorghum, fish, reeds, baskets, thatching grass, fibre, poles and firewood. This rural scene highlights the importance of ecosystem services to household well-being in southern Africa.

The ecosystem service approach is a very practical way of applying the sometimes highly theoretical ideas about ecosystems to very concrete policy decisions. For instance, it makes the definition of 'desertification' and 'degradation' real and quantifiable (see Key Issue II on Desertification).

Human well-being

Human well-being, in the MA, is defined as having sufficient access to the basic material for a good life, health, freedom and choice, good social relations and security. It is a context-dependent state: what constitutes a state of well-being for one person may be considered awful deprivation to another; but all people, everywhere, strive to improve and protect their well-being.

Human well-being can be measured in a variety of ways, all imperfect or incomplete, but at least giving an indication of trend. In general, the countries of southern Africa are in the lowest quarter of global rankings of human well-being (Table 1.1). In many places in southern Africa human well-being is in decline. There are some counter-examples, which give hope that southern Africa is not intrinsically a hostile place for people to live.

Human well-being is not synonymous with absence of poverty, at least not if poverty is defined purely in monetary income terms. Well-being has many components. One of these is access to the 'basic material for a good life', which includes, for most people, the ability to earn an income. More broadly, it means access to the resources needed for a viable livelihood, which may or may not have a component of cash income. Most of the basic materials for a good life (the agricultural economy and the raw materials that supply the manufacturing economy, which in turn support a service economy) ultimately derive from ecosystems. If they are over-used, or the conditions necessary for their production are degraded, people suffer directly or indirectly.

The health component of well-being includes adequate nourishment, freedom from avoidable disease, access to adequate supplies of clean drinking water and clean air, and supplies of energy to keep warm or cool. Water and air are cycled through ecosystems, which purify them and regulate their composition and flow to within the tolerance limits of humans. We do not argue that ecosystems were designed for this purpose, but that humans and other organisms evolved to survive under a particular range of conditions. If these conditions change suddenly, it is hard to adapt. The notion of 'security' refers to a condition where people are not vulnerable to shortages of 'basic materials for a good life' and are sheltered from ecological shocks, stressors and natural hazards.

Table 1.1 Standard indicators of human well-being in southern Africa, around the year 2000. Source: Scholes and Biggs (2004), extracted from the Human Development Report (UNDP 2003).

	Human Development Index[1] 2001		Under-five mortality rate 2001	Adult HIV prevalence 2001	Adult literacy rate 2001	Population living below $1 a day 1990-2001	Refugees in country of asylum 2001
	value	*rank*	*per 1000 live births*	*% age 15-49*	*% age 15 and above*	*%*	*thousands*
Angola	0.38	164	260	6	42	..	12
Botswana	0.61	125	110	39	78	24	4
Burundi	0.34	171	190	8	49	58	28
Congo	0.50	140	108	7	82	..	119
DRC	0.36	167	205	5	63	..	362
Eq. Guinea	0.66	116	153	3	84	..	..
Gabon	0.65	118	90	..	71	..	16
Kenya	0.49	146	122	15	83	23	239
Lesotho	0.51	137	132	31	84	43	0
Malawi	0.39	162	183	15	61	42	6
Mozambique	0.36	170	197	13	45	38	0
Namibia	0.63	124	67	23	83	35	31
Rwanda	0.42	158	183	9	68	36	35
South Africa	0.68	111	71	20	86	<2	19
Swaziland	0.55	133	149	33	80	..	1
Tanzania	0.40	160	165	8	76	20	647
Uganda	0.49	147	124	5	68	82	200
Zambia	0.39	163	202	22	79	64	284
Zimbabwe	0.50	145	123	34	89	36	9
REGION[2]	**0.46**	**150**	**155**	**13**	**71**	**24**	**212**

[1] The HDI combines measures of income, education and health. The highest possible score is 1, and the lowest is 0.
[2] The regional averages are weighted by the national populations
.. No data

Well-being includes less material components, such as 'good social relations'. Many societies emphasise cultural and spiritual values and an absence of social conflict above material well-being. This category includes the opportunity to express aesthetic and spiritual values associated with ecosystems, and to find recreation, knowledge and inspiration in nature. The spiritual and cultural dependence on ecosystems is very obvious in peoples who have lived in a given environment for many generations. For such people, their entire sense of who they are is inseparably tied up with the landscape where they live and the organisms that inhabit it. But it is not limited to such 'first peoples'; many 'colonists' have similar feelings towards their environment, even if they express them in different ways, or derive them from a completely different world-view. The conservation movement, for instance, is largely driven by urban people. The phenomenal growth of nature-based tourism is another manifestation of the same basic need.

Finally, human well-being is ultimately about freedom and choice. It is not for one group of people to determine what is good for another group of people, but it is the collective responsibility of all people to keep options open, both for the present and the future, so that people can make their own choices. The connection of human well-being to freedom and choice raises several issues worth considering. At one level it is the basis of the 'precautionary principle'. If we don't know what the consequences of our actions are, the safest choice is not to risk reducing our options in the future. At a more pragmatic level, it is striking how closely associated loss of ecosystem services and loss of human freedom, well-being and life are in southern Africa (see Fig 3.1, section 3.5). This correlation can be argued in both directions. Declining ecosystem services, in some instances, lead to competition for resources and conflict. In other instances, erosion of freedoms and the rise of conflict leads to the breakdown of institutions which regulate the use of ecosystems, and the result is ecosystem degradation.

It is therefore clear that all humans, everywhere, are absolutely dependent on ecosystem services, even if they don't realize it. Even astronauts living in a tiny human-manufactured ecosystem orbiting in space, depend immediately on the proper functioning of their life-support systems, and ultimately on the life support systems on earth which supplied these for their journey and to which they must return. The immediacy of the connection between ecosystem services and human well-being is very obvious to people who live 'close to nature': indigenous peoples, farmers and rural dwellers in general. It is often ignored by urban populations living in a modern economy, who are usually one or more steps removed from the actual source of the food they eat or the water they drink. This apparent disconnect creates great risks of inappropriate policies and actions, since 'modern' and urban people are often more powerful, politically, economically and in terms of their consumption patterns, than 'traditional' and rural people. Whenever people are separated by space, time or class from the consequences of their actions, there is a tendency turn them into 'externalities', or costs borne by someone else.

1.2 THE MILLENNIUM ASSESSMENT CONCEPTUAL FRAMEWORK

The many studies that constitute the MA around the world are unified by the adoption of a common conceptual framework (Fig 1.3). The MA framework explicitly links human well-being to ecosystem services, while also noting that well-being is affected by non-ecosystem service factors. Human well-being acts via indirect drivers of change (such as population size) on direct drivers of ecosystem change, such as changes in climate and soil that directly influence the provision of ecosystem services. Most linkages in the coupled human-ecological system are subject to human intervention, which make the linkages stronger or weaker. Ecosystem services are embedded in a more general context, 'life on earth', which has biodiversity as a key component. Finally, this set of interacting factors can be expressed and analysed at a range of scales in both space and time. Importantly, the interactions can often act across scales. For instance, global economic changes can have strong consequences at a local level.

In the developing world context, and particularly in southern Africa, human well-being is closely allied to the concept of poverty. In development circles, poverty reduction is generally defined in terms of improved well-being, rather than solely in financial terms (e.g. income greater than a dollar a day). Human well-being is at the core of global political initiatives, such as the Millennium Development Goals agreed by the United Nations at the turn of the century, and endorsed by the World Summit on Sustainable Development in Johannesburg in 2002. It is also the core of the New Partnership for Africa's Development (NEPAD), a regional initiative for the upliftment of Africa. This observation allowed the SA*f*MA regional-scale study to use the MA conceptual framework, with its explicit linkage between ecosystem services and human well-being, as a way of exploring future scenarios.

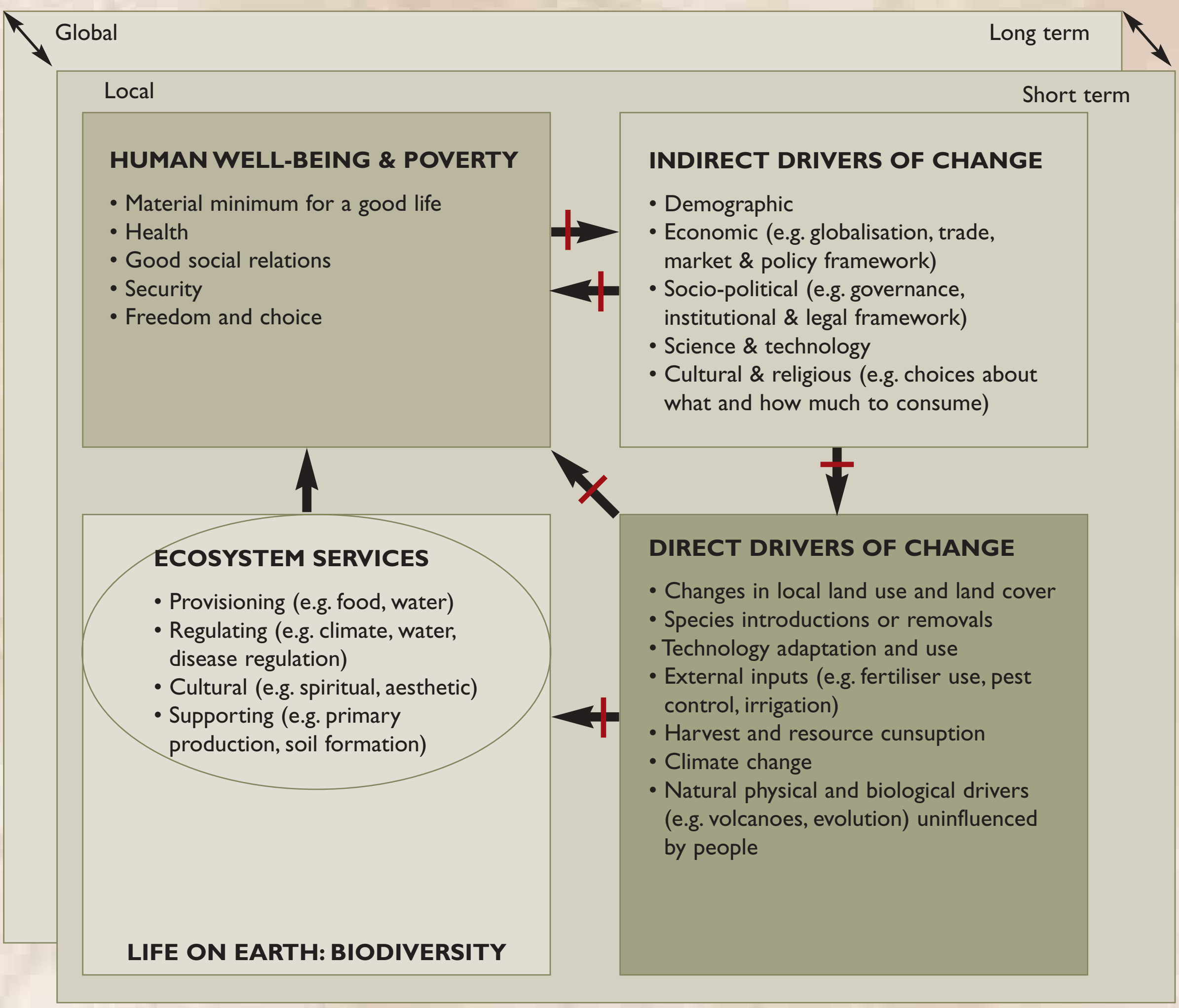
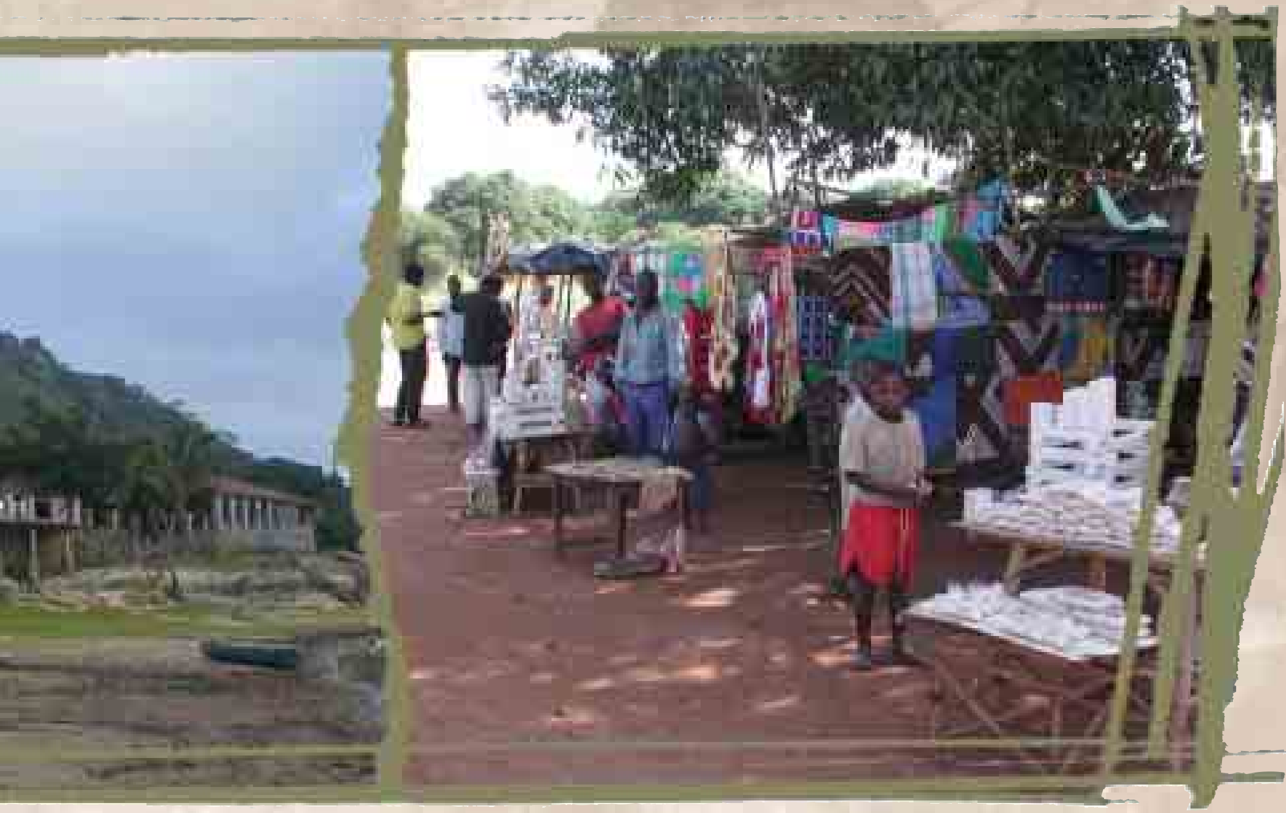


Figure 1.3 The Millennium Ecosystem Assessment conceptual framework (MA 2003). Human well-being is partly dependent on the availability of ecosystem services. Underlying the provision of these services are supporting ecosystem processes such as nutrient cycling, hydrology and climate. Ecosystem services may be affected by direct factors such as pollution and land cover change, and indirect factors such as population and economic policies. Ultimately, the drivers of change are themselves influenced by human well-being. Feedbacks occur at all scales, from an individual household to the entire globe, and interventions at key points can influence these feedbacks in beneficial ways.

In Southern Africa the indirect drivers of change are dominated by demographic, economic and socio-political factors. Unlike many other parts of the world, which have already or will soon pass a 'demographic transition', the human population of southern Africa continues to grow at a relatively high rate. This is despite the dramatic impact of the HIV/AIDS pandemic, which alters the age structure and availability of both labour and domestic savings. Along with net population growth comes a strong trend towards urbanization, which together with slow but real economic growth, is altering patterns, locations and quantities of food, water and energy consumed. Although southern Africa is a minor player in the global economy, globalisation has had a major impact on food and income security in the region, often eroding the resilience of local supplies. Africa has been a place of rapid socio-political change for the past four decades, and that process is still underway. Traditional institutions have in many cases been replaced by central state authority, sometimes successfully, but more often not. New structures of governance and law are developing, and a key branch point ('bifurcation') in the future of the region is between a highly integrated region, with strong governance at nation-state and regional level, or a more fragmented region with greatly different governance styles and strengths in different areas.

The direct drivers of ecosystem change in southern Africa include widespread land-use change, leading in some cases to degradation. Forests and woodlands are being converted to croplands and pastures at a rate somewhat slower than those in south-east Asia and the Amazon during the 1990s, but nevertheless sufficient to endanger ecosystem services at a local scale. Half of the region consists of drylands, where overgrazing is the main cause of desertification. In the timeframe of the first half of the 21st century, climate change is a real threat to water supplies, human health, and biodiversity in southern Africa. This is partly because the projected warming may over large areas be accompanied by a drying trend, and partly due to the low state of human welfare and weak governance in the region which increases vulnerability to climate change.

Human inventions in the links between human well-being, indirect and direct drivers and ecosystem services are referred to in the MA as 'responses'. The MA recognizes that humans and their societies are characterized by adaptability, and do not simply react passively to changes in their environment. Many of these responses take the form of 'policy', at a variety of levels from the household (e.g. keeping livestock as a store of wealth) up to intergovernmental agreements (e.g. UN Framework Convention on Climate Change). The national government is an important level at which policy is made, but it is not the only one. Non-governmental organizations, community-based organizations and private sector businesses all create and implement policies. Many of the sustainable and successful responses in ecosystem-human interactions are changes in 'institutions', rather than direct interventions such as damming a river or rehabilitating eroded soil. When researchers in this field refer to 'institutions', they don't typically mean bricks-and-mortar structures, but the sets of rules by which society works.



Understanding processes is essential

An assessment is incomplete without understanding the underlying processes that determine the fluctuations of ecosystem services. Processes are sequences of interactions between different components of a system, and are governed by the feedbacks between the different system components. An example of a local process is soil erosion, which is the result of interaction of soil types, landscape characteristics, animal factors, human factors and weather. Drivers can catalyze processes, speed them up or slow them down. These interactions can operate synergistically to produce unexpected results for people and ecosystems. It becomes even more complicated when factors operating at different spatial scales, and processes running at different speeds, interact.

A knowledge and understanding of the processes underlying social-ecological change is essential for designing the right kinds of interventions such as policies, laws or management strategies. Predictive models and scenarios in social-ecological assessments are built on the best current understanding of the system processes. They help decision makers to be proactive, by avoiding or ameliorating those factors that contribute to undesirable outcomes, and augmenting or facilitating those factors that contribute towards desirable outcomes.

The cheapest and most elegant interventions are based on an understanding of the underlying processes that govern social and ecological change, and of the interactions between those processes. This means that our knowledge of these processes, and our understanding of how and when to intervene, are inseparable. Even then, management can have unintended consequences. A water transfer scheme may, for example, lead to new unanticipated problems when disease and exotic plants and animals are inadvertently spread. Our knowledge of the processes and their interactions will never be complete. In general, however, actions guided by our limited knowledge are better than random actions, and society often knows more than is available to the decision-making process. It is important to start off with the right questions in order to start intervening appropriately (Box 1.1).

Box 1.1 Questions that help us focus on the most important issues

In order to identify the sensitive and critical aspects of a system, ecosystem managers need to ask:

- Which components of the system are critical for human well-being?
- Which components are critical for ecosystem integrity?
- Which processes are essential to keep the critical components functioning at an adequate level?
- How do these processes work?
- What are the key inputs and outputs, including energy and material requirements and pathways?
- Where are the major leaks in the system, what causes them, and how can they be 'plugged'?
- At what spatial scales and temporal rates do the processes function?
- What are the upper and lower thresholds, above or below which the critical processes will cease to function or will function differently?
- Which other processes are linked to these critical ones, and how?

1.3 WHAT MAKES ECOSYSTEMS TICK?

The brief overview of ecosystem theory that follows is intended to help decision-makers and the public understand how, and why, ecosystems respond as they do to human actions.

Processes occur at specific spatial and temporal scales

It is useful to visualize both ecosystem processes, and the human actions that influence them, by defining their characteristic scale in time and space (Fig 1.4). Often, the failure of particular responses to have the desired effect is because there is a mismatch between the time or space characteristic of the response, and that of the underlying ecosystem process. Conversely, some policies or actions have a completely unintended impact on ecosystem processes because they inadvertently invade the space and time characteristics of a particular process. An example is provided by industrial air pollution. The massive electricity generation plants east of Gauteng in South Africa were designed with tall chimneys so that they did not exceed the local air quality standard. As a result, the flue gasses are injected into a layer of air that often circulates over the entire region. Sulphate emissions traceable to Gauteng have been detected as far afield as Mount Kenya. Counteracting the local-scale problem has therefore led to regional impacts.

Some processes, such as changes in rangeland species composition, or valve change in society, move slowly, while others such as floods, fire, and animal migrations, or armed conflicts and legal reform can occur much more rapidly. When these fast and slow processes interact or interfere with one another, the consequences can be unpredictable. Processes operating at coarse spatial scales such as tectonic movements and climatic change are generally correspondingly slow, while fine-scaled more localized processes can either be fast (the majority) or slow. When regional- or national-scale and local-scale processes cross paths, new and unforeseen events and consequences can unfold.

Ecosystem services and their drivers are patchily distributed in space and time. The supply of a given ecosystem service is often concentrated in a 'key resources areas' within the landscape. Human populations, and their attributes such as poverty and health status, are also patchily distributed. The processes that characterize these key resource areas are different to those taking place in the areas in between. An understanding of the location of key resource areas, and the processes that create and maintain them, is critical for the management of the entire system.

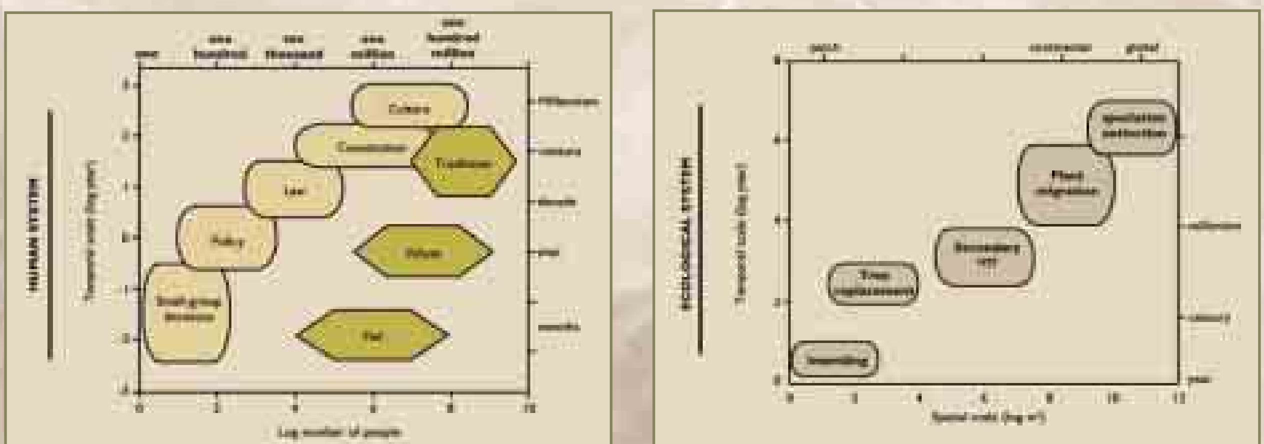


Figure 1.4 Ecosystem processes and human system processes mapped into a space and time domain (MA 2003). The area each occupies is determined by its 'characteristic scale', which is the distance or time-period over which a process is expressed. Thus, for instance, drought in southern Africa typically lasts one to two years, and occurs over about half of the region. Food security response must match this scale if it is to be fully successful.

Feedback loops

Ecosystems are highly interconnected, both within and between themselves, but also to the human systems that link to them. Ecosystem change, once started, can be amplified or dampened by feedback loops, depending on the type and strength of the feedback. The concepts of feedback are particularly relevant to the 'regulating' ecosystem services.

Feedback loops come in two basic types: positive (amplifying) and negative (dampening). The effect of a negative (dampening) feedback is to reduce the magnitude of the original perturbation. Negative feedback loops are stabilizing influences in ecosystems. An example is provided by fuelwood harvesting. As the nearby resource gets depleted, the cost (either in money or in time) of harvesting more goes up, so people harvest less, and the area deforested stabilizes at some distance from the point of consumption.

A positive (amplifying) feedback occurs when the effect on the original component is to change it a bit more in the same direction as the original perturbation. This does not necessarily lead to 'runaway', out-of-control behaviour, but it always has the effect of destabilizing the system. An example is land degradation by overgrazing. Domestic livestock, if present in numbers greater than the productivity of the vegetation can support, reduce the amount of vegetation present. This tends to increase soil erosion, which in turn further reduces vegetation productivity. If the stocking rate remains unchanged, the impact on vegetation becomes even greater, leading to more erosion and further loss of productivity. In principle, a reduction of stock below the vegetation productivity level has the opposite effect, leading to more and more plant cover and less and less erosion. Thus positive feedbacks can have either beneficial or detrimental consequences depending on whether they fall above or below a given threshold. As a result, positive feedbacks are sometimes divided into 'vicious cycles' or 'virtuous cycles'.

Positive (amplifying) feedbacks are more often 'vicious' than 'virtuous' because of delays and asymmetries in the feedback loop. A delay means that the feedback effect is not felt immediately, but some time later. Graziers may for instance not detect the severity of the impact they are causing, and adjust their stocking rate, until it is too late. Delays cause inertia in the system and result in a tendency to overshoot targets. Due to asymmetries in the feedback loops, it is often easier to cause a change than to reverse it (a phenomenon called 'hysteresis'). For example, soil loss can occur over a few hours in a severe storm, but takes centuries to replace. Soil formation is a 'slow' variable, while soil loss can be a 'fast' variable. When hysteresis is extreme, we refer to 'irreversible change'. Few changes, perhaps other than global extinction of a species, are truly irreversible. But many are so slow that from a human perspective the system is effectively stuck in its new state. A good definition of degradation is therefore that it results in a persistent loss of ecosystem services.

