Ecosystem Services in the Gariep Basin

Edited by E. Bohensky, B. Reyers, A.S. van Jaarsveld and C. Fabricius

A Basin-Scale Component of the

Southern African Millennium Ecosystem Assessment

Millennium Ecosystem Assessment

STRENGTHENING CAPACITY TO MANAGE ECOSYSTEMS SUSTAINABLY FOR HUMAN WELL-BEING

Ecosystem Services in the Gariep Basin

A contribution to the Millennium Ecosystem Assessment,
prepared by the Gariep basin team of SAfMA,
the Southern African Millennium Ecosystem Assessment

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Edited by

Erin Bohensky (University of Pretoria)
Belinda Reyers (Stellenbosch University)
Albert van Jaarsveld (Stellenbosch University)
Christo Fabricius (Rhodes University)

Contributors

Louise Erasmus (University of Pretoria)
Aimee Ginsburg (Stellenbosch University)
Claudia Holgate (Monash University)
Tony Knowles (Stellenbosch University)
Lefulesele Nteletsana Lebesa (Agricultural Research Division, Lesotho)
Michele Pfab (Gauteng Department of Agriculture, Conservation and Environment)
Marna van der Merwe (CSIR)
Charlie Shackleton (Rhodes University)
Lethiwe Zondo (University of Natal)

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EXECUTIVE SUMMARY

- *The Millennium Ecosystem Assessment (MA)* is a four-year international initiative to evaluate the state of Earth's ecosystems across multiple scales and the current capacity and future potential of ecosystems to deliver services of value to people. Central to the MA is a conceptual framework that describes the relationships between ecosystems, their services, and human well-being, and their drivers of change. The MA is being conducted in a suite of sub-global assessments around the world. The Gariep Basin Millennium Ecosystem Assessment is a component of the southern Africa sub-global assessment (SAfMA).
- *The Gariep Basin Millennium Ecosystem Assessment investigated the condition and trends of ecosystem services and human well-being in the Gariep basin from 1993 to 2003*. The assessment features highlights from four local-scale assessments nested within the basin: Sehlabatebe, Great Fish River, Richtersveld, and Gauteng Province. Scenarios were constructed at both basin and local scales to depict possible alternative futures of ecosystem service supply and demand in 2030. Past, present, and possible future responses to change in ecosystem services were considered. Conducted with input and technical support from a User Advisory Group (UAG) comprising basin stakeholders, the assessment is aimed primarily at the international assessment community, decision-makers at national and provincial levels of government, research institutions, as well as the private sector and the general public.
- *We define the Gariep basin for the purposes of this assessment as the area of South Africa and Lesotho drained by the Senqu-Gariep-Vaal River system, as well as two primary catchments connected to this system by major water transfer schemes*. Extending over 665,000 square kilometers across south-central southern Africa, the catchment encompasses the entire mountain nation of Lesotho, the urban-industrial complex of Gauteng Province, the "grain basket" of the central plateau, the extremely arid western regions of South Africa, and two international biodiversity hotspots.
- *Human well-being in the basin is highly variable*. The basin's population is characterised by diverse ethnic and cultural backgrounds, a multitude of languages, and high socio-economic inequity. The majority of people live in the higher-rainfall areas in the east, with significantly lower population densities in the arid west. High unemployment, low rural literacy, and high HIV/AIDS incidences have significant consequences for the livelihood options available to people across the basin.
- *The Gariep is a water-scarce basin, with runoff distributed disproportionately across the landscape.* It is the region's most regulated basin, with large dams and extensive transfer schemes, most notably from the Lesotho highlands to the growing urban-industrial complex of Gauteng. Transformation of freshwater and groundwater systems have resulted in biodiversity loss and water quality problems, causing a range of ecological, economic, and human health impacts. The water sector is currently being decentralised and new pricing policies are aimed at full cost recovery of water services. The South African National Water Act of 1998 prioritises the allocation of water to ecosystems and basic human needs, but ecological requirements have yet to be clearly defined. Infrastructure to deliver water is lacking in some rural areas and some households cannot afford to pay for water services.
- *Food production in the Gariep contributes to livelihoods, markets, raw materials, foreign exchange, and surplus or "savings."* Agriculture is a source of water and air pollution and mismanagement has resulted in significant land degradation. Fertilizers and pesticides can have negative effects on health, while GMOs are controversial but can boost agricultural productivity. Subsistence farming, food gardens, wild foods, game farming, and bushmeat are important food sources not usually reflected on national balance sheets. Biodiversity contributes substantially to local livelihoods, both in terms of its direct nutritional value in the form of bushmeat and wild fruit, but also indirectly as a buffer during periods of acute food shortage. Food security is being compromised by declining household incomes, changes in land tenure and market access, and HIV/AIDS. Contemporary and historical national and international political events and policies also affect the types and amounts of food produced and determine local access to food.

- *In rural areas and the informal economic sector, biofuels remain an important energy source, while electricity or fossil alternatives supply urban households***.** About 70 percent of South Africa is electrified, dropping to 50 percent in rural areas and 3 percent in Lesotho. Local fuelwood depletion occurs in some rural areas, while in others fuelwood supply is adequate and exceeds the demand. The sustainability of fuelwood use is a function of human population density, primary production, and intrinsic plant properties. Burning of coal, though abundant, produces high carbon dioxide and sulphur dioxide emissions, affecting air quality and contributing to greenhouse gas emissions. Potential for solar power is very high in the Gariep, but investment in alternative energy technologies remains limited.
- *Minerals are of special interest in the Gariep basin because of their contribution to the economy and employment.* However, mineral extraction also creates ecological disturbance that interferes with ecosystem functions and biodiversity. Furthermore, by-products of mining affect air and especially groundwater quality. Mining legislation passed in recent years has required the sector to implement more sustainable and equitable practices, though in general, the benefit flows from minerals are still captured by a narrow margin of society.
- *Cultural services* such as sacred pools and forests, taboos, rituals, religion, language, and ecological knowledge systems exist across the landscape but are often specific to fine-grained landscape patches or individual species in communal areas. Cultural services in some areas are threatened by land use pressures, increasing urban contact, modernisation, and influences of other cultures. Some cultural services in the Gariep basin are formally recognised by South Africa's Natural Heritage Act and the World Heritage Convention.
- *The ecological integrity of the Gariep basin is in reasonably good condition,* with 84 percent of the basin in its natural state, while the rest is transformed by cultivation (93 percent), urbanisation (four percent), and overgrazing and fuelwood removal (four percent). In addition to land cover change, climate change and alien invasions are major drivers of changes in integrity. The basin is less well protected than South Africa on average, despite the occurrence of two important biodiversity areas within its boundaries. The grasslands, nearly 30 percent transformed, is the most threatened biome and most poorly protected, but contains many of the region's areas of biodiversity value, making it a conservation priority.
- *Fine-scale ecological integrity in the Gariep basin is variable in its condition*. At the local level, key resource areas that may appear insignificant in size enable communities to survive or even thrive in areas that, at a coarser scale, appear to be severely degraded or unproductive.
- *While total protected area is increasing and several large transboundary parks have been or will soon be established*, conservation in the region is moving away from a sole focus on protected areas and is embracing other approaches, such as economic incentives for promoting conservation on private or communal land.
- *Gauteng Province, the urban hub of the southern African region, is highly dependent on ecosystem services from outside the province, especially water and food***.** Gauteng's entire water supply is delivered by inter-basin transfers from other catchments, and it consumes nearly 30 times the amount of wheat produced within the province. The effects of urbanisation on biodiversity can be radically different from those posed by other forms of land use. Gauteng lies mostly within the Grasslands biome, and contains many endemic and severely threatened species, as well as numerous wetlands which filter pollutants.
- *In the Gariep basin, the challenge of making trade-offs between different ecosystem services and biodiversity* is intensified by the need to reverse past discrimination in South Africa that prevented the majority of the population from fully realising or gaining access to the benefits provided by ecosystem services. We use various techniques to explore trade-offs between food and water, between the utilisation and protection of water, and between food and biodiversity. These approaches show promise, but this is clearly an area where additional research will be required in the future.

- *The major indirect drivers of change in ecosystems and their services are* (1) governance change, (2) demographic change, (3) economic change, (4) climate change, (5) social/cultural change, and (6) large-scale interventions on behalf of government, the private sector, or other institutions. Indirect drivers in turn affect direct drivers of change such as land and water use. Local-scale drivers were identified as generic (common to all sites), such as large-scale interventions, or site-specific, such as access to key resource areas (Richtersveld), international donor priorities and sentiments (Sehlabathebe), and exceptionally high levels of HIV/AIDS (Great Fish River).
- *Alternative scenario storylines for the Gariep basin were explored around the key uncertainty of governance. Fortress World* depicts a situation with weak national and local governance, while *Local Learning* reflects a situation in which national governance is weak but civil society networks are strong. *Market Forces* represents an active economy but with limited distribution of wealth and an absence of effective social and environmental policies. In the *Policy Reform* scenario, both national and local governance are strong, and social and environmental policy interventions succeed. Scenarios are intended to stimulate thinking about plausible future events and trends rather than project the future, but they can help to identify types of responses that may be possible under these alternative conditions.
- *Response options to improve flows from ecosystem services* include those that target the management of the condition of the ecosystem; technological interventions; legal, institutional, and economic policies; and social, behavioural, and cognitive responses, including improvements in knowledge and education. Responses are most likely to succeed when they are scale-appropriate and integrated, and when they are made through a participatory process. Among the more promising or novel responses in the basin are the water legislation in South Africa, the privatisation of conservation, and the Working for Water Programme for poverty reduction and eradication of invasive alien vegetation. The local-scale assessments focused on coping strategies adopted by people to deal with change. These include diversification of livelihoods, entry into the wage economy, building social capital, and risk avoidance strategies.
- *Ecosystem service and human well-being "hotspots" exist at both basin and local scales*. These include areas of high service production, high irreplaceability (uniqueness), or sources or locations of conflict or potential conflict in the near future. The overlap of areas with high levels of service production or irreplaceability does not imply conflict, but the management of such areas will require an integrated, multiple-use approach in which different stakeholders are represented. True "hotspots" may exist where technical, institutional, or ideological barriers constrain the implementation of such an approach.
- *In conclusion, this assessment emphasises the crucial need to incorporate ecosystem services into future decision-making processes related to environment and development issues in the basin.* The Gariep basin is an information- and data-rich region of southern Africa, but major knowledge gaps remain. 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 in the Gariep basin 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.

CHAPTER 1
Introduction

1.1 An Ecosystem Services Approach

Around the world, ecosystem services support human livelihoods, societies, and economies. These services include the *provisioning services* of water, food, fuel, pharmaceuticals, and fibre, *regulating services* that control climatic processes, land degradation and disease, *supporting services* such as soil formation and nutrient cycling, and *cultural services* that provide nonmaterial benefits (Daily 1997, Millennium Ecosystem Assessment 2003). Ecosystem services command a range of direct and indirect values (Noss and Cooperrider 1994), but with a few exceptions (e.g. timber, agricultural products, medicine), standard economic measures fail to adequately capture these values. Concerted efforts have been made to estimate the natural capital that ecosystem services provide (Costanza *et al.* 1997), but these continue to grapple with the challenge posed by the intrinsic linkages between ecosystem components, and the resistance of some services to economic valuation. Furthermore, while some ecosystem services are obtained by harvesting or destroying a resource, or transforming an ecosystem, others are derived only by leaving the ecosystem intact. As resource extraction escalates, the increased benefits of any particular service may be gained at the cost of other services.

Historically, ecosystems have been managed within the context of individual economic sectors, each of which produces a single service, leaving managers unaware of the inherent trade-offs that exist among services (Ayensu *et al*. 1999). For this reason, these trade-offs are largely ignored until their multiple cascading effects culminate in ecosystem collapse. An exotic species is introduced to boost production but out-competes a native species that maintains an essential ecosystem function. A community clears indigenous forest to expand cropland but increases its vulnerability to erosion and floods. The construction of a dam improves water supplies but disrupts the migration of spawning fish and inundates critical resource patches used by local people. Despite the value of maintaining a full suite of ecosystem services, exploitation of ecosystems will continue where the benefits – economic, political or otherwise - appear to exceed the costs for the exploiter.

In essence, decisions to utilise or conserve ecosystems are embedded in complex ecological, social, and economic dynamics. To understand and interpret these dynamics requires collaborative, multiple-scale investigations of ecosystem services that compare the full range of trade-offs over competing land uses (Balmford *et al*. 2002). It also requires a dynamic approach that views humans and ecosystems as part of the same social-ecological system (Westley *et al*. 2002).

The Millennium Ecosystem Assessment (MA) is an effort to answer this call. The MA is an initiative to evaluate the state of Earth's ecosystems across multiple scales, and in particular, the current capacity and potential of ecosystems to deliver services. The MA marks a departure from other global assessments in several ways: its spatial extent reaches from globe to village, temporal extent spans past, present, and future, and its integrated, multi-sector nature draws on expertise from ecologists, sociologists, and economists. This approach illuminates the trade-offs inherent in exploiting the array of services that an ecosystem offers, preserving the integrity of the ecosystem, and securing human well-being. The MA achieves this through a conceptual framework that identifies the relationships between drivers of ecosystem change, ecosystem services, and human well-being (Figure 1.1).

While we may be able to identify these drivers at present, it is uncertain how these relationships will change over time. To envision future arrays of ecosystem services, scenarios are used to explore possible alternative trajectories for ecosystem services and their consequences for various aspects of life on earth. Scenario planning is a useful, structured way to stimulate thinking and debate about future events or trends, and to state explicitly our uncertainty about them (Huntley *et al*. 1989, Peterson *et al*. 2003). The use of scenarios complements the development of response options that may be available to assessment users. Their responses assist further scenario generation and feed back into the assessment in an iterative, interactive cycle.

Crucial to this framework is a participatory approach that engages ecosystem users and managers who have a stake in the future of an ecosystem. Too often, scientific assessments exclude the people most closely connected to the assessed ecosystems and services, and comprise their credibility and effect. The MA recognizes the value of stakeholder knowledge and perceptions by incorporating these into the assessment process in a variety of ways, including the establishment of User Advisory Groups (UAG). A UAG may either participate in the assessment or provide feedback to the team conducting the actual assessment. Two key objectives of the MA process are to encourage experimentation with different methodological assessment approaches and to build scientific capacity in deficient areas. Involving stakeholders in the assessment is one way to ensure that the MA experience and ideas reach beyond a small group of scientists and technical experts[1].

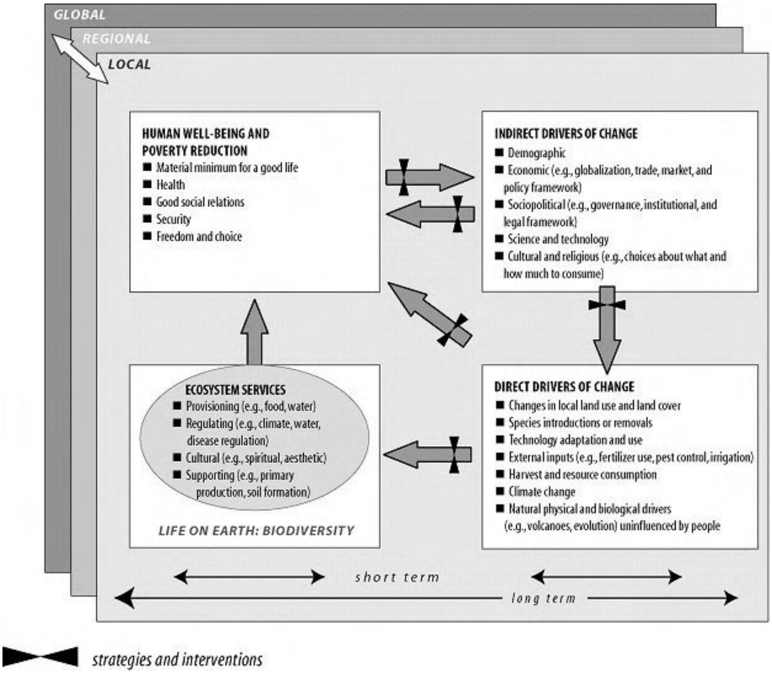

Figure 1.1 Conceptual Framework of the Millennium Ecosystem Assessment (2003). *Notes:* The framework defines the relationships between *indirect drivers*, *direct drivers*, *ecosystem services*, *human well-being, and poverty reduction*. Indirect drivers can affect human well-being directly or indirectly via direct drivers which act on ecosystem services. Human well-being in turn feeds back on indirect drivers. Within the framework, there are opportunities for strategies and interventions that can halt, reverse, or otherwise change a process. This cycle operates at multiple spatial scales, from the local to the global, and multiple temporal scales, from the short- to long-term, with particular aspects taking prevalence at their characteristic scales.

As the knowledge and technological capacity to perform such assessments advance, it has become increasingly obvious that integrated environmental problem solving often lacks a mechanism to deal explicitly with uncertainty and variability, multiple data sources and types, evolving datasets, and human adaptation to change. An inability to make findings useful or relevant to decision-makers also hampers the process. The MA, through its suite of sub-global assessment sites that span the globe, provides a unique experiment for testing the application of different approaches to these challenges.

[1] The list of participants in the Gariep Basin UAG is in the Acknowledgements. For detail on the UAGs involved in the Gariep local community assessments, refer to Shackleton *et al*. 2004.

1.2 The Southern African Millennium Ecosystem Assessment (SAfMA)

As an assessment region, southern Africa presents many unparalleled opportunities. A number of political and demographic changes currently taking place – including democratic transition in South Africa, political instability in Zimbabwe, migration, HIV/AIDS, decentralization as well as multi-national resource management, and the establishment of pan-African initiatives such as the New Partnership for Africa's Development (NEPAD) – render it one of the most dynamic regions of the globe. The region is actively engaged in forging new relationships in a global marketplace, while attempting to address the legacies of historical and emergent trade asymmetries that have resulted, respectively, from colonisation and globalisation (Stiglitz 2003). The region spans a wide range of political systems, economies, livelihoods, and cultures. While sophisticated databases and modern scientific methodologies, and the expertise to use them are prevalent in parts of this region, other areas are data sparse and sorely lacking in the infrastructure needed to support even basic technology. Much information about southern African ecosystems exists outside of the formal literature and remains to be tapped.

SAfMA includes eight assessments conducted at three scales[2]: a regional-scale assessment of the nations of mainland Africa that lie south of the equator, including the Southern African Development Community (SADC), two basin-scale assessments within this region (Gariep and Zambezi), and five local-scale assessments distributed across the two basins (Figure 1.2). The focus of this report is on the Gariep basin assessment and highlights from four local assessments that lie partially or fully nested within the basin: Sehlabatebe in Lesotho, and the Great Fish River in the Eastern Cape, Richtersveld in the Northern Cape, and Gauteng Province in South Africa.

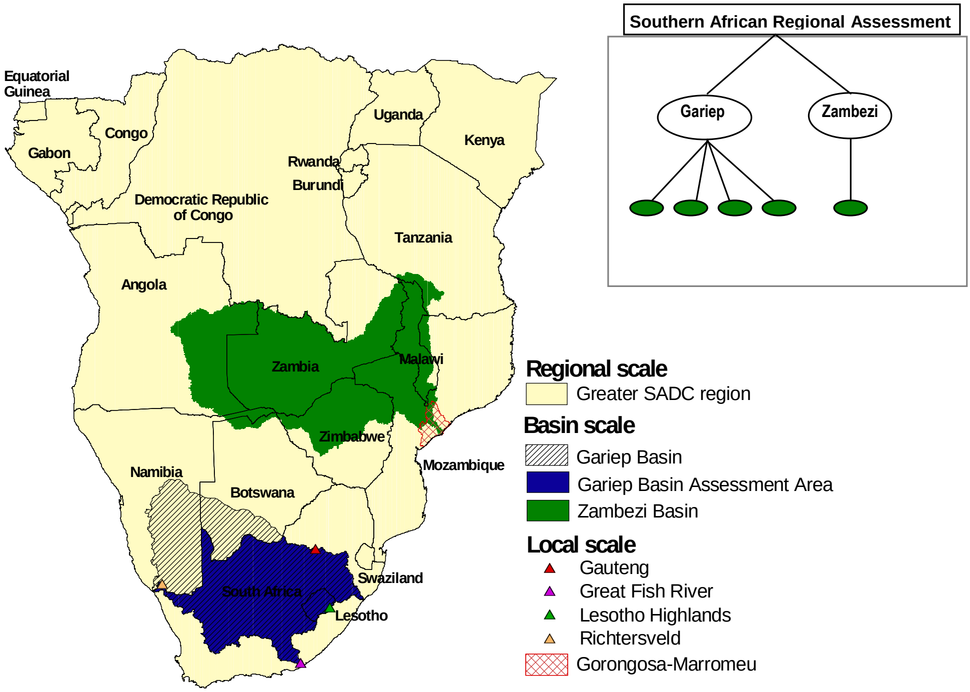

Figure 1.2 The location of assessment sites in the Southern African Millennium Ecosystem Assessment (SAfMA). The focus of this report is the Gariep basin assessment, the extent of which is illustrated in blue. The inset (upper right) shows the nested assessment design. Note that the actual Gariep basin (indicated by a dashed line) extends beyond the area assessed.

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[2] See Desanker *et al. in prep.* (Zambezi basin), Shackleton *et al.* 2004 (Gariep local assessments), Lynam *et al.* 2004 (Gorongosa-Marromeu), Scholes and Biggs 2004 (regional), and Biggs *et al.* 2004 (Integrated SAfMA).

1.3 The Gariep Basin Assessment

Among the river basins of the region, the Gariep is more significant as the locus of southern Africa's socio-economic powerhouse than for the volume of water it delivers, modest in comparison to basins such as the Zambezi. Despite this, it is the largest catchment in South Africa, spanning some 665,000 square kilometres and delivering the third largest discharge in southern Africa. About three-fifths of the catchment area lies within South Africa, with the remainder shared by Lesotho, Namibia, and Botswana, the latter only occasionally forming part of this system when the area drained by its Molopo River spills over to the Gariep (Basson *et al*. 1997).

The Gariep basin begins at the Senqu River, rising in the Maluti Mountains of Lesotho and draining the majority of Lesotho before crossing the Lesotho-South Africa border. Here the Senqu becomes the Gariep, also known as the Orange River, and feeds the extensive "grain basket" of the central plateau. The Gariep joins the Vaal River to its north, which drains South Africa's Gauteng Province, the greatest concentration of economic activity in the nation and region. This system transfers water from the Tugela River in KwaZulu-Natal via the Tugela-Vaal Project. To the south, the Gariep supplies water to the Great Fish and Sundays Rivers in the Eastern Cape Province via the Orange-Fish tunnel. Downstream, the river traverses an increasingly arid landscape until it meets the Atlantic Ocean.

We define the Gariep basin for the purposes of the Millennium Ecosystem Assessment as the area of South Africa and Lesotho drained by the Senqu-Gariep-Vaal River system, as well as two primary catchments connected to this system by major water transfer schemes: the Tugela (or Thukela) in KwaZulu-Natal Province and the Great Fish in the Eastern Cape Province (Figure 1.3). In previous assessments (e.g. Revenga *et al*. 2000) the system referred to as the Orange River basin excludes these transfers, but includes the areas of the catchment that extend into Namibia and Botswana, which are excluded here. This assessment was limited to South Africa and Lesotho due to a lack of datasets for Namibia and Botswana that would be independent from those used at the regional scale. Hydrological data are available for the catchments shared with Namibia and Botswana, but we were unable to secure data from these countries on other ecosystem services and socio-economic conditions and trends at a sub-national scale.

In addition to serving as an important watershed, the Gariep is home to nearly 40 percent of the South African population and all of Lesotho's, who range from destitute communities which are tightly bound to ecosystem services to highly advanced industrialized societies. Within the boundaries of the Gariep, 70 percent of the national cereal crop production and 80 percent of the regional industrial activity are contained. The basin represents all seven of South Africa's biomes, and encompasses two biodiversity hotspots of international importance, the Drakensberg grasslands at the Gariep River's headwaters, and the Succulent Karoo just east of the river's terminus. Owing to the region's geology, the Gariep contains fuel (coal deposits) and mineral resources of regional and global importance. Certain areas of the basin are important for biofuels, such as fuelwood and dung, on which many rural people depend for energy.

1.4 The Gariep Local Assessments

The livelihoods, cultures, and identities found across the Gariep basin are remarkably diverse. A suite of local-scale assessments captures the intricate ways in which this diversity plays out on the landscape, revealing how human reliance and use of ecosystem services depends on history, culture, governance, population makeup, natural and human-made barriers, and opportunism. While the basin assessment presents the 'big picture', these more detailed local-scale investigations serve to tell the stories of different communities, their dependence on ecosystems, and the challenges they face that are not evident from the coarser-scale basin assessment. Community-scale studies in particular strive to assess the dynamics of social-ecological systems by incorporating historical information and local knowledge *(see Box 1.1)*.

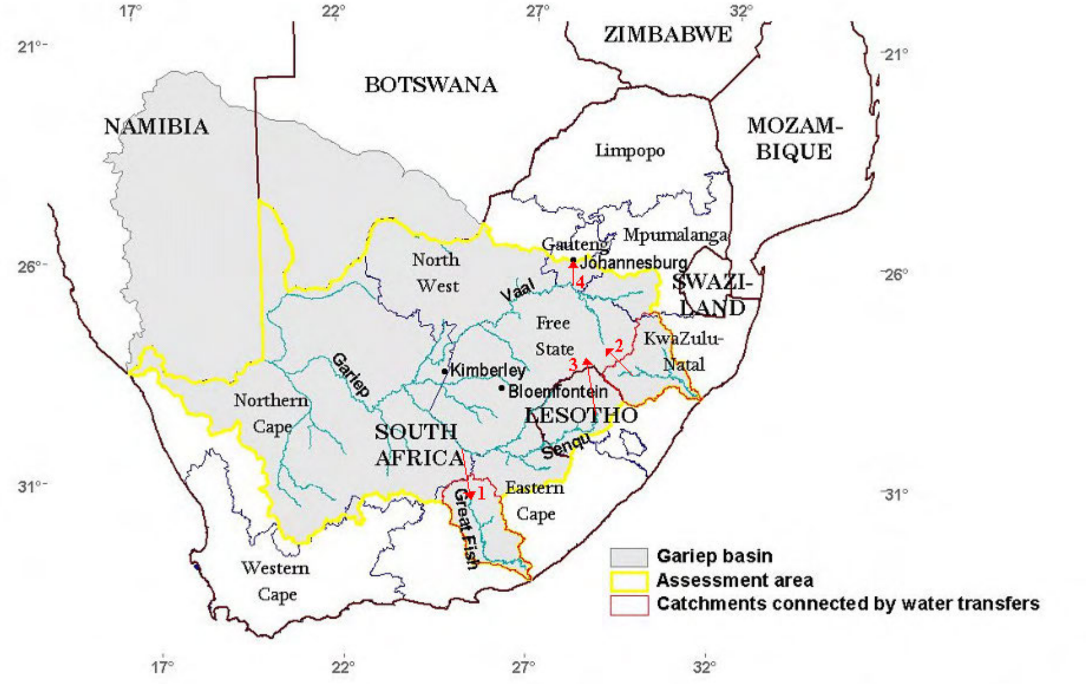


Figure 1.3 The location of the Gariep basin, international boundaries, South African provincial boundaries, major rivers, and major cities. Major water transfers are indicated with red arrows: 1 = Orange-Fish (Orange River Project); 2 = Tugela-Vaal Scheme; 3 = Lesotho Highlands Water Project; 4 = Rand Water transfer to Johannesburg. Sources: Water transfers data from Basson *et al.* (1997), Herold and Rademeyer (2000).

They also attempt to understand the role of humans in influencing ecosystem processes through local adaptations to social and ecological change, as well as local management strategies and tactics.

The three community assessments are situated in diverse locations across the Gariep basin: the Richtersveld National Park, Sehlabathebe in the Lesotho Highlands, and the Great Fish River Valley (see Figure 1.2). A fourth local-scale assessment, at an intermediate scale between the basin and community assessments, focuses on Gauteng Province. The result is a multi-scale perspective of the dynamics between people and ecosystems across the Gariep basin.

Box 1.1 Ecosystem Services in Rural Livelihoods

Rural communities in the Gariep basin are highly dependent on ecosystem products and services for their survival. In the Richtersveld, Nama herders would not be able to make a living without access to key resource areas inside the Richtersveld National Park. They are entirely dependent on the Gariep River and natural fountains for their water supply and for fuelwood, and rely on wild food such as fish for their survival. In the Great Fish River, local people obtain most of their energy for heating and cooking from indigenous trees and shrubs, saving close to R1600 per family annually by using fuelwood instead of paraffin. In Sehlabathebe, where natural resources have become scarce, cow dung is the most important source of energy for heating and cooking. No scrap of meat is wasted when an animal is consumed. Because their options are few, people in this community have become increasingly vulnerable to climatic fluctuations.

The co-evolution of rural people and ecosystems has provided a rich body of knowledge about ecosystems and their functioning, and yields unique insights into the sustainability of relationships between humans and their environment. Despite the substantial challenges to integrate this knowledge with formal science, we attempted to tap into this major source of information for the community assessments.

Community Assessment Sites

Each of the three community sites has a unique environment and 'typical' household socio-economic profile *(see Boxes 1.2 - 1.4)*. Yet there are significant variations between households with respect to access to infrastructure and affluence, as well as the range of opportunities and livelihood activities in which people engage. For example, most people at the Fish River site do not engage in arable agriculture, but for some it is a vital and significant component of their livelihood portfolio, which is overlooked when households and situations are portrayed as typical. Indeed, at the local level, livelihood diversity in time and space and within and between households is a vital ingredient of survival in rural areas.

1.5 Ecosystems and Livelihoods

The varied cultural and socioeconomic characteristics of the Gariep population have emerged against a backdrop of contrasting biophysical properties. In some cases, properties such as rainfall, soil type, and vegetation characteristics influenced the nature of the social and economic systems that were able to evolve in different areas. In other cases, the reverse is true; where social or economic systems were already strongly intertwined, or where opportunities existed to make social or economic gains, inhabitants changed the biophysical environment to suit their systems.

Box 1.2 Community Sketch of Sehlabathebe, Lesotho (upper catchment)

Sehlabathebe is located in the eastern highlands of Lesotho, where altitude ranges from 2300 to 3100 m. Two highland streams drain the area as major tributaries to the Senqu River and ultimately the Gariep River. Mean annual rainfall is up to 1200 mm. Frost and snow can occur at any time and is an important form of water. Temperatures are harsh, and severe winters limit agricultural production. The natural vegetation is highland grassland, differentiated by aspect and altitude. Dominant genera are *Festuca*, *Mexmuellera* and *Themeda*. Small and isolated pockets of woody vegetation are scattered in the valleys, dominated by *Rhus*, *Buddleja*, and *Olea*. Wetlands and bogs are common. The Sehlabathebe district comprises ten villages (comprising 590 households) covering an area of 33,000 ha. Three villages within the Sehlabathebe area were the focus of the study, namely Ha Semenyane (98 households), Ha Mavuka (62) and Lebenkeleng (95). The communal areas border on the 6475 ha Sehlabathebe National Park, proclaimed in 1970. No villages are electrified, but bulk water is available from communal standpipes.

There is limited commercial activity, other than two general stores in the villages and a guest lodge in the National Park. All villages have a primary school. Most inhabitants are nominally subsistence farmers, but the majority of households have a diverse livelihood portfolio, including arable farming, collection of natural resources, livestock husbandry, small-scale entrepreneurial activities, and migrant labor in the urban areas of Lesotho and mines of South Africa. About 45 percent of households do not own any livestock. Access to land is another determinant of wealth, and about 19 percent of households do not have access to land. Cattle and sheep on the rangelands are the main stock, and chickens around the homestead. Cattle are important for income generation as well as provision of goods and services within the household, such as milk, dung, draught for ploughing, savings, and cultural purposes. The major subsistence crops are maize, wheat, peas, and vegetables. Wild resources, such as wood for construction and energy, medicinal plants, and edible herbs, are collected for domestic use. There is some trade in medicinal plants, as well as the rare endemic *Aloe polyphylla* sold to collectors. Wage employment is in larger centers away from Sehlabathebe. Approximately 15 percent of households in the region receive income from relatives working on South African mines, and a further 15 – 20 percent receive income from employment (largely government) in Lesotho. The remoteness of the area and its poorly maintained roads are a constraint to further economic development and marketing of products.

The patterns of human reliance on ecosystem services in the Gariep that one observes today are the product of a long history. Archaeological records suggest that hominid habitation in the Gariep basin dates to 1.5 million years ago. It is believed that the San people lived along the Gariep River for at least 20,000 years. Khoikois moved in around 2000 years before present, and are thought to have given the river the name *Gariep*, Khoi for "great river". Settlements in the 19th century consisted of pastoralists and subsistence farming communities composed of Korana people who settled the banks of the Gariep River. The arrival of Europeans in the late 1800s saw the construction of an irrigation scheme at Upington, where a small trading station was located (Chutter *et al.* 1996), and sparse pastoral settlements in the grasslands.

It was the discovery of diamonds in Kimberley in 1869 and gold on the Witwatersrand in 1885 that attracted the first substantial numbers of European settlers into the interior of South Africa. These discoveries, together with the subsequent wave of mining, industrial and urban expansion that were ushered in during the years that followed, constitute a critical event of history that influenced South Africa's divergence from the social, economic, and political pathways taken by much of the rest of southern Africa (van Onselen 1997). All other ecosystem services – water, food, and energy – have been usurped and manipulated to support the steady population and socioeconomic growth that transpired from this era. However, it can be argued that the legal and political ramifications of the mineral discoveries, e.g. those paving the way for the formalisation of the apartheid system in the 1960s, played a larger part in shaping the course of South Africa's history (Reader 1998), as well as the spatial pattern of impacts on its ecosystems.

Access to ecosystem services has long been the source of great conflict in the region, both between and within groups of European and non-European inhabitants. While Europeans launched conquests and established colonies in the region, tensions stirred among the various indigenous groups across southern Africa in the early 19th century. The gruesome battles initiated by Shaka, the Zulu leader, are collectively referred to as the *mfecane* ("the crushing") by the Ngoni people and *difequane* ("the scattering") by the Sotho and Tswana of the interior (Reader 1998). The ultimate effect was to consolidate Zulu power and to force migration of other groups to various refuge areas across the region. The next century saw more reshuffling of populations. The creation of "homelands," or areas to which non-whites were confined, under the Land Act of 1913 restricted the movements of these people to less than 10 percent of the land area of South Africa, and as such, put tremendous pressure on ecosystem services in those areas. The government's Betterment Areas Proclamation of 1967 followed, which confined the movements of nomadic populations to the homelands and required them to cultivate land. This had disastrous consequences for land degradation (Hoffman *et al.* 1999) which continue to exert ecosystem pressures to this day although the policies have been revoked. Elsewhere, European agricultural practices converted and transformed the natural habitats and resources of South Africa. Similarly, today there is ongoing conversion of natural habitat as demands increase for resources and services.

A different history emerged for the small, landlocked, and mountainous kingdom of Lesotho. A single group of people, the Basotho, established themselves there as a result of Shaka's reign of terror and averted much of the subsequent colonial rule in South Africa, at least partly by nature of the region's intimidating terrain. During the apartheid era, the principle interactions between these nations were economic and related to the exchange of labour for the mines on the Witwatersrand. More recently, the tightest ecosystem service-related bond is the joint participation by the two nations in one of the largest development projects in the continent's history: the Lesotho Highlands Water Project (LHWP). Since the 1950s the then British Protectorate of Basutoland had been targeted for a major water transfer scheme in which it would lend its comparatively vast supply of water resources to support South Africa's urban and industrial requirements. The plan became a reality in 1986, and eight years later the LHWP began delivering water to support Gauteng Province's economic and population growth in exchange for a number of economic and trade development benefits to Lesotho. The trade-offs associated with the project are discussed further in Chapter 2.

The Face of the Gariep

Today, a diverse population, whose members are directly and indirectly dependent on these services to varying degrees, inhabits the Gariep basin. Lesotho's two million inhabitants are composed almost entirely (99.7%) of Basotho people. By contrast, the rest of the basin's nineteen million people represent a range of ethnic (Figure 1.4a) and language groups (Figure 1.4b). Compared to South Africa, Gariep basin inhabitants are more likely to be black African or white individuals, less likely to be coloured or Indian individuals, and are more likely to speak Isizulu, Sesotho, Setswana, or Afrikaans. Agriculture employs more than half of the basin's population, many of whom reside in rural areas, while the remainder of the population lives and works in industrialised areas. This rural-urban dichotomy is a prominent feature in the divergent livelihoods of the inhabitants of the Gariep as well as their use of ecosystem services.

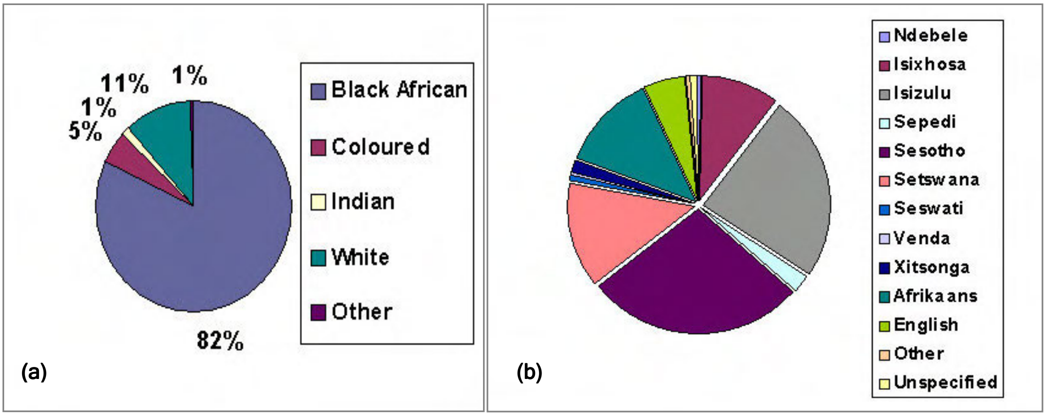


Figure 1.4 The face of the Gariep. (a) Ethnic and (b) linguistic profiles of the Gariep basin population. Sources: South Africa: Hirschowitz *et al*. 2001; Lesotho: Lesotho Bureau of Statistics 2001.

In addition, considerable differences exist in the nature of the rural economies. For example, the two provinces that make the largest agricultural withdrawals of water from the Gariep River – the Northern and Eastern Cape – have highly divergent economies. The Northern Cape derives the majority of its gross geographic product (GGP) from mining and agriculture, while the Eastern Cape receives much of its GGP from manufacturing (Table 1.1). In Lesotho, a more rural nation than South Africa, agriculture plays a more important role in contributing to GDP, though South African mines and industries provide a significant source of employment.

Human Impacts on Ecosystem Capacity to Deliver Services

Although the ecosystem services of the Gariep support and benefit substantial populations and industries, recognition and protection of these services has been poor. Thus, over time, the capacity of these ecosystems to continue supporting the needs of human society has been eroded. Land-use practices – notably urbanisation, industrial and mining developments, agriculture and forestry – as well as extractions and diversions of water resources are among the most commonly cited threats to the maintenance of ecosystem service delivery in the basin (Table 1.2).

These threats tend to result from the conversion of ecosystems to obtain the benefits of one service, or to improve well-being, without regard for the potential secondary effects on other services or long-term sustainability of such actions. Of particular note are the impacts on the Gariep's ecosystems by inter-basin transfers into the basin (Tugela River), across tributaries (Lesotho Highlands), and also out of the basin (Great Fish River). These inter-basin transfers are of great importance to the regional economy, as indicated by the proportion of gross geographic product (GGP) that is supported by inter-basin transfers (IBT) in each province in Table 1.3.

Table 1.1 Land area, population, and economic characteristics of Lesotho and the eight South African provinces in the Gariep basin.

Country/ Province	Area (km^2)	Province within basin (%)	Population in millions (2001)	Percentage of provincial gross geographic product (GGP) derived from:			
				Agriculture	Manufacturing	Mining	Trade
Lesotho	30,355	100	1.9	15.6	18.0	0.1	n/a
Eastern Cape	169,580	40	6.4	5.4	24.4	0.1	16.4
Free State	129,480	100	2.7	10.8	15.1	18.0	12.3
Gauteng	17,010	45	8.8	0.6	27.5	4.5	17.9
KwaZulu-Natal	92,100	40	9.4	5.4	29.4	1.7	17.1
Mpumalanga	79,490	25	3.1	7.8	25.3	18.1	7.3
Northern Cape	361,830	85	8.2	9.7	4.4	30.0	14.8
North West	116,320	70	3.7	7.9	10.4	38.3	10.5
Western Cape	129,370	2	4.5	6.0	23.5	0.2	20.3

Sources: South Africa: StatsSA 2003, Urban-Econ 2000; Lesotho: Lesotho Bureau of Statistics 2002a, 2002b.

Table 1.2 Threats to ecosystem services and examples identified by the Gariep Basin User Advisory Group at the onset of the assessment process.

Type of threat	Examples given
Land use	Grazing and pastoralism, urban/industrial development, irrigated agriculture, fuelwood and dung harvesting for domestic energy use, canalisation, riparian habitat loss or use, invasive plant aliens, land-use intensity change
Alteration of hydrological regime	Inter-basin transfers, impoundments, hydroelectric schemes
Climate change	Exacerbation of land use threats, biodiversity loss
Poverty and wealth	Consumption patterns, land use
Water quality change	Mining drainage, agrochemical runoff, soil loss, salinity, eutrophication
Institutional issues	Poor coordination, fragmentation, weak influence of technical studies on decision-making processes
Globalization	Marketing, livelihood decisions in farming, economic viability
Tourism	Poorly-managed recreation, game ranching, trophy hunting

Box 1.3 Community Sketch of the Great Fish River (mid-catchment)

The Great Fish River site stretches from just west of the confluence of the Great Fish and Koonap Rivers in the west to the town of Peddie in the east, an area of 145,000 ha. The primary focus area was the eleven villages of Tyefu Location (24,218 ha). Reference and comparisons were also made to adjacent land in (i) the Great Fish River Reserve Complex (45,000 ha), a nature reserve, and (ii) adjacent freehold commercial farmland under freehold tenure (about 50,000 ha) under extensive livestock production (angora, cattle, sheep, and Boer goat), intensive cropping under irrigation, and increasingly, game farming and associated activities such as trophy hunting.

Mean annual rainfall varies between 350 and 500 mm, and is largely received in the summer months (November – April). Droughts are common. Mean monthly maximum temperatures range from 21.8°C in June to 30.1°C in February when extreme temperatures exceed 40°C (De Lange *et al*. 1994). The area experiences between 15 and 30 days of light ground frost in winter, but the higher-lying areas are generally frost-free. Acocks (1988) originally classified the vegetation in the study area as Valley Bushveld, but it is now more commonly termed Xeric Succulent Thicket (Fabricius 1997). The structure and species composition of the vegetation can be accurately predicted from elevation, modified by the effects of prevailing management regimes (Palmer and Avis 1994). Dominant woody species are *Acacia karroo* (on disturbed sites), *Azima tetracnatha*, *Diospyros* spp., *Euphorbia* spp., *Pappea capensis*, *Portulacaria afra*, *Rhus* spp., and *Schotia afra*. The vegetation is highly sensitive to mismanagement.

The population of Tyefu Location was approximately 14,000 in the early 1990s, at approximately 58 people/km² (Ainslie *et al*. 1995). Population in the nature reserve and commercial farming sector is low (< 3 people/km²). The mean number of individuals per household is six. Approximately 45 percent of the population is 18 years old or younger. All the Tyefu villages have primary schools, and a few have secondary schools. Piped water is available via communal standpipes. Some villages have recently received electricity.

Livestock play an important role in local livelihoods. People own a wide variety, including, cattle, goats, sheep, pigs, equines, and chickens, but ownership is highly skewed. Approximately one-third of households own cattle, while two-thirds own goats. Meat and wool are sold on local markets. Livestock have numerous direct use roles including milk, manure for fields and walls, savings, cultural, and ritual roles. However, there is little household slaughter for direct consumption except at times of celebration, ritual or funerals. Although some families do engage in arable production from fields (maize and vegetables), it is generally in decline for a number of reasons, including a lack of land, poor markets, high costs of inputs, theft, poor returns, and a variable climate. A greater proportion of households maintain a kitchen garden (< 1 ha) around the homestead. There is widespread use of natural resources for home consumption and income generation. The most common are edible herbs and fruits, fuelwood, medicinal plants, bushmeat, and wild honey. People collect and sell medicinal plants, prickly pear, fuelwood, *Aloe ferox,* and fish. Approximately 70 percent of households regard state pensions as their main source of household income. There is limited wage employment within the area, largely in government services. Hence, migration is a core livelihood activity for most households. Migrants send home cash or goods on a regular or *ad hoc* basis.

However, water transfers, together with impoundments, have stabilised and transformed the flow of portions of the Gariep River to an extent where blackfly *(Simulium chutteri)* has become a pest to domestic livestock, costing the livestock industry up to R33 million per annum along an 800-kilometre stretch of river (Chutter *et al*. 1996). In the Great Fish River, transfers of not only water but also biota such as sharptooth catfish *(Clarias gariepinus)* have impacted the river, and its conversion from an ephemeral to perennial system has resulted in unanticipated problems such as the salinisation of alluvial soils. Blackfly has also spread to the Eastern Cape due to the construction of the Orange River Project tunnel and subsequent water releases.

Table 1.3 Gross Geographic Product (GGP) per province supported by inter-basin transfers (IBTs). Source: Basson *et al*. (1997)

Province	GGP supported by IBTs (%)
Gauteng	100
North West Province	80
Eastern Cape	70
Western Cape	70
Mpumalanga	70
KwaZulu-Natal	70
Free State	65
Northern Cape	50
Limpopo	25

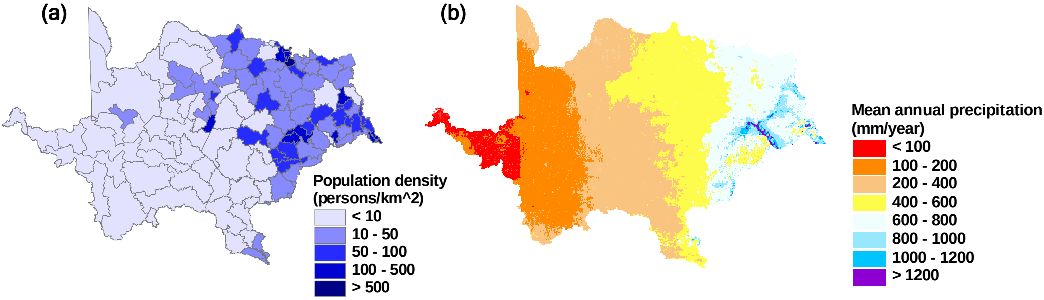


Figure 1.5 (a) Population density per municipality. Population density exceeds 500 persons per square kilometer only in parts of Gauteng Province, and exceeds 100 persons per square kilometer in several districts in the northern and eastern parts of the basin; (b) Mean annual precipitation, illustrating the region's east-west rainfall gradient. Sources: (a) Municipal Demarcation Board 2001, (b) Dent *et al*. 1989.

Land-use patterns in the Gariep basin, particularly dry-land agriculture and grazing practices, pose a serious desertification threat, especially in the more arid western regions. Land degradation is exacerbated by the highly variable and unpredictable precipitation patterns that occur across the region. The population density varies in response to this aridity gradient (Chown *et al*. 2003). The highest population densities are in the moister east, with the lowest population in the arid west (Figure 1.5). The basin is also under significant threat of climate change with considerable predicted contraction and possible disappearance of the Succulent Karoo biome from the region (Rutherford *et al.* 1999, van Jaarsveld and Chown 2001).

The governance of the area that forms the Gariep basin falls upon the shoulders of the four countries it drains. In South Africa alone it is also managed by six provincial governments and 139 local authorities, while in Lesotho, a parliamentary constitutional monarchy and ten administrative districts are recognised. In addition, the basin is subjected to a complex mix of private, tribal, and traditional local council tenure arrangements (Figure 1.6), which makes for a rich cultural diversity and heritage, yet further complicates the management of ecosystem services across the landscape.

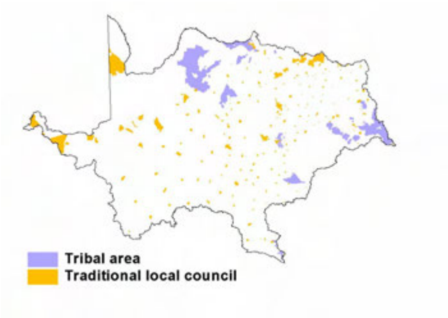


Figure 1.6 Land tenure systems within the Gariep basin. Source: Municipal Demarcation Board 2001.

Assessment Objectives

Collectively, these biophysical, social, economic, and political conditions precipitate change in ecosystem services and human well-being across the Gariep basin. The overarching objectives of this assessment are to:

- review our current understanding about the *condition and trends* of ecosystem services, human well-being, and biodiversity, or ecosystem integrity, across the Gariep basin and *response options* available to decision-makers to manage ecosystems (Chapter 2);
- assess the trade-offs inherent in *decision-making* in ecosystems (Chapter 3);
- identify the principle *drivers* of changes in ecosystem services and human well-being and explore what the future of the basin may look like with *scenarios* (Chapter 4);
- present a synthesis or “big picture” of ecosystem services and human well-being in the Gariep basin, and conclude with a discussion of lessons learned from the assessment process and recommendations for decision-making (Chapter 5).