Certain processes, once set in motion, are difficult to slow down or halt. These are the runaway cycles of institutional collapse, accelerated soil erosion, alien plant or animal invasions, landscape fragmentation, or 'desertification'. These so-called 'irreversible' processes, once set in motion, may have so much inertia that an extreme external input is required to slow down or halt them. It is essential that such high-inertia processes are well understood and identified in advance, to enable their management before they assume runaway status.

If the links between ecosystem services and human well-being are so strong, why do people often behave in a way that undermines their own livelihoods? Coupled human-ecological systems can fail when the feedbacks that should regulate them are disrupted or disconnected. Disconnections in time may operate when the negative consequences of current actions are borne by future generations. In other cases, the negative impacts on ecosystem services are disproportionately felt by a sector of society that is not benefiting from the action causing the impact. For instance, urban shareholders may profit from a mining operation, but local fishermen may be affected by the pollution it causes in a river system. In a third common situation, the negative consequences are spatially separated from the actions. For instance, land use changes in the upper part of a catchment may have a major impact at the coast.

Stability and change

Ecosystems naturally change and vary over time. The idea that nature, left to its own devices, is almost always 'in balance' is no longer widely held by ecologists. Most ecosystems are now known to wander far from their point of balance (if it exists), either due to their internal processes or due to natural disturbances such as rainfall variability. In highly variable systems (such as the semi-arid parts of southern Africa) the notion of an equilibrium state is somewhat irrelevant, since the system is so seldom near it. Some systems may have such a broad range of 'normal variation' that it is more useful to think of them as 'non-equilibrium' systems.

A corollary of the old 'balance of nature view', still widely held by the public and many decision-makers, is that nature will fix itself if we just stop doing what we are doing. That is not always the case. Even moderately complex systems are likely to have more than one possible stable state. Ecosystems are fabulously complex, so in general we should expect multiple possible states rather than one 'right' state to which the system always returns. The different stable states of a system are separated by thresholds. If the system is pushed further than this point, it will change to another state, from which it may not return in any reasonable amount of time, or ever.

The concept of 'resilience' measures how far a system can be pushed before it crosses a threshold into another state. Thus resilience is actually a response of a particular state of the system to a particular type of perturbation, rather than a property of the system as a whole. Some ecosystem states may be resilient, and others not. No ecosystem state is resilient to all possible perturbations, and especially not if they are a form of stress that the system has never previously experienced. Resilience, stability, productivity and complexity are all somehow connected, but in complicated ways that ecologists are only beginning to understand.

Renewable resources are based on ecosystem productivity

The supply of provisioning ecosystem services (food, timber, fuel etc) is ultimately controlled by ecosystem productivity. Productivity is a rate at which a resource is produced, not the amount that is present at any given moment. This is analogous to the difference between interest and capital in economics. Where the economics of renewable resources differs from standard economics is that in nature, productivity is often affected by the rate of harvest, while for non-renewable resources it is not. For instance, the size of a gold ore resource (non-renewable) is not dependent on whether you mine it quickly or slowly. But the total amount of timber you can take from a forest, or the fish you can harvest from the sea (both renewable resources) depend on how rapidly you exploit them. If the harvest rate is less than the ecosystem productivity for that component, the exploitable amount is theoretically infinite; if it exceeds the replacement rate it will be finite, and run out at some stage. This is a key principle underlying the concept of ecological sustainability.

Ecosystem productivity is broadly determined by the availability of water, nutrients and energy. In southern Africa, for terrestrial ecosystems, energy from the sun is generally not limiting to ecosystems, but the other two often are. The matter and energy captured by plant growth is called 'primary productivity' and drives the rest of the ecosystem. The broad patterns of crop production, livestock numbers and human population density in the region are all fundamentally related to the factors limiting primary productivity. Ecosystem productivity can be reduced or increased by human actions.

1.4 HOW DO WE INTERPRET SUSTAINABILITY?

'Sustainable Development' is widely accepted to mean the capacity to satisfy current needs without unduly restricting the options to satisfy future needs. Sustainable development is generally seen as having three necessary components: ecological, economic and social sustainability. Numerous attempts have been made to measure these components in an integrated way (Fig 1.5). Strict ecological sustainability requires that consumption rates for all ecosystem products remain less than the production rates. It also requires that the rate of waste production remain less that the rate at which the environment can absorb waste. In the broader sustainability context, the former restriction can be relaxed somewhat, because of the possibility of substitution. For instance, food and water consumption rates of urban areas far exceed the local production rates, but the excess economic value addition in cities allows food and water to be imported from far away – effectively, money has substituted for adjacent croplands and rainfall. Similarly, an unsustainable activity (such as gold mining) is 'sustainable' in the bigger context if the wealth that it produces allows future generations to build a livelihood on some other resource; for instance by getting an education and creating a service industry such as nature-based tourism.

A great deal of policy is built on the concepts of efficiency and optimality. For instance, what is the maximum economic value addition that can result from the use of a cubic meter of water? How can water allocation institutions be set up so that they channel water resources to optimal uses? Efficiency (getting the greatest output per unit resource input) is good, provided basic needs of people and ecosystems are met, but a sole focus on efficiency as a development goal can run afoul of considerations of resilience, which are particularly important for social sustainability. For instance, high-yielding crop cultivars may provide the maximum yield per hectare, but are more vulnerable to drought, pests, and the vagaries of fertilizer supply than are the low-yielding but resilient land races that they replace.

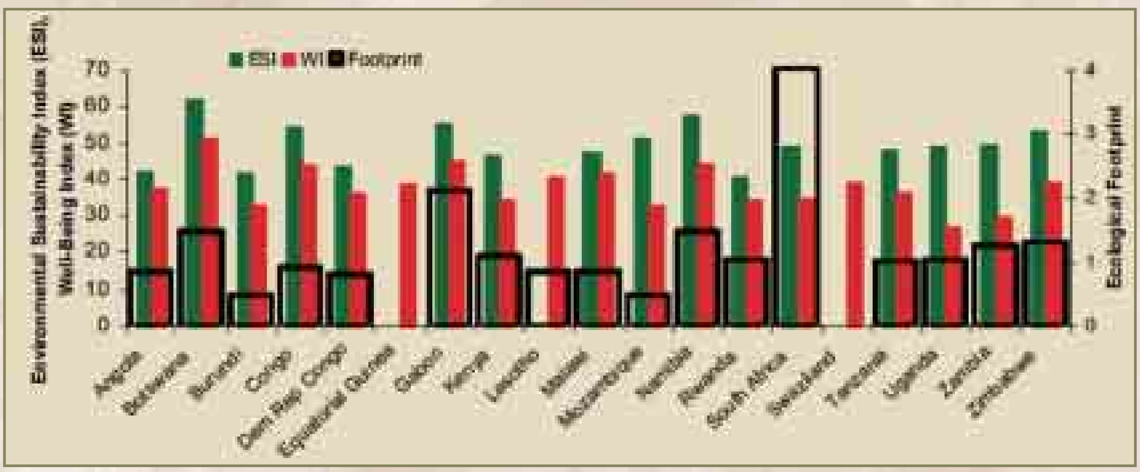


Figure 1.5 A comparison of three indicators of sustainable development, the Environmental Sustainability Index (ESI) (World Economic Forum et al. 2002), the IUCN-sponsored Well-being Index (WI) (Prescott-Allen 2001), and the Ecological Footprint (Wackernagel et al. 2002). These indicators are generated by global groups, using globally-available data, but quantified for individual countries. While indicators vary in the detail of their results, there are broad correlations between measures, at least when countries are compared within a regional context. Of the indicators presented, the highest correlation (44%) is between the Environmental Sustainability Index and the Well-being Index. The correlation is statistically significant and underscores the main point of this report: human well-being is related, substantially but not exclusively, to the state of ecosystems.

PART II: ECOSYSTEM SERVICES IN SOUTHERN AFRICA

Ecosystem service supply and demand are uneven in both where and when they occur. Thus certain areas of southern Africa have an adequate supply of water, food, fuelwood and fodder, while others have a shortage, and the pattern changes with time. Many factors affect this balance: climate, soil, human population density, wealth, history, policies and ecosystem management technology, to name a few. Whether a problem is apparent or not can depend on the scale of analysis as regional averages hide local variation. This is true even at small scales: families within one village have different access to resources. In this section we highlight several ecosystem services assessed at multiple scales in SA*f*MA.

2.1 FRESHWATER IS VITAL

Water is an ecosystem service that has no substitutes. Essential for human consumption and sanitation, water is also crucial for the maintenance of critical ecosystem processes and the viability of many economic sectors, such as agriculture, industry and tourism. In addition, freshwater ecosystems (including wetlands) provide a range of regulating services such as natural flood control, water filtering, water storage, erosion control and a whole range of food and material products such as fish, shellfish, timber and fibre. Growing human populations, increasing levels of household and industrial consumption, deteriorating wastewater treatment, necessarily restrictive water policies and climate change are some of the factors that will affect future water availability in the southern African region.

Water and human well-being

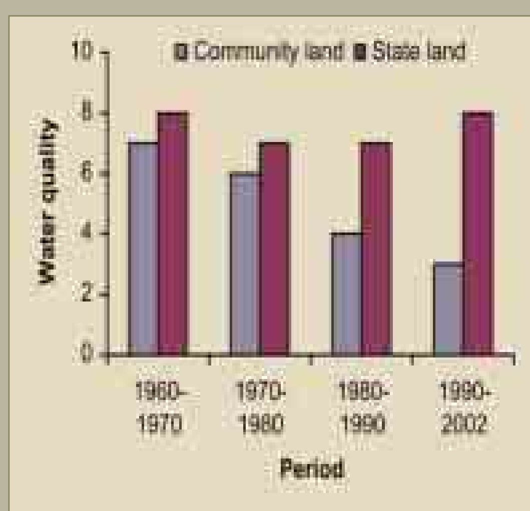
Access to an adequate supply of safe water is a fundamental need and human right. The United Nations sets a minimum target of 1000 m^3 of water per person per year to satisfy human needs. If supply drops below this level, it can limit food production and economic development. However, it does not necessarily do so: people can apply technologies for regulating water use and promoting conservation or re-use, or countries can concentrate on economic activities which use less water, and import goods that demand more water for their production. Adequate access to water means that the considerable amount of the time women and children spend fetching water can be spent on more productive tasks that improve livelihoods and economic productivity, a key component of poverty alleviation.

Box 2.1.1 Water Quality in the Great Fish River Valley, South Africa

In the Great Fish River Valley, water quality varies with land ownership. Local people have perceived a decrease in the quality of water on community land, but believe that water quality on state land has remained high. This example shows the use of participatory assessment techniques, and their conversion to quantitative data.

Perceived water quality on community land

Perceived water quality on State land



While the absolute quantity of available water is an important issue, the key problems of water access usually relate to obtaining water of an adequate quality (Box 2.1.1). Lack of access to safe water is a leading cause of illness and death in developing countries, especially amongst children (Table 2.1.1). The most common water-related diseases include diarrhoea, intestinal worms, cholera, trachoma and schistosomiasis (bilharzia). Frequent exposure to parasitic and diarrhoeal illnesses associated with poor water quality and sanitation can also speed the progress of HIV infection to full-blown AIDS. Deteriorating water quality resulting from pollution can also be a barrier to the use of water for irrigation and even industrial development. Treating water that has been polluted by mining and industrial activities, fertilizer application or poor waste disposal is both difficult and expensive.

Degradation of freshwater ecosystems (e.g. by siltation, eutrophication and invasion of alien species) has further important impacts on human well-being. In parts of the region such as the Zambezi River Basin, fish from rivers, lakes and wetlands are a major source of protein. Habitat degradation and pollution of freshwater ecosystems, resulting in the decline of fish stocks, can therefore have important impacts on both food and water security and associated economic activities. Land clearance in river catchments and the degradation of wetlands may increase the risk of episodic flooding with associated losses of infrastructure. Degradation also reduces the water storage capacity and, consequently, the seasonal water availability across the ecosystem.

Table 2.1.1 Water availability and use in southern Africa, as compiled in the SA*f*MA regional scale study (Scholes & Biggs 2004). Water availabilities below 1000 m^3 per capita per year (highlighted) can lead to serious problems with food production and economic development. On average, agriculture is responsible for 74% of the region's water use; domestic and industrial uses respectively comprise 17% and 9% of total water use. Lack of access to safe water is a major cause of illness and death, especially amongst children in rural areas, where access is usually poorer than in urban areas.

Country	Renewable water resources[1]	Total water use	Water per person	Access to improved water	Access to improved sanitation	Under-five mortality
	km^3 p.a.	*km^3 p.a.*	*m^3 per cap*	*% Tot pop*	*% Tot pop*	*per 1000 births*
Angola	184.00	0.34	13620	38	44	260
Botswana	14.40	0.14	8471	95	66	110
Burundi	3.60	0.23	519	78	88	190
Congo	832.00	0.04	268387	51	..	108
Dem Rep Congo	1283.00	0.36	24508	45	21	205
Equat. Guinea	26.00	0.11	55319	44	53	153
Gabon	164.00	0.13	130159	86	53	90
Kenya	30.20	1.58	982	57	87	122
Lesotho	3.02	0.05	1467	78	49	132
Malawi	17.28	0.11	1641	57	76	183
Mozambique	216.11	0.64	11960	57	43	197
Namibia	17.94	0.27	10022	77	41	67
Rwanda	5.20	0.08	656	41	8	183
South Africa	50.00	15.31	1156	86	87	71
Swaziland	4.51	0.83	4215	48	44	149
Tanzania	91.00	2.00	2642	68	90	165
Uganda	66.00	0.30	2896	52	79	124
Zambia	105.20	1.74	10233	64	78	202
Zimbabwe	20.00	2.61	1560	83	62	123
REGION[2]		**26.87[3]**	**11390**	**61**	**63**	**155**

.. No data

[1] Total surface and groundwater resources within a country's borders, plus or minus the natural flows entering and leaving the country, as well as flows secured through treaties and agreements with other countries. Aggregation cannot be done for the region as it would result in double counting of shared water resources.

[2] Population-weighted averages

[3] Weighted by total renewable resources of each country.

Water availability at different spatial scales

Why a multi-scale approach?

The multi-scale approach of SAfMA makes it possible to investigate processes at the scales at which they occur. For example, water availability at the local scale is most influenced by community adaptations and social institutions that protect natural sources, fountains, sacred pools and wetlands, as well as institutions that maintain water reticulation systems (tap water) and promote technology transfer such as wells, rainwater tanks, and cost-effective water pumps. National water policy is the dominant factor at the basin scale, including issues such as inter-basin transfer schemes and land use (specifically maintaining indigenous vegetation ground cover). At the regional scale, climate patterns and climate change are critical.

A multi-scale approach also takes into account feedbacks between scales. For example, a local assessment of water supply in a downstream farming community would be incomplete without information about the activities in upstream parts of the basin. Larger-scale assessments provide context for local-scale studies, while local assessments can ground-truth regional-scale findings.

Assessments at different scales give different answers

The regional scale 'view' may differ from basin and local-scale views due to averaging over local differences (Fig 2.1.1). For example, the national averages in Table 2.1.1 may lead one to believe that Namibia has water supplies far in excess of demand. In fact, most of Namibia is hyper-arid and only the extreme northern parts have excess water supplies. While on average everyone has sufficient water, people in many areas of Namibia experience extreme shortages while people in the northern parts have more than enough water. In other cases, local communities may have adapted in ways that overcome the shortages predicted by regional scale models. For example, Windhoek, the capital of Namibia, manages to sustain industrial activities in a very arid part of the country by means of a sophisticated water-recycling system. Shortages apparent at the local scale but not predicted at the regional scale may be due to localised high demand activities (e.g. irrigation in the lower Gariep Basin) which are not included in the larger scale models.

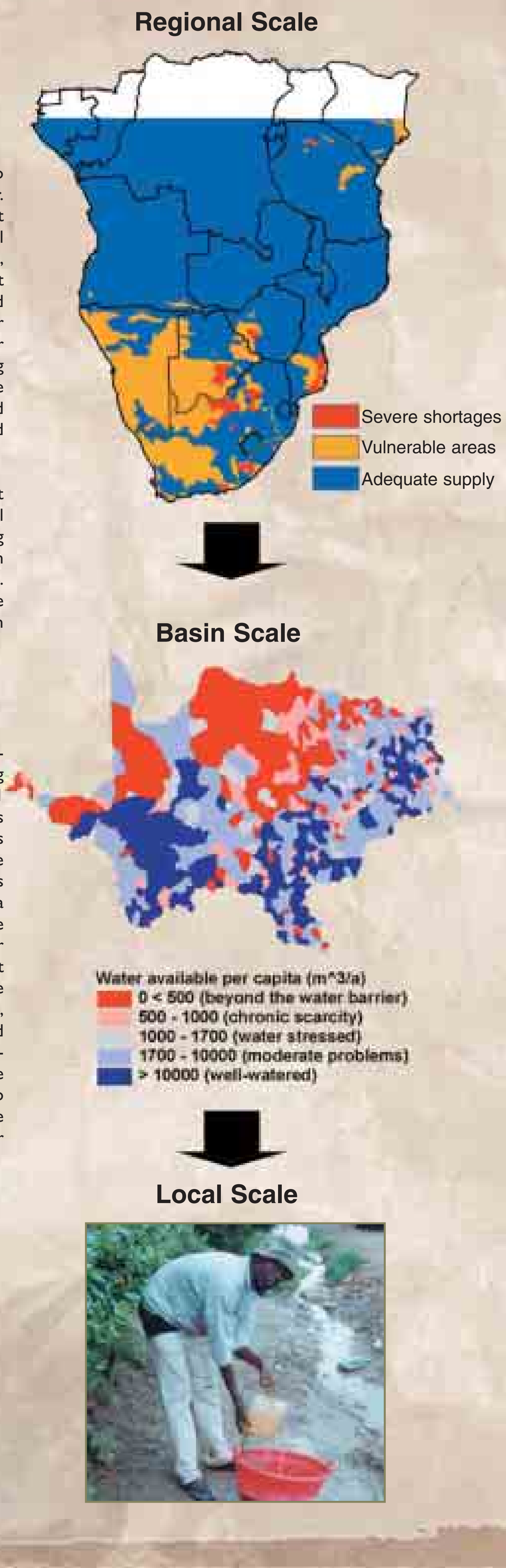


Figure 2.1.1 Water is unevenly distributed in the southern African region, and this 'lumpiness' is apparent at multiple scales. When one 'zooms in' on an area that appears uniform at the regional scale, localised areas of excess and deficit appear. Assessments at more detailed scales, such as the Gariep Basin assessment, tend to use localised datasets (e.g. national statistics), and often give results that differ significantly from those derived in larger scale studies that use global or continental datasets. At the local scale, socio-economic factors are usually the most important in determining household water availability.

Water availability over time

Assessments over different time periods give different answers

Similar to the differences that emerge when one 'zooms in' at finer spatial scales, important differences emerge when one 'zooms in' at finer temporal scales. An analysis of the average annual water availability may hide the fact that certain areas experience severe water shortages during specific times of the year. For example, while the rift valley region of Tanzania has an annual excess water supply, it experiences severe shortages during the dry months (Figure 2.1.2). It is often these 'bottlenecks' in the provision of ecosystem services, rather than the average annual conditions, that determine human well-being in specific regions.

'Surprises' and rare events

Large infrequent disturbances, such as prolonged droughts and severe floods, have major impacts on water provisioning, and their effects on infrastructure and human well-being may last for several years. For example, the major floods that occurred in Mozambique in 2000, destroyed not only people's crops for that year, but also left many without the homes and possessions they had built and accumulated over many years. Droughts similarly have massive impacts on people's capital and responsiveness to future crises when, for example, large numbers of livestock die. The importance of such extreme events lies not only in their magnitude, but also in their unpredictability. The frequency of extreme events such as droughts and floods are expected to increase under future climate change (see Key Issue 1 on Climate Change). Even in the absence of climate change, ecological mismanagement can precipitate the collapse of ecosystem services that can result in irrevocable harm to human well-being. For instance, the addition of fertilisers to agro-ecosystems inadvertently provides the nutrients that fuel more frequent cholera outbreaks in untreated and polluted waters in KwaZulu-Natal province, South Africa. Limited historical data present a major obstacle to planning and policy development; in many instances only general areas at risk can be identified based on factors such as topography (Fig 2.1.3).

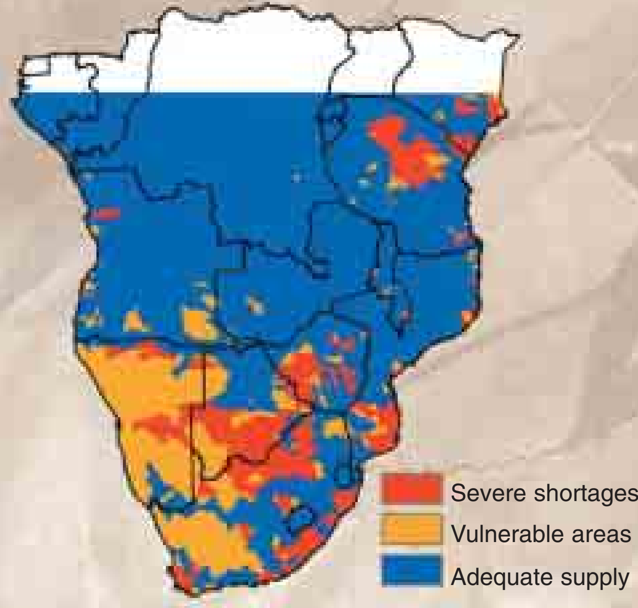


Figure 2.1.2 Water availability in the driest month. Human well-being is often more directly related to "bottlenecks" than to average resource availability.

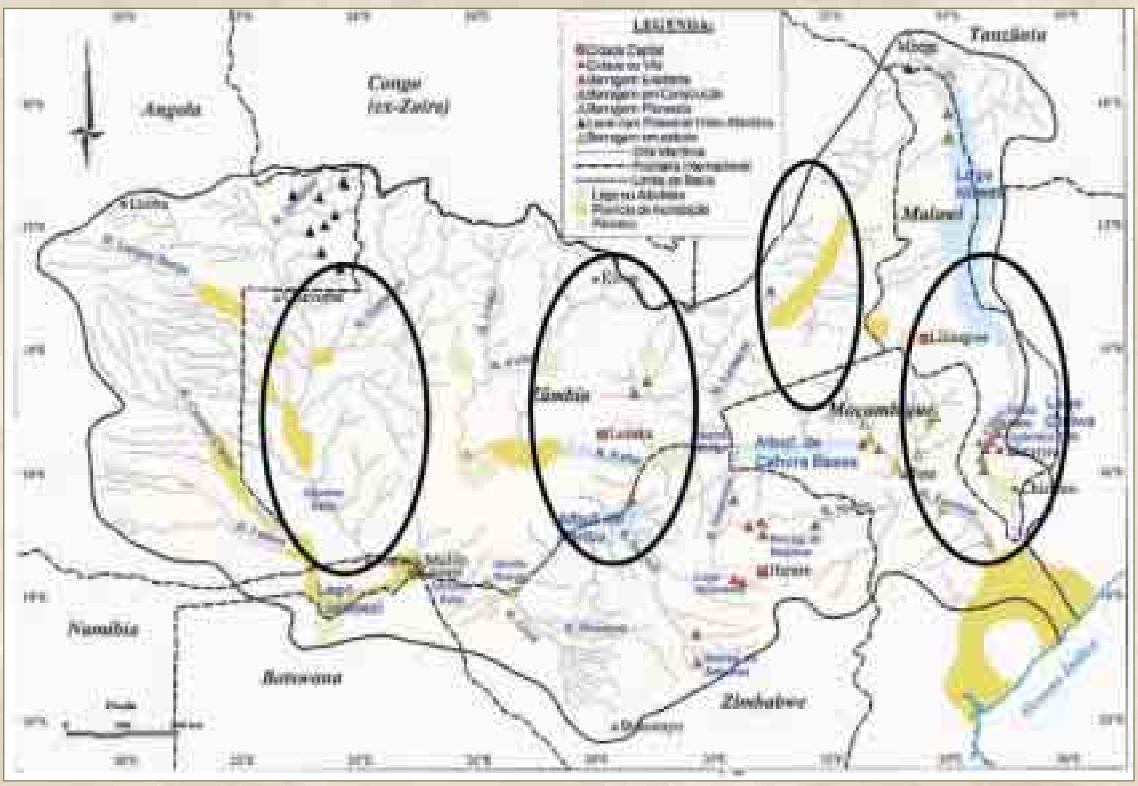


Figure 2.1.3 Areas at risk of flooding in the Zambezi basin. Extreme events such as droughts and floods are projected to increase over coming decades due to climate change.

KEY ISSUE I: CLIMATE CHANGE: A MAJOR CONCERN IN SOUTHERN AFRICA

Climate change poses a serious threat to ecosystems and human well-being in Southern Africa, both in the medium- and long-term. The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report published in 2001 has clearly established how human activity is modifying the global climate. Ranges in temperature rise of 2 to 6°C are projected for the next 100 years, and will be accompanied by changes in precipitation patterns, rises in sea-level and increased frequencies of extreme events (droughts and floods). These changes are projected to have serious impacts on human welfare as well as other forms of life. While the exact nature of the changes is not known, there is general agreement about general trends as simulated by global climate models using a consistent set of emission scenarios according to the latest IPCC social economic scenarios (IPCC 2000):

- The historical climate record for Africa shows warming of approximately 0.7°C over most of the continent during the 20th century, a decrease in rainfall over large portions of the Sahel, and an increase in rainfall in east central Africa.
- Climate change scenarios for Africa (Hulme et al., 2001; Desanker and Magadza 2001) indicate future warming across Africa ranging from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario). This warming is greatest over the interior of semi-arid margins of the Sahara and central southern Africa (Fig B).
- Although model results vary, there is a general consensus for increased rainfall in East Africa and drying in southwest Africa. Future changes in mean seasonal rainfall in Africa are less well defined. Under the lowest warming scenario, few areas experience changes in rainy season totals (December - February or June - August) that exceed natural variability by 2050. The exceptions are parts of equatorial east Africa, where rainfall increases by 5-20% in December - February and decreases by 5-10% in June - August. Under the most rapid global warming scenario, increasing areas of Africa experience changes in summer or winter rainfall that exceed the level of natural variability. Large areas of equatorial and East Africa experience increases in December - February rainfall of 50-100%, with decreases in June - August over parts of the Horn of Africa. There are some June - August rainfall increases for the Sahel region.
- Globally, sea levels are projected to rise by about 0.5m this century, and much more if warming continues.

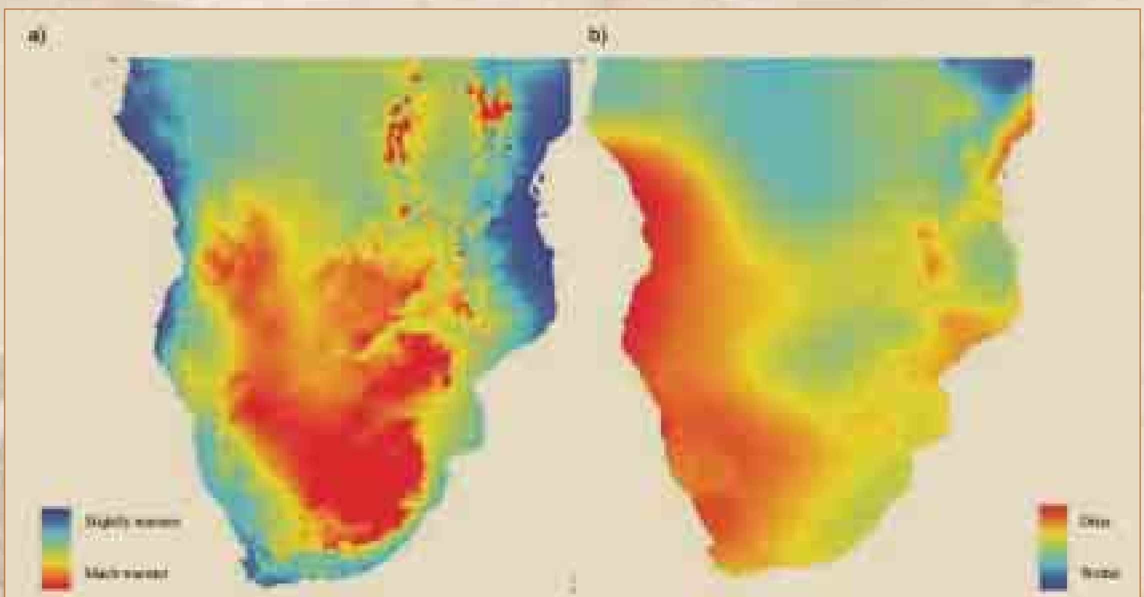


Figure B. HADCM3 climate model projections of changes in temperature (a) and precipitation (b) for 2050 relative to mean conditions over the 1961 to 1990 period, under the IPCC SRES A2 (high emissions) scenario. Source: Scholes & Biggs (2004), data interpolated by G. Hughes, National Botanical Institute, South Africa.

Impacts on biodiversity in southern hemisphere Africa

Several key centres of plant endemism occur in southern Africa and are particularly vulnerable to climate change. The Cape Floral Kingdom (fynbos) has 7,300 plant species, of which two thirds occur nowhere else in the world (Gibbs 1987). The adjacent Succulent Karoo biome contains an additional 4,000 species, of which over half are endemic (Cowling et al. 1998). Both these floristic biodiversity hotspots occur in the winter rainfall fynbos region at the southern tip of the continent and are threatened particularly by a shift in rainfall seasonality (for instance, a reduction in winter rainfall amounts or an increase in summer rainfall, which would alter the fire regime that is critical to regeneration in the fynbos).

Many flagship protected areas in southern Africa are projected to see major changes in their species composition under climate change (Rutherford et al. 1999, Erasmus et al. 2002, van Jaarsveld & Chown 2000, WWF 2001). A very large fraction of African biodiversity occurs outside of formally conserved areas, as a result of a relatively low rate of intensive agricultural transformation on the continent. This will no longer be true if massive expansion of agriculture and clearing of tropical forests occurs in the humid and subhumid zones, as is predicted to occur in the next century by some land-cover change models (Alcamo 1994). Land-use conversion effects on biodiversity in affected areas will overshadow climate change effects for some time to come.

Several studies have already noted changes in biodiversity associated with the warming that has occurred during the 20th century (Hulme 1996, Rutherford et al. 1999, Erasmus et al. 2002). There is evidence that *Aloe dichotoma* is dying in the northern part of its range, but stable in the southern part, as predicted by the global change models (Foden et al. 2003). There is also experimental evidence that the recorded expansion of tree cover into grasslands and savannas may be driven by rising global CO_2 concentrations (Bond et al. 2003). The ability of species to disperse and survive these pressures will be hampered by a fragmented landscape made inhospitable by human activities. The AIACC project is currently analysing response options that may conserve biodiversity under future climate and land cover scenarios in southern Africa.

Impacts on water resources

Climate change could severely impact upon water resources, already scarce in the southern part of the region. Higher temperatures increase evaporative demand even if rainfall remains unchanged; however the balancing effect of simultaneously rising carbon dioxide is not fully understood. Increased incidence of droughts would pose obvious hardships on all systems. Increased rainfall intensity and flooding can destroy agricultural systems, as well as infrastructure for transport and irrigation. Water management in internationally shared catchments is likely to be most affected by governance issues rather than water quantity as affected by changes in climate (Pahl-Wostl et al. 2002).

Response options under the UNFCCC

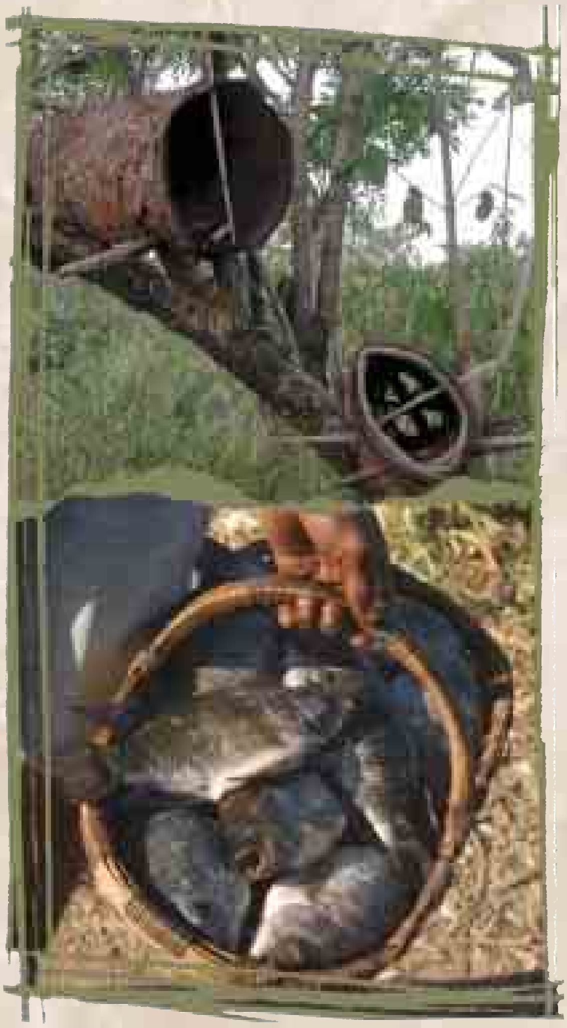
Several response opportunities for protecting ecosystem services are provided for under the United Nations Framework Convention on Climate Change (UNFCCC):

- The National Adaptation Programme of Action (NAPA), is being implemented by the UNFCCC to enable least developed countries to identify and address their urgent needs for adaptation. Countries in southern hemisphere Africa that can take advantage of NAPA include : Angola, Burundi, Lesotho, Rwanda, Malawi, Mozambique, Zambia and Tanzania (Desanker 2004).
- A new window under the Global Environmental Fund (GEF), open to all developing countries, now exists for funding pilot adaptation projects .
- Sustainable development activities that sequester carbon can be funded through the Clean Development Mechanism (CDM). These require countries to set up what is called a 'Designated National Authority' (DNA), a legal entity that will negotiate and coordinate contracts associated with CDM activities. Carefully designed projects can have multiple benefits, from carbon sequestration to protection of critical watershed areas and conservation of biodiversity, and can contribute to socio-economic development if implemented jointly with communities.

2.2 ECOSYSTEMS PROVIDE FOOD AND FOOD SECURITY

All our food ultimately comes from ecosystems. Agricultural fields are a highly modified and specialised type of ecosystem. 'Natural' ecosystems also provide a significant amount of food in southern Africa, such as range-fed livestock, fish from lakes and the sea, fruits, honey, and 'bushmeat' from forests and woodlands. Ecosystem degradation, and the consequent reduction in these ecosystem products, therefore makes people vulnerable to food insecurity.

Food security may be defined as access, at all times, to sufficient food for a healthy and active lifestyle. Food insecurity compromises human well-being in a number of ways, and in its extreme form leads to an inadequate intake of macronutrients (protein, carbohydrates and fats) and/or micronutrients (vitamins and minerals), which in turn causes hunger, undernourishment and malnutrition. Sub-Saharan Africa is considered the most food-insecure region of the world, having the highest prevalence of malnutrition (FAO 2002). The situation is exacerbated by the high HIV prevalence in the region (Box 2.2.1, Table 1.1). Between 1992 and 2001, the average prevalence of population-weighted weight stunting in the region amongst children under five was 25%.



Ecosystems underpin livelihoods

Adequate food and nutrition is fundamental to human well-being. Apart from the food that ecosystems provide, they also provide the water, nutrients and pest-regulation that permit agriculture to occur. Ecosystems support a suite of livelihood strategies and opportunities that are derived both from agriculture and non-food ecosystem services (such as employment associated with ecotourism), which allow people to trade for the food that they do not grow or collect themselves. Thus food and non-food ecosystem services together determine whether people have access to sufficient nutriment to ensure their well-being.

The environmental factors that determine the capacity of ecosystems to provide food and non-food services include soils, rainfall, climate, pests and diseases and ecosystem integrity. Food supply at the household level, however, is not only determined by the biological capacity of ecosystems. There are numerous human factors which determine the level of ecosystem service provision, as well as intervene to determine whether people gain access to cultivated, wild and imported foods. These include economic factors such as food prices, the level of exports, market access and household income; demographic factors such as labour availability, population density, migration, age and gender; political factors such as land access and tenure, governance, conflict, education and government policies; technological factors such as agricultural expertise, levels of agricultural inputs and pest control, infrastructure and distribution networks; and cultural factors such as crop and food preferences and cultivation practices.

Box 2.2.1 The mutually compounding effects of HIV/AIDS and food insecurity

In the greater context of livelihood strategies and vulnerability, HIV/AIDS is accelerating the breakdown of social structures and farming systems in rural areas in southern Africa into forms characterised by higher levels of poverty, vulnerability and food insecurity (Drinkwater 2003). Food insecurity exacerbates the spread and impact of HIV/AIDS by: increasing migration and therefore increasing the risk of exposure to HIV/AIDS, alternative livelihood strategies being sought (e.g. prostitution) which increase the risk of exposure to AIDS, and through leading to malnutrition which weakens immune systems and makes those infected with HIV/AIDS more vulnerable to opportunistic diseases.

The impacts of HIV/AIDS are, moreover, set to exacerbate gender inequalities in food security. Women are both physically and socio-economically at greater risk of infection. Additionally, women in sub-Saharan Africa are traditionally the purveyors of child care and food provision. Lastly, women and children are frequently excluded from access to the household land and other assets of a deceased husband or male family member (Drinkwater 2003).

Staple carbohydrate crops

The supply of staple carbohydrates is just adequate in good years

The region as a whole has the agricultural potential, with respect to climate, soil and terrain slope constraints, to produce enough cereal to satisfy projected kilocalorie requirements in 2020, even in the face of anticipated levels of climate change and population growth. Socio-economic and political factors result in this potential not being realised. Projecting current trends in the indicates that in the absence of major interventions, tens of millions more people will be insecure in 2020 than at present, and the Millennium Development Goals with respect to reducing hunger will not be met.

Tremendous spatial disparities in food production capacity exist at national and sub-national levels (Table 2.2.1). For example, a food supply-less-demand map of the Gorongosa-Marromeu region (Fig 2.2.1), illustrates a trend of a deficit in the north-western districts, where there are high population densities, low rainfall and water availability, and large areas that have soils that are unsuitable for agriculture. Where people are unable to produce sufficient quantity or variety of food for their nutritional needs, food must be imported, which means that food access becomes highly mediated by social factors such as markets, infrastructure, institutions and food pricing. Short and long-term local, national and regional deficits in food production make for high food prices as well as food price volatility.

Table 2.2.1 Estimated percentage contributions of carbohydrate- and protein-supplying crops in southern Africa to total dietary intake around year 2000 (Scholes & Biggs 2004). Several countries fall significantly short of the recommended minimum daily calorie intake of 2100 per person (highlighted). The region as a whole falls below the recommended minimum daily intake of protein, which is 52 g per person (highlighted). The Democratic Republic of Congo and Mozambique fall significantly below this requirement. Note that these figures are national averages: within-country disparities are often larger than those between countries.

	CARBOHYDRATE NUTRITION					PROTEIN NUTRITION				
	Grand total (cal/cap/day)	Percentage contribution[1]				Grand total (grams)	Percentage contribution[1]			
		Cereals[1]	Roots	Pulses	Fruit & Veg		Cereals[2]	Roots	Pulses	Animal products
Angola	1885	33	35	4	3	41.3	39	15	11	23
Botswana	2264	47	2	5	3	71.2	40	1	12	31
Burundi	1632	16	33	24	11	44.1	15	14	51	5
Congo	2159	25	38	1	6	42.8	36	13	4	24
Dem Rep Congo	1616	19	58	2	4	24.1	32	23	9	9
Eq. Guinea	..	..	..	..	..	..	..	..	..	0
Gabon	2569	28	18	0	16	73.7	24	8	0	32
Kenya	2020	50	7	3	6	53.2	51	3	8	27
Lesotho	2298	78	3	3	1	63.7	77	3	6	9
Malawi	2133	60	16	5	4	53.4	62	11	13	6
Mozambique	1919	41	35	4	1	38.0	56	14	15	8
Namibia	2650	55	12	2	2	77.6	48	7	4	28
Rwanda	1919	15	33	14	25	48.1	21	18	40	6
South Africa	2875	54	2	1	3	76.6	57	2	2	28
Swaziland	2529	47	2	2	2	63.7	47	1	4	33
Tanzania	1942	50	21	5	4	47.6	49	10	13	16
Uganda	2324	22	22	8	23	56.2	20	11	22	17
Zambia	1888	65	13	1	1	47.1	68	4	2	11
Zimbabwe	2080	57	2	2	1	49.9	65	1	4	12
REGION[3]	**2088**	**42**	**21**	**4**	**6**	**48.8**	**45**	**11**	**11**	**17**

[1]Percentages do not add to 100, as not all sources are listed, [2] Excluding beer, [3] Population-weighted totals

Protein Nutrition

Protein nutrition is inadequate and falling north of the Zambezi

Africa south of the equator is chronically under-supplied with protein, and the situation is steadily worsening. The recommended daily intake of protein is 52 g per person; on average the supply is below 50 g/person/day (Table 2.2.1). There are clear within-region differences: south of the Zambezi the average is 75 g/day and stable, north of this line it is 42 g/day and declining. Domestic animal-based products provide, on average, 14% of the recorded protein consumption in the region. Fish provide 4%, and the remaining 81% comes primarily from plant sources, especially cereals. The countries with the most severe protein deficiencies are also those on the relatively moist, but infertile interior plateau of Africa, where carbohydrate diets are dominated by root crops rather than maize and pulses. The limited nitrogen-supplying capacity of the soil is the underlying factor, and the decline in protein coincides with a levelling off of the (low) levels of fertiliser input in these regions.

Freshwater fisheries are overexploited

Fish in southern Africa come 43% from the Benguela Current fishery of the west coast of South Africa, Namibia and Angola; 36% from freshwater fisheries, primarily in the great lakes region; and 21% from the warm-water marine fisheries off the east coast of South Africa, Mozambique, Tanzania and Kenya. The Benguela fishery shows no overall trend in its total stocks, despite significant inter-annual variability and shifts in species, and a sustained offtake of over a million tons per year for several decades. The lakes fisheries show classical signs of overfishing. Data on the east coast fisheries are sparse. Anecdotal evidence of international illegal fishing, personal observation of damage to reefs, and extrapolation from similar tropical marine fisheries elsewhere make it likely that in many instances they are overfished.

Wild plants and animals play a critical role in food security in southern Africa

Wild plants and animals play a critical but under-reported role in food security and nutrition across southern Africa, particularly during times of drought or food insecurity and in arid and semi-arid areas. Wild species are consumed on a regular basis as part of the diets of rural southern Africans, including antelope, monkeys, rodents and reptiles, as well as a range of invertebrates such as snails, termites and caterpillars. Estimates of the contribution of 'bushmeat' to the total daily dietary intake of protein range from 0.1% in South Africa to 8.5% in the DRC (Scholes & Biggs 2004). Estimates are, however, based on very limited data and are not considered to reflect the true intake for many rural communities. The absence of reliable records is in part due to the fact that bushmeat is largely consumed within the household or sold through local markets, so that the volumes are not easily captured on formal information systems. Furthermore, bushmeat harvesting is often illegal. Subsistence hunting and gathering of bushmeat is estimated to account for 90% of bushmeat supply on the African continent, and for many communities it increasingly constitutes a major informal industry critical to livelihoods.

Despite an unduly restrictive policy and legislative environment, the formal legal game meat production in Botswana, Mozambique, Zimbabwe, Zambia, Malawi, Tanzania and Kenya is estimated to total 8 500 metric tons annually, with a value of over US$7.5 million. Larger sectors exist in Namibia and South Africa, where game farming is a recognized and supported land use. Illegal bushmeat harvesting, meanwhile, is increasing, but the same policy constraints and lack of support for programmes aimed at the sustainable use of wildlife, are leading to unsustainable off-take and a depletion of the wildlife resource base.

Multiple factors determine food security

People everywhere pursue a range of livelihood strategies to increase their income or asset base, spread or reduce risk, mitigate the impact of shocks, and, at the extreme, ensure survival. At the local level, for individuals and households, food acquisition is just one of the needs that people must meet by drawing on their livelihood resources. People acquire food through various combinations of producing it themselves, hunting or gathering it, purchasing it, exchanging it for other goods or receiving it as a gift. In general, there is a high reliance in southern Africa on food purchases to meet calorie requirements. In South Africa, for example, access to food is primarily a function of total household income, rather than own production.

Vulnerability is related to livelihood choices

The ability of households and communities to cope with adverse livelihood conditions (such as illness or drought) is determined by the nature and extent of their livelihood choices, and is described by their level of vulnerability. When people are vulnerable, they frequently have to choose livelihood strategies – particularly coping, adaptive and survival strategies – that further undermine their resilience and increase their vulnerability to the negative impact of adverse conditions. Examples of these 'trade-offs' include reduced expenditure on healthcare and education and missing meals, such as routinely done by the poor in Malawi and elsewhere.

What causes food insecurity at the local level in southern Africa?

The factors causing the high levels of food insecurity and malnutrition that are so extensively felt in southern Africa were synthesised from 49 local-level case studies that examined food security from across the region (Misselhorn in prep.). Food insecurity was found to be one element in an entrenched and escalating cycle of socio-economic frailty and vulnerability, mainly associated with chronic, ongoing elements in the lives of the communities, upon which short-term crises acted to further exacerbate vulnerability (Fig 2.2.2). A failure to access food through purchase was found to be more prevalent than food insecurity due to local production deficits. Many factors act to undermine community resilience, including: decreased expenditure on essential goods and services (education, staple foods, healthcare, agriculture and livestock inputs), in- and out-migration (return to the community due to retrenchment or a search for work elsewhere), sale of assets (such as livestock at reduced prices), as well as a decrease in the number and dietary variation of meals. Climate and environmental stressors and poverty featured most prominently amongst the direct drivers of food insecurity, while poverty, climate and environmental stressors and social and political unrest and war accounted for half of the indirect driver impact.

Direct drivers of food insecurity	%
Climate & env. stressors	12
Poverty	7
Increase in food prices	5
Failure in land rights/land access	5
Lack of employment	5
Lack of education	5
Poor market access	4
Pests & diseases	4
Poor human health	4
Low regional cereal availability	4
Poor dist. networks & infrastructure	4
In and out migration	4
Inflation	4
Social and political unrest or war	3
Sale of assets	3
Insufficient agriculture inputs	3
Government policies	3
Total	**80**

1/3 sudden shock effects, 2/3 ongoing chronic effects

Underlying drivers of food insecurity	%
Poverty	21
Climate & env. stressors	17
Social & political unrest	12
Prevalence of HIV/AIDS	5
Government policies	5
In and out migration	4
Poor human health	4
Sale of assets	4
Low regional cereal avail.	4
Lack of education	3
Population pressure	3
TOTAL	**81**

Fig 2.2.2 The processes driving food insecurity in Southern Africa, identified from a synthesis of 49 local-level case studies (Misselhorn in prep.)

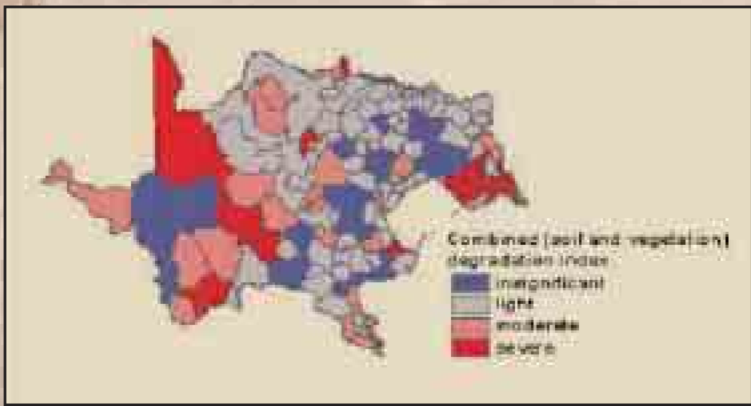


Fig 2.2.3 Combined index of soil and vegetation degradation per municipality in the Gariep assessment (Bohensky et al. 2004).

Loss of ecosystem integrity undermines food security

An example of a significant environmental stressor in southern Africa is provided by the analysis of soil erosion in the Gariep assessment (Fig 2.2.3). More than 70% of South Africa is estimated to be affected by soil erosion, which reduces agricultural capacity through loss of physical capacity for crops and vegetation, as well as through nutrient losses. Soil degradation, primarily by erosion, is perceived to be more of a problem in the communal farming and former homeland areas than in commercial farming areas. Increases in soil losses from these areas were partly attributed in the report to in-migration, poor infrastructure, poor education, poor runoff control, increases in stock numbers and shifts to different breeds of grazing animals.

Structural adjustment and market liberalisation tend to increase vulnerability of small farmers

An example of an intervention that has negatively affected food security, through lowered food production and loss of income, is the impact of structural adjustment on agricultural markets. From the mid-1980s through to the mid-to-late-1990s, changes in African agricultural policy were typically aimed at eliminating government control over input and output markets, withdrawing agricultural subsidies and facilitating privatisation in order to stimulate agriculture through market integration, increased competition and more cost-effective private-sector trading. The changes have not lead to the anticipated aggregate boost to agricultural productivity, and between 1990 and 1997 food production over sub-Saharan Africa failed to keep pace with the population growth rate. In many instances, liberalisation took place too quickly and without appropriate changes to other areas of policy, so that institutional support structures were removed without alternative, transitional institutional and regulatory frameworks in place. This lead to reduced incentives for agricultural productivity as well as an increase in the vulnerability of smallholder farmers to market failures and food insecurity.

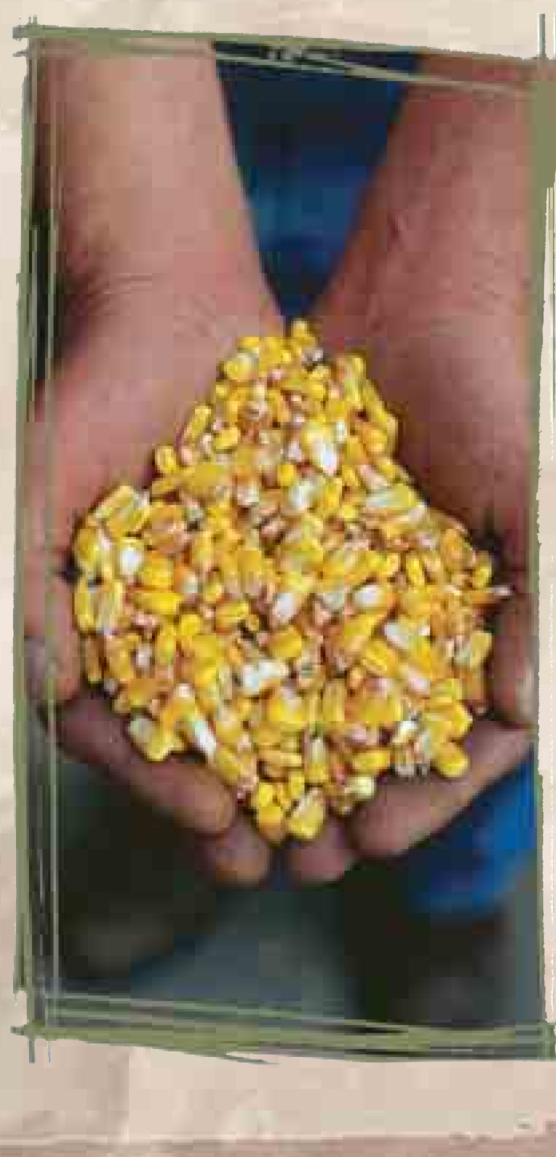
Implications for response strategies

Humans depend on multiple ecosystem services for their food. Apart from edible products, ecosystems also provide a range of non-food services that support livelihoods and affect people's ability to access food.