Box 1.4 Community Sketch of the Richtersveld (lower catchment)

The Richtersveld National Park (RNP) covers 162,445 ha in the arid region of the Namaqualand magisterial district of the Northern Cape Province. The Gariep River forms the northern boundary of RNP, north of which lies Namibia. The landscape is rugged and varies from sandy floodplains adjacent to the river to steep and stony mountains with little soil. The average temperature varies between 25°C during January and 14°C in June. Temperatures can easily rise above 50°C in the summer and plunge to freezing on winter nights. Mean annual rainfall varies between 50 and 150 mm, with extreme variability within years and between years. The Richtersveld area is one of the world's richest succulent areas (Jürgens 1985, Cowling and Roux 1987, Hilton-Taylor and Le Roux 1989, von Willert *et al.* 1992, Cowling *et al.* 1999). It is located in the winter-rainfall part of southern Africa's Succulent Karoo biome (Rutherford and Westfall 1986, Milton *et al*. 1997). Dominant families include the Mesembryanthemaceae, Asteraceae, Crassulaceae, Geraniaceae, Euphorbiaceae, and Asclepiadaceae (Cowling *et al*. 1999).

The majority of people living in the Richtersveld are descendants of the Namaqua pastoralists (Webley 1992, Boonzaier 1996), and locally they refer to themselves as Namas. The land is under communal tenure. The average household consists of five to six people. In total, 26 permanent and temporary farmers are allowed to graze inside the RNP under contractual agreements. The RNP, proclaimed in 1991, is unique in that it is the only completely Contractual National Park in southern Africa (Hendricks 2003a). South African National Parks initiated a 30-year lease in 1991 with the local communities surrounding the RNP. The aim of the Contractual National Park is to conserve the biotic diversity and manage the grazing resources of a portion of their communal area in cooperation with the local communities of the Richtersveld. The original inhabitants remain within the park and have agreed to limit the total number of livestock grazing within the confines of the park to 6600 small stock animals.

Within the RNP, there is little infrastructure for the pastoralist herders. Because they are semi-nomadic, bulk services cannot be supplied to them. The roads within the RNP are rough. In the greater Richtersveld area, four villages recently received electricity. Each has a clinic, and there is a mobile clinic service for the more distant areas.

The primary source of livelihood is herding of livestock, mainly Boer goats and a few sheep. These animals provide a limited source of meat and milk. Some stock is marketed on an *ad hoc* basis to buyers that come into the area, or to local butchers. The average income from selling goats and sheep for each farmer in the RNP was about R9000 per year for the last six years (Hendricks 2003b). There is no cropping due to lack of water, extreme heat, and damage by wildlife. There is an abundance of wild resources in the RNP, including edible and medicinal plants and fuelwood. Approximately 60 percent of households also receive cash income from other sources. This is in the form of state pensions or disability grants, or employment in the local diamond mines. One-third of the registered farmers in the RNP are employed by these mines. Many households also have members working further afield in regional and national centres who send home remittances.

CHAPTER 2

Condition and Trends of Ecosystems Services and Human Well-Being

2.1 Approach

Selection of Services and Scope of Analysis

The condition and trends component of this assessment focuses on ecosystem services and human well-being in the Gariep basin since 1993. Each of the SAfMA studies agreed to assess two core ecosystem services: *water* and *food.* An additional ecosystem property assessed across all SAfMA studies is *ecosystem integrity* or *biodiversity*, which is viewed as a basic condition for ecosystem function and continued ecosystem service delivery. This assessment focuses on these principle ecosystem services. Four services of particular importance in the Gariep basin are also assessed: *energy services*, *mineral services*, *air quality*, and *cultural services*. Some of these services are essential for human survival, while others play a significant role in the region's economy or provide employment.

At the basin scale, the condition and trends assessment primarily uses a demand and supply approach. Areas where the supply of ecosystem services does not meet the user demands are identified as areas of potential concern. In addition, we evaluate the outlook for future provision of services. For some services, such as ecosystem integrity, a demand and supply approach is inappropriate, and it is therefore assessed through an evaluation of threats and potential biodiversity losses from changing land use. Furthermore, because human well-being is not necessarily a function of demand and supply of ecosystem services, we also look, where relevant, at the quality of services, access to services, drivers of change in services, and the capacity of ecosystems to continue producing services. At the community level, we conducted a more detailed and contextual investigation of key resources, especially those that contribute to human well-being. We also investigated the trends in those key resources over the past decade, and local people's coping strategies for dealing with changes in goods and services.

The condition and trends of ecosystems and their services cannot (and should not) be easily separated from the many human response options, coping strategies, and interventions that modify ecosystems and services. As illustrated by the MA's conceptual framework in Chapter 1, these strategies and interventions can change relationships between drivers, ecosystem services, and human well-being. We identify response options to manage each ecosystem service, including practices adopted by governments, organizations, industry, societies, and individuals to deal with deficiencies in the availability of ecosystem services or the negative consequences of using services. We adapted a classification system for responses from the MA Responses Working Group to assess food services (Millennium Ecosystem Assessment, first review draft, 2004a), but we find it to be generally applicable to other services we assessed. Interventions and strategies to improve benefits from ecosystem services while maintaining ecological integrity and human well-being are generally described as 1) those that target the management of the resource base and state of ecosystem; 2) technological interventions; 3) legal, institutional, and economic policies, and 4) social, behavioural, and cognitive responses, including improvements in knowledge and education.

We first assess each service individually, as services are largely managed on a sectoral basis and data are available correspondingly. In Chapter 3, we examine some of the links between these services and explore ways to address trade-offs. Lastly, the evaluation of the basin's ability to continue delivering services requires that assumptions be made about future demand and supply trends. Chapter 4 explores these dynamics qualitatively with a scenario planning approach that poses alternative pathways to the year 2030.

Indicators and Data

Indicator development for this assessment drew extensively from the National State of the Environment Reporting Initiative of the South African Department of Environmental Affairs and Tourism (DEAT 1999). We also consulted a variety of global assessments such as the Pilot Analysis of Global Ecosystems (PAGE) and sectoral analyses of indicator selection (e.g. Walmsley *et al*. 2001, Walmsley 2002 for water). We used only indicators for which data were reasonably available for the full extent of the study area. The Gariep Basin User Advisory Group provided input regarding the indicator selection and in many cases supplied data.

South African data were derived from sources such as land cover maps and national databases on water, forestry, biodiversity, agriculture, mining, energy, industry, and population. Data were collected at several scales, and included national, provincial, municipality, water management area, quaternary catchment, quarter-degree grid square, and point data. For some analyses, it was necessary to aggregate data at different resolutions to a single scale.

Data for Lesotho were obtained at primarily three scales: national, administrative district, and quaternary catchment. Catchment data for Lesotho and South Africa were extracted from the South African Department of Water Affairs and Forestry's Water Situation Assessment Model (WSAM) version 3 (Watson, *pers. comm.*) which allowed for easy integration of data sets. Elsewhere it was necessary to aggregate data or to analyse it at different scales. Because certain datasets for Lesotho were unavailable, and the fact that South Africa comprises the greatest percentage of land area of the Gariep basin, we acknowledge some bias towards a South African perspective in this assessment. Where feasible, we made an effort to balance these contributions and perspectives.

Where data are lacking, uncertainty about relationships is high, or where an assessment of future condition and trends is concerned, models can often play an important role. For example, the WSAM calculates a risk-based water resource, land use, and water use situation assessment for 1995 at the quaternary catchment scale, allowing for a finer-scale analysis of a large river basin than was previously possible. The International Water Management Institute's (IWMI) model PODIUM (Kamara and Sally 2002) was used to examine future food security and the implications for water resources. These models and others employed in this assessment are likely to benefit from additional data and fine tuning, but nonetheless provide useful insights on a broad scale.

Local Assessments

The Gauteng assessment was pursued as a unique case study. Existing data were synthesized in a similar manner to the approach used in the basin assessment. The Department of Agriculture, Conservation, and Environment (DACE) holds the data sets employed. The exception was an additional survey conducted to assess plant composition and use in residents' yards.

The three rural community assessments are discussed in detail in a separate report (Shackleton *et al*. 2004), with select findings highlighted throughout this assessment. At the community assessment sites, the human use of ecosystem services was assessed by means of four complimentary approaches: (i) summaries of literature, (ii) household surveys, (ii) interviews with key informants, and (iv) Participatory Rural Appraisal (PRA) group sessions. Abundance and status of ecosystem services were quantified or ranked on either relative or absolute scales, using PRA approaches, direct measurement via transects and/or interpretation of satellite images (with ground-truthing).

2.2 Human Well-Being

Ecosystem services are fundamental to human well-being, a term that embraces issues such as quality of life, health, social relations, security, and freedom and choice. At the same time, conditions of human well-being can enable or constrain the ability to derive benefits from ecosystems and their services (Figure 2.1). The goal of sustainable development is to attain adequate levels of human well-being without eroding the ecosystems that serve as its very foundation.

While some relationships between ecosystem services and human well-being are familiar − food is essential to nutrition, for example, and water to hygiene − there is less certainty regarding the degree to which ecosystems can be degraded before human well-being declines. This is in part due to differences in requirements and preferences among individuals. Other mediating factors also play a role, such as the nature of people's livelihoods (if they are less directly connected to ecosystem services, their well-being may be able to sustain higher levels of degradation, at least initially) or a region's political stability (if the government collapses, their well-being may deteriorate faster in the absence of health care services). Perhaps even less clear is how conditions of human well-being influence people's ability to maintain ecosystem services.

A standard measure of human well-being, the Human Development Index (HDI), is used as an indicator of the opportunity for people in the Gariep to reach their full potential longevity, knowledge, and standard of living. HDI is a composite value between 0 and 1, with 1 being the highest possible score. South Africa's HDI in 2001 was 0.684 and ranked 111th worldwide among 175 nations; Lesotho's was 0.510, ranking it 137nd. They are both viewed as "medium-development" countries, while a score of 0.80 or higher delineates the "high-development" nations (UNDP 2003). The variables used to measure HDI may vary, but usually include life expectancy, educational attainment, and income. The six measured components for which data are available at the municipality or provincial scale are income, literacy, life expectancy, unemployment, inequality, and age dependency. Each component is discussed below.

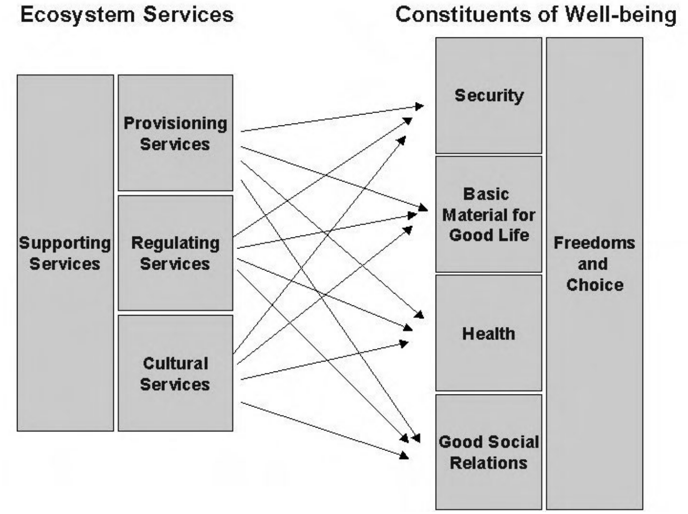


Figure 2.1 Ecosystem services and constituents of human well-being. There are intrinsic links between ecosystem services and between ecosystem services and human well-being. Provisioning, regulating, and cultural services have direct effects on human well-being, while supporting services underpin the other services. Changes in these services affect human well-being through impacts on security, the basic material needed for a good life, health, and social and cultural relations. They are in turn influenced by and have an influence on the freedoms and choices available to people (adapted from Millennium Ecosystem Assessment 2003).

The community assessments provide an alternative view of human well-being *(see Box 2.1)*. In particular, they highlight the large variation in human well-being, even within the same village. In the Great Fish River study, for example, 17 percent of the community classified themselves as "very poor, those who have almost nothing". Forty-four percent were classified as "struggling", and 30 percent as "better-off". Eight percent of the population were classified as "well-off".

Human Development Index

INCOME

More than half of the population maintains a livelihood off the agricultural sector, though agriculture contributes less than five percent to South Africa's gross domestic product (GDP). The remainder of the population is concentrated around industrialised areas that account for 93 percent of the GDP (Huntley *et al*. 1989). Consequently, the average GDP per capita is as much as four times higher in industrialised areas (such as Gauteng Province) than in the central rural region (Figure 2.2a). The majority of Basotho (approximately 85 percent) live in rural areas (United Nations 2000), most of which are poor.

UNEMPLOYMENT

Unemployment is very high in most parts of the Gariep basin, reaching 50 percent and higher in the former black homelands in which subsistence farming is the major form of livelihood (Figure 2.2b). Even in the highly industrialised regions, such as Gauteng, the average unemployment rate is 30 percent. The areas with the lowest unemployment rates are the sparsely populated areas in the arid western regions of the basin that are also characterised by large mining activity. Largely due to the high incidence of unemployment, the informal (non-tax paying) sector in South Africa serves as a survival strategy for the poor. In 1990, an estimated 3.4 million people were self-employed in the informal economy throughout South Africa, contributing nearly 12 percent of GDP (Kirsten and Sindane 1994). In the rural areas of Lesotho, only 5 percent of the households have members in the formal employment sector while three out of every ten rural households rely on casual labour for income (Lesotho Vulnerability Assessment Committee 2002).

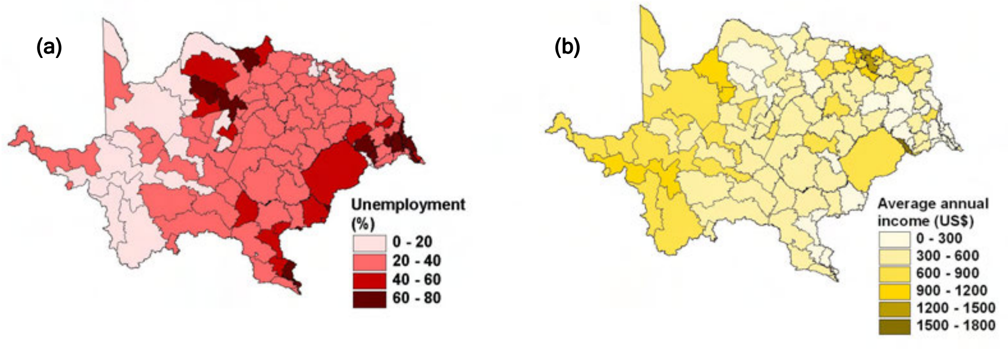


Figure 2.2 (a) Average annual income per capita (in 2000 US dollars); (b) Percentage of the economically active population that is unemployed. The areas with the highest unemployment rate are the former black homelands, which are characterised by subsistence farming and little formal economic activity. *Notes:* Low population densities exert a strong influence on income figures in the west, but the low per capita incomes in the former homeland areas are distinctive. Areas with the lowest unemployment rates are those with intensive industrial activity, such as Gauteng in the northeast and areas with high mining activity in the western parts of the basin. *Source:* MDB 2002.

Box 2.1 Wealth, Income, and Unemployment: Local-scale Perspectives

It is difficult to assess community well-being with the measures of income used at the basin scale. This is because local livelihoods are dynamic, people adopt a variety of strategies to make a living, and non-tangible values contribute significantly to local people's definition of their well-being. "Not being vulnerable" was, for example, an important criterion of well-being stated by people in Sehlabathebe and the Great Fish River sites. "Self-determination" featured strongly as a well-being criterion in the Richtersveld. In the Kat River area, a tributary of the Great Fish, communities' sense of belonging was more important than cash.

In the three community assessment localities, monthly cash income and mean household income varied considerably within and between study areas. The Richtersveld people, for example, had considerable assets because of their large herds of livestock. In the Great Fish River site, small numbers of affluent urbanites lived next to very poor households. At the Lesotho site, everybody was poor, earning less than R200 per month. Livestock ownership was a significant indicator of wealth in the three rural study sites (Table A). Although most households own livestock, individual herds are small.

Table A Livestock ownership at local sites in the Gariep basin.

Locality	**Percentage livestock ownership**	**Modal herd size**	
		Sheep/goats	*Cattle*
Sehlabathebe (Lesotho)	51%	4	2
Great Fish River	68% goats; 30% cattle	Unknown	Unknown
Richtersveld	> 50%	250	0

Unemployment is also an unreliable indicator of community well-being as most people have some form of cash income, either through selling local products (many of which are derived from ecosystems), or social grants. Table B indicates the diversity of income sources at Sehlabathebe. At Great Fish River, 48 percent of those of employable age were unemployed in 1994 and the figure is believed to have increased. At Richtersveld, most pastoralists work in the diamond mines for some months of the year.

Table B Sources of income at Sehlabathebe. Many households have multiple sources of income, resulting in a total percentage greater than 100.

Sources of income	**Number of households**	**Percent of total**
Salary	18	45
None	20	50
Piece Jobs	10	25
Food Aid	5	12.5
Relatives	4	10
Selling Animals	3	7.5
Donations	3	7.5
Selling Vegetables	2	5
Selling Beer	2	5

INEQUALITY

The Gini Index serves as an indicator of equality of income distribution. South Africa has inherited great disparity in income distribution from the past apartheid regime. More than 60 percent of the population receive less than 10 percent of the national income (Figures 2.3a and b). With the exception of Lesotho, the poorer regions of the Gariep basin also have the greatest disparity in distribution of wealth, with the largest shares of income landing in the fewest hands in the former homelands. These areas are characterized by subsistence farming, little economic activity, and high unemployment rates. The wealthier industrialised areas, such as Gauteng, have the most even distribution of income in the South African part of the Gariep basin.

LITERACY

South Africa's literacy as reported in UNDP (2003) is 85.6 percent, though Figure 2.4a reveals a different picture for the Gariep basin *(see also Box 2.2)*. Only in its industrialised regions, with higher incomes and accessibility to schools, is there a high functional literacy meaning that people aged fifteen and older are able to read, write, and do arithmetic well enough to meet basic job requirements. This effect of averaging over sub-national differences may in part be responsible for the high average literacy rate reported for Lesotho. Primary school enrolment is above 80 percent for most parts of the basin (Stats SA 2001), yet literacy remains extremely low in rural areas. The South African government has tried to make education accessible to the poor population by providing it free of charge, but the low density of, and travel distances to, rural schools challenge this strategy.

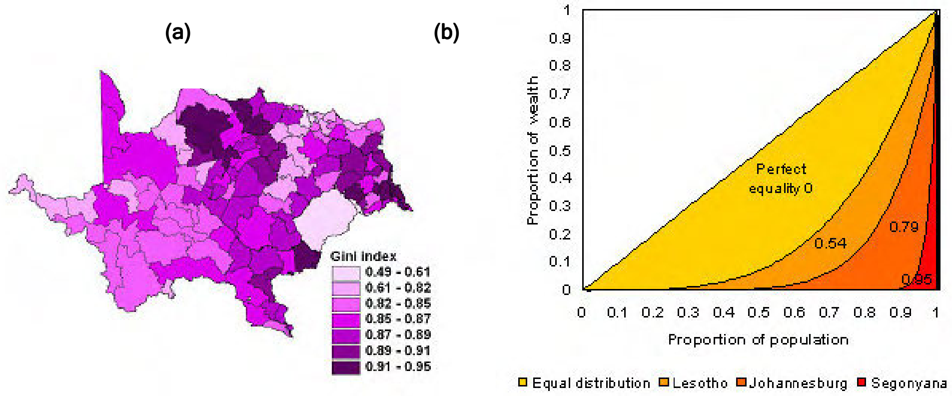


Figure 2.3 (a) The Gini index as indication of the equality of income distribution in the economically active populations (0: perfect equal distribution, 1: most disparate distribution of income). The greatest disparity in income distribution coincides with regions characterised by high unemployment rates and low average income per capita, with the exception of Lesotho, which has the most even distribution in income in the basin; (b) An example of the share of incomes for Lesotho, Johannesburg (industrialised, high income), and Sengonyana (formerly within the Bophuthatswana homeland). In the latter, the top 5 percent of income earners in the economically active population earn all the income. In Johannesburg, approximately 30 percent of the total income goes to the top 5 percent of income earners (calculated from data obtained from the MDB 2002).

Box 2.2 Literacy and Education in Sehlabathebe

Literacy at the community assessment site in Lesotho was low. Of 40 households interviewed, 35 percent stated that the highest education level attained within the household was eight years of schooling (Grade 8), with only 10 percent stating that they had members that had reached tertiary levels of education. Of the total population, eight percent had never attended school, 15 percent had education levels classified as unknown and six percent were not attending school yet. The remaining 26 percent had achieved between one year and 13 years of schooling.

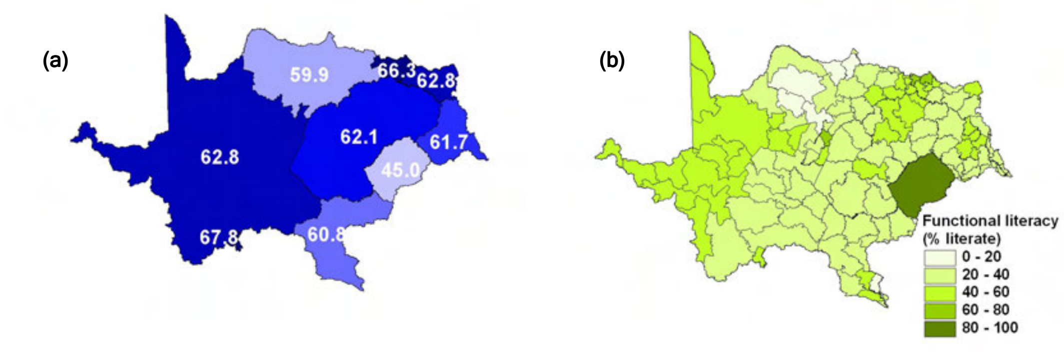


Figure 2.4 (a) Percentage of the population 15 years and older that is literate, per municipality; (b) Life expectancy at birth, per province. *Notes*: Central rural areas have a lower literacy than the highly urbanised region in the northeast of the Gariep basin. Lowest life expectancies are found in the North West Province and Lesotho, which has a lower degree of urbanisation and greater poverty than South Africa. *Sources*: (a) South Africa: Stats SA 1995; Lesotho: World Bank 1996; (b) Stats SA 2001.

LIFE EXPECTANCY

The South African province with the highest life expectancy is the Western Cape (lying mostly outside the Gariep basin) at 67.8 years, followed by Gauteng and the Northern Cape. Residents of the North West Province and Lesotho have the lowest life expectancies at birth (59.9 and 45 years respectively), as illustrated in Figure 2.4b. Life expectancy has decreased gradually but noticeably during the past decade due to increasing HIV/AIDS prevalence, as discussed below.

AGE DEPENDENCY

Age dependency is an indication of the degree of demographic transition that has taken place in society, where a high age dependency ratio would indicate a significantly younger than average population. In the Gariep basin, Gauteng has made the most progress of all regions in its demographic transition, having an age dependency that resembles that of an industrialised country (Figure 2.5). The former poor homelands have a very large age dependency ratio, showing early progress of demographic transition where the birth rate is still far above replacement level.

RECENT TRENDS IN HUMAN WELL-BEING

The poorer members of the Gariep population are caught in a time-lapse behind the demographic transition which has already occurred in the richer parts of the basin's population. Continued high fertility rates in the poorer population segment means that the annual population growth in the region is outstripping the annual increase of the GDP. The GDP per capita has been decreasing steadily since 1980 (Erasmus and van Jaarsveld 2002). Although Lesotho has a relatively even distribution in wealth, the income per capita is about one-sixth of that of South Africa.

Lesotho experienced similar population demographic trends to those observed in the poor population of South Africa (UNDP 2001). The widening gap between the uneducated and rapidly increasing poor population in South Africa and Lesotho and the educated wealthy population has resulted in a steady decrease of the human development index for both countries to a level that is currently lower than that observed in the 1990s (UNDP 2001). Consequently, life expectancy decreased between 1991 and 1996 across the Gariep basin after an initial increase between 1980 and 1991, and is currently lower than in 1980 (Stats SA 2001).

The rate of unemployment in the Gariep basin has also increased during the past two decades, due to population growth (specifically of the potential economically active population) outpacing economic growth. This has caused the formal economic sector's absorption capacity to decrease from levels of 73.6 percent in the 1960s to 12.5 percent in 1990, and has forced people to seek alternative options for income in the informal sector (Beukes 1990, Kirsten and Sindane 1994). Between 1990 and 1991 alone, the number of workers in the informal economic sector increased by 40,000.