Food security, defined as access to sufficient food for human well-being, is only partly determined by the quality and quantity of food produced by the ecosystems in which the affected population lives. Availability, affordability and access all affect food security. These, in turn, are affected by a range of interrelated social, political, economic and physical factors.

The ecosystem's inherent capacity for agriculture and provision of wild food forms one limit to the amount and quality of food produced. Numerous human system factors, including among others agricultural finance, availability of markets, inadequacy of infrastructure, apply another set of constraints. In southern Africa, the human system constraints are often the key factors determining production levels.

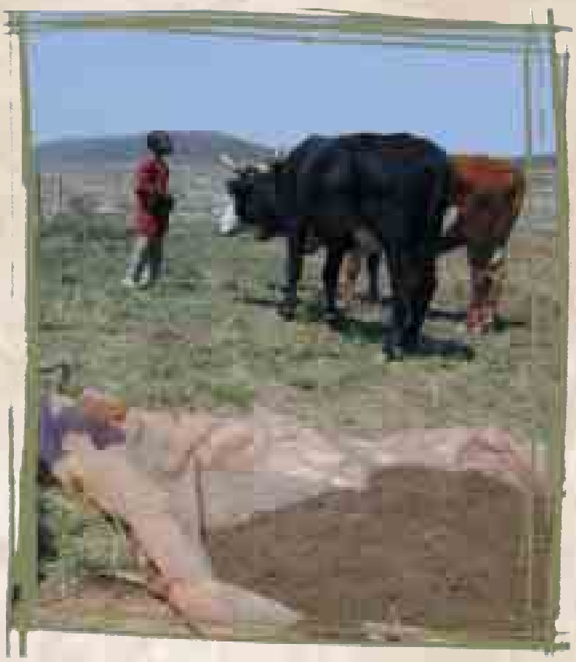
Planners and policy-makers dealing with food security and natural resource management need to communicate, at all scales from the local to the global. To enhance food security, planners need to explicitly take into account the direct and indirect ecosystem services that underlie people's livelihoods.



2.3 LIVESTOCK: ECOSYSTEM-DEPENDENT SOCIAL CAPITAL

Livestock and livestock management is central to the identity and livelihoods of southern Africa's rural communities, and even many urban communities. Among the people of southern Africa, those owning livestock (cattle in particular) have savings and status, can participate in rituals, are able to communicate with their ancestors, can cultivate and fertilize crops, and can cook and warm themselves in winter. But many trade-offs and feedbacks exist between livestock and other ecosystem services, such as crop production and water quality. Livestock owners have, in relative terms, the greatest negative effect on the resilience and productivity of rangelands, the costs of which they share with others in the community, regardless of livestock ownership.

This feedback loop between livestock density, range condition and human well-being is strongly visible throughout southern Africa's communal areas. The holy grail of communal areas management remains: 'how to create incentives for pastoralists who own livestock as a private resource, to reduce their animals on rangeland, a communal resource, in the interest of the common good'. The answer is as elusive as it is complicated, and the solution is certain to be multi-dimensional: better extension services, revival of traditional social institutions or the evolution of new ones, improved rural infrastructure to facilitate the development of stock markets, improved veterinary services, and, ultimately, land redistribution and land tenure reform.



At Emalahleni, in the Eastern Cape of South Africa , stocking rates exceed the recommended agricultural rates by more than 40%, although this figure does not take the use of crop residues for forage into account. Overstocking has an effect on the quality of animals produced, their resistance to disease, and on people's ability to cultivate crops because animals are a source of traction for ploughing, and manure the only source of nitrogen fertilizer. Livestock losses are high during drought periods.

In the South African Richtersveld area, for example, small stock ownership is a way of living that few would give up. Owning goats means having insurance against job losses, being wealthy, having a foot in the contractual National Park, and being part of the way of life of the Nama people. In Richtersveld, a contractual agreement between the Nama people and the National Parks Board, based on flawed carrying capacity models, resulted in the long-term over-stocking of the Park. Other institutional problems were a contractual clause that penalized farmers for grazing outside the park, poorly informed land trade-offs, and a dysfunctional co-management committee. The combination of these factors has resulted in a deadlock for biodiversity: the pastoralists refuse to reduce their stock numbers, infrastructure development in the Park has come to a stand-still, and tourism could be negatively influenced. There are fears for the survival of rare endemic succulents, although any change in their status is unknown. Co-management exists on paper but not really in practice.

Livestock carrying capacity and productivity

The concepts of livestock 'carrying capacity' and 'overgrazing' have come under considerable debate and revision in southern Africa. The two main criticisms are that arid land grazing systems that are intrinsically highly variable in both space and time should not be characterised using a single, unvarying number; and that the concept has a implicit assumptions regarding the desired state and purpose of the land. Notwithstanding this debate, long-term stocking at rates more than twice the wild grazing herbivore biomass that the ecosystems evolved under, as currently occurs in many places, is widely identified as a driver of land degradation in arid and semi-arid areas in southern Africa (see Key Issue II on Desertification). Overall, the 'productivity' of livestock in southern Africa, if defined as the annual offtake of animals as a percentage the standing stock, is low.

KEY ISSUE II: DESERTIFICATION IN SOUTHERN AFRICA

The United Nations Convention on Combating Desertification (UNCCD) defines desertification as 'land degradation in arid, semi-arid and dry sub-humid areas'. Degradation is in turn defined in terms of loss of productivity. The concept of ecosystem services, as used by the Millennium Assessment, can be used to make these definitions easier to implement. For instance, the South African National Action Programme for Combating Desertification defines degradation as '… a persistent decrease in the supply of ecosystem goods and services as a result of loss or changes in the composition of soil or vegetation'. This approach means that the needs of all users of drylands are considered, and not, for instance just those of graziers or crop farmers.

The services definition lends itself to the detection and mapping of desertified areas using remote sensing. This has been attempted in the MA. A range of approaches can be used, all of which show broad agreement for most areas, but differ in the details. All approaches work better when fine-tuned using local knowledge. The gaps in a fine-resolution monthly climate dataset for southern Africa for the period 1985-2004 hampers the interpretation of a purely satellite-derived product, since it is hard to separate climate variability from human-induced trends without such data.

The sub-national scale livestock density data, used in conjunction with a reference grazing level based on long-term African wildlife populations in protected areas, suggests that most countries south of the Zambezi are stocked close to or above the sustainable maximum (Fig C). The areas of degradation revealed by satellites broadly correlate with the degree of overstocking. The correspondence between the degraded locations and areas of communal land tenure is also striking. The causal interpretation must take into account the racially-based land policies in South Africa, Namibia and Zimbabwe over the past century.

Conversion of lightly used but largely intact ecosystems to croplands is the main mechanism contributing to biodiversity loss at present, but the greatest threat in the future is likely to be land degradation. Thus the greatest opportunity for biodiversity protection is the avoidance of degradation in grazed landscapes (Scholes & Biggs 2004).

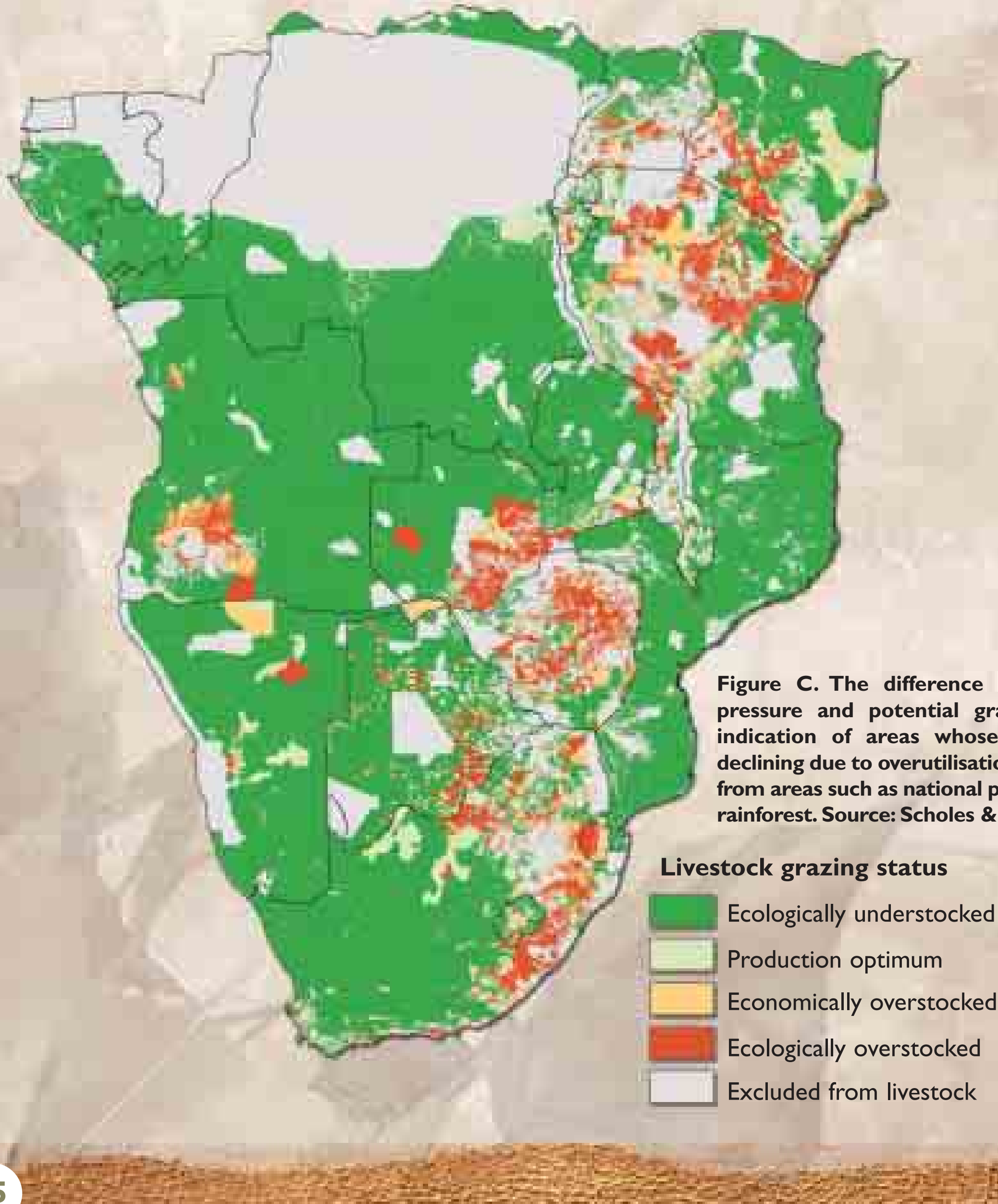


Figure C. The difference between actual grazing pressure and potential grazing capacity, gives an indication of areas whose productive capacity is declining due to overutilisation. Livestock are excluded from areas such as national parks and the Congo Basin rainforest. Source: Scholes & Biggs (2004).

2.4 WOODFUEL AS SUSTAINABLE ENERGY

About a third of the energy used in southern Africa as a whole is derived from trees. Four-fifths of the population use biomass energy for cooking and heating. Excluding South Africa, the fraction of biomass-derived energy rises to about 60%. Even in coal-rich South Africa, biomass energy accounts for about 12% of total energy consumption, and despite strenuous efforts at electrification of informal settlements and rural areas, about half the population still use wood as a domestic energy source. At national to regional scales, the main drivers of fuelwood demand are national energy policies, macro-economic factors (such as alternative employment, affecting the affordability of liquid fuel) and technological factors (such as the availability of affordable alternative energy sources).

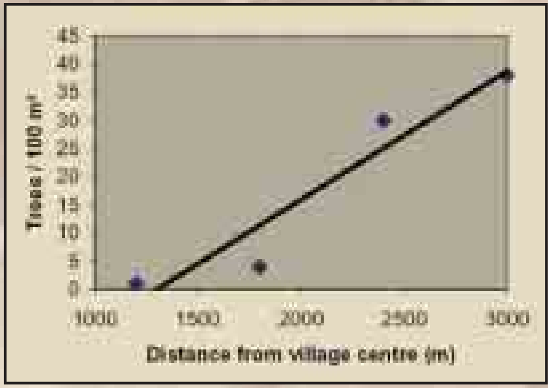


Figure 2.4.1 The availability of wood fuel increases with distance from the village centre (Shackleton et al. 2004).

Wood tends to be the form in which the biofuel is used when the source is close to the place of consumption, for instance in rural situations, while charcoal is the preferred fuel in urban areas. This is because the energy per unit mass of charcoal is about twice that of wood. Where distances exceed about 20 km, the cost of transporting fuel from where it grows to where it is consumed constitutes a large part of the total fuel cost, making charcoal a more viable economic option in most large centres. If the wood is carried by head-load, this distance shrinks to about 5 km. This is very clearly illustrated in data on fuelwood depletion as a function of distance from the village, in the SA*f*MA Eastern Cape study (Fig 2.4.1). A further reason that charcoal is favoured is that it is relatively clean-burning, resulting in the health impacts of charcoal being four times lower than those of wood. There are significant human health problems resulting from the indoor pollution that accompanies the use of chimney-less open-hearth wood fires.

In terms of total energy efficiency and global atmospheric pollution, converting wood to charcoal is a poor option. In most of the region charcoal is produced using relatively primitive methods. Trees are felled and cut into logs, which are stacked nearby and partly dried before being covered with earth and ignited (Box 2.4.1). Following several days of slow, oxygen-starved combustion, which drives off water and large quantities of volatile hydrocarbons, the heap is cooled, opened and the charcoal is extracted. The mass of charcoal is typically only 7 - 22% of that of the original wood. 'Improved traditional' methods can raise this to approximately 30%, and more modern techniques to close to 50%. Although charcoal itself is relatively clean-burning, the total emissions produced when the charcoal-making process is included exceed the total emissions if the wood were directly burned in a well-aerated hearth.

Wood is likely to remain an important energy source in Africa in the coming decades. Although the fraction that it contributes to national energy supply is likely to decline, the absolute number of people needing wood energy by 2030 is predicted to rise by 50%, and an estimated three quarters of the total residential energy will still be supplied by biomass fuels. As the population continues to urbanise, charcoal is set to make up an increasing share of biomass energy. The FAO projects a 25% increase in wood consumption and a doubling of charcoal consumption in Africa during this time period. At local scales, the key factors are the density of human population that is not serviced by affordable energy services, in relation to the growth rate of woody biomass in the locality. Where dung is an important fuel, such as in Lesotho, livestock ownership is also an important factor.

Is there a ‘woodfuel crisis’ in southern Africa?

Southern Africa has been predicted to be on the brink of a fuelwood crisis for decades. The problem has not gone away, but neither has it resulted in general, national-scale catastrophes. One of the reasons is that the early analyses of the ‘woodfuel gap’ were coarse. Although wood scarcity is widespread, it is a relatively local-scale phenomenon and does not lend itself to large-scale averages. The SA*f*MA approach has the advantage that it undertook fuelwood analyses at a variety of scales, from regional to local.

As wood is a renewable resource to bulky to transport for long distances, the correct technical analysis is to compare the local production rate to the local harvest rate. Where harvest exceeds production, the stock will inevitably decline, and despite some regrowth in the depleted area, the zone in which harvesting occurs expands until the effort required to transport the wood exceeds its value. Initially only large, dead, fallen branches are taken, focussing on the most preferred species. As wood becomes scarce, all species are targeted, and living trees first pruned and then felled. The price of fuel rises (either the actual market price, or the opportunity cost of the wood-gatherers, who are typically women) and per household consumption declines. Eventually all twigs, leaf litter, agricultural residues and dung are collected, with negative impacts on soil structure and fertility, and the household is forced to switch partly or completely to alternative energy sources.

Averaged over the entire region, much more wood is grown than is consumed as fuel (Fig 2.4.2). Nevertheless, several clearly defined areas of local insufficiency (i.e. inferred local unsustainable use) emerged from the SA*f*MA regional scale analysis: i) Western Kenya, southeast Uganda, Rwanda and Burundi; ii) Southern Malawi; iii) The area around Harare in Zimbabwe and Ndola and Lusaka in Zambia; iv) Lesotho and; v) Locations in the former homelands of South Africa in the KwaZulu, Eastern Cape and Limpopo provinces, and around Gauteng.

SA*f*MA local studies confirmed that fuelwood shortages are experienced in the Lesotho and South African areas, with the exception of the Gauteng area. The generalised ‘rural Africa’ model that predicts per capita woodfuel used clearly breaks down in highly urbanized situations where electricity and coal are well-established and relatively cheap sources of energy. The Gariep Basin study indicates that where electricity is available, the majority of households use it (but a proportion of households do not, even in urban areas) (Fig 2.4.3). In rural areas where electricity is not available, paraffin is the substitute of choice. In the Gariep study area, liquefied petroleum gas was only adopted by a few percent of the households, probably for reasons of higher cost.

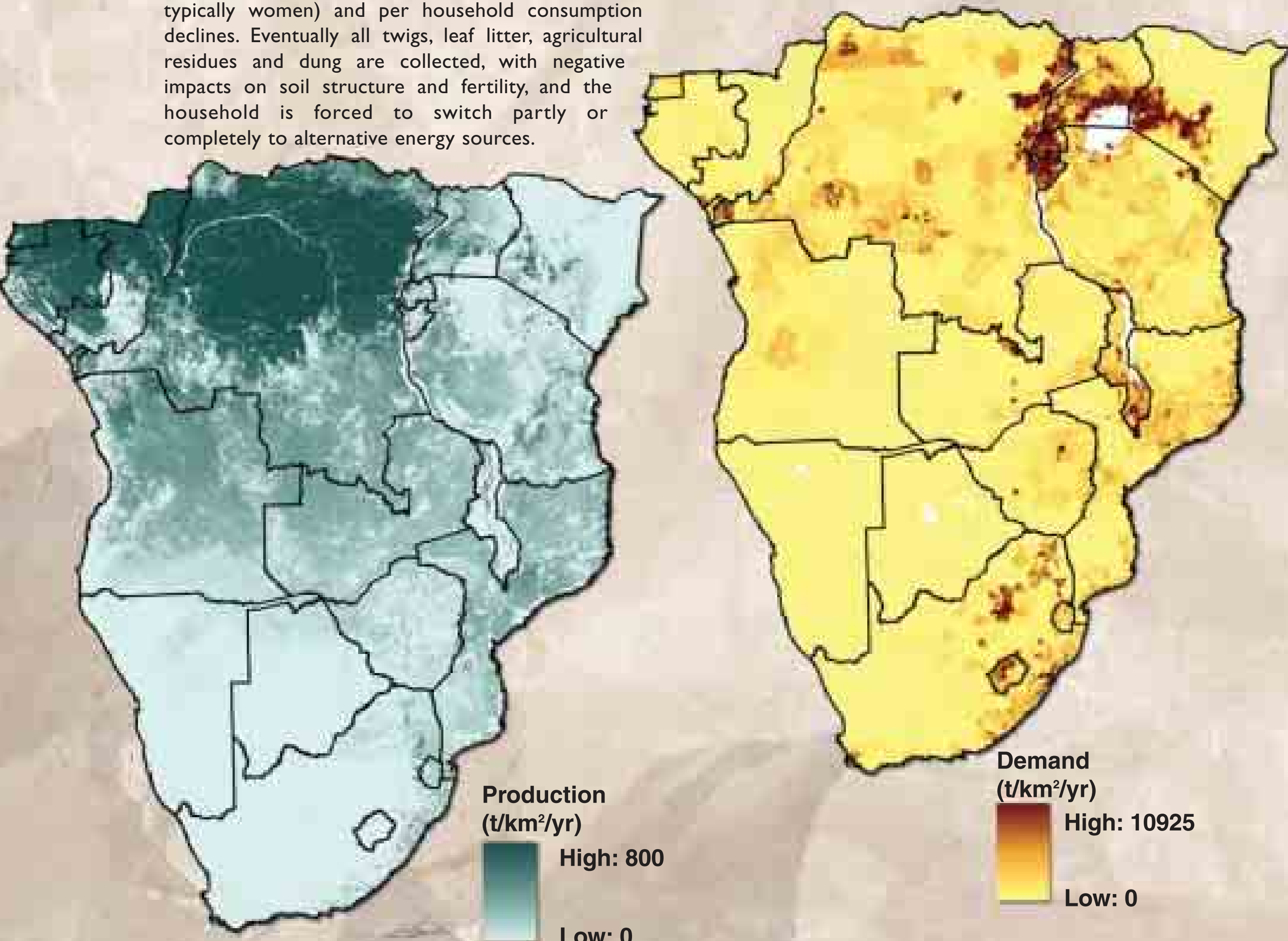


Figure 2.4.2 Woodfuel harvesting is sustainable when the rate of wood growth (a) exceeds the rate of wood use (b). The predicted areas of sufficiency and shortage for the year 1995 are shown in (c). Source: Scholes & Biggs (2004).

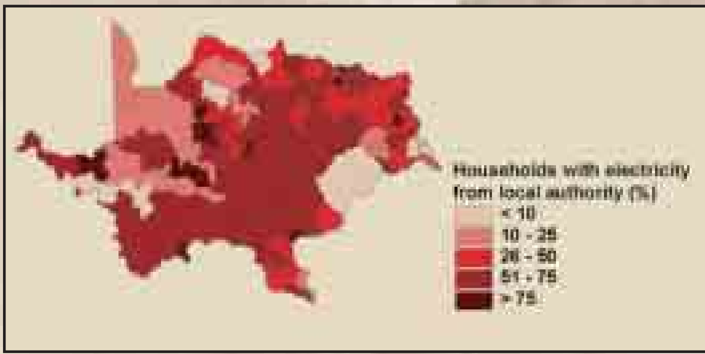
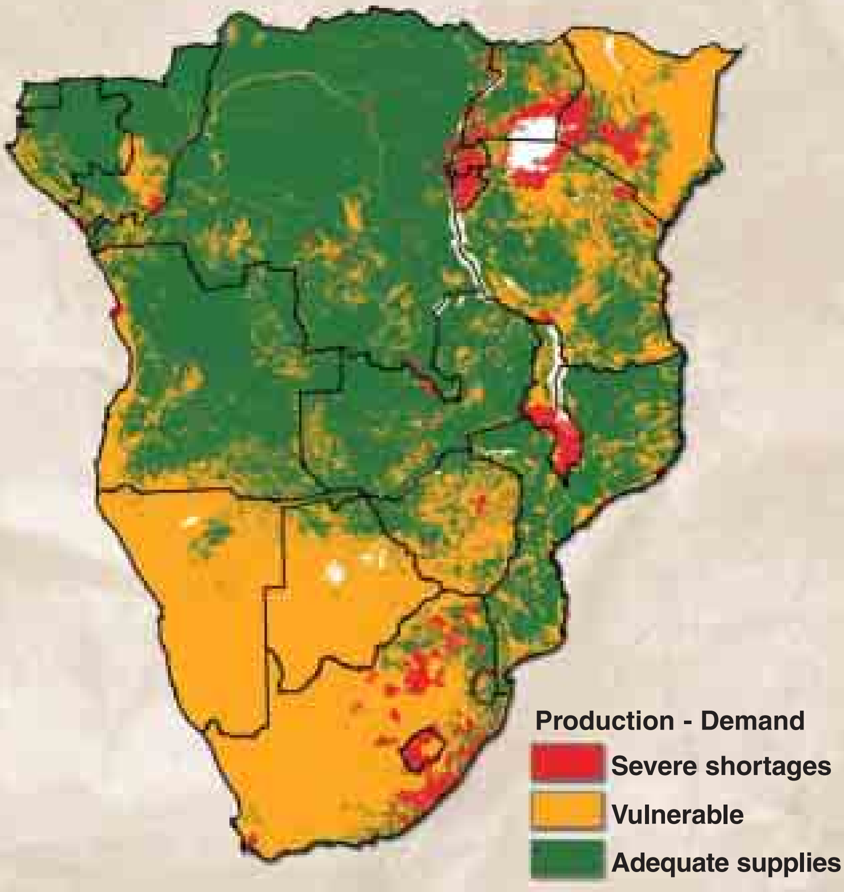


Figure 2.4.3 Percentage of households in the Gariep Basin with electricity supplied by the parastatal company Eskom (Bohensky et al. 2004).

Conversely, SA*f*MA local studies in the Richtersveld and a Gorongosa-Marromeu confirm that in areas indicated by the model to have a fuelwood sufficiency, this is indeed the case. Local experts and personal experience in the team confirm that locations (i), (ii), and (iii) experience severe fuelwood deficiencies. Therefore it seems that the regional-scale assessment generally correctly identifies problem areas at a local scale. We attribute this to the fact that although the analysis has regional extent, the underlying wood production and fuel demand models work at a resolution of 5 km, which is about the same scale as at which fuelwood depletion occurs. This finding does not mean that local studies of fuelwood are redundant. Fuel consumption tends to focus on particular species, and it is not possible to assess such targeted impacts at a regional scale.