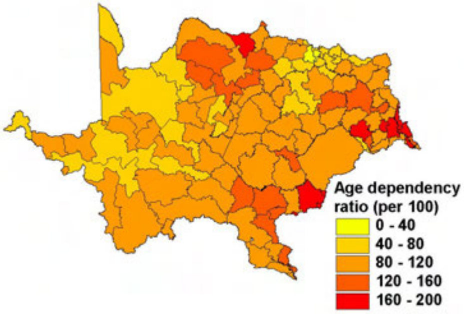


Figure 2.5 The number of dependants (persons younger than 19 or older than 65) per person of economically active age (between 20 and 65). Age dependency provides an indication of demographic transition within the Gariep basin. A very high age dependency ratio is indicative of a very young, rapidly growing population. Lower age dependency ratios (50 or less) are representative of stabilising populations in industrialised countries. In general, the poor regions are those with extremely high dependency ratios. The lowest dependency ratios are found in the most industrialised regions (calculated from data obtained from the MDB 2001).

In contrast to the above patterns, literacy in the Gariep steadily increased between 1980 and 1995 (Figure 2.4a). Literacy has recently improved further, especially in the provinces of Mpumalanga (from 61.35 to 79.42 percent) and KwaZulu-Natal (from 71.09 to 89.17 percent) (Stats SA 2001). Literacy estimates in Lesotho range from 72 (rural males) to 92 percent (urban females) (Lesotho Bureau of Statistics 2002b).

PROSPECTS FOR HUMAN WELL-BEING IN THE FUTURE

Slow economic growth relative to population growth in the Gariep basin indicates that the decreasing income per capita is likely to persist for some time. Disparities in income and employment opportunities between rural and urban communities are expected to lead to an increase in unplanned urbanisation. Depending on the abilities of planning authorities to provide services such as water, sanitation, and infrastructure, this may lead to an increase in literacy and accessibility to health services in the long term. Given the decrease in secondary enrolment in Lesotho (UNDP 2001), it is unlikely that Lesotho will follow the same trend, and a stabilisation of, or even a decrease in literacy can be expected in Lesotho.

There are concerns that the HIV/AIDS epidemic may further exacerbate the quality of life and increase social dependency. A shortage of labour could inhibit the labour-intensive economy (Rosen *et al.* 2000, Erasmus and van Jaarsveld 2002). These are all factors that affect human well-being. The incidence of HIV/AIDS in Lesotho and South Africa (Table 2.1) is reportedly extremely high, exceeding 30 percent of the economically active population in Lesotho and KwaZulu-Natal Province, largely due to the migration of labour in the mining and transport industries between the two countries and poor health education (Lurie 2000). Although these official figures have been the subject of some debate (see, for example, Malan 2003, Geffen 2004), the reality of HIV/AIDS impacts at a household economic level cannot be ignored. Given the current reported prevalence of HIV/AIDS, elevated mortality rates are expected to lead to an eventual shortage in unskilled labour (rural and urban), which in turn can be expected to negatively impact on economic growth (Erasmus and van Jaarsveld 2002). Strategies for the promotion of public awareness about HIV/AIDS as well as the provision of anti-retroviral treatment have been put in place by the South African government (Department of Education 2002). Should these be successful, the spread of HIV/AIDS could be contained within the next decade. If not, the impact of the disease on the population can be expected to cause further impoverishment of the region.

Despite these negative trends, there are positive prospects for human well-being. Unpredictable events such as a surge in tourism due to the successful implementation of the Richtersveld Ai-Ais Transfrontier

National Park, or the implementation of irrigation schemes that work in the Great Fish River area, for example, may create unexpected improvements in the well-being of certain communities.

Overall, these indicators suggest that human well-being is variable in the Gariep basin and that for many individuals, satisfactory well-being remains beyond their grasp. In itself, however, the HDI does not reveal how human well-being interacts with ecosystem services in positive and negative feedback loops. In the condition and trends assessment that follows, we attempt to identify how people's access to and use of specific ecosystem services affect their well-being.

Table 2.1 Mean values and 95% confidence limits of HIV prevalence per province in antenatal clinic attendees in South Africa, 2000 - 2002. *Source*: Department of Health 2003.

Province	**Est. (HIV+) 95% CI 1998**	**Est. (HIV+) 95% CI 1999**	**Est. (HIV+) 95% CI 2000**
KwaZulu-Natal	36.2 (33.4 - 39.0)	33.5 (30.6 - 36.4)	36.5 (33.8 – 39.2)
Gauteng	29.4 (27.2 – 31.5)	29.8 (27.5 – 32.1)	31.6 (29.7 – 33.6)
Free State	27.9 (24.6 – 31.3)	30.1 (26.5 – 33.7)	28.8 (26.3 – 31.2)
Mpumalanga	29.7 (25.9 – 33.6)	29.2 (25.6 – 32.8)	28.6 (25.3 – 31.8)
North West	23.1 (20.1 – 25.7)	25.2 (21.9 – 28.6)	26.2 (23.1 – 29.4)
Eastern Cape	20.2 (17.2 – 23.1)	21.7 (19.0 - 24.4)	23.6 (21.1 – 26.1)
Limpopo	13.2 (11.7 – 14.8)	14.5 (12.2 - 16.9)	15.6 (13.2 – 17.9)
Northern Cape	11.2 (8.5 – 13.8)	15.9 (10.1 - 21.6)	15.1 (11.7 – 18.6)
Western Cape	8.7 (6.0 - 11.4)	8.6 (5.8 - 11.5)	12.4 (8.8 – 15.9)
National	24.5 (23.4 - 25.6)	24.8 (23.6 – 26.1)	26.5 (25.5 – 27.6)

2.3 Freshwater Services

Though the Gariep River is South Africa's main hydrological artery, it transports only one-tenth of the volume of the Zambezi River and only one percent of the Congo (DWAF 2002a). Nonetheless, few opportunities have been wasted to tap the potential of the Gariep River, clear evidence of which is offered by the 31 dams that regulate its flow (Heyns 2004). Massive undertakings such as the Orange River Development Project (ORDP) and more recently the Lesotho Highlands Water Project (LHWP), the largest transfer scheme in African history, impound and divert water to serve the Gariep River's competing uses: the irrigation of the agricultural heartland, the urban and industrial demands of Gauteng Province, and the daily requirements of the region's people and environment.

Freshwater is unique in that it is a provisioning, regulating, supporting, and cultural ecosystem service. As is common nearly worldwide, the great efforts expended in the Gariep to harness the provisioning services of freshwater have typically come at a cost to other services, severely altering the system, compromising its water quality, ecosystem integrity, and underlying ability to continue providing water. As the Gariep flows west to the Atlantic Ocean, it bears the marks of the many human modifications made upstream: dams have converted seasonal flows to perennial ones, hydropower creates rapid pulses in flow, and flood events are rare or absent, confounding the natural fluctuations on which the river's biota depends. Much concern abounds over the impacts of the flow regime on the Orange River Mouth Wetland, a Ramsar Site and Important Bird Area (see Chapter 2.9 Ecosystem Integrity).

These engineering feats to ensure the region's water supply have also had significant social impacts. Despite their many benefits, access to water and sanitation services remains problematic for those who inhabit isolated rural areas and informal settlements that lack infrastructure. The South African water sector, however, is currently embarking on a major transformation as laid out by the National Water Act (DWAF 1998), which emphasises equity, sustainability, and efficiency *(Box 2.5)*. The management of the Gariep basin extends beyond South Africa's borders; the basin's water is shared with Botswana, Lesotho, and Namibia, underscoring the importance of joint stewardship, a provision for which is made by several international agreements, including the SADC Protocol on Shared River Courses.

Supply

SURFACE WATER RESOURCES

The majority of South Africa's utilisable water is in the form of surface water, which is unevenly distributed across the country; 60 percent of the flow is generated on only 20 percent of the land (Basson *et al*. 1997). The total virgin mean annual runoff of the Gariep basin is 15 408 million cubic metres, about one-third of the total runoff of South Africa, which includes 4800 million cubic metres that originates in Lesotho (DWAF 2002a) (Figure 2.6a). Average per capita water availability for the Gariep basin is 1096 cubic metres per year, nearly placing it in the category defined as "chronic scarcity" by Falkenmark and Widstrand (1992) (Figure 2.6b). A higher-resolution examination reveals that 28 percent of the basin is beyond the "water barrier," and experiences continual wide-scale water supply problems, while 57 percent has an adequate supply.

The natural runoff in the Gariep basin is subject to high rates of evaporation and pronounced seasonal effects, which have been largely averaged out by the construction of dams. On average, less than three percent of total annual natural runoff occurs during the dry season (the four consecutive months of the year with the lowest cumulative runoff). About 80 percent of the Gariep basin receives less than one percent of its total runoff during the dry months, while less than five percent receives more than five percent in this season. Because of the pronounced low flows during the dry season, the *mean* annual runoff as an indicator of surface water availability is actually misleading (Mackay 2003). While the *median* reflects the situation more accurately, hydrological sampling schemes have traditionally reported the mean.

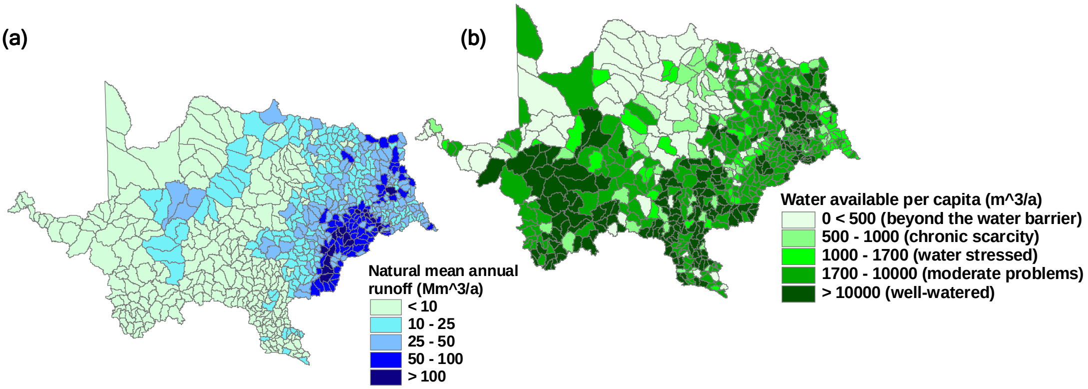


Figure 2.6 Measures of available surface water supply in the Gariep basin. (a) Natural mean annual runoff per quaternary catchment in millions of cubic metres; (b) Water availability per capita per quaternary catchment in cubic meters per person per year. *Source*: Water Situation Assessment Model (WSAM). *Note:* Runoff is adjusted for evaporative losses. Water available per capita was calculated by dividing natural mean annual runoff per catchment by its population. Categories of per capita water availability are those used by Falkenmark and Widstrand (1992). Some areas are considered "well-watered" not due to significantly high runoff, but to low population density.

GROUNDWATER

Groundwater supplies many rural areas and has played an important role in the region historically; Pretoria, Potchefstroom, and Mafekeng were all settled near streams fed by springs from aquifers. Today, more than two-thirds of South Africa's population depends on groundwater for its domestic needs. Groundwater has several advantages over freshwater resources: it occurs widely in the region, including the driest two-thirds of South Africa where surface water is limited or non-existent, and it can meet domestic needs in a cost-effective manner (DWAF 2000b). However, utilisation is limited by the geology of the region as no major aquifers exist that lend themselves to large-scale development. (Basson *et al.* 1997). Where they do, quality may be the limiting factor, both naturally and due to pollution. In about one-fifth of the South Africa, particularly in its extremely arid zones, poor quality makes groundwater unfit for domestic use (Haupt 2001). In the Upper Vaal catchment where surface water resources are fully developed, only 5 to 20 percent of groundwater supplies have been exploited, but because of pollution by mining, further development of these resources would require substantial investments in treatment.

The potential exploitable groundwater resources of the Gariep constitute approximately 3868 million cubic metres per year, 341 million of which are located in Lesotho (Lesotho Meteorological Services 2000). Use totals about 366 million cubic metres per year. Figures 2.7a and 2.7b depict the distribution and use of groundwater in the basin. The breakdown of use by sector is given in Table 2.2.

A number of difficulties exist in assessing the quantity of groundwater. There is little information available on abstractions of groundwater by the mining and industrial sectors, although the mining industry reportedly constitutes five percent of total groundwater usage (Godfrey *et al.* 2002). The accuracy of borehole data varies considerably, and in some areas, very few data points exist. It is likely that borehole yield, and hence exploitable groundwater potential, may be underestimated in many instances (Haupt 2001). Assessing quality issues also presents a challenge, as discussed later in this chapter.

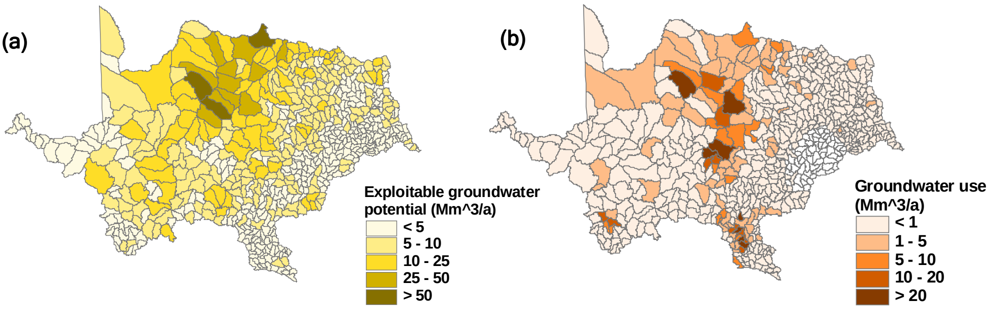


Figure 2.7 (a) The distribution of exploitable groundwater potential and (b) groundwater use in the Gariep basin. *Sources:* (a) Haupt 2001; (b) SA: Haupt 2001; Lesotho: WSAM. *Notes:* (a) Groundwater availability is represented in terms of its *exploitable potential,* or the amount of water that is realistically possible to abstract from the ground, which was derived from borehole yield; (b) SA: Groundwater use includes municipal, rural, livestock, and irrigation use only, as information was not obtained from the mining and industrial sectors for this analysis. Lesotho: Groundwater use is reported per municipal district.

The groundwater balance reflects the availability of groundwater relative to utilisation, defined as the extent of the development of resources (Figure 2.8a). In areas of high abstraction, groundwater may be exploited at a rate faster than it is recharged, leading to the unsustainable use of the resource. Throughout most of the basin, groundwater is an underutilised resource, although there may be no viable options to develop it. In addition, the relationship between groundwater and surface water may present a barrier, as groundwater abstractions can reduce the amount of surface water available. The extent of this interaction can be estimated by calculating baseflow, the portion of groundwater that contributes to the low flow of streams, or in other words, the portion of the total water resource that can be abstracted either as groundwater or as surface water (Haupt 2001). The proportion of water can be abstracted as both determine the amount of expected impact of groundwater abstraction on surface water availability (Figure 2.8b). The impact is most significant in the higher rainfall areas of the region.

Table 2.2 Groundwater use per sector in the South African catchments of the Gariep basin. *Source:* Haupt (2001).

Sector	Groundwater use, 2000 (millions of cubic metres)	Percent of total (%)
Irrigated agriculture	313.0	94
Municipal	7.5	2
Rural	6.2	2
Livestock	5.7	2
Total	332.4	100

RETURN FLOWS

A substantial volume of water is recyclable, in the form of return flows from agriculture, urban areas, and mining developments. Return flows may come from both surface and groundwater resources. Depending on the source, water may be discharged directly to a stream or returned as treated effluent.

The amount of water that contributes to return flows in the Gariep basin is indicated in Table 2.3. Total return flows from the irrigation, urban, and mining sectors equal 869 million cubic metres per year, equivalent to about 21 percent of the combined water requirements of these sectors. Because of consumption levels and sewage infrastructure, urban return flows are high in Gauteng Province and the Bloemfontein area. Effluent returns from mining and decanting (groundwater discharge by mines) are substantial in the Mooi catchment and in the East Rand area of Gauteng. Despite their contribution to total water resources, return flows do not always return to the same catchment or river from which they originate, nor do they return at the same level of quality. Return flows from irrigation along the Gariep River are often highly saline, while those from mine pumpage in the Vaal catchment may be both saline and polluted (Basson *et al*. 1997). While treatment of concentrated water-borne sewage is increasing, vast amounts of diffuse untreated effluent are still released locally. An estimated 16 percent of total urban water supply is diffused annually, often untreated, leading to pollution of both groundwater and surface water resources (DWAF 2002b).

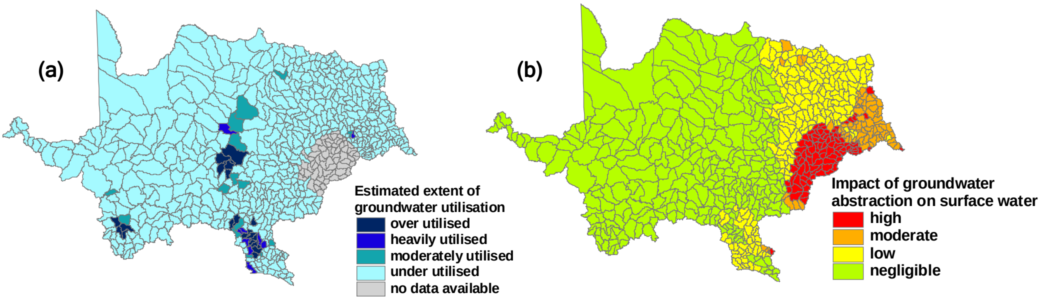


Figure 2.8 The Gariep basin's (a) groundwater balance and (b) effect of groundwater abstraction on surface water. *Source:* Haupt (2001). *Notes:* (a) Groundwater balance is calculated by comparing exploitation potential and harvest potential with total groundwater use. Over-utilisation occur where total use exceeds the harvest potential, or the maximum volume of ground water that may be abstracted in an area without depleting its aquifers. Heavy utilisation results where total use exceeds exploitation potential but not harvest potential. A moderately utilised catchment's total use exceeds 66 percent of exploitation potential, and an underutilised catchment uses less than 66 percent. (b) The contribution of groundwater to baseflow is determined by the impact of abstraction on surface water. Baseflow is defined here as the annual equivalent of the average low flow that is equalled or exceeded 75 percent of the time during the 4 driest months of the year (Haupt 2001). A baseflow factor is calculated by dividing baseflow by harvest potential. A baseflow factor of 0 implies a negligible impact, a factor of ≤ 0.3 a low impact, a factor of 0.3 – 0.8 a moderate impact, and a factor of > 0.8 a high impact.

Demand

Water requirements fall into one of seven major sectors: irrigation, urban, rural, power generation, mining and other bulk industrial, afforestation, and transfers between basins or water management areas (DWAF 2002a). Additional consumption by alien vegetation and dryland crop production reduce streamflow. A national reserve mandated by the Water Act allocates water firstly to fulfil basic human requirements (25 litres per capita per day within 200 m of the home), secondly to meet ecological requirements (which vary from catchment to catchment), thirdly to honour legally binding international commitments, and fourthly to satisfy strategic requirements such as power generation. Under the new law, users may withdraw water only after reserve requirements are met.

Table 2.3 Contribution of return flows to the Gariep basin from irrigation, urban developments, and mining. *Source:* WSAM. *Notes:* Return flows from mining exceed 100 percent of the sector's requirements due to the large discharges of groundwater.

Sector	Return flows (millions of cubic metres)	Percent of sectoral requirements (%)
Irrigated agriculture	306	9.8
Urban	416	45
Mining	147	124
Total	869	20.9

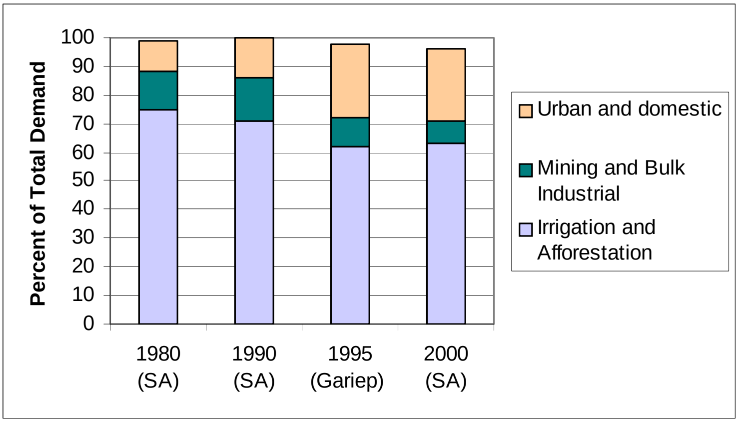


Figure 2.9 Proportion of sectoral water requirements in South Africa and the Gariep basin, 1980 - 2000. *Sources:* SA data from Department of Water Affairs 1986, DWAF 2002a; Gariep basin data from the WSAM. *Notes:* Total requirements are less than 100 percent in some years because demand from other sectors was not reported. These totals exclude the human and ecological reserve requirements, which had not yet been established in the earlier years.

Sectoral water demand in South Africa in 1980, 1990, and 2000 and in the Gariep basin in 1995 is shown in Figure 2.9. Historically, irrigation has used the largest proportion of water, though the agricultural sector contributes less than 5 percent to the South African GDP (of which irrigated agriculture contributes 25 to 30 percent) (DWAF 2002a), and its output per unit of water consumed is only one-fiftieth of that produced by industry (Eberhardt and Pegram 2000). Until recently, records of sectoral water requirements were available only at the national scale or per water management area, posing a challenge to a fine-scale analysis of temporal use in the Gariep basin. Definitions of water use sectors have also varied. Table 2.4 shows the total breakdown of sectoral requirements in the Gariep basin in 1995. The spatial distribution of water requirements drives much of the region's water resource management. As Figure 2.10a illustrates, the bulk of irrigation occurs along the Gariep, Fish, and Sundays Rivers. This contrasts with the distribution of the second largest consumer, the urban sector, with demand reflecting the location of urban areas (Figure 2.10b).

Table 2.4 Water requirements in the Gariep basin. *Source:* WSAM. *Notes:* Requirements are at a standard (98%) level of assurance (i.e. requirements will fail to be met once in 50 years). Alien vegetation and commercial forestry requirements are determined in WSAM in terms of the impact of the land use on catchment yield or runoff. While the model also calculates the impact of dryland crops (i.e. sugar cane) on the available yield, this is an insignificant amount of water in the Gariep basin.

Sector	**Water Requirement – 1995 (millions of cubic metres)**	**Percent of Total (%)**
Irrigated agriculture	3122	63.9
Urban	916	18.8
Rural	297	6.1
Other industrial	209	4.3
Mining	119	2.4
Power generation	85	1.7
Alien vegetation	115	2.4
Commercial forestry	19	0.4
Total	4882	100.0

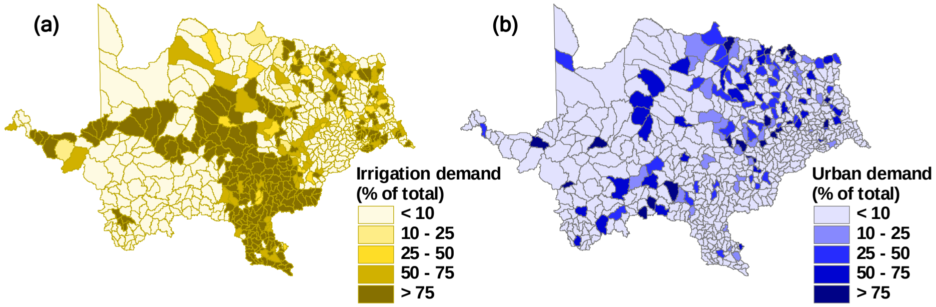


Figure 2.10 Distribution of water requirements in the Gariep basin by (a) irrigated agriculture and (b) the urban sector. *Source:* WSAM.

ECOLOGICAL RESERVE

By law, ecological reserve requirements must be satisfied before water can be allocated to other water use sectors. The *ecological reserve* refers to the quantity, pattern, timing, water level, and assurance of water required to remain in a natural body of water in order to ensure its ecological functioning (DWAF 2002a). The ecological reserve is a relatively new and evolving concept in southern Africa (King and Louw 1998, Hughes 2001, Hughes and Hannart 2003) that has emerged in response to the need to deal with increasing human impacts on aquatic ecosystems. It entails a particularly challenging task in a region in which many people are without access to basic water needs. Furthermore, the understanding of relationships between hydrology and ecological functioning, and the data needed to assess them, are both limited at present (Hughes and Hannart 2003). Typically, for a given river, wetland, estuary or aquifer, the process involves the identification of a maintainable pre-defined, desired state and the recommendation of a flow regime needed to sustain it. This has been done using specialist input, hydrological models, and building consensus among stakeholder groups. For the Gariep basin, provisional estimates calculated by the WSAM indicate that approximately 16 percent of the basin's annual runoff is required for the ecological reserve (Figure 2.11a), but for some catchments the reserve requirements are as high as 50 percent depending on hydrological and ecological characteristics. Because natural flow regimes vary throughout the year, stakeholders will usually opt to define requirements on a monthly or seasonal basis. As allocated at present, the Gariep's total yield would be unable to satisfy the provisional estimates of about 43 percent of the basin's quaternary catchments (Figure 2.11b).