Box 2.4.1 Charcoal production in Mozambique

Fazbem Joaquim together with his giant (20x3x1.5 m) charcoal kiln in the district of Nhamatanda. He expects to collect between 200 and 250 charcoal bags, corresponding to about US$ 167-208. Fazbem and his father and two brothers work together on the kiln, which took them three weeks to cut down the trees, and two weeks to arrange the convoy-like kiln. The process will take more time to cover and burn the kiln, and to collect and pack the charcoal into the bags. Fazbem is now covering the kiln himself and is lining up his plans to get married next year, using the money from the charcoal sale.

Like Fazbem, there are other sixty charcoal makers associated to the Associação Comunitária de Mucombedzi in the district of Nhamatanda. The community association is licenced to manage 29 000 ha, of which 17 000 are to produce charcoal and the remining for agriculture, conservation, and wildlife. The forest areas include open woodlands and closed forests providing. The area is strategically located, with high accessibility though the Beira-Chimoio (EN6) highway and the Inchope-Gorongosa (EN1) highway which facilitate the regular penetration of 15 buyers-transporters from Beira. Apart from charcoal making and subsistence agriculture, there is no employment available to provide alternative source of income. The community association is seeking to establish groups of interest for other forestry-based activities such as beekeeping, bamboo harvesting, carpentry, domestication of guinea fowls, among others, to generate incomes.

For the year 2003, the association is licensed to produce 25 000 charcoal bags. The Community Forestry Unit (within the Provincial Forest Service) is assisting the association in legal and technical matters. The selling price of one charcoal bag in the forest is US$ 1.1 of which US$ 0.83 is retained by the producers and the difference covers the cost of the licence and contributes to the community fund. Between April and August 2003, the association sold 9 455 charcoal bags, which averages 158 bags per producer, the equivalent to US$ 22.0 per producer per month. This average could vary depending on the number of activities in which the producer is involved and the dedication to work. However, a maximum of 350 charcoal bags per producer per year has been established by the community association.

The price of charcoal tends to increase during the wet season because the charcoal producers turn to agricultural activities to produce the food to cover the family needs for the duration of the year. Although women are not particularly active in charcoal making process, those who are heads of family produce reasonable quantities to satisfy the basic needs.

Source: Lynam *et al.* 2004

KEY ISSUE III: CONSERVING BIOLOGICAL DIVERSITY

Considering biodiversity as "the diversity of life on earth" that supports ecosystem services, means that the condition of biodiversity impacts on the service delivery of ecosystems. This relationship is, however, complex. Some ecosystem services are a function of only one or a few ecosystem properties or processes while others are a function of many. Some ecosystem services involve single scales while others integrate across many scales. Moreover, the production of services and the maintenance of biodiversity depends on the variability among the components of biodiversity and also on their quantity and quality. It is therefore important to assess the condition and trends in both the amount and variability of components of biodiversity.

It is the nature of an ecosystem's biomass that ultimately determines its specific conditions and functions. In order for an ecosystem to function adequately, it often requires only the biomass of a limited number of species and the resources necessary to sustain them. However, such ecosystems are extraordinarily limited in their capabilities in comparison to diverse ecosystems. If an ecosystem's biomass consists of a variety of plant, animal, and microbial species, each in sufficient abundance, so that the ecosystem functions over a wide range of conditions, the system is likely to exhibit the characteristics of adaptability and resilience in the face of environmental change.

Biodiversity and human well being

Although the link between biodiversity and human well being often plays out through the ecosystem services supported by biodiversity, some links are more direct than others. Climate regulation, which is essential for human well being, plays out through a variety of ecosystem services, while the services of rural food production, traditional medicines and cultural services are more directly related to human well-being. These direct links are often more discernible in local community studies. The SAfMA assessment demonstrated how biodiversity can impact on human well-being through the intrinsic value that many of the residents of the region ascribe to biodiversity resources.

Vulnerability of biodiversity

It would appear from SAfMA's results that regional biodiversity is in a good condition, with more than 80% of the region in a natural or semi-natural state under no or very light use intensities. However, there is a discernable increase in biodiversity threats across the region. Although threatening processes in the form of land transformation have slowed down in some regions, such as afforestation in South Africa, these same processes have accelerated elsewhere, for instance in Mozambique. Thus, the region's biodiversity remains vulnerable to land use change. Land degradation, which encompasses more subtle modification of natural landscapes, is considered a bigger threat in southern Africa (see Key Issue II on Desertification). The impacts of alien invasives, overgrazing, and overharvesting have already made a large impact on the region's biodiversity, ecosystem services and human well-being and these are likely to spread in the absence of interventions. Climate change also poses serious threats to the region's biodiversity and consequently human well-being (see Key Issue I on Climate Change).

Regional responses

The majority of countries in the southern African region have set about formalising their policy responses after becoming parties to the Convention on Biological Diversity (CBD), including biodiversity legislation and National Biodiversity Strategy and Action Plans. These formal responses have, however, not yet turned into concrete actions capable of reversing biodiversity declines in the region. One of the more positive influences on regional biodiversity trends has been made by the privatisation of the conservation (see section 3.4). A combination of private game farming, trophy hunting and nature-based tourism has expanded the conservation estate to a remarkable degree. Other influences have included novel approaches towards incentivising conservation on private and communal land, collating spatial data on the distribution of biodiversity and systematising conservation planning and implementation in the region e.g. Cape Action for People and the Environment (CAPE) and the Succulent Karoo Ecosystem Plan (SKEP). The biggest recent additional influence in the region has been the establishment of transboundary conservation areas through the efforts of NGO's and national conservation authorities (see Key Issue V on Transboundary Issues).

2.5 BIODIVERSITY UNDERPINS ALL OTHER SERVICES

Southern Africa has an impressive wealth of biodiversity per unit area (Table 2.5.1); this is particularly so for the plant species where 10% of the worlds plants occur in 1% of the world's area in Southern Africa. Although there is less information on animal biodiversity, this biodiversity wealth is also reflected in the vertebrate and invertebrate taxa. Several biodiversity hotspots (Myers et al. 2000), containing high numbers of endemic species facing large threats, also fall within the region, including the Cape floral kingdom (fynbos), the Succulent Karoo, the Pondoland-Inhabane and the Great Lakes (for fish).

Although biodiversity is not treated directly as an ecosystem service in the MA (Box 2.5.1, section 1.1), the valuable biodiversity assets in southern Africa are the basis for important services including nature-based tourism, rural diets and traditional medicines. Biodiversity also underlies supporting and regulating services such as recycling nutrients and sequestering carbon (see Key Issue III on Biodiversity).

Box 2.5.1 What is biodiversity?

Biodiversity refers to the *variety of life* on earth, but this is not simply the number of different species on the planet. Biological variation occurs at three levels: genetic, species and ecosystem (Fig 2.5.1). Variation at each of these levels is expressed in terms of composition (e.g. the genes of different maize cultivars), structure (e.g. mix of tall and short trees in different ecosystems) and function (e.g. primary production). Biodiversity is an underlying condition necessary for the delivery of ecosystem services.

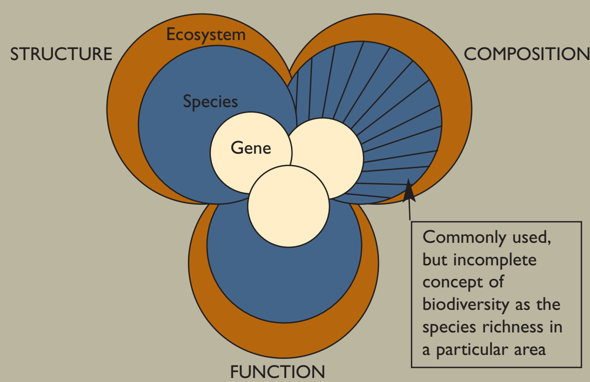


Figure 2.5.1 The multiple facets of biodiversity

Table 2.5.1 Estimated richness of the major taxa in each country, together with the estimated number of species endemic to each country. The exceptional plant diversity in South Africa results from two biodiversity hotspots: The Cape Floral Kingdom (fynbos) and the Succulent Karoo. Source: Scholes and Biggs (2004), collated from UNEP-WCMC database. Numbers in other sources may vary slightly..

	Plants		Mammals		Birds			Reptiles		Amphibia		Freshwater Fish
	Total	*End*	*Total*	*End*	*Total*	*TotBr*	*End*	*Total*	*End*	*Total*	*End*	*Total*
Angola	5185	1260	276	7	909	765	12	..	18	..	22	..
Botswana	2151	17	164	0	550	386	1	157	2	38	0	92
Burundi	2500	..	107	0	596	451	0	..	0	..	2	..
Congo	6000	1200	200	2	569	449	0	..	1	..	1	..
Dem Rep Congo	11007	1100	450	28	1096	929	24	..	33	..	53	..
Eq. Guinea	3250	66	184	1	322	273	3	..	3	..	2	..
Gabon	6651	..	190	3	629	466	1	..	3	..	4	..
Kenya	6506	265	359	23	1068	844	9	187	15	88	11	..
Lesotho	1591	2	33	0	281	58	0	..	2	..	1	8
Malawi	3765	49	195	0	645	521	0	124	6	69	3	..
Mozambique	5692	219	179	2	678	498	0	..	5	62	1	..
Namibia	3174	687	250	3	609	469	3	..	26	32	1	102
Rwanda	2288	26	151	0	666	513	0	..	1	..	0	..
South Africa	*18388	**11033	247	35	790	596	8	299	81	95	45	94
Swaziland	2715	4	47	0	485	364	0	102	1	40	0	40
Tanzania	10008	1122	316	15	1005	822	24	245	56	121	43	..
Uganda	5406	..	338	6	992	830	3	149	2	50	1	291
Zambia	4747	211	233	3	736	605	2	..	2	83	1	..
Zimbabwe	4440	95	270	0	648	532	0	153	2	120	3	112

Total = Total number of species recorded in country
TotBr = Total number of breeding bird species in country
End = Number of species endemic to country

.. no data
* Huntley (1999)
** Based on 60% endemism (Le Roux 2002)

Measuring changes in biodiversity

The loss of biodiversity in the modern era, at rates unequalled since the major extinction events is of considerable concern around the world. The UN Convention on Biological Diversity (CBD) has as its objectives to ensure the conservation and sustainable use of biodiversity while all benefits are shared equitably. The World Summit on Sustainable Development set a goal of reducing the rate of biodiversity loss by 2010. The question is: how can progress in this regard be monitored?

The *number of extinct species* is often used as a measure of biodiversity condition. About 41 plant and 12 animal species are known to have become extinct in the region during the past two centuries (Golding 2002, IUCN 2002). This measure is not very useful due to the difficulty of documenting extinctions and the fact that it records a change only once it is too late to do anything about it. A more useful indicator, which can be used to indicate relative threats within different regions as well as providing an early warning system, is the number of threatened species. For example, the Gariep basin assessment highlighted 112, 102 and 73 threatened species in the grassland, savanna and Nama karoo biomes of the basin, respectively (Table 2.5.2).

Other groups of species often cited during assessments of biodiversity include *endemic species* i.e. species restricted to a particular region (Table 2.5.1). This is a useful measure of how valuable or unique a region's biodiversity is. Another traditional measure of biodiversity status is *protected area coverage*, which shows that 14% of the land area in southern Africa is classified as formally protected or under sustainable use; the region therefore well exceeds the international guideline of 10% coverage. It is important however to understand the spread of protected areas across biome types. For example, while 16% of the Gariep Basin is protected, most of this area lies within the savanna (Table 2.5.2; Figure 2.5.2). It is unlikely that protected areas in the region will expand much further due to conflicting land uses.

Although useful, most of these indicators are not ideal (see Table 2.5.3 for summary of indicator shortcomings). The SA*f*MA regional team developed a measure, namely the Biodiversity Intactness Index, which avoids some of these problems.

Table 2.5.2 Biodiversity status in the three major Gariep biomes.

Biome	Area km²	*Species richness	**Endemic spp.	***Endangered spp.	[a]Protected area	†Transformed area
Grasslands	215508	1377	144	112	2.7%	28.77%
Savanna	190646	1424	106	102	10.58%	6.7%
Nama Karoo	237147	979	99	73	1.28%	1.48%

*Species data for birds, butterflies, mammals, reptiles and scarabs from SAISIS
**Endemic to South Africa
***Endangered if listed in the Red Data Books for Birds and Mammals. Other taxa according to expert opinion.
[a] Based on data from DWAF
† Based on National Land Cover Database (Thompson 1996)

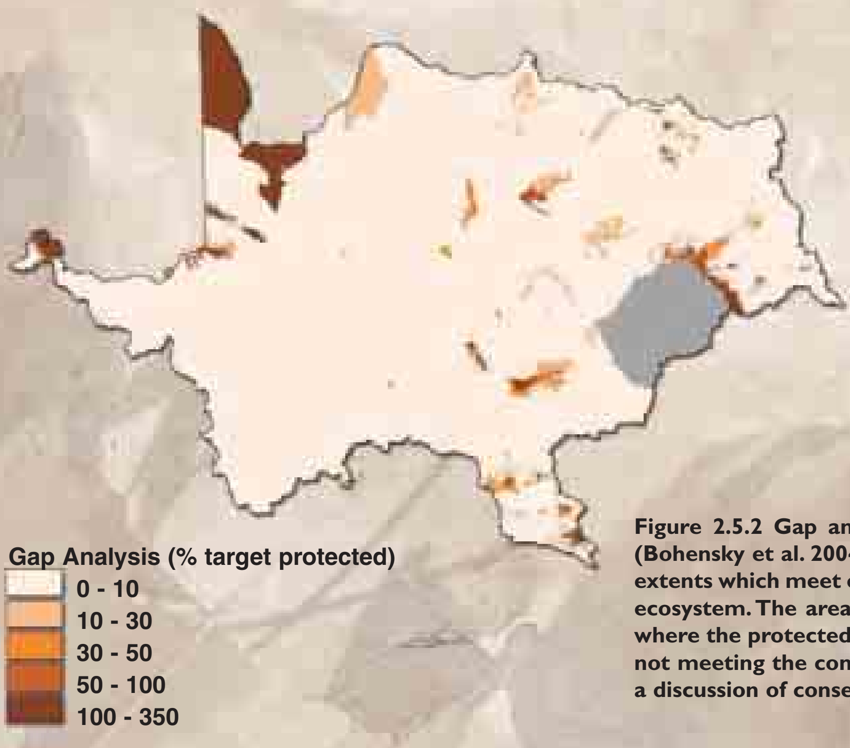


Figure 2.5.2 Gap analysis of the ecosystems of the Gariep (Bohensky et al. 2004). The darker areas have protected area extents which meet or exceed the conservation target for the ecosystem. The areas of concern are the lighter ecosystems where the protected areas cover very little of the ecosystem, not meeting the conservation targets of the ecosystems. For a discussion of conservation targets see Box 2.5.2.

Table 2.5.3 Indicators of biodiversity condition and their shortcomings

Indicator	Shortcoming
Number of extinct species	Information comes too late to take any action
Number of threatened species	Some groups better studied than others. Some experts are more prone to call a species 'threatened' than others
Number of species or endemic species	Not itself an indicator of condition, and rather insensitive to change
Protected area coverage	Some parks exist only on paper. It ignores the other 90% of the land. The area of parks is not likely to increase much in future
Land cover change	Time series required, fragmentation often ignored, often lumps land uses together as having the same impact on biodiversity

Box 2.5.2 Conservation status of ecosystems

The assessment of conservation status in the Gariep Basin calculates the proportion of the ecosystem still remaining in a natural condition, and then categorises this value into 4 classes which correspond with categories used in Red Data assessments. These categories include:

- Not threatened = more than 80% of the ecosystem remains in a natural state
- Vulnerable = between 60 and 80% of the ecosystem remains in a natural state
- Endangered = ecosystems with less than 60% natural area remaining and more than the area required by the conservation target
- Critically endangered = ecosystems with less than the natural area required to meet conservation target.

A conservation target is the proportion of land in a specific ecosystem that must be managed under some form of conservation. One well-known conservation target is the 10% set by the IUCN. Several techniques have been developed recently to determine the conservation target for an ecosystem. The SA*f*MA Gariep assessment used ecosystem specific targets similar to those used by Pressey and Taffs (2001) and Reyers (2004) which depend on the rarity, threat and vulnerability of each ecosystem.

These conservation status thresholds correspond closely with those used by Franklin and Forman (1987), where ecosystems with between 20 to 40% transformed require some attention and are classified as Vulnerable, those with more than 40% transformed are already experiencing some ecological collapse with the accompanying loss of ecosystem function and service provision and are classified as Endangered. Critically Endangered ecosystems have a very low ecological integrity and are of serious concern if the ecosystem services delivered by that area are of importance to human well-being. Figure 2.5.3 shows that most of the ecosystems are Not Threatened, these ecosystems fall mostly within the western and central regions of the basin. The next category is Vulnerable with 9% of the ecosystems falling into this category. These ecosystems have lost between 20 and 40% of their original extent to other land uses and require consideration in land use and conservation plans. These ecosystems fall into the north east of the basin along with the ecosystems in the Endangered and Critically Endangered categories.

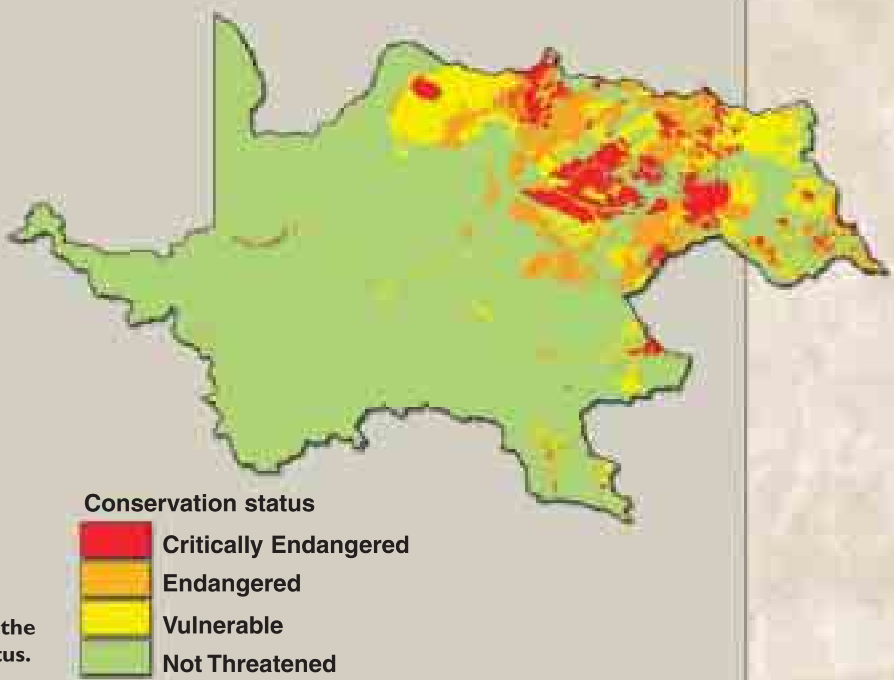


Figure 2.5.3 The ecosystems of the Gariep and their conservation status.

The Biodiversity Intactness Index

The Biodiversity Intactness Index (BII), developed for use in SA*f*MA, is an attempt at defining an index that can be used to monitor changes in biodiversity, but that avoids the problems of excessive data requirements and scale dependence that limit the use of most existing indicators. BII is an indicator of the state of biological diversity within a given geographical area, which may coincide with a political or an ecological boundary, or any other defined area, and is primarily a function of land use and exploitation. It is defined as the average, across all selected species in a particular area, of the change in population size relative to a reference population. An easily-grasped reference for large parts of the world is the state of the landscape before it was altered by modern industrial society. A practical reference that serves as a proxy is the populations in large protected areas in the current era.

Based on the BII, the population abundance of wild organisms (plants, mammals, birds, reptiles and amphibians) in Africa south of the Zambezi River is estimated to be, on average, about 84% of the pre-colonial abundance, despite the greatly increased human demands on ecosystems that have occurred over the past 300 years (Table 2.5.4). In contrast, over 99% of the species persist, illustrating the insensitivity of extinction-based indices. Also, only 15% of the land is protected, showing that this is an over-pessimistic indicator if used alone.

Biodiversity impacts are uneven

The impact of humans on biodiversity is expressed very selectively. The small number of mammal, bird and reptile species that are large-bodied, and thus easy to hunt or harvest, are most highly impacted. This is especially so if they are either valuable, or in direct conflict with aspects of human well-being, for instance large predators or very large herbivores. The vast majority of species are affected mainly through loss of habitat to cultivated lands or urban areas, both of which are relatively small fractions of the landscape in southern Africa. The greatest impact on biodiversity in southern Africa has occurred in the grassland biome, followed closely by fynbos. In both cases, the major cause is conversion to cultivated land, followed by urban sprawl and plantation forestry.

The arid shrublands, savannas, woodlands and forests that make up most of the land area of southern Africa are overall less impacted, and the major cause of biodiversity loss in those systems is land degradation. Land degradation is defined here as land uses that do not alter the cover type, but lead to a persistent loss in ecosystem productivity. Aggregated at a national level, Lesotho and Swaziland, the most densely populated countries in the assessed region (Africa south of the Zambezi), have lower BII scores than the sparsely inhabited countries of Botswana and Namibia.

Table 2.5.4 The average fraction of the 'natural' populations of plant and vertebrate groups estimated to remain in the major biomes of southern Africa. Averaged across all species and ecosystems, wild populations have declined by 16% relative to pre-colonial times. Wetland refers only to large wetland ecosystems, such as the Okavango Delta.

	Area (km^2)	Plants	Mammals	Birds	Reptiles	Amphibia	ALL TAXA
Forest	176 893	0.75	0.75	0.92	0.86	0.85	**0.78**
Savanna	2 329 550	0.86	0.73	0.96	0.89	0.96	**0.87**
Grassland	408 874	0.72	0.55	0.90	0.76	0.81	**0.74**
Shrubland	750 217	0.86	0.72	1.06	0.93	1.27	**0.89**
Fynbos	78 533	0.75	0.78	0.91	0.77	0.79	**0.76**
Wetland	95 166	0.91	0.83	0.94	0.92	0.95	**0.91**
ALL BIOMES	**3 839 233**	**0.82**	**0.71**	**0.96**	**0.88**	**0.95**	**0.84**

Degradation of sustainably-used land is the biggest threat to biodiversity in the region

The BII results suggest that the policy action with the greatest potential to prevent further loss of biodiversity in southern Africa is to prevent lands which are currently used sustainably, from becoming degraded.

Sustainably-used land (e.g. grazed within stocking norms, or selectively logged using low-impact methods), which constitutes about 80% of the land area in southern Africa, shows almost the same level of biodiversity as protected areas. Degradation, in the form of overgrazing or clear-felling, on average reduces species populations by 40-60%. As rehabilitation is uncertain and expensive, preventing degradation is the best option.

Biodiversity and land use

In southern Africa, changes in land use are closely linked to biodiversity change. Therefore, monitoring and understanding land cover change (Box 2.5.3), is critical to the assessment of biodiversity. Remotely sensed or satellite data are valuable tools for measuring the threat status of different ecosystem types, by indicating the extent of areas in their natural state, degraded or transformed to uses such as agriculture. In addition to the use of land cover data in the Gariep Basin to highlight areas of large scale habitat conversion (Table 2.5.2), the SA*f*MA Gariep team made use of land cover data to determine the conservation status of ecosystems as a measure of their condition (Box 2.5.2).

Different land uses have different impacts on species (Fig 2.5.4). Some species may increase under disturbance (e.g. insect-eating birds, and terrestrial snakes and lizards that benefit from a reduction in vegetation cover), while others that need vegetation cover for their survival (e.g. weevils) are negatively affected. Conservation targets therefore need to be set per guild or functional group, rather than for all species collectively.

At fine scales anthropogenic disturbance can create a patchwork of different landscapes, which may contain more useful species than a homogeneous area consisting only of, for example, a protected forest. The SA*f*MA local livelihoods study found that people in the Kat River area rated disturbed landscapes higher, in terms of their utilitarian value, than undisturbed forests. Heavily disturbed and over-grazed areas, on the other hand, had a much lower value to local people than either undisturbed or heavily disturbed landscapes. Meanwhile, at Machibi village in the Eastern Cape, valuable trees such as sneezewood *(Ptaeroxylon obliquum)* were only found in the protected state forest, which also had a much higher abundance of honey, water and wild fruit than community forests.

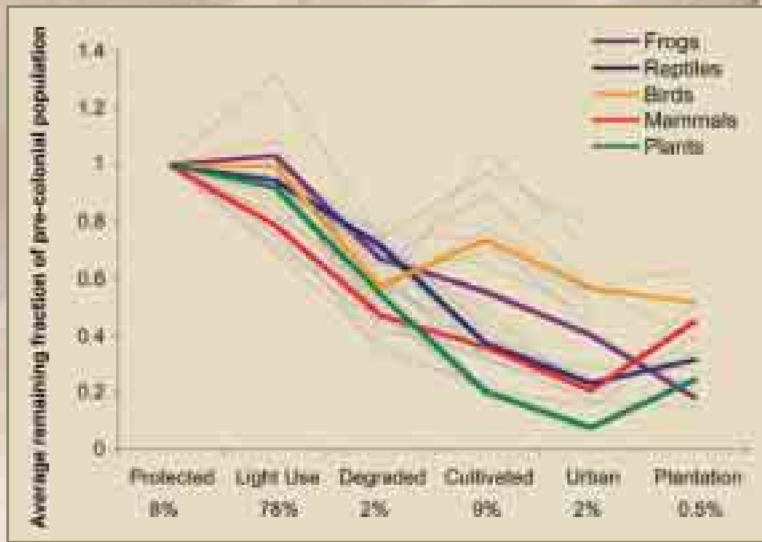


Figure 2.5.4 The effect of increasing land use intensity on the fraction of the inferred original population of different taxa that remains. The x-axis percentages refer to the percentage of southern Africa under the respective land uses. Grey lines show the variation among biomes for the different taxa (Scholes & Biggs 2004).