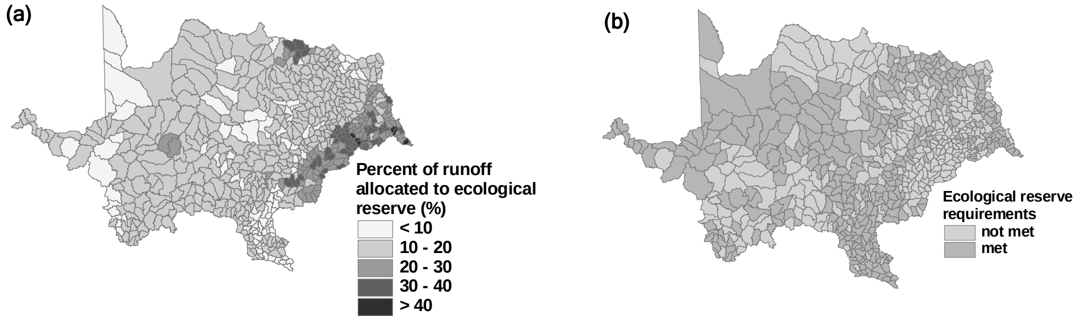


Figure 2.11 (a) Spatial distribution of ecological reserve requirements in the Gariep basin; (b) Quaternary catchments in which the provisional ecological reserve estimates are able or unable to be met with current yield. *Source:* WSAM. *Note:* Runoff refers to the cumulative natural runoff at the catchment outlet. The drier western half of the basin contains many endoreic areas, which are flat and often have pans that do not spill water. The pans usually have clay type surfaces that do not allow infiltration of water; thus, water evaporates and is lost to the river system. These endoreic areas do not normally contribute to catchment streamflow. In these cases, ecological reserve requirements may not be met within those particular catchments.

INTERNATIONAL COMMITMENTS

As stipulated in the South African Water Act, international commitments to nations sharing its water resources must be honoured before water may be licensed to South African users other than the human and ecological reserves. The Gariep River forms the border between South Africa and Namibia for 1000 kilometres before it reaches the Atlantic Ocean. Under a bilateral accord, Namibia currently abstracts an estimated 54 million cubic metres of water annually from the ORDP and is entitled to 60 million more (DWAF 2002a). Water from the Gariep River is estimated to be adequate for both countries until 2007, at which time additional water will be required by improved management measures or a new dam, options which are both under consideration at present (Heyns 2004). Under the Water Act, international obligations also extend to protection of the quality of water released downstream.

Relative Distribution of Demand and Supply

The spatial mismatch between demand and supply in the Gariep has its roots in historical patterns of settlement in the region, which followed mineral rather than water resources. An elaborate network of dams compensates the difference between annual surface water availability and total demand (Figure 2.12a) and inter-basin transfers that move water to areas of highest need (Figure 2.12b). Of these, the LHWP stands out among them as the region's most ambitious scheme to date *(see Box 2.3)*.

Currently there are sufficient resources to meet all needs, but if current trends continue, an expected shortfall will occur due to increasing population growth and urbanisation, as well as the still unmet need to supply the millions of individuals who are without services. Some debate surrounds the prediction that South Africa will reach full utilisation of its current water resources (as well as Lesotho's) within the next 30 years (Basson *et al.* 1997), for reasons related to the effects of HIV/AIDS on water demand and economic productivity (Eberhardt and Pegram 2000), and the uncertainty associated with climate change. Unrealised potential exists mainly in the well-watered south-eastern part of the country; elsewhere, surface and groundwater resources are nearly fully utilised. The adoption of demand and resource management strategies would minimize current losses and reap further gains from improved return flows, as discussed later in this chapter.

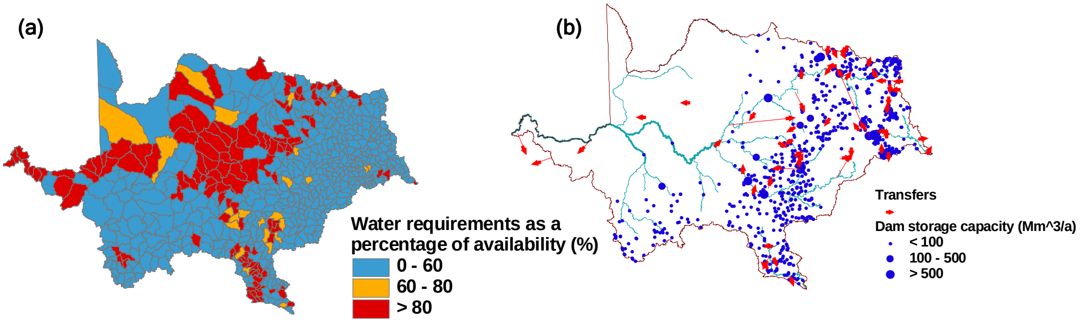


Figure 2.12 Relative distribution of demand and supply of surface water resources in the Gariep basin. (a) Water requirements as a percentage of mean annual runoff. Where requirements exceed 60 percent of availability, a situation of physical water scarcity is said to occur, or alternatively, 80 percent after accounting for the ecological reserve (Kamara and Sally 2002); (b) Major interbasin transfers and dams. *Source:* WSAM.

Access

Past allocation of water was economically inefficient and inequitably shared. A system of riparian rights governed much of the resource and favoured property owners with water on their land (Thompson *et al.* 2001). The present strategy in South Africa aims to achieve a more sustainable distribution of water, yet a lack of or poor maintenance of infrastructure and management and funding problems present barriers to its successful nationwide implementation. At present, there are some 5 million people obtaining water from rivers and springs and some 16 million people without adequate sanitation facilities (DWAF 2004), but this is an improvement since 1998, when the numbers were 12 million and 21 million, respectively (King and Louw 1998). Figure 2.13 depicts the percentage of the urban population without access to water services. Access to water services and sanitation in rural populations is more difficult to define, due to the reliance on groundwater supplies in rural areas that may not be routinely monitored.

Box 2.3 Making up the Shortfall: The Lesotho Highlands Water Project

Borne out of concerns for the future development of water-scarce South Africa and in particular the growing Gauteng complex, the Lesotho Highlands Water Project (LHWP) was formally initiated by the two countries in 1986. In 1998, its first year of operation, 505.7 million cubic metres of water was delivered to the Vaal catchment, with a projected maximum long-term yield of 27 cubic metres per second. The original plan, to come to fruition in 2027, envisioned a transfer scheme that includes five dams, a network of tunnels, and hydropower stations and collectively would be second in size only to the Three Gorges Dam in China. The estimated total project cost in 2000 was US $8 billion, half of which was for the now completed first phase. Phase 2 is on hold, largely because of the realisation that earlier demand forecasts for water were too high. In exchange for water, Lesotho receives royalty payments, compensation for lost assets, and electricity generated by the 'Muela Hydropower station. The project also provides infrastructure, including two border crossings, 120 kilometres of tarred roads over mountains, a bridge 420 meters in length, three clinics and one trauma unit, 145 kilometres of power lines, more than 200 houses in five construction villages, and a microwave telecommunications system.

Since the inception and design of the project in the 1970s and 1980s, the fields of environmental and social impact assessment have developed significantly, but the LHWP initially inherited the disregard for these issues that prevailed during those decades. Hence, many of the potential downstream impacts of the LHWP were not thoroughly considered, in-stream flow requirements (IFR) were not calculated, and an environmental impact assessment began only after the first dam, Katse, was already underway. During 2000 to 2002, Metsi Consultants completed studies to compare the economic, environmental, and social costs and benefits of four scenarios for reducing the amount of water released: one as specified by the treaty, and three that pose varying reductions in the releases, with corresponding reductions in the impacts on downstream ecosystems. These studies suggest an estimated 3.1 to 8 million Maloti (0.45 to 1.26 million 2004 US dollars) of resource losses (fish, forage, medicinal plants, wild vegetables, and trees and shrubs) and mitigation costs (public and animal health), depending on the scenario. Others counter that the royalty and hydropower revenues to be foregone by increasing the downstream IFR releases would far outweigh downstream losses.

It is difficult to assign an economic value to many of the costs. The project affects an estimated 8250 households along 5 kilometres of river, having required the relocation of 24 000 people under Phase 1A, flooded large amounts of cropland and grazing land, and caused soil erosion. It has substantial implications for health and biodiversity: slower flows and higher nutrient and algal levels will change aquatic invertebrate composition and may pose health risks, diversion of water will affect quality downstream, while fish populations, particularly the threatened endemic Maloti minnow, are predicted to plummet drastically and possibly disappear from some reaches. The potential political costs of the project are also high: South Africa has been the principal architect of the endeavour, but Lesotho has the water, and the continued success of the arrangement depends on maintained good relations between the two nations and public support on both sides of the border. A large deal of controversy has attended the project since its inception, with some levelling the charge that the project is unneeded and that Gauteng's requirements could be better met by repairing infrastructure and managing demand. Other criticisms relate to the "heavy-handedness" of the project implementation which was felt to exclude stakeholders, the web of corruption that has subsumed project officials and international construction firms, and the hike in water tariffs because of the project, which many of Gauteng's poor cannot afford.

Meanwhile, in Lesotho, the LHWP has not ameliorated the inadequate delivery of water to rural areas. Although a safe water supply reaches 83 percent of its urban population, only 54 percent of its substantially larger rural population shares this benefit. Furthermore, in 2002, only 3 percent of Lesotho's population had access to electricity.

Sources: Lesotho National Environment Secretariat 1999, Eberhardt and Pegram 2000, Lesotho Meteorological Services 2000, United Nations 2000, World Commission on Dams 2000, Lesotho Department of Energy 2002, Klasen 2002, Metsi Consultants 2002, Tricarico 2002.

Hirschowitz et al. (2001) report that between 1995 and 1999, the proportion of South African households with access to clean water from pipes in the dwelling or on site, communal taps, or public tankers increased from 78.5 to 83.4 percent. Over the same period, the proportion obtaining water from boreholes and rainwater tanks declined from 10 to 4.7 percent, while direct abstraction from rivers, streams, and dams remained constant at about 11.5 percent. A United Nations Population Foundation (UNPFA) survey of Lesotho households revealed that approximately 72 percent of the population has access to safe water, defined as one of the following: piped water from either a private or public yard, boreholes, or covered springs (UNPFA 2001). Among the urban population, 83.4 percent has access to private or public piped water, while only 54.2 percent of the rural population does. More than half of Lesotho's population is without access to facilities to dispose of human waste.

In 2001, the South African government initiated a policy of "free basic water" under which municipalities are to provide the poorest households with 6 kilolitres of free water per month. This policy is currently serving about 57 percent of the South African population, but only 29 percent of the very poorest population, largely because no mechanism exists in these communities to deliver the water at present (Mackay 2003). It is at the discretion of the municipalities to decide how to implement the policy as quickly as possible while maintaining its financial viability.

Groundwater, though a largely neglected resource in the past, is likely to fill the gap in many areas. The 1998 Water Act changed the legal status of groundwater from that granted to "private water" to that of a "significant resource" which must be treated as a common resource for all (Braune, *pers. comm.).*

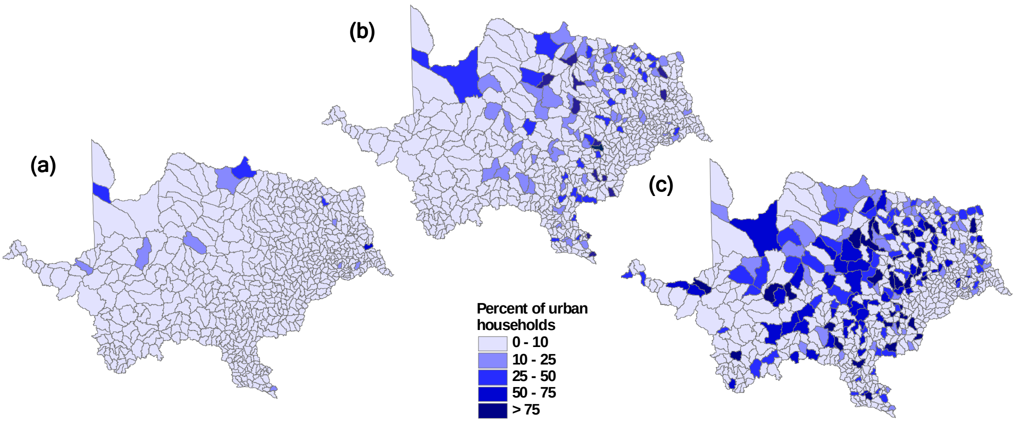


Figure 2.13 Percentage of urban population per quaternary catchment with (a) no service from any water distribution system; (b) informal houses or shanties serviced only by communal taps and no water-borne sewage; and (c) small houses or shanties with water connection, but no or minimal sewage service. *Source:* WSAM.

Water Quality

Water quality is in many instances coupled to water quantity, but is a specific concern due to the direct effects of many human activities that alter its physical and chemical properties, including those associated with other ecosystem services, notably agriculture and mining in the Gariep basin. Because ecosystems and human and livestock health are influenced by changes in water quality, guidelines have been established with recommended target levels for each (DWAF 1996a, 1996b). As water quality declines, consumers may be forced to lower their standards of acceptability or, if they are able, to seek out alternative sources. Domestic use and irrigation generally require water of higher quality than mining and industry.

The issue of quality concerns water abstracted from rivers and streams, as well as return flows. Among the most common problems in the region are salinity, eutrophication of dams, acidification by mines and atmospheric deposition, potential toxicity, particularly downstream of mining and industrial areas, and excess deposition of nutrients from fertilizer and sewage treatment. Rural land use can have tremendous impacts on quality as well as quantity of runoff. The highly altered state of the Upper Tugela catchment, for example, has led to major sedimentation problems for the Tugela-Vaal transfer scheme, with significant economic impacts on rivers downstream. This has been exacerbated by the uncontrolled destruction of hundreds of small wetlands that intercept sediment (Braune, *pers. comm.*).

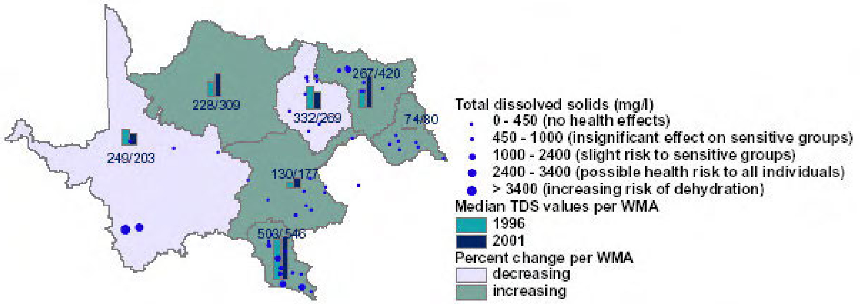


Figure 2.14 Median TDS concentrations (mg/l) at national sampling sites and median values per water management area in 1996 and 2001. *Sources:* Hohls *et al*. 2002; Guidelines for domestic use from DWAF 1996a, Hohls *et al*. 2002.

Salinity is the costliest of the water quality problems to manage (Herold and Rademeyer 2000). It is measured by total dissolved solids (TDS), an indicator of various inorganic salts dissolved in water (Figure 2.14). As water moves downstream and is increasingly affected by natural erosion and land use occurring upstream, salts tend to accumulate. Salinity levels exceeding 450 mg/l are above the recommended guidelines for target water quality (DWAF 1996a), although noticeable health effects are unlikely until levels reach about 2000 to 3000 mg/l. Changes in salinity affect aquatic ecosystems by altering water chemistry, which in turn can affect individual organisms, community structure, and microbial and ecological processes such as metabolic rates and nutrient cycling (DWAF 1996b). The nature and degree of the effect will depend on how much these changes deviate from the natural TDS concentration of a given site. Thus, absolute changes in TDS at a site are less indicative than the rate and duration of change in TDS.

Eutrophication (nutrient enrichment) of dams, caused by the accumulation of organic matter from industrial plants or residential areas, is a significant concern, with both biodiversity and economic implications. Eutrophication can lead to toxic algal blooms that may be lethal to fish and livestock and cause gastro-intestinal infection in humans (Holhs *et al*. 2002). Figure 2.15 illustrates the most problematic dams in the Gariep basin in terms of current trophic status or potential for related water quality problems. The majority of the dams experiencing serious eutrophication are located in the Crocodile West and Marico WMA that drains the northern half of Gauteng Province, just outside the Gariep basin.

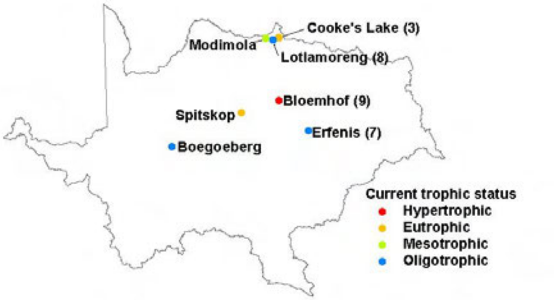


Figure 2.15 Trophic status of dams with eutrophication problems in the Gariep basin, October 2002 to September 2003. *Notes:* Numbers in parentheses following dam names indicate the dam's position on the national priority list. This includes only those dams monitored by DWAF for eutrophication purposes. *Hypertrophic* = very high nutrient concentrations where plant growth is determined by physical factors; serious and potentially continuous water quality problems ensue. *Eutrophic* = rich in nutrients, very productive in terms of aquatic animal and plant life; increasing signs of water quality problems. *Mesotrophic* = intermediate levels of nutrients, fairly productive in terms of aquatic animal and plant life; emerging signs of water quality problems. *Oligotrophic* = low in nutrients and not productive in terms of aquatic animal and plant life. *Source:* DWAF 2003d.

Quality is a major barrier to the further development of groundwater resources. Because quality is determined in part by the lithology and in part by land use, it may be difficult to distinguish between causes of poor quality. Changes in groundwater quality may take a long time to detect, and options to improve quality are limited, as treatment of groundwater tends to be both difficult and expensive (DWAF 2000a). The principal activities that compromise groundwater quality are mining and industrial activities, fertilizer application, wastewater discharge and sewage, and waste disposal. Salinity, fluoride, and nitrate are among the constituents of groundwater quality that most often exceed recommended guidelines for drinking water quality in South Africa (Hohls *et al.* 2002). All are at their highest concentrations in the arid western regions of the Gariep basin (Figure 2.16). The target water quality level for fluoride is 1 mg/l. Above 1.5 mg/l, tooth damage may occur and above 3 mg/l, skeletal fluorosis is possible; both are conditions that affect aquatic organisms as well as humans. Fluoride levels may be naturally high in hot, arid areas. Nitrate plus nitrite (NOx) is an indicator of nutrient levels, typically high in areas of intensive agricultural activity or where pit latrines are common (Hohls *et al.* 2002). The target drinking water quality range for nitrate plus nitrite is 6 mg/l. Above 10 mg/l, hypertrophic conditions (excessive eutrophication) may occur, though the effects tend to be system-specific (DWAF 1996b).

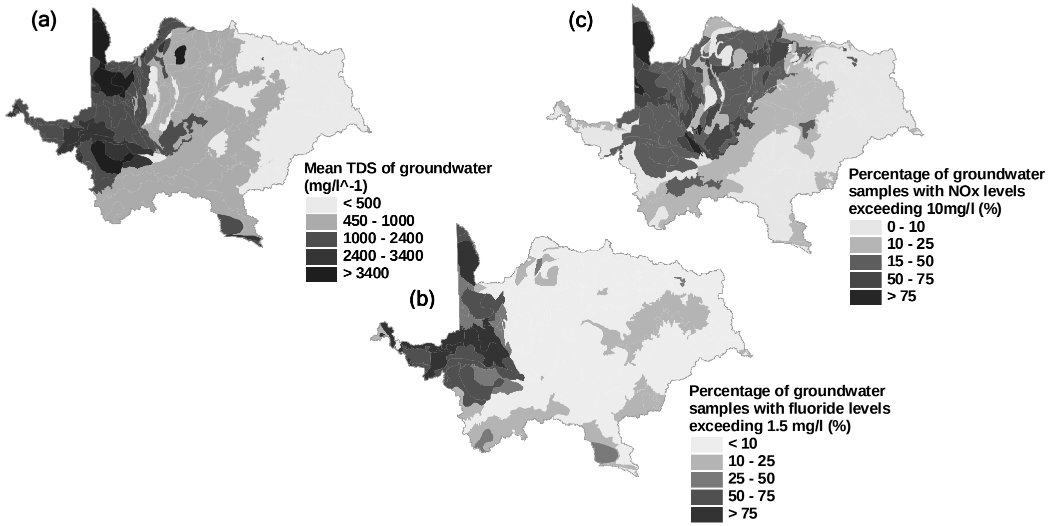


Figure 2.16 Groundwater quality in the Gariep basin, as indicated by (a) salinity (TDS); (b) fluoride; and (c) nitrate. *Source:* Resource Quality Services, DWAF.

In summary, salinity in both surface and groundwater and fluoride and NOx in groundwater is at its highest concentrations in the arid western downstream catchments, where resources are most limited. Lesotho's water is naturally very low in salinity. The Fish River catchment in the south-eastern part of the basin has high TDS concentrations due to its natural characteristics, but the inflow of water it receives from the Gariep River via the Orange-Fish transfer scheme has reduced salinity to lower levels (Braune, *pers. comm.*). However, the Vaal River's TDS levels are occasionally high from mine pumpage, as are the irrigation return flows to the Gariep River further downstream. This emphasizes the importance of assessing quality within the context of the entire system, including return flows and transfer schemes. Quality parameters must also be assessed over long enough time intervals to be able to detect significant changes that have implications for human health and ecosystems.

Capacity of Ecosystems to Continue Providing Water Services

The capacity of ecosystems to produce water relates to variables such as climate, topography, and geology, which are generally beyond human control, although in the Gariep much has been done to overcome their limitations. Changes brought about by human activities can drastically transform the ecosystems that underpin the continued provision of an adequate and safe freshwater supply. Land use and impoundments alter flow and riparian habitat, causing biodiversity loss and water quality declines, and impairing the ability of ecosystems to function. Wetlands, critical components of the freshwater system that naturally filter water and improve quality, are especially sensitive to the effects of dams and over-abstraction of groundwater.

Chutter et al. (1996) discuss the impacts of the Gariep and Vanderkloof dams on the ecological condition of the Gariep River at length. The flow of the river is far from natural, with peak seasonal flows occurring much later in the summer than they did prior to impoundment, and winter flows increasing at the expense of summer flows. This has had a series of unintended effects, one being that the more stable flow has allowed certain species to proliferate along the Gariep River's banks such as the blood-sucking blackfly *(Simulium chutteri)*, outbreaks of which have devastated the agriculture sector. These conditions have also allowed alien invaders and *Phragmites* spp. reeds to replace large riparian trees. These prolific reeds lead to increased risk of flooding, compete with agricultural crops, are a fire hazard, and change riparian characteristics. While the reeds help to conserve soil and protect rivers banks when a flood occurs, and provide habitat to a number of organisms, they are thought to also aid the spread of blackfly due to the increased surface area they offer for larval attachment, and may also increase fine organic material on which the blackfly larvae feeds. A control program treats the blackfly breeding sites with larvicide, although flow manipulation has also been recommended.

The middle and lower reaches of the Gariep River are biogeographically isolated; thus, recolonisation possibilities are limited, making these reaches vulnerable to permanent loss of their biota. The two major dams on the Gariep produce hydropower, and release pulses of power generation twice a day, the effects of which can be observed 200 kilometres downstream of the Vanderkloof Dam. This section of the river, together with the area between the two dams, is referred to as an 'ecological desert,' indicative of the flow pattern that is prohibitive to the establishment of nearly all forms of aquatic life.