Climatic change in the 21st century is a matter of great concern to biodiversity specialists as it is projected to cause unprecedented rates of species loss (see Key Issue 1 on Climate Change). While extreme climatic fluctuations throughout the past 4 million years are thought to be among the factors that generated the diverse fauna and flora of southern Africa, the rate of change currently observed and projected is at least ten times more rapid than anything experienced in the past million years. Secondly, in order to stay within their climatic habitat species need to migrate, but migration is now severely hampered by a landscape fragmented and made inhospitable by human activities. Furthermore, the world is entering a state unlike anything that it has experienced before in its combination of climate, atmospheric composition and other key environmental factors.

Trade-offs between biodiversity and other ecosystem services

The tradeoffs particularly between food, water and biodiversity are crucial: they represent not only choices between different proportions of a 'buffet' of ecosystem services, but may impact on the productive base on which some ecosystem services depend in the long term, particularly in cases where biodiversity is lost.

Land use planning requires knowledge of the impacts of various decisions on other components of the landscape. A decision to commercially afforest an area should take into account the impacts of afforestation on the provision, regulation and maintenance of ecosystem services such as water, food production, carbon storage and biodiversity. Evaluating such trade-offs is a complex task. One technique for evaluating trade-offs is the valuation of services in a common currency (e.g. dollars) and the subsequent comparison of the economic consequences of various land use decisions. However, it is nearly impossible to include all components of the landscape, especially biodiversity, in such a framework. An alternative approach recommended by the MA is the use of graphical depictions of the trade-offs in ecosystem services associated with alternative policy options. Such depictions can take various forms, including the "spider diagram" approach, which depicts hypothetical trade-offs among ecosystem services associated with a policy decision. Data and time restrictions forced SA*f*MA to investigate other methods of trade-off evaluation.

Box 2.5.3 Measuring changes in forest cover: importance of agreed definitions

Until we agree on what a forest is, we cannot be sure about the rate at which it is being lost. This is because the difference in the area covered under different definitions is greater than the change measured over a period of a decade. Most of southern Africa is partly covered by trees. The FAO definition of forests includes all areas with more than 10% woody cover. In contrast, forest professionals and lay people in the region typically refer to areas with closed canopies (greater than 60% canopy cover) as forests, 40 to 60% cover as woodlands and 5 to 40% as open savannas (Scholes 2004). The relationship between these cut-off points and the 'forested' area that they predict is shown in Figure 2.5.5. The area of 'closed forest' is clearly fairly insensitive to assumptions made about cover percentage, and is about 2 million km^2, or 18% of the land area of southern Africa. Mixed tree-grass systems (i.e. savannas in the broad sense) occupy 60% of the area, with a continuum between woodlands and the more open forms. Much of the disagreement in forested area stems from how much of the savanna component is included in 'forest'. Clearly, in their submissions to the FAO, none of the countries in the region are following the FAO definitions. They are not following the narrower definition of forest either, but in general appear to be reporting the total of forest and woodland.

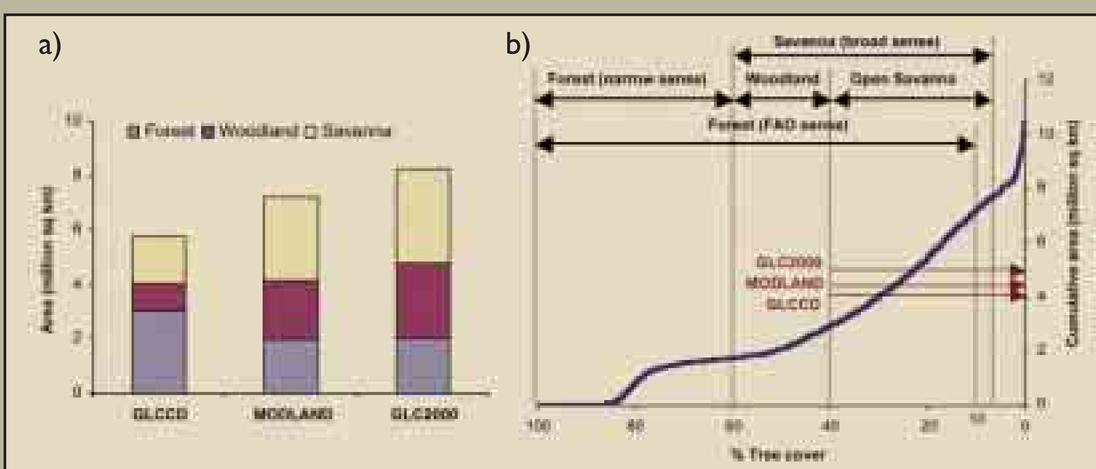


Figure 2.5.5 a) Comparison of the total area in southern Africa estimated to be under forest cover in the FAO sense based on three recent land cover products. b) The total land area in southern Africa with a tree canopy cover of at least the percentage given on the x-axis. The combined forest and woodland areas recorded by three studies are shown on the y-axis. Source: Scholes and Biggs (2004).

Table 2.5.5 Total calories and protein produced by cereals and meat in the Gariep basin in relation to the amount needed to feed the population of the basin.

Service	Quantity currently produced			Quantity needed to meet nutrional needs in the Gariep basin		
	From cereal	From livestock	*Total*	Total	Cereals	From livestock
Calories (billion kcal)	18.13	4.44	22.58	14.95	8.07	6.88
Protein (million kg)	447	664	1111	400	228	172

Irreplaceability analysis in the Gariep Basin

In the Gariep Basin assessment, the notion of 'irreplaceability' (Pressey 1999) was used to assign comparative values to areas of land, based on their calorie production, protein production and biodiversity. In this way trade-offs between food production and biodiversity could be assessed. Irreplaceability is a measure of how important the features of a specific area are to the achievement of some defined target. The availability of maps of calorie and protein production in the Gariep Basin allowed an investigation of the amount of each service produced annually in each area of the basin (e.g. the amount of calories produced by a municipality). Targets for each service were calculated for the basin; for example, nutritional targets were derived by multiplying the recommended daily allowances for protein and calories by the number of reliant people in the basin (Table 2.5.5). The contribution of each unit of land in the basin to the overall target of each service could then be assessed, and the most important areas for each service highlighted (Fig 2.5.6a).

As is obvious from Table 2.5.5, the total calories and protein produced in the basin are about two to three times the requirements of the population of the basin. This is not surprising, as the basin provides 70% of South Africa's cereal requirements (including the 20% used for livestock feed), and half of the total production is exported. The targets were therefore modified to include the requirements of 70% of South Africa's population (this is the estimated number of people that rely on the Gariep's food production - in essence another 30% of the population), another 20% of cereal for food for livestock and an additional 50% for the export of food. This doubled the targets which provided a more realistic picture of requirements in the basin. For the sake of simplicity, this assessment assumes that the food produced within the basin can be transported to all other areas of the basin where demand exists.

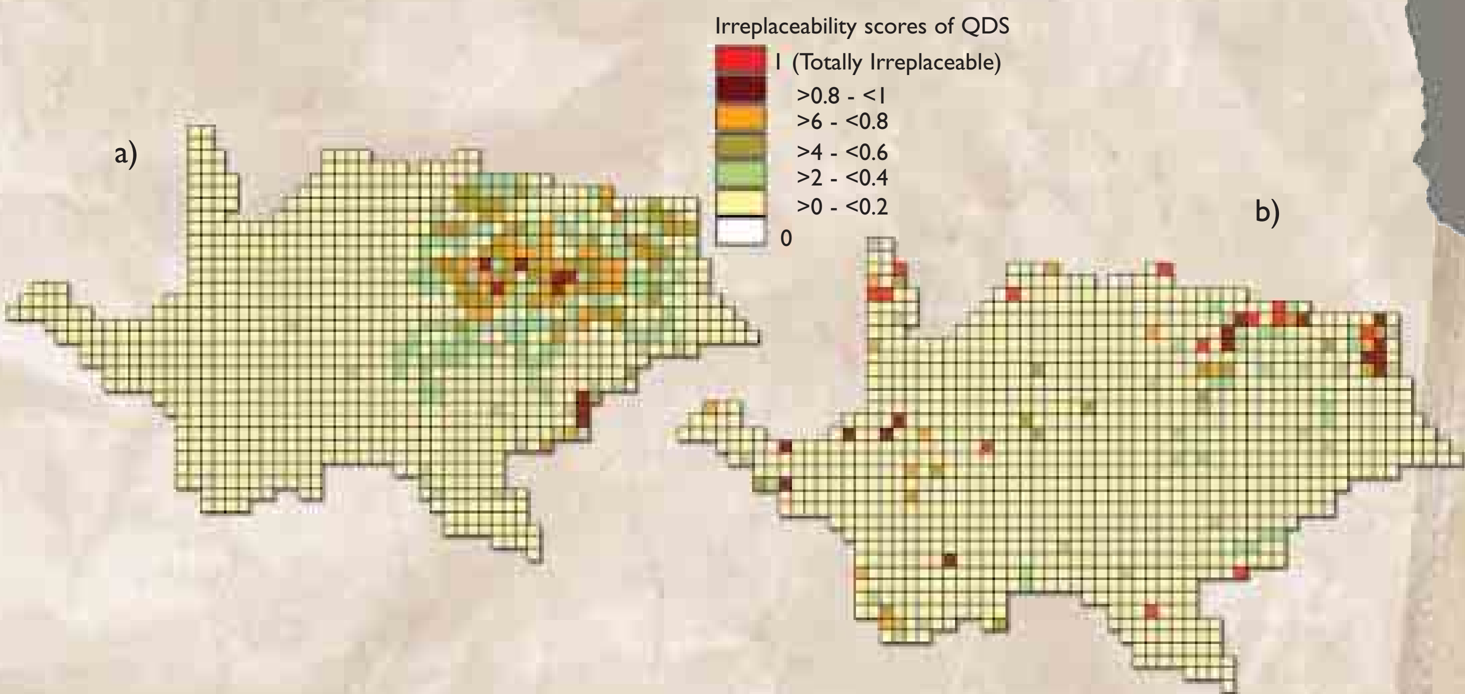


Figure 2.5.6 Irreplaceability maps for the Gariep basin based on targets for (a) proteins and calories and (b) biodiversity. Irreplaceability values range from 0 (very low importance for the goals and many options for this cells substitution with another cell to achieve the goals) to 1 (totally irreplaceable, if this cell were not included in the provision of services, the goals for those services would not be met. Source: Bohensky et al. (2004).

Irreplaceability values for biodiversity were based on the bird, butterfly and mammal species found within each grid and how important those species were in meeting a conservation target. In this case the target was one of each species. Thus a grid with the only known occurrence of a species will be totally irreplaceable when it comes to meeting this target. The resultant figures are shown in Figure 2.5.6b.

The irreplaceability analysis of the Gariep Basin illustrates that there is some overlap between areas important to food production and biodiversity, especially in the north east of the basin. These regions of overlap are important potential areas of conflict, which also coincide with areas of high water production. One alternative to the irreplaceability assessment of protein and calorie production would be to use the potential production of all areas in the Gariep Basin rather than the actual production. This would add value to a land use-planning framework as it would highlight areas best suited to food production, not areas currently utilized. South Africa's history of land use planning is well known for its inappropriate use of land and as such one cannot assume that the current pattern of land use is the most beneficial and efficient way to harness ecosystem services (Reyers et al. 2001).

2.6 LESS TANGIBLE SERVICES: CULTURAL, RECREATIONAL, SPIRITUAL AND AESTHETIC

The SA*f*MA studies revealed that less-tangible ecosystem services, such as cultural, spiritual and religious aspects associated with ecosystems, are nevertheless highly valued, by all populations, and at all scales. The cultural capital of a local group, i.e. the 'means and adaptations to deal with its local environment' (Berkes and Folke 1998) have co-evolved over centuries of interaction with the natural environment through learning, innovation and experimenting. An example of a management practice based on cultural capital is a sacred area, which protects certain habitats and creates refugia for species that can later re-colonize heavily-disturbed landscapes. Sacred areas are an example of cultures responding to feedback: people respond to scarcity by completely restricting access to certain resources, allowing the ecosystem to recover. In principle, this is identical to formal conservation strategies advocated by ecologists.

At the regional scale, nature-based tourism (by both southern African residents and foreigners, but largely by urban-dwellers) already contributes 9% of the SADC-country economies overall, and is growing several times faster than the traditional ecosystem-based extractive sectors, such as forestry, agriculture and fisheries. The implication is that traditional power-relations with respect to natural resource policy are likely to shift in the future, with much more influence accruing to the 'conservation' lobby. Much of this tourism focuses on protected areas, and our projections suggest that the tourist absorption capacity of protected areas may limit the future growth of this sector before the supply of tourists abates.

The link between human symbols and the natural world is expressed as cosmologies, worldviews, values and belief systems. Values based on this type of relational experience with the landscape profoundly affect the way people interpret, understand and manage their local ecosystems. Most of these belief systems, either directly or indirectly, have a positive effect on ecosystem resilience. Many, but not all of them, are geared towards protecting key resource areas, protecting certain species from extinction, allowing populations of plants and animals to recover, or enhancing landscape diversity with the ultimate effect of reducing the risks to people and ecosystems

The cosmology of the AmaXhosa people

The basic needs of the AmaXhosa people of the Great Fish River, represented by four Xhosa villages, are met by resources in the natural environment, including fuel wood, medicinal plants, building materials, cultural species, food supplements and species of economic value. Consequently, local AmaXhosa people experience a strong dependence and place high utilitarian and cultural value on their local natural environment as expressed in the following two respondents quotes: "I am entirely dependent on the environment. Everything that I need comes from this environment" and "it (the environment) will be important for ever because if you have something from the environment it does encourage you to love the environment."

A result of this connection between the AmaXhosa and the natural environment is that individual well-being is closely related to a healthy environment. Respondents often described positive emotional and physical symptoms when the bush was healthy: "When the environment is healthy, my body and spirit is also happy," and when describing people's feelings towards a healthy environment, a respondent stated that "people love such an environment. They really adore it. Such an environment makes them feel free." In addition respondents described the feelings of peace when walking in the bush and how they would go to the natural environment to pray. This compares to experiences of de-motivation, a lack of hope and disrespect when the environment becomes degraded.

Coupled with this high dependence on the local environment is the experience of continuity to place, where many villagers born in a village, plan to die there, emulating the practice of their forefathers. Abandoning their respective villages would mean abandoning the ancestors. There is also a fear that they will soon die in the new place, as experienced by many other people, and they feel a close connection and place high value on the place where they were born.

The beliefs and traditions, i.e. cosmology of the AmaXhosa in the Great Fish River play an important role in guiding resource use and management and encouraging values to be place centered. The ancestors are central to this cosmology where the very identity of a Xhosa person is based on performing traditions and rituals for the ancestors. The majority of respondents stated that practicing one's traditions and thus communicating with the ancestors is what is of value to a Xhosa person.

The reason for their importance is twofold. Firstly, it is a way of emulating their forefather's way of life, the significance of which is expressed in the following informants quote: "the traditions are important to us as amaXhosa people because they were being performed by our forefathers. If we don't perform them there is a saying that we are calling death to us." Secondly, respondents draw many parallels between health, quality of life and the satisfactory performance of traditions; i.e. following the correct procedures which, as demonstrated below, are intimately tied to use of the natural environment.

A number of sites and species are fundamental to the performance of rituals and maintaining a relationship with the ancestors. When respondents were asked what would happen if these sites were to be destroyed, they replied "It means that the ancestors would be homeless", "That can't happen here at this village because our health depends entirely on these sites" and "It means that our culture is dead."

PART III: RESPONSE OPTIONS FOR ECOSYSTEM SERVICES AND HUMAN WELL-BEING

3.1 RESPONDING IN COMPLEX SYSTEMS

An assessment of the relationships between ecosystem services and human well-being would not be complete without an investigation of responses (Box 3.1): the ways people change ecosystems to suit their needs and the ways people adapt to ecosystem change. Of special interest are the kinds of responses that lead either to successful adaptation to environmental change, or to unexpected crisis. These can give us insight into the design of more effective responses in the future.

Together, ecosystems and the people who use and manage them comprise complex, social-ecological systems. Part of what makes these systems complex is that responses are constantly occurring, and people and ecosystems respond in multiple, interacting, and sometimes surprising ways. They may be adaptive; that is, they respond reactively (to what is experienced or conceived) and proactively (to what may still happen). For example, people change their purchasing behaviour when prices or incomes change or when they anticipate an inflationary increase. Vegetation communities change structure and composition when the hydrological regime changes. It is seldom if ever possible to fully comprehend the many processes operating in a complex system and reliably predict the outcome of a response. In this way, any response is also an experiment.

While we may not understand all aspects of a complex system, there are usually only a few major structures or processes that determine its behaviour. If we can identify these, then we can determine where to focus our responses. Therefore, while complexity makes the design of effective responses a challenging prospect, it does not make it impossible. Here we use the term "effective" to mean the ability of a response to maintain the social and ecological integrity of the system and preserve the resilience (discussed in section 1.3) of ecosystems and their services.

Why is it so difficult to effectively respond?

By viewing ecosystems and people collectively as complex systems and understanding their typical characteristics, we begin to see why responding effectively is difficult. SA*f*MA observed that, despite a wealth of human experience with responses, several problems repeatedly arise in complex systems. These include:

Simplification. Complex social-ecological systems are coupled. Whether we are scientists, managers, or decision-makers, we tend to simplify the complexity of these systems by breaking systems down – by decoupling their components - but fail to put the pieces back together again. This is evident in the historical tradition throughout most of the world of a sectoral approach to resource management, in which obtaining the maximum benefit possible from individual services has been of paramount concern. While this strategy makes sense when the objective is efficiency or productivity, it is not well suited to integrated problem-solving.

Scale mis-matches. Ecosystem processes have characteristic scales at which they operate (see section 1.3). Management processes, however, typically occur at social or political levels of organization - nation, province or district - and are often correlated with time scales of social or political significance. This can cause a mismatch between ecosystem processes and management. Spatial mismatches are clearly observable in the design of protected areas that truncate ecosystems at national borders. The temporal equivalent is a response that is too slow or too quick (or more often, too short-term) to appropriately deal with the process.

Trade-offs. Responses in complex systems often involve difficult choices - between ecosystem services, or between ecosystem services and other social or economic benefits, or between social groups. These trade-offs and their consequences are often poorly understood. Making trade-offs may involve the process of simplification discussed above, in that a system is simplified in making a choice to derive benefits from one part of a system rather than from others, or the whole. Decision-making frameworks can help to identify and weigh the consequences of a response, but ultimately a decision must be made and evaluated based on a defined set of objectives, and consideration of which responses are feasible given certain conditions.

Limits to knowledge and understanding. Because complex systems are poorly understood, decision-making is sometimes based on incomplete, uncertain, or even incorrect information. People also rely on their mental models, which are influenced by available information, their interpretation of the information, and power structures that control information flows. Responses in complex systems are therefore often biased by prevailing mental models, which tend to be those of the people or groups with the greatest influence. When certain mental models dominate, responses are not representative of the mental models of all who are affected, and therefore are not beneficial to everyone.

The changing face of responses in southern Africa

Responses that recognize the problems identified above often tend to be more successful than those that ignore them. A number of responses now being implemented in southern Africa demonstrate an awareness of the problems noted in the previous section. This recognition has come about in part because of novel opportunities in several nations to draft new legislation in recent years, and signals an understanding of the flaws in some past policies. Significant change is occurring with respect to governance and ownership of and access to ecosystem services, and is redefining the portfolio of response options available to people.

In the past, many responses were of a technical or regulatory nature. In the case of the former, responses were often intended to improve service delivery (e.g. dams, fertilizers), and in the case of regulatory responses, to control use of a service. Technical interventions have underwritten the development of many human societies, but have often had negative consequences on ecosystems over the longer term. Large dams are a well-known example. Dams secure water supplies and protect against floods by regulating the flow of rivers, but change the hydrological regime on which many aquatic organisms depend (see Key Issue IV on Wetlands), which in turn can alter water chemistry and ultimately have deleterious effects on biodiversity, human health, and the ability to irrigate farmland. Institutional responses use laws, policies or economic instruments to change the way in which ecosystem services are used. These, however, have sometimes denied access to services to certain groups (e.g. the riparian rights principle of South Africa's previous water law), externalised the costs of using services and passed them on to society (e.g. agricultural subsidies), or achieved short-term goals at the expense of long-term sustainability (e.g. agricultural policies that encouraged national self-sufficiency in food production at a cost to soil conservation).

Box 3.1 How did SAfMA assess responses?

The Millennium Ecosystem Assessment (MA) defines responses as "human actions, including policies, strategies and interventions, to address specific issues, needs or problems in different domains." Responses may be technological, institutional (including policies or economic measures), social and behavioural, or cognitive in nature. When people do not respond to a problem, ecosystem responses, such as floods or pest outbreaks, may serve as a natural intervention.

The MA assesses past, current, or possible future response options for improving ecosystem service delivery or the benefits of ecosystem services for human well-being. Within SAfMA, approaches spanned a range of methodologies. At coarser scales (regional and basin), the approach consisted of reviewing past and existing responses put into practice by governments and institutions. At local scales, interactive processes such as interviews with stakeholders and dramatic performance were employed to elicit information about coping strategies used or likely responses under different scenarios. Here, two types of responses were identified: responses that are immediate and reactive to change that affect the well-being of a community, and responses representing longer term adaptations. The latter type of response is often carried over from one generation to the next, in the form of customs, folklore, taboos, and rituals that have developed to manage risk and cope with uncertainty.

KEY ISSUE IV: COMPLEX LINKAGES AND MANAGEMENT CHALLENGES: WETLANDS

Wetlands in southern Africa provide a multiplicity of services to people living in and around them as well as to communities living downstream. In Gauteng, for example, a 2km stretch of river with instream reed beds was shown to assimilate up to 98% of the bacterial populations of *F. coli* and up to 58% of ammonia (Holgate 2002, COJ 2001).

A major wetland in the SAfMA area is the Marromeu Complex in the delta of the Zambezi River. This 11,000 km² area has been heavily affected by changes in the hydrological regime of the Zambezi River following the closure of Kariba Dam in 1959, Cahora Bassa in 1975 and the construction of roads and embankments along the lower Zambezi River. Hydrologically, the Marromeu complex has come to depend on the inflows of silt-free runoff from the adjacent Cheringoma Plateau which maintains a small section of the extensive wetland that is sufficiently moist to support key vegetation types upon which many mammal and water bird species depend. Desiccation of the major part of this important wetland due to the reduced flood regime has resulted in dramatic changes in the vegetation of the system, which has reduced the carrying capacity of the Marromeu Complex for wildlife, and contributed to the decimation of wildlife populations.

The historical changes in resource states are summarised in Table A. Many of the factors bringing about change appeared to be outside the control of local people - war, drought and large floods were commonly cited. Land tenure and access to resources are also critically important. Most of the delta is controlled by large hunting concessions that limit community access to, and hence benefit from, local resources such as forests and wildlife. In some cases (e.g. with bee keeping), lack of equipment or knowledge is an important factor limiting resource development. The lack of locally enforceable institutional controls on resources was also a very commonly cited reason for changes in resources (Lynam & Barbossa 1998).

The Marromeu wetlands have played an important role in the livelihood systems of communities living in and around the wetland areas (Lynam & Barbossa 1998; Chilundo et al. 2002). Communities in the Delta region noted the importance of both land and surface and ground water resources to their livelihood systems and well-being. Turpie and colleagues (Turpie et al. 1999) estimated the consumptive use values of wetlands to households in the Delta area as an average annual value of US$194 or US$8.00 per hectare. This is lower than the estimated economic returns per hectare of cultivated land (US$34.7), suggesting that land will be converted to agriculture where this is feasible unless the benefits of resource exploitation are devolved to local communities in the areas of high productivity and biodiversity.

Without major changes in the flood regime of the Zambezi River, it seems highly likely that the Marromeu wetland will become something entirely different – a coastal savanna with patches of wetland. The future of the Marromeu Complex depends in large part on restoring more natural flooding conditions through environmental flow releases from upstream dams on the Zambezi River and the rehabilitation of the floodways connection to the Zambezi River and Delta (Beilfuss & Davies 2000). The recent declaration of the Marromeu complex as a Ramsar site is a first step along the road to restoration. A team of international and Mozambican scientists are negotiating for the establishment of an ecosystem flow regime in the Zambezi River, and have demonstrated that substantial socio-economic and ecological benefits can be obtained through improved flooding without significant reduction in hydropower production (Beilfuss 2001). Not only would these changes increase the chances of restoring the functioning of the system as an important wetland area but would also enhance the livelihood systems of the approximately 80,000 people living in Marromeu District.

Acknowledgement: Richard Beilfus

Table A. Summary of trends in resources in Mozambique. Over the past few decades and for the Zambezi Delta as a whole, arable land has decreased, animals have decreased, whilst availability of water, vegetation, fish and birds has changed in ways specific to the sites.

Resource	Cax	Chu	Dan	Mal	Nvu	Saf	Tan
Animal	↘	↘	↘	↘	↗	↘	↘
Forest	↗		↘	↗	↗		↘
Arable land	↘		↘				↘
Water			↗		↘		↘
Birds				↗		↗	
Fish		↘				↗	

1 Cao - Caoxe, Chu - Chueza, Dan - Dande, Mal - Malingapanse, Nvu - Nvunganha, Saf - Safique, Tan - Tanque

Increasingly, a greater number of responses today focus on behavioural and cognitive change, on the premise that these are the drivers of ecosystem change that hold the greatest potential for managing ecosystem services more sustainably. Behavioural responses relate to people's preferences and values, while cognitive responses are associated with information and awareness. Technological and institutional responses continue to play an important role, but more often as part of a broader strategy encompassing multiple types of responses. Many laws, policies, and economic instruments are now incorporating principles of sustainability. Other responses are focused on expanding the knowledge base for decision-making by involving and providing access to information to stakeholders. This includes formal and informal education, public awareness campaigns, and publishing information on the internet. Scenario planning exercises have been conducted in the region by NGOs, private corporations, and multi-stakeholder associations, and while their objectives have varied, most have succeeded in stimulating thinking about complex issues. The role of adaptive management – a longtime coping strategy of local people in the region - is coming into the fore, with an emphasis on its principles promoted in the conservation and water sectors in South Africa.

3.2 DEALING WITH COMPLEXITY THROUGH INTEGRATED RESPONSES

In some situations in southern Africa, the sectoral approach to management of natural resources (as opposed to ecosystems) of the past is being replaced by the adoption of more integrated, sustainable, and equitable policies. This allows for a greater level of complexity to be tackled with a single response.

Licensing ecosystem service use: charcoal production in Mozambique

Throughout much of southern Africa, woodfuel is an important ecosystem service that provides charcoal for heating and cooking (see Section 2.4). Local woodfuel depletion in some areas, however, is a serious concern. In the Gorongosa – Marromeu component of SA*f*MA (SA*f*MA-GM) the assessment of woodfuel as an ecosystem service indicated that the major drivers in the system (i.e. the key structures and processes) were the following:

- *Poverty.* Many rural households had no other means of obtaining cash income. Urban households who purchased the charcoal sought the lowest cost energy option to satisfy their energy needs.
- *Ambiguous property rights.* The poorly specified property rights and limited ability or willingness of the government to enforce existing property rights meant that charcoal producers could use woodland resources from very large areas without paying for the resources.
- *Transport networks.* Production of charcoal was found along functional road transport routes.
- *Lack of re-investment of resource rents* in the management of the resource itself. Incomes generated from the woodland resources used were converted into consumption or urban wealth.
- *Perceptions of woodfuel resources.* The resources were seen as being almost inexhaustible and best used to produce income for the rural poor.

In an attempt to make the charcoal production system sustainable, the Provincial Government of Sofala has responded by trying to license the producers. This, however, does not address the broader system structures and processes (e.g. poverty and property rights). Instead of trying to influence the indirect or ultimate drivers of fuelwood consumption, the Sofala government only attempted to regulate the more proximate cause of woodfuel depletion, access to the resource.

In a resource-poor environment poor people will easily find ways around licensing and taxation. Urban people are not likely to be aware of the future impacts of current consumption rates nor of possible interventions that could make the system a sustainable income-generating and energy supply system. While there may well be an awareness of the different drivers as independent structures or processes, the solutions are not constructed to address the coupled system.

Improving human well-being through ecosystem rehabilitation: Working for Water

Alien invasive plants are a significant problem in South Africa, with particularly negative impacts on water: they reduce approximately 10% of total streamflow (Görgens & van Wilgen 2004), consuming an amount of water on par with that used by the urban and industrial sectors in major urban areas (Basson et al. 1997). The Working for Water Programme in South Africa is an integrated multi-agency intervention to address the alien plant problem, and among the largest and most expensive of its kind. By hiring previously unemployed individuals to clear and eradicate invasive alien plants, Working for Water addresses the multiple objectives of ecosystem rehabilitation, water conservation, and poverty relief through job creation, as well as environmental education and awareness raising about alien plants and water conservation. It is also encouraging the development of secondary industries to generate additional income and employment through the creation and marketing of products made from the cleared alien species.

In this example, a synergy is created between social development (job creation/poverty relief) and ecosystem rehabilitation (alien eradication, restoration of hydrological flows, improved production potential of land). It has raised awareness amongst both the people employed by the programme and the many others who have learned about it due to its high visibility and public awareness campaigns. The model has been expanded to other ecosystem services, such as those provided by wetlands and coastal ecosystems.

A potential drawback of the program is its high cost of clearing, which is invariably higher than land prices. These costs are, however, offset by the benefits to water and biodiversity. Should funding for the initiative cease, there is unlikely to be further incentive for the work to continue, unless driven by bottom-up forces, such as revenues gained from the sale of alien plant products. Even so, this would be unlikely to allow the program to achieve and maintain operation at its current scale, or according to its current objectives and priority areas.

3.3 MATCHING SCALES OF RESPONSES AND ECOSYSTEM PROCESSES

The scale at which ecosystem problems arise can vary from local to global; in contrast, policy responses tend to emerge at scales of governance (e.g. national), while individual and community responses occur at local scales. In southern Africa, we are beginning to observe the creation of management structures that can respond at scales that more closely match those of ecological and social processes. For example, management of ecosystem services is being devolved or "evolved" to more appropriate scales or organizational levels. The underlying idea is that services will be most effectively managed by giving all affected parties a stake in their management.

Devolution of water management to catchments

Several countries in the region are embracing devolution of water management. Namibia, for example, has been promoting this concept for several years, and it forms part of its National Biodiversity Strategy and Action Plan, draft National Wetlands Policy, and Water Act.

In South Africa, the Water Act of 1998 mandated the establishment of nineteen catchment management agencies (CMAs) to govern water resources in conjunction with local governing boards that represent a wide range of stakeholders. This decentralizes decision-making in the water sector, and while the national Department of Water Affairs and Forestry (DWAF) oversees the national water strategy, the authority to execute the strategy will eventually lie with the CMAs and their locally-elected governing boards. Each CMA is responsible for a water management area, for which it can license water users and establish charges for the provision of water for different uses, the revenues being used to fund management activities. The CMA will also be responsible for implementing the appropriate resource protection measures in order to meet the requirements of the ecological reserve as mandated by law.

Although catchment-scale management is a promising response to the challenge of allocating water to competing users while ensuring the needs of the environment, the existing backlog of under-serviced populations presents a challenge, which will only be intensified by likely increases in water use by the urban and industrial sectors. While the new arrangement allows management to occur at a scale more appropriate to ecosystem functioning, in South Africa it is unclear if the CMAs, which are to be fully functioning in the next five to ten years, will have the capacity within these institutional arrangements to successfully implement the Water Act.

Of concern is that they are being charged with both the allocation of water and protection of the resource in their catchment, two not necessarily compatible tasks that were never before administered by a single authority (Rogers et al. 2000). The role of local and district municipalities is also unclear, and many lack the capacity to implement these new regulations.

A potential problem also lies in the spatial configuration of the hydrological system, whereby some CMAs will be managing catchments that impact on (i.e. are upstream of) other CMAs. The Water Act is designed so that in principle, a CMA cannot negatively impact the water resources of another, suggesting that a broader-scale resource protection plan needs to be in place, and that all CMAs must govern responsibly to benefit from the arrangement.

Evolution of ecosystem management to supra-national scales

At the same time that management of some ecosystem services is being devolved to lower levels, it is also evolving to deal with large processes with many stakeholders. Large-scale problems such as regional water scarcity and conservation of large ecosystems require large-scale management structures. As most of the major rivers in southern Africa flow across international borders, international water co-management organizations, such as the Orange-Senqu River Commission (ORASECOM) recently established by South Africa, Lesotho, Botswana, and Namibia, are designed to share the management of riparian resources in the Gariep and Senqu River systems and ensure water security for all members, on the premise that political instability in one state negatively affects others. In reality, power among stakeholders is likely to be uneven. Currently, about five international water-sharing agreements and studies, in various stages of implementation, concern the Gariep River alone. Cooperation in terms of water sharing is the jurisdiction of the SADC Protocol on Shared Water Courses, coordinated by the SADC Water Sector based in Lesotho.

In the conservation arena, transboundary or transfrontier conservation areas (TFCAs) cross international boundaries and are managed jointly by the participating nations (see Key Issue V on Transboundary Issues). Several such areas either exist or have been proposed in the SAfMA region, although the design of these areas has often been driven by political rather than ecological criteria, and the role these areas play in conservation and development is still unclear. In addition, they have sometimes bred resentment among local communities who fear restrictions on their use of the land without adequate redress (Box 3.2).

Devolution and evolution of authority to different scales does not always result in better management. In the case of CMAs, their power is constrained to their catchment, but impacts may be from outside or upstream. At the supra-national scale, there is no guarantee of adherence to principles of SADC treaties that are not embedded in national laws, which are likely to differ, sometimes irreconcilably, between members. There also may be too many members for any one to assume accountability. Furthermore, some impacts are likely to be exogenous to the region (i.e. world markets, tourism, climate change), but their impacts will at least in part need to be managed through the governance structures that exist in the region.

The best situation is likely to be one with multi-subsidiarity or multiple levels of management. Subordinate or local organizations take responsibility for management on the ground because they have the best information about what happens there, while a central organization functions as a centre of support, coordination, and communication.

Box 3.2 "Grand Schemes"

During the past decades, Southern Africa has seen a wave of large-scale government interventions designed to improve delivery of ecosystem services. The Orange River Project to irrigate and bring hydropower to the Eastern Cape, the Lesotho Highlands Water Project to deliver water to Gauteng Province and generate hydropower for Lesotho, and the South African government's 'betterment' policies to control land degradation feature among these.

At the local scale, these "grand schemes" can pose significant problems to communities because they exclude them from the design and implementation of the interventions and therefore interfere with local livelihoods and coping strategies. The Gariep community assessments noted a prevalence of such large-scale government interventions at its study sites. These interventions include the creation of protected areas at all three sites, and the introduction of large-scale agricultural or range management schemes at others. Their impacts vary: protected areas, for example, tend to restrict access to land but can also provide jobs and income from tourism.

Multiple landscapes and livelihoods are valued by community members. Because people appreciate the value of access to a range of landscapes and habitats, as well as the risk avoidance benefits of multiple livelihood strategies, they are resistant to external interventions that seemingly propose homogenization of livelihood strategies or landscapes. People cope with change by using a diversity of livelihood strategies, and switch from one strategy to another. Grand schemes reduce this adaptive capacity.

KEY ISSUE V: TRANSBOUNDARY ISSUES

In past millennia, human and wildlife populations straddled, or migrated unimpeded across what have now become international or jurisdictional boundaries. The 1992 Treaty establishing the Southern African Development Community (SADC) reflects 'cultural and environmental realities' and acknowledges that 'many people, wildlife, natural resources and ecological zones have always transcended national boundaries in the region'. SADC 'strives to improve the quality of life of SADC people by means of a regional approach to sustainable utilisation of wildlife resources' (SADC 1997).

The management of southern African ecosystems is increasingly transboundary. For example, the region has fifteen major 15 river basins that are shared by two or more countries, covering 78% of the land area (Hirji et al. 2002). Intergovernmental basin management authorities are in place for some of them, including the Gariep and Zambezi. Another example is the large number of transfrontier conservation areas established in the past decade, or in a stage of advanced planning. The Kgalagadi Transfrontier Park, established between Botswana and South Africa, was the first to be formally legislated. The Kruger National Park – Limpopo Park project between South Africa and Mozambique is underway. The three nations Namib Desert initiative will link the Richtersveld in South Africa with Iona Park in Angola via the Skeleton Coast of Namibia. The Zimbabwe-Mozambique-Zambia Transfrontier Conservation Area was established in 2003.

The concept of Transboundary Conservation Areas (TBCAs) is a multilateral approach to ecosystem use and management encompassing conservation and sustainable development, including tourism and peace. They have multiple objectives: protection of endangered species; promotion of sustainable use of natural resources; preservation of cultures that were split by borders; increased cross-border cooperation in economic development; and better control over border areas while promoting peace (Singh 1999). International Peace Parks are TBCAs that are largely symbolic in nature. They have definite political objectives to confirm, strengthen, or re-establish good relations between a neighbouring states, prevent escalation of border disputes, and safeguard biodiversity areas from military activities. More recently, a new concept, 'Transboundary Natural Resource Management' (TBNRM), has been introduced in the sub-region and is gaining wide recognition as an appropriate expanding developmental land use form. It builds on the ideas of 'Community Based Natural Resource Management', based on the recognition that the resource users are the best managers (Mayoral-Phillips 2002).

In addition to conservation-based transboundary areas, Spatial Development Initiatives (SDI's) have been widely promoted to unlock economic potential in specific spatial locations in the region. For example, the Lubombo SDI was established in 2000 between South Africa, Swaziland and Mozambique. The Okavango Upper Zambezi Tourism Initiative comprises 260 000 km^2 of savanna, woodlands, rivers, wetlands and game parks in a contiguous area of the five countries of Angola, Namibia, Botswana, Zambia and Zimbabwe.

Traditional knowledge of many communities in the sub-region is shared across borders, as are many of the resources that have potential for biotrade. Regional harmonisation of legislation that deals with access to genetic resources and the associated traditional knowledge, in order to ensure adequate and meaningfull benefits from bioprospecting and biotrade, is currently being considered.

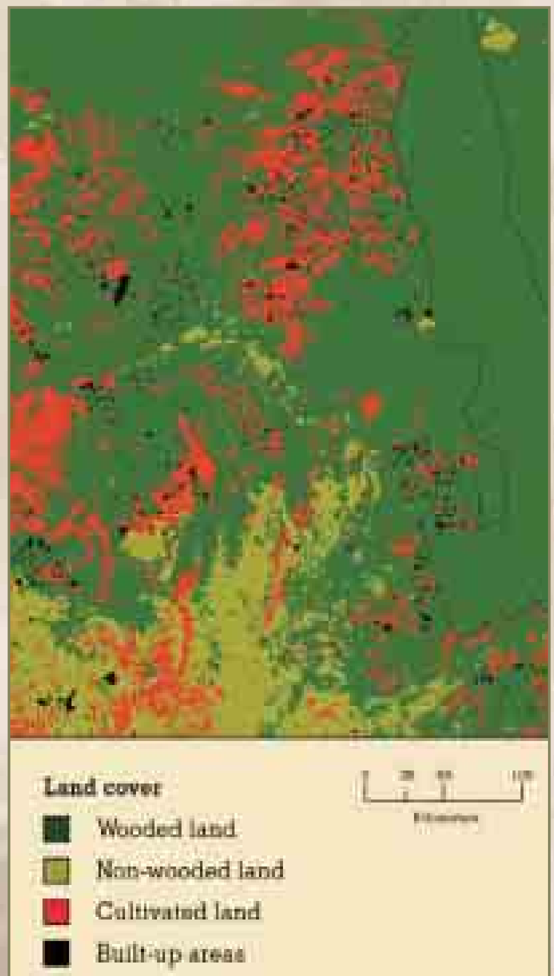
3.4 DEALING WITH TRADE-OFFS

The need to make trade-offs between different ecosystem services, or between ecosystem services, biodiversity, and human well-being is an inherent part of the decisions that ecosystem users and managers face. Because this often involves diverse actors with different values and competing objectives, choosing between trade-offs can sometimes be a contentious and conflict-ridden process. Trade-offs in southern Africa often must be made against the backdrop of the pressures that arise from the need to achieve social and economic development goals while sustaining ecosystem functions. Trade-offs may be between:

- different ecosystem services (representing different livelihoods or means of economic benefit),
- current and future benefits of ecosystem services,
- the needs of society and of ecosystems (related to the point above, because society is usually concerned first and foremost with its present needs, and secondarily its future needs),
- the provision of ecosystem services and human well-being benefits to one population in one time or place at the cost to another.

Part of the difficulty surrounding such situations owes to the fact that they almost universally come down to a trade-off of values or desires of different stakeholder groups. An upstream industry may value the Gariep system as a sink for wastes; downstream, tourists may value the Gariep river for recreation; commercial irrigators may value water from the river to cultivate crops for local sale and export, and pastoralists in the downstream Richtersveld may value the grazing lands along the river's banks. At the Gariep river mouth is a bilaterally proclaimed transboundary wetland of international importance (Ramsar site) which is likely to take the brunt of the many trade-offs upstream. As noted earlier, while the values of some services can be expressed in monetary terms, others cannot. In addition, there may be several shortcomings in framing a question of ecosystem services as a matter only of economics.

Numerous examples of responses that address trade-offs were explored in the SAfMA assessments. These include responses that reduce the impact of one ecosystem service on another, such as protecting water quality by avoiding the excessive use of pesticides or fertilisers in agricultural production, or introducing stoves with chimneys in communities to improve air quality and reduce health risks. They also include responses that make it economically viable to reap the benefits of multiple services from a single area of land. Below we discuss one such example common to all studies, the trade-off between food production and biodiversity.



As pressure for agricultural land increases, protected areas start forming islands surrounded by transformed land. The boundary of the Kruger National Park in South Africa is clearly visible in this land cover map.

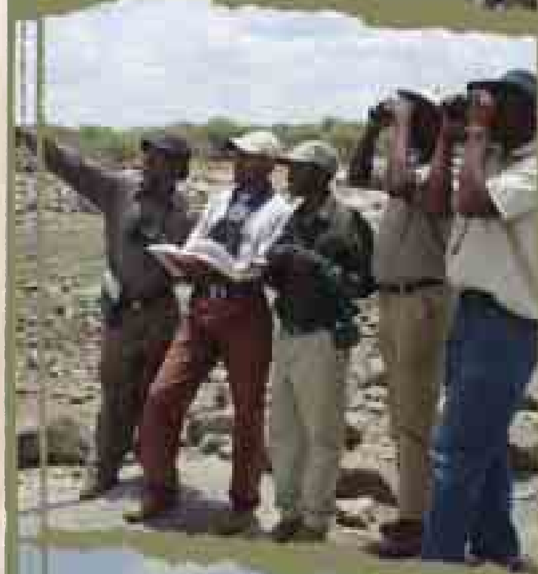
Livelihoods based on conservation

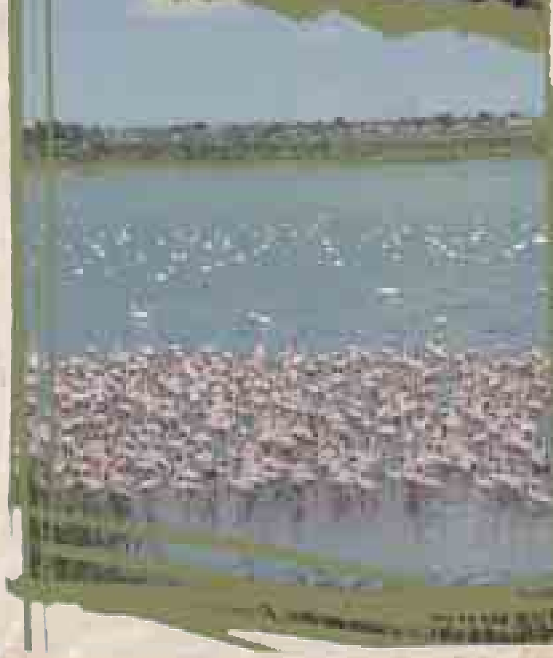
The need to make a living and biodiversity conservation have clashed particularly dramatically in southern Africa, where the need to feed a growing and largely impoverished, undernourished population has more often than not resounded more urgently than pleas to conserve biodiversity. Food production occurs in many forms, and while some, such as intensive cultivation, transform ecosystems, others, such as low-intensity grazing, have much more modest impacts on ecosystems. The challenge in those areas best suited to the latter form is to make biodiversity conservation economically viable. One way to do this is to give the users of ecosystem services a stake in management through the transfer of rights to own, use or manage resources from the state to private entities.

The privatisation of conservation in several southern African countries is not a new concept. In Namibia, private landowners had been granted rights to use and manage wildlife on their land since the 1960s. Similarly, private landowners in South Africa benefited from changes in wildlife protection legislation in the 1980s that allowed a shift in ownership to occur. This resulted in a conversion from cattle and sheep farming to game farming, which was more profitable and enabled the conservation of indigenous wildlife, initially through the lucrative trophy-hunting market and later to nature-based tourism. The result was an increase in protected area in the countries that adopted such legislation. In 1980, about 5% of South Africa's surface area was protected; the figure is 14% today and increasing.

Initially, this shift in land use was limited to private land, and increasingly a need was recognized to effect such a change on lands under communal management. In 1996, similar rights were extended to Namibian communities on communal lands that enabled them to establish conservancies to manage natural resources, mostly wildlife. By 2001, 14 conservancies had been registered, about 20 more were in establishment, and five conservancies had drawn up management plans (Barnes et al. 2001). The CBNRM initiative in Namibia has thus far been considered a great success in its ability to simultaneously deliver economic benefits to communities, contribute positively to national development, and conserve wildlife.

The Campfire programme in Zimbabwe was launched in communal areas on the periphery of national parks or game hunting areas where cultivation and livestock ranching were coming into conflict with wildlife. Here, sustainable community-managed use of wildlife, mainly through trophy hunting, was able to generate more income than the other major forms of livelihood. Income was then distributed amongst community members. The Campfire model was not only implemented in Zimbabwe, nor was it limited to wildlife. In the context of recent economic decline in Zimbabwe, however, the viability of the Campfire programme has been severely challenged, as the state repossesses areas given to communities. Transferring rights to own and manage services to private individuals or communities gives them a stake in conserving those services, but these can backfire without adequate levels of institutional support.





3.5 RESPONSES AND FEEDBACKS

In complex systems, feedbacks occur when multiple processes or responses (human or ecological) interact. These feedbacks may be positive (amplifying) or negative (dampening) (see section 1.3). It is important to be aware of feedbacks when designing responses. Subsidisation of natural resources is one example of a response that suppresses natural feedback mechanisms because it distorts perceptions about the true costs of using ecosystem services. This in turn creates dependency, and it can therefore be difficult to simply restore natural feedbacks. For example, the South African government has begun to phase out agricultural and irrigation subsidies, and has had to make special provisions for some small farmers and communities for whom farming is no longer an economically viable form of livelihood.

Positive feedbacks characterize the "poverty trap," the inescapable cycle of poverty, resource exploitation, and poor human well-being. In some areas in the region, a situation of "zero-options" results in illegal activities and crime. At some of the local assessment sites, for example, an increasing prevalence of theft threatens community cohesion and livelihood security. Households react by withdrawing from certain livelihood strategies altogether (e.g. no longer own cattle), or invest in efforts and capital accumulation closer to the homestead (e.g. abandonment of distant arable fields in favour of more intensive cultivation of the homestead garden).

Across all scales of the SA*f*MA assessment, specific areas were identified as a way to prioritise areas of concern (Fig 3.1). The regional scale figure depicts the spatial co-occurrence of problems with ecosystem services and social and economic decline. At the basin scale, key resource areas are illustrated that have high levels of ecosystem service provision or irreplaceability. At the local scale, key resource areas for water, fuel, food, and security that are critical for service provision in communities were identified. The overlap of areas with high levels of different ecosystem service provision does not imply that conflict does or will occur, but the management of such areas will require an integrated, multiple-use approach in which different stakeholders are represented. Conflict is likely to arise where technical, institutional or ideological barriers constrain the implementation of such an approach.

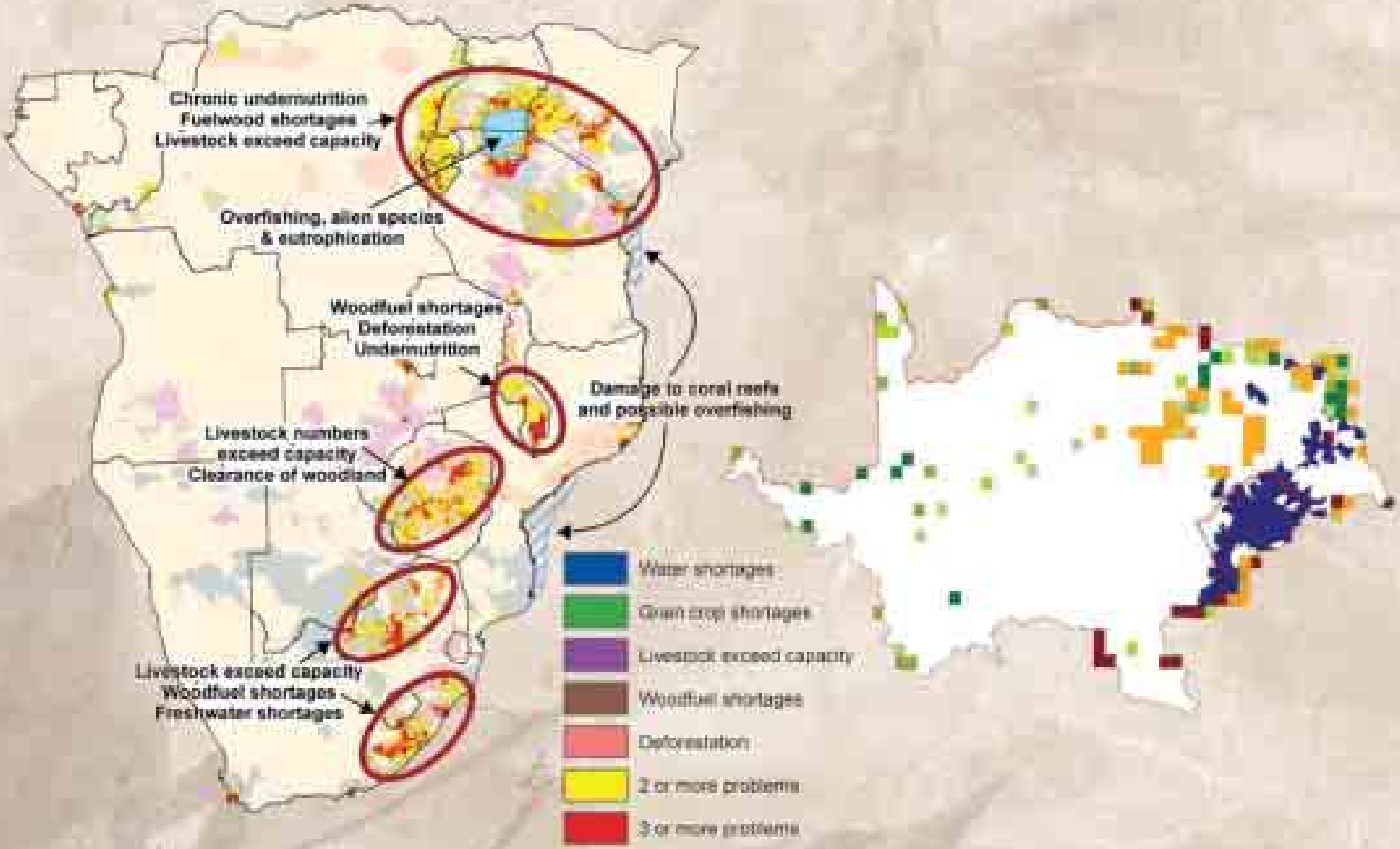


Figure 3.1 (Left) Synthesis map illustrating the main areas of concern regarding ecosystem services in relation to human well-being in southern Africa, as identified in the regional-scale assessment. The co-occurrence of problems in several areas suggests a manifestation of a downward spiral of poverty, declining ecosystem services, and deteriorating human well-being. The correspondence between areas of ecosystem service loss and social conflict is suggestive of a link in both directions: conflict creates conditions promoting ecosystem degradation, and environmental resource depletion could be a cause of conflict. (Right) Synthesis map of key ecosystem service areas in Gariep basin for surface water (blue), cereal production (orange), protein production (brown), and biodiversity features with high irreplaceability (green; intensity of colour increases with irreplaceability value).