In some cases, species, communities, and whole ecosystems have been able to adapt to anthropogenic change without losing their internal structure and function. Elsewhere, a small change can trigger a system-wide collapse. There is yet only a limited understanding of the resilience of freshwater systems to change *(see Box 2.4)*. The immediate − and monumental − task at hand for management of the Gariep's water resources is to achieve a sufficient understanding to be able to effectively implement the ecological reserve as required by the Water Act. Because of differences in the eco-hydrological characteristics of rivers, different management objectives and variance in allowed deviations from natural conditions, reserve requirements must be determined on a case-by-case basis (Hughes and Hannart 2003). In general, the most important factors in determining IFRs include site-specific ecological functioning, the hydraulic characteristics of the channel that govern the relationship between flow and habitat, and the hydrological regime characteristics. Ecological functioning is based on the natural biota of the river and its habitat requirements such as depth and flow velocity during different life stages (Hughes and Hannart 2003). To do this for a single site, let alone for a large river basin, will require substantial investments of time and resources to gather and collate data and to ensure stakeholder participation. Consequently, several efforts have focused on rapid assessment methods and desktop models to expedite establishment of reserve requirements while studies that are more detailed are undertaken (Dickens and Graham 2002, Hughes and Hannart 2003).

Box 2.4 Resilience of Freshwater Systems

The capacity of freshwater ecosystems to withstand change is a crucial yet poorly understood issue. While declines in water quantity and quality can have immediate, pronounced effects on human well-being, deteriorations in the ecological integrity that underpins these services may be slower to appear. The danger lies in the non-linearity of these changes, and the existence of critical thresholds, beyond which the system may unravel or collapse completely and irreversibly. Ecosystems and human systems all have some degree of *resilience*: the amount of change a system can withstand while retaining its structure and the variables and processes that control its behaviour (Holling and Gunderson 2002), or more simply, the capacity to be flexible (Redman and Kinzig 2003). When a system lacks resilience, a disturbance or change may push it over some critical threshold, forcing the system to transform or flip into another state – which often appears to be the collapse of the system. However, a system may have “multiple stable states”; that is, it can persist in different forms under alternative conditions.

At face value, freshwater systems in the Gariep basin may appear to be highly resilient. Although human activities have transformed them considerably, these systems still manage to provide water and support many aquatic communities. But where are these systems in relation to their critical thresholds? While advances in technology have abated many of the problems that have arisen because of human activities, system non-linearities may ultimately trump technology. The Vaal River that delivers water to Gauteng Province’s urban and industrial complex provides a particularly illustrative example. As early as 1949 salinity problems emerged in the Vaal due to increasing industrial activities, requiring a series of purification works and other infrastructure to clean or divert highly saline water, each intervention being subsequently defeated as the pollution caught up with the raw water. Eventually, a suite of modelling tools was able to advance the hydrological knowledge base and identify an appropriate blending scheme for water treatment, which, although the most cost-efficient of options, costs consumers at least R6 million per year for every one milligram per litre increase in the total dissolved solids (TDS) concentration (Herold, *pers. comm.*).

Some would say that technology has helped to avoid critical thresholds. Others counter that the thresholds have already been passed, on the grounds of the large costs required to treat salinity, and because the Vaal system is unlikely to be restored to anything near its pre-industrial condition. Hence, the Vaal catchment may be in a “stable” state, but one that has imposed great costs on society and ecological integrity. Yet another alternative is that the critical thresholds are still to be reached, because the processes responsible for salinisation have not been sufficiently curtailed. While the current levels of salinity may be treatable, atmospheric pollution from coal and gold mining, power stations, petrochemical industries, and agriculture are considered partly responsible for further increases in salinity in the Vaal Dam (Herold *et al.* 1992). Given the non-linearities and high uncertainty in human-dominated ecosystems, the idea that a solution can always be found with the right combination of technology and budget expenditures is not particularly comforting.

What can be done to enhance resilience when confronted with such uncertainty? The style of water resource management contributes to a large degree to the adaptive capacity (and hence resilience) of freshwater systems. In the past, a command-and-control water management regime in the Gariep basin optimised for a single output – water – and strove to reduce the variability and uncertainty of water supplies by regulating flows. This was successful in the short term but created a range of ecological as well as social problems in the long term because this optimisation approach failed to account for trade-offs between water and other ecosystem services and consequences for human well-being. Instead, a more flexible management approach is needed that recognizes system complexity and is equipped to deal with surprises. Adaptive management - a structured process of “learning by doing” - has been heralded as a sound approach for managing the uncertainty of freshwater systems and is slowly being introduced in the region (Walters 1997, Rogers 1998). This approach includes identification and careful monitoring of the variables that are likely to indicate changes in system structure and function.

Several types of indicators have been developed to evaluate conditions of aquatic habitat integrity. The River Health Programme (RHP) employs the South African Scoring System (SASS) to gauge the robustness and resilience of aquatic systems by measuring the presence of selected aquatic taxa with known levels of sensitivity to physical and chemical pollutants (Chutter 1998, Dickens and Graham 2002). The method is yet to be applied at the national level, and intensive studies have been completed for several catchments, mainly areas that lie outside of the Gariep basin. SASS scores have been calculated for Lesotho and continue to be recorded to determine impacts of the LHWP on water quality (Chutter 1998).

In general, there is a paucity of quantitative information about the impacts of anthropogenic change on Gariep basin ecosystems. A survey of available literature on Gariep River biota revealed that 36 percent of the studies conducted were on fishes and 16 percent on birds while only two studies were on sediments, and one each was on water temperature, invertebrates, and bacteria (Chutter *et al.* 1996). This illustrates not only the bias towards certain taxa, but the segregated nature of the ecological research done on this system. Accompanying this shortcoming are the general decline and variable accuracy of hydrological data for this region over the years, a trend that is nearly worldwide in its proportions (Brown 2002), and the expense of establishing monitoring programmes.

Response Options for Managing Water Services

MANAGING ECOSYSTEMS TO ENSURE WATER DELIVERY

Among the key strategies to ensure the continued provision of water is the establishment of ecological reserve requirements for all catchments in the basin. Failing this, water services cannot be managed sustainably. The Department of Water Affairs and Forestry (DWAF) is drawing up complementary sets of Resource-Directed Measures, of which the Reserve requirements are part, and Source-Directed Controls, aimed at managing impacts, to achieve this objective (DWAF 2002a). In addition, improved management of groundwater resources, as well as of the conjunctive use of surface and groundwater, could improve supplies and minimise conflict between the two resources. Improving water quality, control of alien vegetation, and preservation of in-stream habitat (rocks and gravel beds) would also serve to boost the capacity of ecosystems not only to deliver clean water but also to sustain ecological functions and aquatic biodiversity.

Significant efforts to launch monitoring programmes as well as to compile and synthesise existing data will be required to develop an understanding of and capacity to manage ecosystems that provide water services. Programmes to monitor specific problems such as eutrophication are now being established. The State of Rivers Reporting initiative of the Rivers Health Programme will evaluate and report on the current condition of and apparent trends in South Africa's rivers, drivers of change, and recommended interventions. It has already been initiated for several catchments and will be produced for all of the country's major river systems by 2008.

"Working for Water" is a programme involving several government departments and supported by both public and private funds with the objectives of water services management, land restoration, and poverty reduction through the employment of South Africans in alien vegetation clearing operations. In 2000/2001, the 23 998 people employed at the programme's 313 project sites across all nine provinces cleared 70 660 hectares, undertook follow-up clearing of an additional 180 736 hectares, and began rehabilitation of 20 wetlands (DWAF 2003b). 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.

Integrated Catchment Management (ICM), the coordinated management of agricultural, forestry, and water resources, has become an increasingly important strategy. While the Mountain Catchment Areas Act was introduced in South Africa in the 1970s to manage the high mountain areas which produce over 60 percent of the country's runoff, its effectiveness was reduced when the authority for these areas was devolved in the late 1980s from national to provincial level, where resources were lacking (WRI 2000).

TECHNOLOGICAL INTERVENTIONS

During much of the 19th century, technological, supply-side responses characterised water management in southern Africa, as elsewhere. This is beginning to change with recent and major shifts in the water policy arena, as discussed below. However, technology continues to play a key role in developing water resources. Additional phases of the LHWP are presently on hold, but a shortlist has been drafted of possible large-scale water resource developments to either serve irrigation purposes or meet domestic, urban, industrial, and mining needs (DWAF 2002a). A variety of alternative technological or development approaches have been highlighted. These include improvements in existing infrastructure, additional inter-basin transfers, improved release management, intensified re-use of water and return flows, reduction of evaporation and distribution losses, and desalinisation, though the latter would be applicable mainly to coastal urban areas. While unlikely to occur in the near future, cloud seeding and iceberg importation have been offered as potential technologies to augment water supplies. An alternative option, and potentially economically competitive with desalinisation, is to import water to the Gariep from the water-rich Zambezi or Congo (Basson *et al.* 1997), though this is not yet being seriously considered.

Improvements in information technology and particularly hydrological and ecological information systems collectively form a major area of response options for water management. Two examples expected to go online in 2004 are the National Groundwater Archive and the Water Use Registration and Authorisation System (DWAF 2002a). The National Groundwater Archive is a web-based database to catalogue, store and retrieve data on modelled groundwater recharge, impacts of abstraction, and impacts of aquifer contamination. The Water Use Registration and Authorisation System is designed to register water use and licensing as well as track water charges.

LEGAL, INSTITUTIONAL, AND ECONOMIC POLICIES

South Africa is credited with developing one of the world's most forward-thinking water management strategies, embodied in the White Paper on Water Supply and Sanitation of 1994, the Water Services Act of 1997, and the National Water Act of 1998 *(see Box 2.5)*. This ensures that 25 litres of water per day are provided to all individuals free of charge, introduces compulsory licensing for other uses, which should effect a more efficient reallocation of water, and grants the right of water for the environment. Demand-side management, which focuses on controlling demand for existing resources, is a key part of the new water strategy. Changes in demand for water by different sectors are expected to ensue from a water pricing structure, in which the value of water for different uses will be more accurately reflected as scarcity increases. As of 1999, Water Resources Management Charges must be paid for all abstractions of raw water for irrigation, mining, industry, and municipal purposes, as well as commercial aforestation (DWAF 1999) *(see Box 2.6)*.

Water availability is highly vulnerable to climate change, and thus responses must take this threat into account, especially in the more arid regions of the country, nearly all of which fall within the boundaries of the Gariep basin. The Third Assessment Report of the IPCC (2001) notes that the strain imposed by climate change will be greatest in developing countries with a limited capacity to respond, not only to climate change but also to population growth and increasing competition for resources, as well as to changes in demands, technology, and economic, social, and legislative conditions.

While climate change is a concern, water scarcity is primarily a governance problem (Pahl-Wostl *et al.* 2002). Stable, effective governance structures are requisite for water management both within the basin as well as across shared catchments. International co-management organisations, 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 and ensure water security for all members, on the premise that political instability in one state negatively affects others (Turton 2003). Currently, about five international water-sharing agreements and studies, in various stages of implementation, concern the Gariep (DWAF 2002a). 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.

Box 2.5 Some, for All, Forever: South Africa's National Water Act

The democratic transition that occurred in 1994 gave South Africa a unique opportunity to reform its water policy, last revised in 1956, in order to better reconcile its resources with the needs of its people, environment, and economy. The resulting 1997 White Paper on National Water Policy and its implementation mechanism, the National Water Act of 1998, are among the world's most modern water legislation, founded on the principles of equity, sustainability, and efficiency – succinctly captured in the overarching goal of the Department of Water Affairs and Forestry (DWAF) to provide "some, for all, forever." Noting the need to redress the results of past discrimination as well as provide for future generations, the law promotes *equity* by its definition of water as a basic human right and guarantees provision of 25 litres of safe water within 200 metres of the home to all South Africans every day. It encourages *sustainability* by protecting aquatic ecosystems through ecological reserve requirements and resource protection measures, and endorses *efficiency* through water allocation and pricing strategies. In essence, human well-being will be improved in the short term by increasing access and in the long term by protecting water resources. The Act entrusts DWAF with the custody of South Africa's water resources and the development of a national water resources strategy. The implementation of the strategy will eventually rest with the nineteen Catchment Management Agencies (CMAs) currently in establishment (eight of which fall within the Gariep basin) and local governing boards that represent a wide range of stakeholders.

While this is a promising response to the challenge of providing water to South Africa's under-serviced population and ensuring the needs of the environment, the existing backlog poses a significant hurdle, as does the trend of increasing water use by the urban and industrial sectors. While the new institutional arrangements devolve management to a scale more appropriate to ecosystem functions, it remains to be seen whether the capacity will exist within these arrangements to successfully implement the Act. Of concern is that the CMAs 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.

Although some CMAs are already taking root, the complete turnover in governance will be nearly a decade in the making: an estimated two to three years to establish each agency and appoint a governing board, followed by another five years to establish its executive structure. However, given that nearly half a century elapsed before a new approach to water use was codified, some suggest that change cannot happen overnight. Many of the functions of the CMAs, such as the setting of ecological reserve requirements, will be part of an evolving process, and are likely to require their flexibility to make stepwise adjustments in the future should there be additional pressure on resources, or if the current requirements do not succeed in protecting ecosystem integrity.

Sources: DWAF 1997a, 1998, 2002a, Eberhardt and Pegram 2000, Mackay 2000, Rogers *et al*. 2000.

The concept of virtual, or embedded, water presents one potential policy response that would require regional participation, whereby surplus grain is produced by countries without water stress, such as Zambia or Angola, and exported to countries such as South Africa to allow them to conserve their more meagre water resources (Eberhardt and Pegram 2000). Because the Water Act's economic principle is designed to favour higher-efficiency uses of water, it may ultimately be cheaper to import food and use the water savings for more economically valuable applications.

SOCIAL, BEHAVIOURAL, AND COGNITIVE RESPONSES

Few people in South Africa, and presumably many city-dwellers, are aware of the great distances their water travels to reach them (Snaddon *et al*. 1998). The fact that the majority of the Gariep basin relies on inter-basin transfers masks the true extent of its existing water scarcity. Even in rural Lesotho, water is considered a free gift from God, sometimes called "white gold" (Lebesa 2003).

Increasing awareness regarding water conservation is being achieved in South Africa in part through the National Education Programme, the largest environmental education effort seen in the country to date. The National Water Resources Strategy makes a provision for communicating issues of water conservation and demand-side management to the general public and in schools, as well as marketing these concepts to water management and water services institutions (DWAF 2002a).

Box 2.6 Water Pricing

In the past, water infrastructure carried costs, but charges were not levied for water itself. Water pricing is an important implement for demand-side, as opposed to supply-side management, intended to reflect the true scarcity and value of water. The water pricing policy of 1997 and water pricing strategy of 1999 charted a course to ensure at least partial recovery of the costs incurred by water resource management and infrastructure development. It also encourages water conservation, by charging for eleven categories of water use, including the abstraction and storage of water, streamflow reduction activities, waste discharge, impeding and diverting flow, altering physical characteristics, and using water for recreational purposes. It thus provides a mechanism to internalise the major negative externalities of supplying and consuming water.

The pricing policy has three tiers, each to govern different types of charges. The first is a water resources management charge for raw, untreated water. A second is for the development and use of government waterworks. The third tier aims to achieve the equitable allocation of water, by such means as auctions or trading. Charges do not apply to water use by the reserve, international obligations, and inter-basin transfers. In addition, no charges are to be imposed on free basic water or on ex-homeland irrigation schemes or emerging farmers, for whom water is to be decreasingly subsidised for five years, after which the full charges take effect.

Water resource charges are established per water management area (WMA), and differ between area and between sectoral unit cost (*see below*). The Catchment Management Agency (CMA) for the WMA determines the rate, based on the costs of managing the water and the modelled water availability, less legally binding allocations. Water resource management charges were to be phased in from 2001, with revenues from these charges to be collected by the CMAs, once established, to fund water management activities.

Perhaps not surprisingly, the policy has bred some resentment among those who perceive an injustice: the previously disadvantaged - and for that matter, the majority of the population - must now pay for a service given to the previously advantaged free of charge. This is a sentiment likely to be echoed with regard to other services as well, as the limits of their existence become evident.

Sources: DWAF 1999, Mackay 2003.

Table A Water resource management charges in the Gariep basin for the 2003/2004 financial year.

Water Management Area	Sectoral Unit Cost (cents per cubic metre)		
	Domestic/Industrial	Agriculture: Irrigation and watering livestock	Forestry
Crocodile (West) and Marico	0.82	0.63	0.61
Thukela	0.33	0.33	0.31
Upper Vaal	0.96	0.78	0.78
Middle Vaal	1.07	1.07	N/a
Lower Vaal	0.59	0.50	N/a
Upper Orange	0.38	0.38	N/a
Lower Orange	0.49	0.40	N/a
Fish to Tsitsikamma	0.89	0.50	0.27

Source: DWAF 2003c

Of crucial importance is the need to impress upon water users the fundamental scarcity of water resources in southern Africa, and to adopt a pro-active approach to water conservation year-round, rather than to conserve only as a reactive measure of “crisis control” in times of drought. Lessons in water scarcity management could be drawn from droughts during the 1980s to the 1990s – indicative of the region's climatic stochasticity and quite possibly a result of global change. In 1995, such a drought led water managers in Gauteng Province to restrict water use unless major rain events occurred during the following summer; they did, and restrictions were lifted. Thus, by implementing quite a localised, short-sighted response, a potential signal to curb water waste was ignored and an opportunity lost to better manage water demand (Snaddon *et al*. 1998).

South Africa's Water Research Act of 1970 led to the creation of the Water Research Commission (WRC), a statutory body funded by a levy on water use. The WRC has come to provide a stable research platform that has been extremely important for supporting the water sector in different stages of management and helped lay the foundation for the Water Act and its implementation. The WRC has identified knowledge management as one of its five key strategic areas of research, with the goal of effective dissemination of research for management as well as for public consumption.

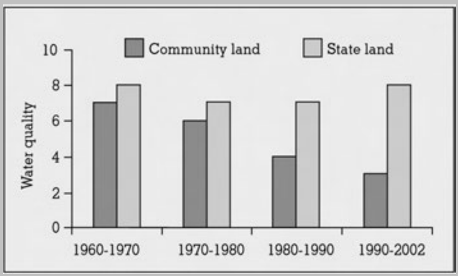
Box 2.7 Water and Communities

At the local level, patterns of water availability and use differ at the three assessment sites. Being high in the catchment, water quality and quantity at Sehlabathebe appear to be good. Land use pressures of residential areas and heavy grazing have had negative impacts on some bogs and wetlands, but not on a sufficient scale to disrupt water quality or quantity in the Sehlabathebe villages. There is only limited use of groundwater. The national park also serves to protect some of the sponge areas from possible misuse. A difference can be observed in the sediment load of the two main rivers in the area: the Leqooa, which runs through a village, has a much higher silt load than the Tsoelikane River, which rises in the park, and joins the Leqooa some 4 kilometres beyond the park boundary.

In comparison, the Fish River area has more severe water constraints. There is limited groundwater potential in the area, and the water is very salty. Residents prefer to walk longer distances to collect water from dams than use hand-pumped groundwater. Surface water is in irregular streams and dams. Most households have domestic rainwater tanks, as well as additional storage drums. Woman who walk long distances to collect sufficient water from the various dams fill these drums. This has high opportunity costs, along with health hazards. Bulk water supply is due within the short term, which would provide communal standpipes.

In the Richtersveld, there is no bulk infrastructure for water delivery. Access to water limits all grazing activities. Key sources are fourteen watering points and the Gariep River itself. Domestic water is obtained from the river, and from natural springs. It is stored in large containers and transported as families move around RNP in search of grazing for their livestock. Currently there is sufficient water to meet the needs of the local population and their livestock.

Local communities monitor water quality as part of their daily use, and are very aware of changes. In the Great Fish River, runoff from cattle dips and siltation affect the water. Using a nearby state forest as a benchmark, people at Machibi village reported that during the past four decades, water quality on community land had deteriorated compared to that on state land. A participatory ranking exercise using stones as markers for the respective periods helped to develop the histogram below of perceived water quality on the two land types. Such monitoring may increasingly play a role in the decentralising water sector, where objectives for catchment management will be determined locally, based on stakeholder knowledge of river systems.



2.4 Food Services

Food is an essential service for human survival, and agriculture plays a role not only in food provision but also contributes to Gross Domestic Product (GDP) and job creation in the Gariep basin. Yet while agricultural production capacity has made tremendous leaps in recent decades through initiatives such as the "Green Revolution", this has not come without severe costs to ecosystems and human health. Currently, agriculture in the Gariep basin, which contains the major "grain basket" of the southern African region as well as significant rangelands, is undergoing a new shift in the wake of political change.

South Africa's apartheid policies dramatically affected the nation's communal and commercial systems of agricultural production. During those decades, agriculture was highly regulated with all commodities marketed through central boards, such as the Maize Board, Wheat Board, and Meat Board. This highly regulated environment was also heavily subsidised, with a large number of financial incentives and disincentives determining agricultural practices. The outcome of this situation was a large number of perverse land-transformation and land use subsidies that promoted unwise land use practices and resulted in a large number of environmental disservices (*see* Biggs and Scholes 2002).

In the Gariep basin these led to significant soil erosion, desertification, and overgrazing. After 1994, the agricultural sector was deregulated and markets were liberalised by the democratic government. This new deregulated environment has had a significant impact on both the supply of and demand for food in the Gariep basin. At the household level, macro-economic effects affect food security, producer access to infrastructure, markets, and credit (Vogel and Smith 2002). The opening up of markets to forces of globalisation led to significant fluctuations in the prices of several agricultural commodities as well as a reduction in government funding for drought or flood relief. Collectively, these changes in the funding regime for agricultural produce have made individual farmers more vulnerable to global market fluctuations and local environmental perturbations.

Since the transition, fundamental changes in the labour laws relevant to farm workers and particularly allowances for "labour tenants" have compromised the perceived viability of numerous apartheid-style farming operations. In addition, a new tax law, which levies taxes based on farm size, has made it uneconomical to maintain large farms with low production. Innovative farming enterprises that reduce the risk profile of these enterprises (crop diversification, precision-farming methods, profit sharing, equity incentives for labour tenants, and even joint ventures) have emerged to set the pace in a rapidly evolving sector.

This assessment focuses on the services that produce cereal (maize, sorghum, and wheat) and livestock (measured in large stock units consisting of cattle, sheep, pigs, etc.), although the agricultural sector of the Gariep includes a number of other crops produced for domestic consumption and export. Along the middle and lower reaches of the Gariep River, for example, grapes, lucerne, and citrus are important products, while elsewhere along the river potatoes, onions, corn (maize-meal) sunflowers, mangoes, and dates are cultivated (Chutter *et al.* 1996).

The Gariep basin assessment illustrates graphically the difference between food production on the one hand and food security on the other. Although these are dependent concepts, they are not the same. Food production in the Gariep contributes to food, livelihoods, markets, raw materials foreign exchange, and surplus or "savings". The relationship between agriculture and ecosystem services features strongly here. Supply-demand issues are also a useful way of expressing these relationships. In contrast, multiple drivers determine food security. In South Africa it is influenced by issues such as HIV/AIDS, access, and importantly household income (HSRC 2004) *(see Box 2.8)*. This in effect means that numerous policy responses exist that fall outside the ambit of a simple balance sheet approach to food production. These issues are considered in turn below.

Food production

Only 14 percent of the total surface area of South Africa is available for crop production, water is in low supply and therefore an important restriction, and natural rangeland is deteriorating quickly throughout the region (Breytenbach and Fényes 2000). Due to previous government protection schemes, such as subsidies and tax relief, large (white-owned) commercial farms boomed under the previous government, leading to theoretical self-sufficiency in the country by the 1980s. However, 2.3 million people were still nutritionally needy in 1989. In the past, increased demand was met by a finite increase in farmed area, improved technology, and cultivation techniques, but the crisis in the sector, peaking in the 1980s, led to slow market deregulation and liberalisation (accelerated after 1994) that now have increased the number of smaller and labour-intensive farms.

Approximately 90 percent of South Africa's food consumption is met by domestic production (Kamara and Sally 2002), with sufficient calories and proteins being produced in the Gariep to meet the nutritional demand of its population as a whole. The Gariep basin is in fact a major exporter of cereal products. However, while South Africa is usually considered to be self-sufficient in food production at the national level, food insecurity at a household level still affects millions, a problem that was entrenched by past policies that restricted access to land and other resources (NDA 1997). The reality on the ground is that poverty, lack of access to resources, land tenure systems, and HIV/AIDS have created impoverished rural and peri-urban communities surrounding pockets of affluence and well-being, a situation that is also reflected in the imbalances in the agricultural sector. The challenge for this sector is to ensure that it maintains or expands present production patterns as the shift to smaller, less commercial farming units takes place.

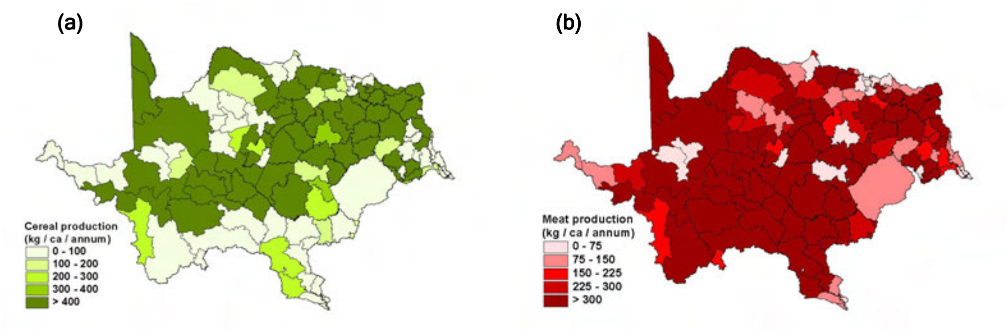


Figure 2.17 (a) Mean annual cereal production per capita per district. These average figures reflect small pockets of arable land and not a broad pattern of land availability, particularly in the arid west of the basin. An annual production of 220 kilograms per capita is adequate to supply a person with sufficient nutritional energy. (b) Potential annual meat production per capita estimated from livestock biomass (in large stock units). Values are likely to be overestimated for the former homelands and Lesotho which have lower turnover rates in livestock. An annual meat supply of 60 kilograms per capita is sufficient to provide nutritional protein requirements. *Sources:* (a) CSIR (2002); (b) WSAM.

Cereals

Cereals form 54 percent of the staple food intake of the South African population, resulting in an annual requirement of approximately 170 kilograms of cereal per capita per annum. For a subsistence standard of living, approximately 220 kilograms of cereal is required per capita per annum (CSIR 2002). When analysed on an area-by-area basis, roughly half of the Gariep basin area is not self-sufficient in terms of crop production (Figure 2.17a). In some parts of the basin this is because environmental conditions or land is unsuitable for cereal production, particularly in the dry western areas. In other parts, this is because the population density exceeds the production capacity of the available arable land, such as in the highly industrialised Gauteng-urban complex and the rural former homeland areas such as KwaZulu and Bophuthatswana. Cereals produced in the Gariep basin are largely exotic and therefore usually produced at a considerable environmental cost. An additional problem in the former homelands and Lesotho is the poor yield, even in areas where environmental conditions are reasonably favourable for cropping. These areas characteristically suffer from a lack of yield-improvement technologies. This flows from the continued widespread use of traditional agricultural practices, reinforced by small farm sizes (~22 hectares) that restrict farmers' capacity to produce enough capital to commercialise their farms and invest in such technologies.

Box 2.8 Food Security and Human Well-Being

Food security is the outcome of numerous interacting factors, including food production patterns. There are numerous ways in which food security is presently determined and can potentially be improved across the Gariep basin. On average, cereal and meat production in the Gariep basin supplies slightly more energy than is required by the 19 million people living within the basin, and enough protein to sustain a population three times as large.

In terms of cereal and meat production, the Gariep basin can supply 50 percent more dietary energy and three times more dietary protein than is required by the population (Figures 2.17a, b). Without exception, all the municipalities in the Gariep basin produce sufficient protein in theory to prevent malnutrition. Nevertheless, mal- and undernutrition seem to become increasingly common amongst the poorer section of the population. This anomaly therefore appears to be driven by social inequalities and disparities in income distribution rather than by a shortage of agricultural production. This is especially the case for meat, which remains largely unaffordable to the poor (see *Box 2.9* for discussion about dietary proteins in local communities).

A major revision of land planning policy is necessary in light of both soil conservation and equitable distribution among citizens (Mkhabela 2002). It should not be ignored that local markets act as a cornerstone for agricultural development, and these markets are highly affected by people's economic security (Breytenbach and Fenyes 2000). Lastly, increasing access to food resources through policy interventions that contribute to poverty alleviation, land distribution, and more equitable distribution and local market mechanisms will not be sufficient in improving nutrition if there is not also an increase in nutritional education at school and adult levels. The diets consumed by most people in the Gariep can improve to promote health, but knowledge and understanding is currently lacking and hampered by low literacy levels (Langenhoven *et al.* 1993).

Despite these anomalies, the Gariep basin in general does provide 20 percent more cereal than is required by its resident population. This is due to extensive production in the maize belt that lies to the west of the South Africa-Lesotho border. The Gariep basin may therefore be considered self-sufficient in terms of crop production, but only half of South Africa's total crop production is used for domestic consumption. The remainder is exported or used as livestock feed (Central Statistical Service 1973 – 2000). This essentially means that numerous people living in a broadly self-sufficient basin are not guaranteed access to sufficient resources to meet their fundamental needs whereas local abundances are exported to support markets that are more lucrative. This is a classic example of an asymmetric global trade regime that favours exports, frequently at an immediate cost to local residents who cannot pay competitive prices to producers or negotiate the required degree of market access.

Since 1960, approximately 80 percent of the estimated arable land in the basin has been cultivated. The average yield of cereal crops increased from approximately two tonnes per hectare in 1960 to 3,5 tonnes in 1975 and has not increased since, despite increased private investment in agriculture. Cereal production has fluctuated along with climatic conditions around an average of 10 000 tonnes per annum (Central Statistical Service 1973 – 2000). Despite sufficient production of food, poor nutrition has become increasingly prevalent in the poorer population (Huntley *et al.* 1989), largely attributable to the increase in the price of food and more recently due to the systemic impacts of HIV/AIDS on local communities and rural livelihoods (Stokes 2003, Topouzis 2003). Producer prices have soared with inflation after the South African government withdrew rebates on cereal production (Central Statistical Service 1973 – 2000).

However, even if exports and animal consumption of cereal crops are excluded from the picture, cereal cropping in the Gariep basin would, in theory, be sufficient to provide the population's calorie requirements until 2010 under prevailing population growth scenarios. Improvement in cereal production within the basin is limited by the lack of arable land and the paralysis of yields on commercial land during the past two decades despite increased investment in cropping (Huntley *et al.* 1989). The adoption of new technologies in South African crop production is unlikely to cause a significant increase in yield. However, the use of genetically modified crops (if able to tolerate the South African environment and gain sufficient consumer acceptance and investor confidence) could lead to an improvement in cereal yields and an increase in cereal production, although such improvement is unlikely to provide the requirements of the growing population into the distant future. The future impact of genetically modified organisms (GMOs) in South Africa is still uncertain and awaits the outcome of a growing but still unresolved public and scientific debate (see http://www.saafost.org.za/gmo.htm). The greatest scope for improvement in agricultural production probably lies in improving production efficiency in the former homeland areas, although this represents only a very small proportion of the Gariep basin's area.

Livestock

On average, the Gariep basin provides enough meat to supply a population three times its current size of required dietary protein as estimated from livestock biomass. Consequently, protein production is theoretically adequate for most of the municipalities to supply the approximate 60 kilograms of meat per capita necessary to meet local protein requirements (Figure 2.17b). The most obvious exceptions are the urban areas, and the poor who cannot afford to purchase meat. Although the former homelands and Lesotho have sufficient livestock to provide the protein requirements of the population, livestock are traditionally considered social capital rather than production assets, so that the turnover in livestock for meat production is merely one-fifth of what it is on commercial farms. The presence of sufficient numbers of livestock is therefore not an indication of sufficient meat production.

Livestock biomass in South Africa has remained at approximately 18 million large stock units over the past two decades. Despite a marginal increase in pork production, South Africa's red meat production has remained relatively constant at 850 000 tonnes per annum (Central Statistical Service 1973 – 2000). This can be considered to approximate the limit for potential stocking rates of the Gariep basin and South Africa as a whole, given that the rapidly increasing demand caused by population growth has not resulted in an increase in either livestock biomass or meat production (Huntley *et al.* 1989, Central Statistical Service 1973 – 2000). Instead, the per capita consumption of meat has decreased from 50 kilogram per annum in 1950 to 20 kilogram in 1995 (Central Statistical Service 1973 – 2000). Together with expanded export opportunities, the summed increase in demand relative to supply in the country has led to rapid price increases, causing red meat to be largely unaffordable, particularly to the poor.

Given the current production of meat in the Gariep basin, it is evident that there is sufficient production for the population on average, and malnutrition in the poor population sector can more rightly be attributed to structural and social problems than to inefficiency in production. Nevertheless, there is ample room for improvement in meat production in South Africa as discussed later in this section.

The contribution of commercial game farming is important as a source of supplementary income and may contribute some 10 percent to the gross income per farming unit in the region (Behr and Groenewald 1990), while fish farming is negligible in the basin. Neither achieves the same order of magnitude as commercial stock ranching. Wild meat or "bushmeat" provides an important safety net for local communities, however *(see Box 2.10)*.

Demand

Nutritional demand in the Gariep basin, measured as the Recommended Daily Allowance (RDA) for calories and protein per person, is distributed unequally across the region (Figure 2.18a and b). As can be expected, the populous areas around Johannesburg and the East Rand in Gauteng Province where mining and commerce have drawn many workers, have the highest demand. South Africa has had a relatively steady annual population increase of about 2.8 percent for the past two decades, and the districts with the highest growth rates (> 4 percent per annum) are in Gauteng, some parts of KwaZulu-Natal and the North West Province (DEAT 1999). Moreover, results from nutritional studies have indicated a broad pattern of sufficiency in nutritional supply, but there is a need for more nutritional variation, as very few people actually eat a sufficiently varied diet (Langenhoven *et al.* 1993).

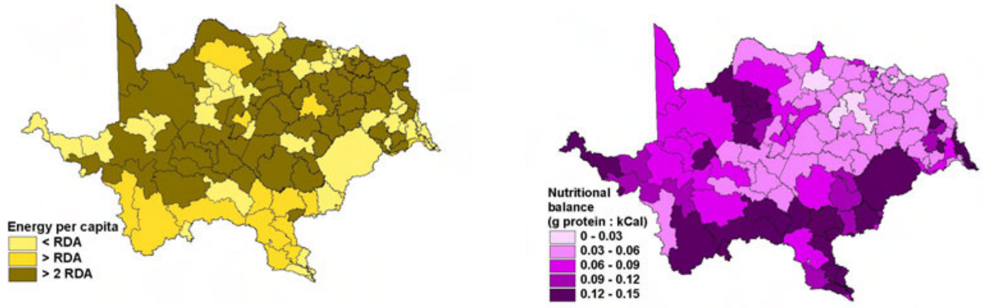


Figure 2.18 (a) Daily calorie supply estimated from cereal and meat production as a ratio of the recommended dietary allowance (RDA) of 2250 calories per capita per day; (b) Protein relative to energy production from cereal crops and meat production. A ratio of less than 0.015 would be indicative of insufficient protein production relative to energy. *Sources:* Large stock units were obtained from the WSAM; yield estimates and cultivated area for maize, sorghum, and wheat were obtained from the CSIR (2002). *Notes*: This average annual reproductive rate for South African large stock units between 1950 and 1995 was calculated as 0.22 per large stock unit. An average weight per large stock unit of 520 kilograms and utilisable meat production per carcass of 50 percent were used. Nutritional values per kilograms of cereals used: maize: 3 700 calories, 80 grams protein; sorghum: 3 705 calories, 97.8 grams protein; wheat: 3 300 calories, 130 grams protein. RDA of 2250 calories per adult and 37.5 grams protein per adult were used.

Capacity of Ecosystems to Continue Providing Food Services

Water (soil) erosion, typically due to agricultural practices, influences more than 70 percent of South Africa. Soil degradation is thought to negatively influence plant growth, biodiversity, and agricultural production in South Africa; more certain is the contribution of soil degradation to siltation and eutrophication in reservoirs and dams, sedimentation in coastal estuaries, and modifications to riparian systems (Hoffman *et al*. 1999). The primary cause of degradation across the Gariep is ecosystem mismanagement through overgrazing, water mining, and cereal production on marginal lands. These often result in desertification in this largely water-limited landscape.

The United Nations Convention to Combat Desertification (UNCCD) requires countries affected by dryland degradation and which ratify the convention to prepare and implement a National Action Programme. To work toward this objective, a study by the National Botanical Institute (NBI) and the University of the Western Cape's Programme for Land and Agrarian Studies (PLAAS) began in 1997 to assess the state of desertification in South Africa. Along with a review of the relevant literature and several case studies, this work produced a consensus map (Figure 2.19) of soil and vegetation degradation that represent the opinions expressed by 453 people who attended a series of workshops devoted to the topic.

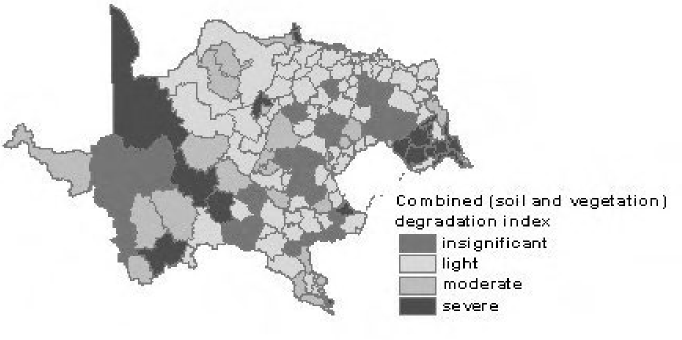


Figure 2.19 Combined index of soil and vegetation degradation per municipality in the Gariep basin as perceived by agricultural extension officers and resource conservation technicians during a series of 34 consultative workshops held during 1997 and 1998. Data are expressed as one or two standard deviations above or below the mean value for the country: Insignificant = -2 to -1 SD below mean; Light = -1 to 0 SD below mean; Moderate = 0 to 1 SD above mean; Moderate = 1 to 2 SD above mean. *Source*: Hoffman *et al*. 1999.

According to the workshop results, soil degradation is perceived to be more of a problem on communal lands than in mainly commercial districts. Participants believed that some forms of degradation are decreasing, mainly in commercial farming areas, for reasons that included better farm planning, subsidies for conservation works, better legislation, education, town planning, reduced stock numbers, and conversion to game farming. However, they indicated that increases in the rate of soil degradation, mainly in communal areas, were in part caused by large influxes of people to peri-urban areas, lack of infrastructure, betterment planning, poor education, poor runoff control, increases in stock numbers, and shifts to different breeds of grazing animals (Hoffman *et al*. 1999).

Climate change is expected to affect subsistence and commercial food production in numerous ways, not all of which will be negative. For example, the result of a national study of the impacts of climate change on the agriculture sector suggests that declines in precipitation and increased temperatures would result in mixed responses (van Jaarsveld and Chown 2001). For rangelands, grassland losses in production would likely be offset by increases in CO_2 fertilisation, while savannah grasses appeared more sensitive with an anticipated 20 percent decline in production. Savannah elements would also encroach on grassland areas, leaving livestock largely unaffected with some impact on the cattle production potential. Moreover, both the commercial aforestation and cereal production sectors would emerge largely unscathed, with a combination of CO_2 fertilisation and the development of resistant cultivars compensating for anticipated precipitation-induced production losses. In addition, some crops will become more susceptible to disease, as some diseases will be able to spread to areas from which they were previously restricted by climatic conditions.

While the effect of current regulations and policies are not yet overwhelmingly evident in the agricultural sector (Vink *et al*. 1998a), there is evidence of some of the arable land that was previously owned by whites being transferred into non-white hands (Vink and van Zyl 1998). As the sector becomes more market-based, there is a move away from large technology-rich farms to smaller, labour-intensive farms that not only contributes to job-creation and food, but also significantly to GDP (Vink *et al*. 1998a). As the policies of land reform, non-discrimination, and improved financial services remove disparities between large farmers and smallholders, the agricultural sector should become more diverse in terms of crop type, farm size, and agricultural practice, and more able to withstand market fluctuations. However, the removal of subsidies could present some initial barriers for small and emerging farmers *(see Box 2.9)*. Horticulture, poultry, and sugar production should increase with the demand from export markets as well as the effects of an increase in general income in the Gariep basin, which usually leads to less demand for staple grains and a higher demand for red meat (Vink *et al*. 1998b, Biggs and Scholes 2002). Especially in marginal crop-producing areas, an increase in livestock production can be expected and the current trend of agricultural exports growing faster than imports may continue (Breytenbach and Fenyes

2000). This will increasingly promote a drive towards more lucrative exports and inflate prices, again at a cost to the less fortunate. The government should make every effort to stabilise grain markets, however, if the downward trend in the production of these staple food sources is to be reversed (Breytenbach and Fenyes 2000).

Box 2.9 Subsidies and the Food-Water Link

One of the fundamental policy issues that the South African government must contend with in the near future revolves around inconsistencies in its policies for land redistribution and water provision. Because of the repeal of heavy subsidisation of agriculture by the state, farming the marginal land that was once profitable to cultivate is no longer economically viable. This is the land that is most likely to become available through the current system of land redistribution in which trades are made by consent, but many new buyers entering the market will not have to means to purchase inputs to make this land productive (MacKay 2003).

While the now-retired riparian rights principle previously declared water sources that flowed across farmland the property of the farm owner, irrigation is no longer "free." In most areas, it is one of the highest priced water uses, reflecting its low economic efficiency. This fact makes the prospect of agricultural land reform especially challenging, and emphasises the need for investments in types of agriculture and other land uses that are less water-intensive to generate social benefits.

Response Options to Manage Food Services

MANAGING ECOSYSTEMS THAT PRODUCE FOOD

In the Gariep basin, important responses to improve the resource base and state of the ecosystem include improving soil conservation, controlling agricultural water pollution, and suppressing the spread of invasive alien species, optimising land use patterns across the available landscape, as well as water pricing and demand management as ways to improve the efficiency of irrigation. Salinisation is a further problem in irrigated areas that requires attention along with the more general rehabilitation of soils. The wider use of natural resources, such as indigenous fish stocks in dams, could enhance food production.

TECHNOLOGICAL RESPONSES

A host of technological responses exist, which include increasing livestock turnover rates, especially in former homelands and Lesotho. Although the full capacity of current grazing area seems to have been reached in terms of stocking rates, an increase in livestock biomass can still be facilitated by improvement of grazing by the conversion of natural grazing into pasture (Huntley *et al*. 1989). Increasing pig farming could also be an option to increase protein production, although the associated environmental costs may be high. In recent years, biotechnology has emerged as a response to environmental and agricultural problems in Africa, and has been attended by significant controversy for both environmental and social reasons. Alternative integrative methods such as organic farming present a more holistic view of agricultural production and ecosystem conservation, although at present these remain loosely defined and have yet to be adopted on a significant scale. Improved disaster warnings and advisories would also be of great benefit.

LEGAL, INSTITUTIONAL, AND ECONOMIC POLICIES

This assessment draws attention to the fact that trade asymmetries are not only an international phenomenon that affects the relationship between international trading partners (Stiglitz 2003) but are also a national issue, where sectors of society are unable to access local resource markets due to their low incomes. Thus, asymmetries are pervasive across societies, and particularly in South Africa, where large sections of the population were historically disenfranchised. Appropriate national policy interventions should be considered to alleviate this imbalance and could be as fundamental as a basic income grant. One way to alleviate some of the economic stress of providing such a grant could be to restrict their distribution to females only (Erasmus and van Jaarsveld 2002), although this could introduce new social tensions.

Possibilities abound to reform food production through policies. Continued land and market reform are paramount. This would include increasing the amount of land transferred to non-white hands, and from large technology-rich farms to smaller, labour-intensive farms that contribute not only to food production and job creation but generate substantial income (Vink *et al*. 1998a). Policies of land reform, non-discrimination, and improved financial services, by removing disparities between large farmers and smallholders, should make the agricultural sector more diverse in terms of crop type, farm size, and agricultural practice, and more resilient to market fluctuations.

Importation of food, where possible, would reduce some of the pressure on land and water resources. Implementation of a certification programme would encourage production according to more sound ecological regulations, and would increase awareness among consumers. Integrated land use planning and analysis of trade-offs between, for example, cultivation and urbanisation, would help to identify optimal investments in agriculture.

The best conceived restructuring plans for the agricultural sector will fail if the issue of HIV/AIDS is not confronted squarely. There is already a better understanding of the vulnerability of the agricultural sector to HIV/AIDS. Small farming households are particularly vulnerable to the combined effects of a decline in household labour quality and quantity, less household disposable income, the erosion of the household asset base, and a decline in experience and skills (Topouzis 2003). The issue of HIV/AIDS emphasises the shortcomings of a production-oriented approach towards food security. Appropriate interventions should also transcend simple health-dominated approaches that are preventative but deal with the full spectrum of the social, economic, and environmental problems created by the prevalence of HIV/AIDS in society. There are a number of interventions which can be adopted to minimise the impact on HIV/AIDS on food production. This includes promoting low-input agriculture through use of lighter ploughs and tools, improved seed varieties that demand less weeding, inter-cropping or minimum or zero tillage, and access to potable water and fuel-efficient stoves for households headed by the elderly, youths, or orphans (Stokes 2003, Topouzis 2003).

SOCIAL, BEHAVIOURAL, AND COGNITIVE RESPONES

Nutritional education for adults and at schools is an important response that would help to combat nutritional problems that are rooted in a lack of awareness. Equally important is raising awareness regarding conservation measures and economic instruments that may be available to farmers. Use of forecasts by farmers to develop preparedness strategies is slowly being introduced and accepted. The establishment of programmes aimed at creating awareness and access to information must become a top priority to ensure that these basic nutritional needs are met.

Box 2.10 Food and Communities

Different patterns in food availability are clear between local assessment sites. At Sethlabathebe, most families aim to produce food locally from fields and gardens. However, the majority of people are food insecure in that annual harvests are rarely sufficient to meet household needs until the following planting season. Additionally, they retain part of the seed for planting. Maize is the preferred food, but has a very low success rate in the high mountains. Thus, food production is supplemented by purchased food and collected wild foods (edible herbs and bushmeat). Local communities obtain considerable quantities of their dietary protein from bushmeat and the plant matter they consume. Key reasons for the poor food production are (i) a short growing season, (ii) possible severe weather even during the growing season, (iii) a perceived decline in fertility of already poor soils, (iv) planting maize of exotic origin and ill-suited to the area, and (v) lack of draught animals because of lack of ownership (45 percent do not own livestock) or theft of animals.

The Government has several food programmes in place, including rations for the elderly, and the distribution of hybrid seed, but it rarely arrives in time to the more remote areas. Apart from chickens, livestock are rarely slaughtered for food, other than at celebrations, rituals or funerals. Reduced food security and production are perceived to be caused by declining soil fertility due to reduced inputs, increasing stock theft (which means the victims can no longer plough), an increasing human population, meaning that new households no longer have an automatic right to an arable allotment, and fallow periods that have decreased or ceased altogether.

In the Great Fish River, the primary sources of protein are chickens and purchased meat. Livestock are rarely slaughtered for consumption except at special occasions. Animal numbers have been reasonably static over several decades, interrupted by crashes brought about by drought. Arable activity is limited. Hence, the bulk of food items (protein and staples) are purchased from local *spaza* shops or shops in the closest towns. Some work indicates that perhaps as much as 90 percent of household cash income is spent on food. This is supplemented by collection of wild foods. Overall trends that respondents describe are a decline in agriculture and a decline in ownership of livestock, with a corresponding increase in reliance on the cash economy, paid for by state grants and migrant remittances.

In the arid and remote Richtersveld region, arable cropping is not practised. All households stated that their main source of protein is the herders' own goats and sheep, supplemented with fish caught from the river. One or two animals are slaughtered per month per family, providing an average of 3 kilograms of meat per person per month. Cash from sales of livestock and migrant remittances is used to purchase dietary staples such as bread flour, maize meal, sugar, and tea, as well as tinned foods and luxury items, from shops in the neighbouring villages or towns further away. Over 90% of herders claimed to collect edible fruits and plants, albeit they were not regarded as significant components of the diet. At least 60% of households consume bushmeat comprising small game, birds, and eggs. This is probably an underestimate, since they are not allowed to do so. According to respondents, the main changes have been a decrease in use of bushmeat and fish and an increase in the use of purchased items. This is attributed to increasing regulations regarding hunting since the establishment of the Richtersveld National Park, and an increase in shops in the neighbouring villages and items for sale at the diamond mines.

Climatic factors and policies have affected the demand for sources of food from natural resources in the villages in the Great Fish River area in the past. The identified key sources of food in households in a typical village are arable fields, livestock, woodlands, shops, familial exchanges, and a government feeding scheme. A trend of dependence on local shops has been identified. Food was the biggest household expense, and shops were highlighted as one of the most important sources of household food.

At Richtersveld, people rated starch staples as their most important food, followed by beverages (coffee) and then meat and milk (Table 1). This is contrary to expectations, as starch staples in this area can only be purchased at shops.

Table A Rating of food items by Richtersveld pastoralists

Category	Average rating (max=5)
Starch staples	5.0
Beverages	4.7
Meat, milk	4.6
Store-bought	2.7
Fish	2.1
Perishables	1.4
Vegetables	1.2
Game	0.8
Cultivated	0

At Sehlabathebe, maize meal was the most frequently consumed staple food on a monthly basis, eaten on average 82 times. Rape was the next most frequently eaten staple, at an average consumption of 24 times, followed by cabbage at an average of 17, bread on average 7, spinach 6, sorghum on average 4 and beans on average 1.3 times per month. Most people had animal protein less than four times per year and many consumed it only at funerals.