3.6 RESPONDING UNDER UNCERTAINTY: LEARNING TO EXPECT SURPRISES

Uncertainties and surprises are part of complex systems, which adds to the challenge of designing effective responses. Responses that maintain flexibility and enhance resilience tend to be better equipped to deal with unexpected events. Examples of these responses include coping strategies used by local communities, such as livelihood diversification and adaptive management. Principles of adaptive management are also being applied by some southern African governments and institutions. The use of scenarios is a type of response for exploring uncertainty, and additionally serves as a tool that enables us to evaluate potential response options and their feasibility.

Exploring complex futures in southern Africa

Scenario planning has been increasingly used in the region in recent decades as a way to stimulate dialogue and debate on uncertainties stemming from novel combinations of political, social, and economic forces. The Mont Fleur Scenarios, for example, were developed in the early 1990s to explore possible trajectories for South Africa's political future. These scenarios were believed to have played an instrumental role in the relatively peaceful political transition that occurred (Kahane 1992). Within SA*f*MA, scenario-planning exercises have served a similar purpose, although they broke new ground in the region by linking social, economic, and political change to ecosystem services.

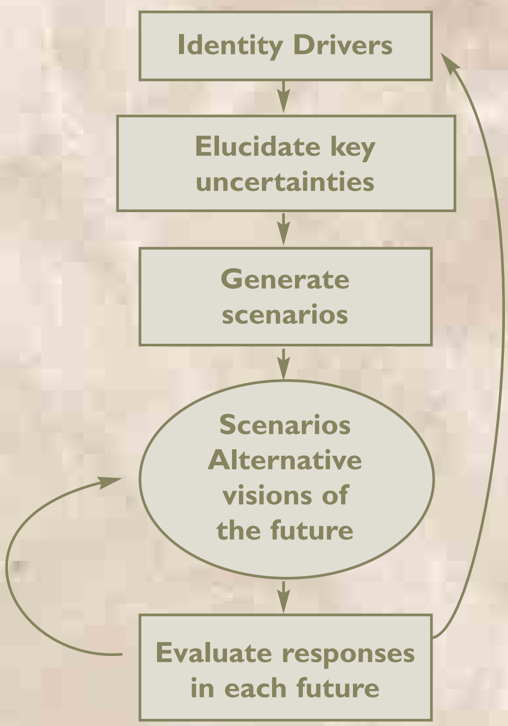


Figure 3.2 Iterative process of scenario and response assessment. Drivers are identified, key uncertainties elucidated, and a set of scenarios is developed that represents alternative futures. In each scenario, possible responses are identified and evaluated. The evaluation of responses is used to refine the scenarios, or, at the implementation level, to address or alter the identified drivers.

Table 3.1 Major drivers of change used to create the SA*f*MA scenarios

SA*f*MA component	Major drivers
Regional	Governance at national and supra-national levels, regional political integration, economic growth and integration, science and technology
Gariep basin	Governance at national and local scales, including strength of civil society networks
Gariep local	International and local economic growth, manner of policy implementation, high-impact interventions (e.g. dams)
Gorongosa – Marromeu	Regional: Capital inflows, governance Local: Armed conflict, rainfall amount and timing, relationship between local communities and government, amount of trade

Box 3.3 Using and Communicating Scenarios

Scenarios play a number of roles in an assessment such as SAfMA. The process by which scenarios are created can be at least as important as the actual outcome. In SAfMA-GM, for example, key stakeholders in each of the target sectors were brought in to construct the scenarios. This has the benefit not only of ensuring that the scenarios are plausible representations but also of raising the awareness of key stakeholders as to what could drive their futures and what they might do about it. The SAfMA-GM team used their scenarios as the equivalent of wind tunnels for testing aircraft. Local communities and decision makers were asked how they might respond in these future worlds. The scenarios thus provided a framework in which the decision makers could test out their policies or management practices.

In the Gariep local assessment, communities initially found it difficult to envision a world that they had not experienced before. Scenario theatre was therefore used to make the scenarios more real to local people. Opportunities were provided during and after the play for local participants to indicate how they would respond to a particular scenario, and to reflect whether their current management practices and responses would be appropriate under this scenario. As a result of the scenario theatre, people became aware that they needed to keep their options open, that their natural resources played crucial roles during critical times such as drought or economic change, and that local institutions were important to maintain ecosystems. People also recognized that many of the factors affecting their well-being were not local, and that they needed to maintain the capacity to respond to these external challenges rather than either ignoring them, or attempting to resist them.

Scenario creation fits into a larger iterative process of assessing ecosystem services and possible responses to manage them (Fig 3.2). The first step of this process involves the identification of the most important drivers in a system. The key drivers of alternative futures in southern Africa were largely the same in all assessments: governance, financial flows and wealth distribution came up in virtually all scenario exercise at all scales (Table 3.1).

While the major drivers provide a common thread through the scenarios across scales, each team proceeded to create its scenarios independently with the input of different stakeholder groups and a range of methods to communicate scenarios (Box 3.3). The resulting scenario storylines differed considerably between assessments. As windows on the future, scenarios thus have great power and flexibility in being able to both capture general drivers of change as well as the subtleties of local variation.

Several assessment teams chose to adapt existing scenarios. A number of scenario archetypes can be identified based on clusters of driving forces, such as economic and geopolitical forces, and social issues (Table 3.2). Because the issue of governance emerged as a common uncertainty, teams produced a set of scenario storylines revealing the implications of at least two divergent futures: one in which effective governance systems take hold in the region and one in which governance systems are weak. Three teams developed scenarios that closely match the Local Resources and Policy Reform archetypes, though modified to reflect scale-specific conditions. A classification of the global MA scenarios, and scenarios developed in three SAfMA studies, is given in Table 3.3.

Table 3.2 Scenario archetypes interpreted for the southern African context (Scholes & Biggs 2004).

Scenario archetype	Main elements
Fortress World	Region torn apart by violent conflict. Elite minorities live in enclaves of wealth and security, mostly in the southern parts of the region. The poor majority are deprived of basic services and rights, and rely on the informal economy for survival. Wealth and power are in the hands of the elite; relations are unequal and exploitative. Little to no regional cooperation exists. General environmental degradation, except in isolated enclaves.
Local Resources	Weak states with little economic growth are ineffective at delivering services. Community organisations and traditional authorities hold power. Absence of state services and formal employment force communities to rely on their own resources, managed communally. Relative stability in the region, although localised conflicts are endemic.
Market Forces	Unbridled private sector economic activity linked to globalized markets for products and labour. Privatisation of many state functions. Countries and economies largely controlled by big business. The majority of people remain poor and survive in the informal economy. Economic growth benefits mainly the elite, and occurs at the cost of the environment. Regional cooperation centred on corporate interests.
Policy Reform	Visionary leadership and strong national governments. Most countries are multi-party democracies. Region still poor and unequal but characterised by political stability, and social and economic progress. Economies diversified to create a competitive industrial base. Market-driven growth constrained by environmental and social sustainability policies. Significant regional cooperation and integration.
Value change	Notions of sustainability fundamentally change the values and lifestyles of society. Markets are the main economic mechanism, but are constrained by social, cultural and environmental goals. Values of simplicity, tranquillity and community displace values of consumerism, competition and individualism.

Table 3.3 Classification of the MA global scenarios, the SAfMA regional scenarios, the Gariep basin scenarios, and the Gariep local assessment scenarios into four scenario archetypes. The Gorongosa-Marromeu scenarios did not match these archetypes and are thus not included here.

Scenario archetype	MA Global Scenarios	SAfMA regional scenarios	Gariep basin scenarios	Gariep local assessment
Fortress World	Order from Strength		Fortress World	
Local Resources	Adapting Mosaic	African Patchwork	Local Learning	Stagnation
Market Forces			Market Forces	Green Engineering
Policy Reform	Global Orchestration, Techno Garden	African Partnership	Policy Reform	Betterment

Identifying Future Responses

In addition to helping to envision how the future might unfold, scenarios in SAfMA were used to elicit ideas from ecosystem users and managers about how they are likely to respond given different future conditions. Identifying which types of responses will be feasible depends on the adaptive capacity of ecological and social systems. This requires us to think about the political, economic, and social context in which responses will be shaped and executed. The nature of the response that will be adopted in a given situation will depend in part on the respondent's perception of the situation, which will depend on values, objectives, and available information, but also on his or her capacity to act. This capacity will vary between individuals and organizations, and will also be influenced by existing circumstances.

The Gariep basin assessment identified types of responses that are likely to be adopted under the assumptions of its four scenarios (Table 3.4). This assumes that a higher capacity to utilize multiple responses, including legal and policy responses, will exist under Policy Reform than other scenarios. However, some additional cross-scale considerations need to be borne in mind. The level of regional stability will place limits on the responses that can be adopted and that will succeed in the Gariep basin. In addition, responses at the basin-scale must recognize the importance of variation in local-scale conditions that will likewise enable or constrain adoption and success. This signifies that the scale of the desired effect of a response should be a significant consideration in choosing amongst responses.

Table 3.4 Which responses in which future? The Gariep perspective (Bohensky et al. 2004).

Scenario	Types of responses likely to be adopted
Fortress World	Economic; limited technological responses (but responses only benefit elites)
Local Learning	Social, behavioural and cognitive responses, etc. (but locally organized)
Market Forces	Technological, economic responses (legal, institutional to lesser degree)
Policy Reform	Legal, institutional, policy responses; social, behavioural and cognitive; knowledge and education (technological to lesser degree)

Local livelihood strategies

The assessment of local livelihoods in SAfMA (in parts of the Gariep basin and in Gorongosa-Marromeu) indicates that people cope with ecosystem change through strategies to reduce their risk. They become seasonally and spatially mobile and flexible, and invest in diverse crops rather than monocultures. They also diversify the household labour force, invest in formal education and scale down, by reducing herd sizes and field sizes. People may try to forecast the future, but in this they are less successful than in planning their day-to-day activities, and may rely on rumours or superstition to forecast. People form local institutions to help them deal with uncertainty. They fall back on traditional customs and rules, but also form new cooperatives such as burial societies, savings clubs, and self-help groups. Religion plays an important role in their lives, and people gather frequently for oral communication.

Another strategy for coping with ecosystem change is to adapt management practices. People try new enterprises e.g. ecotourism, and increase their off-farm incomes. They also explore new technology, such as water tanks, ploughs, and mechanized pumps. As a response to shortages, people broaden and extend their definitions of food, fertilizer, and fuel. They reduce overheads drastically, and tend to spend all their efforts on food security and basic needs.

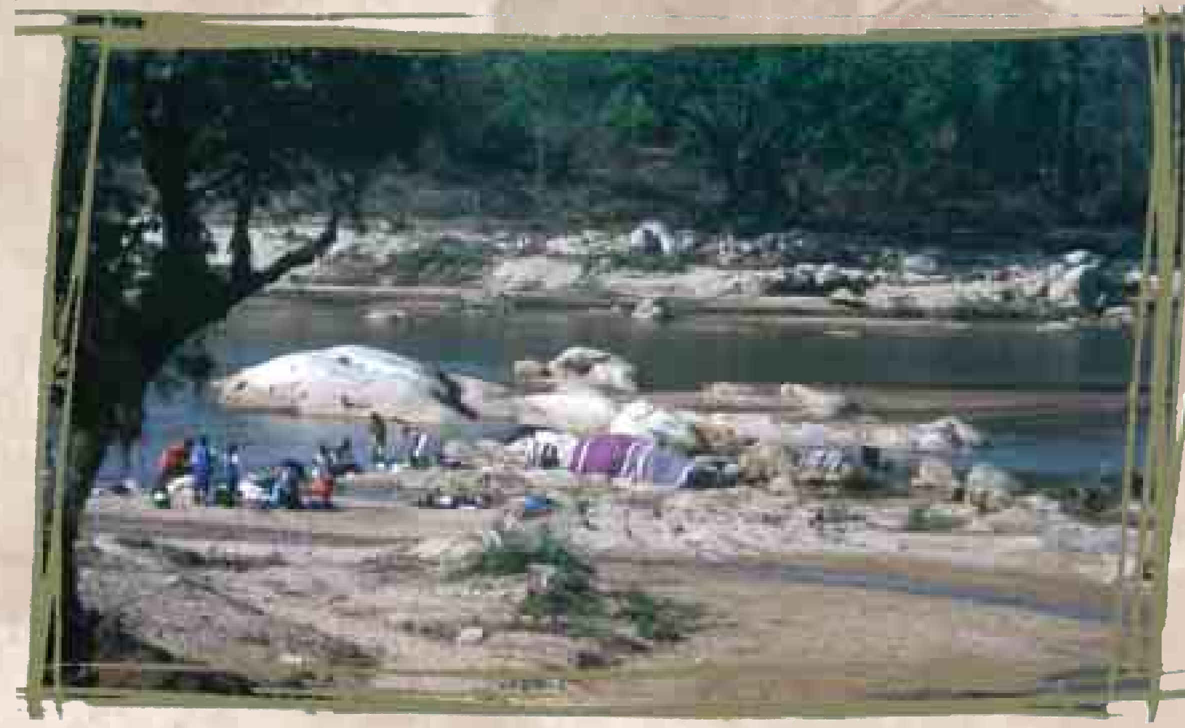
Cultural practices represent an important long-term adaptive response to uncertainty. In the Great Fish River basin, local amaXhosa communities have strong beliefs about taboo areas such as sacred pools and forests (see section 2.6). These are cultural landscapes that are inaccessible to people at certain times of the year, or they may be inaccessible to most community members except a select group such as traditional healers. As a consequence, taboo areas serve as important sites of ecosystem renewal during times of crisis, such as severe droughts. People may maintain important wetlands and fountains in the event that water infrastructure breaks down. The harvesting of resources may also be regulated by cultural practices. For example, live trees are not supposed to be chopped, and some honey must be left for honeyguides.

Rural households and communities interact with and respond to their surrounding environment in innumerable different ways, depending upon the ecological, social, and economic contexts prevailing at any given time. They are both reactive to unanticipated circumstances, and proactive in identifying new opportunities to create sustainable livelihoods and minimize risks. Coping strategies and adaptation common to the three SAfMA local assessment sites in the Gariep Basin include: A diversity of livelihood strategies; temporal flexibility in the livelihood portfolio; internal stratification; links to urban centres; multiple landscapes and environments, with multiple resources and species from each environment; resource and species substitution; secure water resources; mobility; and social and kin networks. These coping strategies can save people's lives. In difficult times, people invest everything in basic needs and security. However, they may increase their vulnerability if they sacrifice future options to make such an investment.

3.7 ASSESSING RESPONSES

How do we determine whether a response is likely to achieve a more sustainable use of ecosystem services or improved human well-being? Based on SAfMA's observations of the consequences of the many responses (and non-responses) that have led to the current condition and trends in ecosystem services and human well-being in southern Africa, we revisit the four problems noted in section 3.1 and use these to gauge the effectiveness of the responses discussed.

Do they recognize complexity? The response of licensing charcoal use in Mozambique simplifies the greater problem of poverty. The Working for Water programme, conversely, creates a synergy between poverty reduction and protection of ecosystem services, although it may be most effective as a short-term solution to the problem of poverty.



Do they address scale differences? In theory, the responses occurring in the water sector that match management to the scales of catchments and large transboundary resources are commendable, although in practice, we note that the management capacity of the new cross-scale institutions has yet to be demonstrated.

How do they handle trade-offs? The privatisation of conservation in southern Africa demonstrates that biodiversity conservation is compatible with some other forms of land use, and thereby enables the provision of multiple services. Responses that make trade-offs and their implications (ecological, social, and economic) transparent to decision-makers can assist the process of choosing between various options and the likely consequences of making alternative choices. Techniques such as the irreplaceability approach presented in section 2.5 have several advantages that make it an effective tool for communicating with decision-makers: it is flexible (targets can be set according to specific objectives), dynamic (options are updated as decisions are made), visual, and transparent.

Do they deal with uncertainty? At the local scale, adaptive management in the form of livelihood diversification is a successful coping strategy for dealing with uncertainty and is widely used by the communities assessed in SA*f*MA. However, lack of access to information, institutional barriers, and the 'grand schemes' of government may reduce the adaptive capacities of local people. Scenario planning has demonstrated success in the region by enabling decision-makers to identify key uncertainties about future events or trends, and by broadening awareness of complex issues among diverse stakeholders. Scenarios can be problematic if misinterpreted, however, and thus careful communication of scenario outcomes to decision-makers is necessary. Scenarios also provide a mechanism for exploring the feasibility of implementing different responses.

3.8 CONCLUSIONS AND KEY MESSAGES

It is hoped that this assessment can provide guidance to decision-makers, by highlighting not only issues of ecosystem services and human well-being that deserve critical attention, but also the aspects of governance and management systems that can contribute to more resilient ecosystems and human well-being. Nothing may be more crucial to the sustainable management of ecosystem services than the free flow of information, and the enabling of individual as well as institutional flexibility, creativity, and innovation.

An important aim for SA*f*MA is to put the ecosystem services concept on the map. The significance of ecosystem services and their intimate relationship with human well-being is likely to increase in coming years and must be made tangible to a wider audience. Building capacity to understand, manage, and communicate the value of ecosystem services must target both new and established managers and scientists from all backgrounds to think in inter-disciplinary, multi-sectoral, multi-cultural, and cross-scale terms. The capacity to build capacity in integrated assessment must also exist, and so create conditions for effective decision-making to continue into the future.

Clearly, a number of response options exist to improve the benefit streams from ecosystem services to human societies without undermining ecosystem integrity. The political and social changes now occurring in southern Africa have far-reaching consequences for the way ecosystem services and human well-being are managed in the future; it is thus imperative to develop an increased understanding of the opportunities and constraints that are faced in choosing and implementing responses.

SA*f*MA indicates that the responses most likely to succeed in problems related to ecosystem services and human well-being will:

1) ***Recognize complexity.*** Ecosystem services and the people who depend on them comprise complex social-ecological systems. Narrow, single-issue or single-sector perspectives are likely to promote unwanted consequences in other sectors. Responses that take all relevant sectors into account when planning for any particular sector are more likely to avoid unexpected surprises, and are better prepared for those surprises when they come.

2) ***Look at the whole picture.*** Strive to create positive synergies. Where trade-offs must be made, decision-makers must consider and make explicit the consequences of all options. Various tools can assist decision-makers in visualising, understanding, and communicating the issues at stake.

3) ***Be made through an inclusive process.*** Making information available and understandable to a wide range of affected stakeholders is key. Asymmetries in society give rise to asymmetries in information, education, and income availability. These are usually translated to unequal distribution of ecosystem service benefits, and reduced adaptability and responsiveness. Collectively, these asymmetries increase the vulnerability of disenfranchised communities. In addition, benefits derived from ecosystem services are pervasive throughout society. The awareness of these benefits among different groups needs to be raised, and social and economic development need to incorporate these benefits.

4) ***Enable natural feedbacks.*** The ability of ecosystems to continue providing ecosystem services depends on natural feedbacks that can be seriously compromised when they are dampened by inappropriate management, policies, and governance models. Perverse subsidies are among the most damaging of incentives that promote inappropriate behaviours, and their eradication is an urgent priority. Responses must also avoid creating artificial feedbacks that are detrimental to system resilience. Frequent, careful, and rigorous monitoring helps to indicate whether feedbacks are functioning.

5) ***Be implemented at the appropriate scale.*** The scale of a response must match the scale of the process; often, a multi-scale response will be most effective. In particular, tenure systems, institutional arrangements, and the role of privatisation have important implications for the continued provision of ecosystem services. That said, there are no "silver bullet" tenure arrangements for managing ecosystem services, and each situation demands a unique, scale-appropriate response based on situation-specific knowledge and consultation with stakeholders.

6) ***Acknowledge uncertainty.*** Given the complexity of social-ecological systems, it is usually impossible to fully understand the structure or functioning of a system to be able to predict the outcome of a response. In choosing responses, we must understand the limits to our knowledge, and we must be prepared for surprises.

7) ***Enhance the adaptive capacity*** of managers and of ecosystems. Resilience is increased if managers have the capacity to learn from past responses and adapt accordingly. Resilience is also increased if the capacity of the ecosystem to deal with change is enhanced or maintained.

8) ***Assess and re-assess*** the feasibility of alternative responses. A change in one or more of the system drivers can lead to a previously unfeasible response becoming feasible, or vice versa. Care must be given to the prevailing social and cultural context in which a response is implemented, as this context also determines what is or is not feasible.

Problems in complex systems require complex responses. Decision-makers, whether ecosystem users, managers, or governments, need to design responses that can meet the challenges above. Responses made in isolation are not likely to succeed, and coordination between those who choose and implement responses is needed across sectors and scales. This will require greater cross-communication between diverse actors, and the free flow of information between them. While our responses must acknowledge the limits to our knowledge about complex systems, we must strive to constantly improve upon it.

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Mr Marcus Lee (MA Secretariat)

The SA*f*MA Technical Team

SA*f*MA COORDINATOR

C. Musvoto, Institute of Environmental Studies, University of Zimbabwe

REGIONAL-SCALE TEAM

R.J. Scholes, R. Biggs, J. Cooper, G. Fleming, T. Malungani, A. Misselhorn

Lead institution: Council for Scientific and Industrial Research (CSIR), South Africa

Partner institutions: University of the Witwatersrand (South Africa), Development Bank of Southern Africa

ZAMBEZI BASIN TEAM

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Partner institutions: Gorongosa National Park (Mozambique), Eduardo Mondlane University (Mozambique), National Directorate of Conservation Areas (Mozambique)

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Lead institution: Stellenbosch University, South Africa

Partner institutions: Council for Scientific and Industrial Research (RSA), Gauteng Department of Agriculture, Conservation, and Environment (RSA), Lesotho Agricultural Research Division, Monash University (South Africa campus), Rhodes University (RSA), University of Natal (RSA), University of Pretoria (RSA)

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Lead institution: Rhodes University, South Africa

Partner institutions: Agricultural Research Council (RSA), South African National Parks

The SAfMA integrated report is based on the following underlying assessments:

Regional-scale assessment

Ecosystem services in southern Africa: A regional assessment.
R.J. Scholes and R. Biggs (eds.), 2004.
Council for Scientific and Industrial Research, Pretoria, South Africa.

Contact: Dr Bob Scholes, Council for Scientific and Industrial Research, Pretoria, South Africa
bscholes@csir.co.za, Tel: +27-12-841-2045, Fax: +27-12-841-2689

Zambezi Basin Assessment

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Miombo Network (www.miomb.org, www.zambezibasin.org)

Contact: Dr Paul Desanker, Dept of Geography, Penn State University, USA
desanker@psu.edu, Tel: +1-814-865-1748, Fax: +1-814-863-7943

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Contact: Dr Tim Lynam, Institute of Environmental Studies,
University of Zimbabwe, Harare, Zimbabwe
tlynam@science.uz.ac.zw, tlynam@gorongosa.org, Tel: +263-4-302-603, Fax: +263-4-332-853

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Sun Press, Stellenbosch, South Africa.

Contact: Prof Albert S. van Jaarsveld, Faculty of Science, Stellenbosch University, South Africa
asvanj@sun.ac.za, Tel: +27-21-808-3071, Fax: +27-21-808-3680

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Contact: Prof Christo Fabricius, Dept of Environmental Science, Rhodes University,
Grahamstown, South Africa
c.fabricius@ru.ac.za, Tel: +27-46-603-8614, Fax: +27-46-622-5524

Other relevant Millennium Assessment publications

The approach and assumptions adopted in the MA are described in the report "Ecosystems and Human Well-being: A Framework for Assessment" (published in 2003 by Island Press). The four reports of the global working groups will be published by Island Press in 2005 (Condition and Trends, Scenarios, Responses and the Sub-Global Studies synthesis). Five shorter, cross-cutting synthesis reports will also appear: General Synthesis, Biodiversity, Desertification, Private Sector and Wetlands.

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