2.5 Energy Services

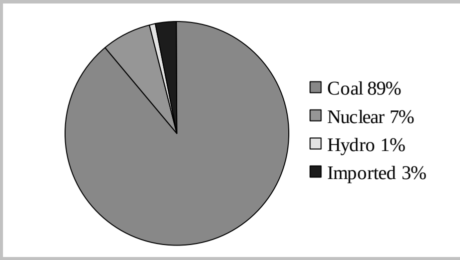
The daily lives of people are improved immensely by the energy services provided by ecosystems, whether in the form of coal, wood, water, or renewable sources. Energy is also crucial to the economic well-being of the industrial, transportation, agricultural, and commercial sectors within the Gariep basin. Because of the wealth of coal deposits in the Highveld region of the Gariep basin, low-cost electricity has allowed for the growth of industry, transportation, and mining, particularly within Gauteng Province. However, its provision is at considerable costs to the environment and human health. In the domestic energy sector, the dichotomous nature of South Africa's economy, which comprises both developed and developing world facets, is apparent (Williams and Shackleton 2002). In the environment of the urban, developed world in which 53.7 percent of South Africa's population lives, most household energy needs are supplied in the form of electricity from the parastatal company Eskom *(see Box 2.11)* (Williams and Shackleton 2002). Lesotho was formerly dependent on imported electricity from South Africa; however, the Lesotho Highlands Water Project (LHWP) recently brought the 'Muela Hydropower Station online as the national supplier of electricity (Lesotho Department of Energy 2002). This has made Lesotho self-sufficient in electricity production, with an energy grid that reaches a considerable portion of the country though it only serves the domestic needs of a small percentage of the population.

Within the poorer rural and peri-urban communities of the Gariep, 80 to 99 percent of households meet their energy needs with biofuels, which include wood from trees and shrubs, dung and crop residues (Williams and Dickson 1996) while coal fires, paraffin, and candles are widely used. Both developed and developing energy sectors need to move towards using more sustainable energy sources. However, the sustainability of energy sources perceived to be more "environmentally friendly" is still contentious in the region and forms the subject of considerable public debate and research. In the rural and informal economic sector, biofuels remain an important energy source due to the prohibitive costs of electricity or fossil alternatives for most households (Williams and Dickson 1996). For example, in Lesotho some sixty percent of the total energy consumption is biomass-based (Lesotho Department of Energy 2002).

Box 2.11 The role of Eskom

- Parastatal company founded in 1923
- Generates and supplies 95 percent of South Africa's electricity
- Over 200 000 newly electrified houses per year.
- The Integrated National Electrification Programme aims at universal household access within 10 to 11 years.

Source: www.eskom.co.za



Source: ERI 2001

Supply

The South African electrification grid covers the majority of the Gariep basin except for the sparsely populated areas of the Northern Cape (Figure 2.20a) (MDB 2001) and Lesotho. The greatest percentage of electrified households lie within the urban Gauteng Province and the greater Bloemfontein area. Where the Eskom grid does not extend, electricity is supplied through other sources such as generators or privately owned solar panels (Figure 2.20b) (MDB 2001) to those who can afford them. Although Eskom's national household supply grid is increasing in size, it is not economically viable to extend the grid to all remote areas (EIA 2002), pointing to the increased need for household energy self-sufficiency in the future.

Coal-burning thermal power stations generate the majority of Eskom's electricity supply. These are situated on the Highveld close to the coal mining areas in order to defray the high transportation costs. Coal is currently economically preferable to other energy sources because externalities such as high levels of air pollution, global warming emissions, consumption of large amounts of freshwater, wastewater emissions, and occupational health effects are not accounted for in the cost of coal-generated electricity in South Africa *(*see *Box 2.12)* (van Horen 1996).

It is in the more environmentally sustainable means of power generation such as hydro-, solar, and wind power that the Gariep basin has considerable potential, although impacts on the environment, biodiversity, and aesthetics need to be assessed. The Northern Cape Province that comprises a large portion of the Gariep basin has the highest solar intensity over the largest area in the world, leading to its official designation as the "Solar Province of South Africa" in 1998. This has not gone unnoticed by Eskom, which, through a partnership with Shell Solar South Africa, has launched a programme to install modular solar home systems within remote areas, especially in the Northern Cape where insulation rates are high. The favourable conditions have led Eskom to plan two large-scale concentrated solar power-generating facilities within the province (EIA 2002).

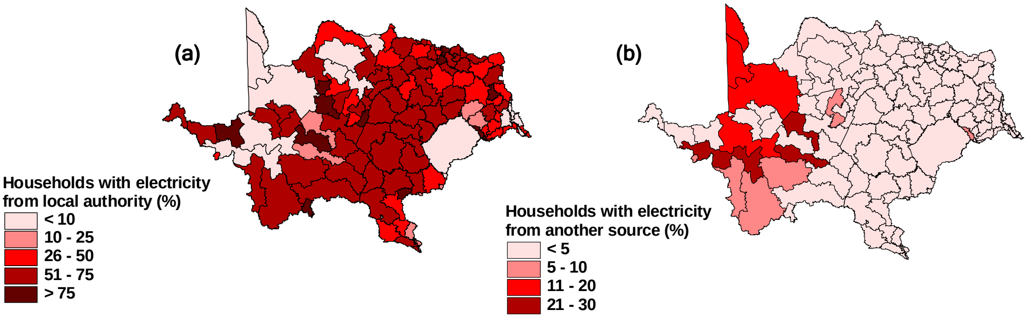


Figure 2.20 (a) Percentage of households with electricity supplied by the parastatal company Eskom and (b) alternative electricity sources within the Gariep basin (MDB 2001).

Lesotho is believed to have a total hydropower potential of 450 MW, although only 76 MW is currently being exploited from the following hydropower stations: 'Muela (72 MW), Mantsonyane (2 MW), Mokhotlong (0.67 MW), Tsoelike (0.4 MW), and Semonkong (0.4 MW) (Lesotho Department of Energy 2002). In South Africa, two dams on the Gariep River, the Gariep Dam (360 MW) and the Vanderkloof Dam (240 MW) generate hydropower. The further development of large-scale hydroelectric plants in South Africa is unlikely due to the lack of remaining suitable sites and declining popular support for large dams related to their detrimental environmental and social effects.

Biofuels supply a large proportion of the energy used in the rural and informal sectors. Rainfall is the major determinant of fuelwood production across the Gariep basin (Williams and Dickson 1996), with supply being dictated by the strong gradient in the amount of precipitation across the Gariep basin (Basson *et al.* 1997) from moist tropical areas in the east to arid areas in the west. In the arid western part of the Gariep basin, less than one percent of the land area is covered by bushland or thicket. However, in the tropical areas in the east, there is a large fuelwood supply from communal land, forestry residuals, bush clearing within conservation and stock farming areas, as well as from the clearance of new cultivation and control of invasive woody vegetation. Particularly in areas where there is a surplus of fuelwood from forestry residuals and bush clearing, there is a large informal industry in the commercial distribution and supply of fuelwood to nearby areas (Shackleton *et al.* 2003a, Gandar 1994). The sustainability of this informal fuelwood industry is frequently questioned. In the intermediate grassland regions of the basin where wood is less available, and where winter frosts and even snowfalls occur, the local population depends on a mix of available biofuels such as dung, shrubs, and crop residues and also place considerable premiums on access to more expensive coal or paraffin as substitute fuel sources.

In Lesotho, those who are not connected to the national grid continue to meet their energy needs primarily with biofuels in rural areas (United Nations 2000), while in the urban and peri-urban areas most households depend on paraffin for lighting and cooking and candles for lighting (Lesotho Environment Secretariat 2000).

Demand

The industrial sector is the largest consumer of energy across the Gariep basin, consuming 41 percent of South Africa's total energy consumption and 57 percent of the country's electricity in 1996 (ERI 2001). South African industry, notably mining and iron, steel, and non-ferrous metal manufacturing, is energy intensive, relying on coal directly or indirectly through the production of electricity as an energy source (ERI 2001). The majority of heavy industry areas within the Gariep basin are based in the Gauteng Province in close proximity to the Highveld coal-burning thermal power stations. Furthermore, most residential and commercial sectors are within Gauteng Province while both sectors are growing within the greater Bloemfontein area.

Within the residential sector, most of the South African urban population has access to electricity; however, the majority of poor households use biofuels as their primary energy source for heating, cooking, and lighting. In rural areas, despite the electrification drive in South Africa since the 1994 election, biofuels are still widely used as most households cannot afford monthly electricity payments or electric appliances (Williams and Dickson 1996, Williams and Shackleton 2002). The demand for any particular energy source depends on the cost and availability of other energy sources, the household size, financial and social status (Shackleton *et al.* 2003a). Consequently, the quantities of biofuels used and their use relative to other available energy sources, for example paraffin and gas, vary greatly across the Gariep basin (Shackleton *et al.* 2003a), as shown in Figure 2.21a and b.

In the Tugela basin, there is high variability in demand for fuelwood due the spatial variability of the landscape. Households in the Tugela use between 327 to 630 kg/month, whereas in the Fish River basin, households use an average of 617 kg/month, and in the more arid areas near Namaqualand, about 108 to 342 kg/month is used per household (Williams and Dickson 1996).

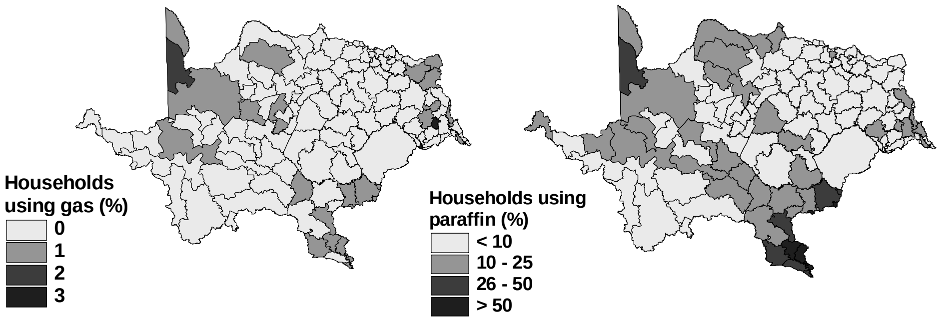


Figure 2.21 (a) The percentage of households using gas and (b) paraffin within the Gariep basin. *Source*: MDB 2001.

Access

Like the free basic water policy, a programme of "free basic electricity" commenced in 2001 to provide 50 KW free of charge each month to poor users, yet delivery via regular paid meter systems has posed challenges and the testing of alternative delivery systems is in pilot phases now. Overall, electrification is one of the success stories of the sector, with about 70 percent of the country now electrified, 80 percent in urban areas, and 50 percent in rural areas (Basson 2003).

Capacity of Ecosystems to Continue Providing Energy Services

As long as coal reserves are exploitable, energy in the form of electricity should continue to be available, in theory if not in reality. The limitations of coal are more likely to revolve around its environmental as well as social externalities, which may eventually motivate a shift to other energy sources. Many of the biofuel sources, on the other hand, are vulnerable to local depletion in the foreseeable future if they are not sustainably managed (Williams and Shackleton 2002). In some locations, available and affordable alternatives could play an important role in stemming the overharvesting of fuelwood.

Lesotho's high rainfall and runoff have enabled the country's self-sufficiency in hydropower production, which is not likely to change in the near term, although the impacts of its dams certainly warrant careful monitoring. Continued production is also dependent on the success of Lesotho's partnership with South Africa. Biofuels, especially for the population residing in the urban areas, are harvested from South Africa, contributing greatly to the depletion of natural vegetation near the South African-Lesotho border.

Box 2.12 Energy Services and Human Well-Being

Due to the low price of coal compared to other energy sources, South Africa and its neighbours rely heavily on coal and biofuels as energy sources. Coal burning in heavy industry and thermal electricity generation on the Highveld, as well as the high reliance on biofuels domestically, leads to high carbon dioxide and sulphur dioxide emissions within the Gariep basin. The use of biofuels can also have negative impacts on human health associated with respiratory diseases resulting from long-term use of open fires for cooking and heating, particularly when used indoors in poorly ventilated rooms (see Chapter 2.7, Air Quality). Simple technologies, such as stoves with chimneys, can significantly reduce these secondary effects and reduce health risks but are not widely used at present (Williams and Shackleton 2002).

Although South Africa's emissions of greenhouse gases do not compete with those of the United States of America or most developed countries, South Africa has the highest per capita carbon emission level in Africa (EIA 2002). However, due to the current price, proximity, and abundance of coal, there has been little investment in sustainable and environmentally friendly energy sources. Current South African coal reserves are expected to last for another 300 years at current rates of consumption (van Tienhoven 1999). Despite long-term historical investments and subsidies on fossil fuel-based technologies, the technologies for clean renewable energy production systems do exist and are continually being explored on an experimental and commercial_basis for solar, wind, and micro-hydropower. Several renewable technologies are already cost-competitive in South Africa: solar passive design in buildings, solar water heating in commercial applications, ocean current electricity generation, and the Green Tower, a combined solar chimney and greenhouse that produce 400 MW for 24 hours at a cost of nine cents per kilowatt, making it cheaper than coal-fired electricity (see http://www.greentower.net). During 1985 and 2000, the conventional fossil fuel based electricity generation in South Africa increased to 139 percent while the workforces were reduced by 46 percent. By contrast, renewable energy technologies have the proven potential to create many new sustainable jobs. By 2020 wind energy alone could employ more people than the current coal-fire based electricity in South Africa (Agama 2003).

Response Options for Managing Energy Services

MANAGING ECOSYSTEMS TO ENSURE ENERGY SERVICES

Rural populations in the Gariep basin have a high reliance on fuelwood, which is detrimental to their health and leads to degradation of rangelands (Williams and Dickson 1996). This reliance has prompted responses that focus on both demand and supply management. One strategy by the South African government to reduce the reliance on fuelwood as an energy source has been to extend the national electricity supply grid. This initiative has had mixed success as many households with access to electricity cannot afford either the monthly charges or appliances and therefore continue to use fuelwood as a primary source of energy (Williams and Dickson 1996, Williams and Shackleton 2002). As fuelwood is typically depended upon by rural and lower income groups, responses and interventions need to be placed in the wider context of rural poverty (Williams and Dickson 1996).

Conversely, other strategies focus on ensuring the long-term supply of fuelwood as an energy source. The 'energy crisis' paradigm of the 1970s to the 1990s (Williams and Shackleton 2002) provoked a response by the South African government to create the Biomass Initiative (BI) or 'Plant for Life' project (Williams and Dickson 1996). The Department of Water Affairs and Forestry, together with Forestek (now Environmentek, CSIR) and the Institute for Natural Resources implemented several support and management initiatives including extension training and the establishment of woodlots. Although the BI too was met with mixed success (Williams and Dickson 1996, Williams and Shackleton 2002), the main reason for its failure was that the needs of the intended beneficiaries were not included in the planning stages of the project (Williams and Shackleton 2002).

TECHNOLOGICAL INTERVENTIONS

Although stoves with chimneys can significantly reduce consumption and reduce health risks associated with burning of fuelwood, they are currently not widely used. They have been found to be too expensive and are not as practical as conventional open fires for cooking, heating and providing light (Williams and Shackleton 2002). Top lit Scotch fires (known as Basa Magogo or Basa Mama) have been demonstrated to reduce coal burning by as much as 30 percent and can consequently decrease air pollution by 42 percent (Schoonraad and Swanepoel 2004).

Eskom is presently investigating the option of 'micro-hydro' plants that will utilise the potential of smaller rivers in remote areas to supply electricity to isolated communities where the extension of the national grid is not economically feasible. Hydroelectric dams are also useful in the 'storage' of electricity, for example in the Drakensberg Pumped Storage Scheme. These facilities are crucial in the management of electricity as the peaks in supply of electricity from hydro and wind generation plants do not necessarily coincide with the peak times of electricity usage.

Although there are strong incentives to generate wind power within the Gariep basin, little implementation has occurred beyond a few investigative projects. This is an ecosystem service with much potential, as it provides an economically viable form of energy that provides a large number of jobs with comparatively few environmental or social costs (for a more detailed analysis of the potential for wind power in South Africa, see http://www.esi.co.za).

A number of small-scale solar projects are in use, including the Green Tower, noted above, and continue to hold promise. Meanwhile, Eskom's most recent foray into nuclear energy, the Pebble Bed Modular Reactor (PBMR), has kept this option for energy production on the table, amid much controversy *(see Box 2.13)*.

LEGAL, INSTITUTIONAL, AND ECONOMIC POLICIES

A number of policies have been put into effect to address energy services. On the biomass issue, the National Forestry Action Programme (DWAF 1997b) builds on the BI and enables the Department of Water Affairs and Forestry to provide support for the development of community forests. Defined in the White Paper on Sustainable Forest Development in South Africa, a community forest aims to meet local social, household, and environmental needs and to favour local economic development through the sustainable utilisation of forests. The Working for Water initiative (mentioned in Chapter 2.3 on Freshwater; *see also Box 2.25* in Chapter 2.9), which aims to control invading alien plant species to improve the long-term supply of ecosystem services, also forms part of this strategy.

Energy trading through improved regional grids would possibly present opportunities for South Africa to import electricity via hydropower produced in the Zambezi basin, as well as to export coal-fired power to other countries (van den Bovenkamp 2002) in addition to Lesotho. Participation by South Africa and other countries in the region in international emissions trading as stipulated by climate change protocols could also shift the energy balance significantly in the future.

Box 2.13 The Nuclear Energy Debate

Nuclear energy in the Gariep basin has received a large amount of attention due to the controversial development of the Pebble Bed Modular Reactor (PBMR). Developed for the parastatal utility Eskom, the PBMR is a high-temperature helium gas-cooled nuclear reactor that is seen as a practical and cost-efficient form of nuclear power generation. Advocates of the PBMR technology have hailed it as a “new sustainable clean source of energy” that is “non-fossil, non-carbon, and non-air-polluting” and can meet the energy needs of South Africa over the long term. The modular reactors can be built in close proximity to demand centres, providing there is an adequate water supply for cooling. This is particularly appealing in the parts of the Gariep basin that are far from the coal generation plants in Mpumalanga Province and currently pay high transmission costs for power.

Opposition to the development of the PBMR is fierce, due to its negative social, economic, and environmental facets (see Earth Life’s webpage: http://www.earthlife.org.za). One problem with nuclear energy is that while the nuclear power plant itself may be non-fossil, non-carbon, and non-air polluting, the fuel’s lifecycle includes the mining and refining of uranium, which emits high levels of carbon and can cause long-lasting damage to aquifers and soils. In comparison to renewable energy, energy generated from nuclear power releases four to five times more CO_2 per unit of energy produced when the entire nuclear fuel cycle is taken into account. There is also concern regarding the storage of nuclear waste and the true environmental and financial costs of decommissioning the plant at the end of the project’s lifetime. (For a full discussion of the nuclear fuel cycle see the World Nuclear Association’s webpage http://world-nuclear.org).

Members of the American Physical Society (APS) have suggested the possibility of a graphite fire similar to that in Chernobyl in 1986. Despite this, proponents of PBMR have proposed a reduction in the confinement of the reactor and the emergency planning zone from 16 kilometres to 400 metres.

A number of alternatives to nuclear energy exist in the Gariep basin. There is large potential in the western regions for wind generation, which is truly non-fossil, non-carbon, and non-air polluting. Wind power creates ten times as many jobs as nuclear power and the manufacture and assembly costs can be recovered in two to three months of operation. While the implementation of PBMR needs further consideration, the social, economic, and environmental costs of nuclear power in the long term and the availability of alternative sources of energy that exist need to be considered thoroughly. A recent South African Royal Society report (Sellschop *et al*. 2003) provides a scientific perspective on this debate.

Box 2.14 Energy and Communities

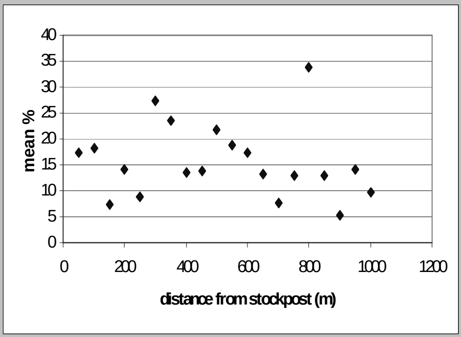
At the local level, the rural nature of all three sites means that households are dependent upon biomass fuels as their primary energy source. However, because of differing natural abundance of woody biomass, and contrasting human population pressures, energy availability and security differs between the three sites. At the Lesotho site, the forest cover is very limited, and hence the primary sources of biomass fuel are dwarf shrubs (*Chrysocoma ciliata, Euryops evansii, Inulanthera calva,* and *Helichrysum* spp.), exotic trees, and cow dung. Households without livestock may assist owning households to collect dung from kraals and shape it into 'bricks.' In return for their labour, the assisting household will receive a portion of the dung 'bricks' to use as fuel. Dung is a preferred source of fuel and burns more evenly and longer than do the shrubs. Some households harvest wood from the small pockets of indigenous forest. A key species is *Leucosidea serciea*. Local perceptions are that there has been little change in the abundance of trees and shrubs over the last few decades. However, escalating stock theft has impacted on dung as a fuel resource. Households that lose many animals to theft experience not only the hardship from the direct loss of animals, but also the loss of ready access to their primary energy source.

In the Fish River up to 70 percent of households use fuelwood for cooking, supplemented by paraffin. Up to two dozen species are used. Preferred species are *Acacia karroo*, *Maytenus undata*, *Pappea capensis*, *Ptaeroxylon obliquum* and *Schotia afra*, with preferences influenced by the species' rate of combustion, calorific value per unit biomass, and amount of smoke produced. Mean household use is approximately 2 500 to 3 000 kg per year. There is a perception of decreasing supplies, as people have to walk increasingly further to obtain adequate supplies of some species. Whilst deadwood is the favoured source, chopping of livewood occurs regularly because of a shortage of deadwood, thereby potentially compromising ecosystem integrity and human well-being. Some households cut wood to sell. Very few trees are maintained in residential areas or arable fields. Some regeneration, especially of *Acacia karroo*, is visible on abandoned lands.

In contrast, availability in Richtersveld is high because of the low human population densities and the high productivity of the Gariep floodplain. Fuelwood is the primary energy source for the Richtersveld National Park pastoralists. Currently levels of harvesting appear sustainable, with collecting confined to deadwood collected in the vicinity of temporary stockposts along the riparian fringe of the Gariep River (Figure a, below) (Shackleton *et al*. 2003b). There is an abundance of deadwood even of key species in the riparian fringe, which is the main harvesting area. Principal and preferred species are *Euclea pseudobenus* and *Ziziphus mucronata*. During the last ten years or longer, respondents felt that there was sufficient wood for their needs, and that there had been no change in availability.

In contrast, on the Namibian side of the river, fuelwood stocks are declining with increased human settlements in association with mining and grape farming (Stewart 2003). Fuelwood shortages affect the well-being of local people: trees are scarcer closer to villages (Figure b) and people walk far to obtain an adequate supply.

(a)



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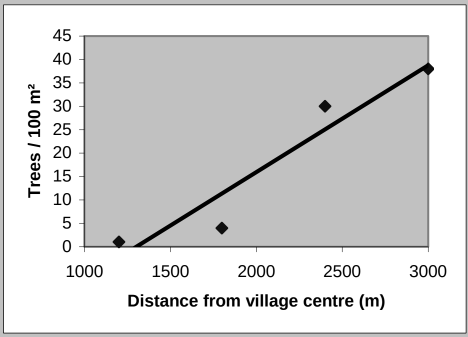


Figure (a): Percentage dead wood on preferred fuelwood trees in relation to distance from stock posts in Richtersveld National Park.

Figure (b): Relationship between tree density and distance from the village centre at Pikoli, Great Fish River Valley.

SOCIAL, BEHAVIOURAL, AND COGNITIVE RESPONSES

Tremendous potential exists to improve energy services through the realm of behavioural change, particularly as more people are expected to lead increasingly energy-intensive lifestyles in the Gariep basin. Demand-side strategies that focus on energy-efficient and energy-saving practices need more encouragement in the region. Efforts to lead initiatives in these areas should come from both the private and public sectors, including Eskom, who would stand to benefit from the potentially large cost-savings. Interestingly, while current debate attends the issue of nuclear power as an alternative to coal-based electricity, other energy sources that would also benefit from such deliberation and exposure have not merited the same attention.

2.6 Mineral Services

While minerals are considered a natural resource, they are not readily characterized as an ecosystem service, possibly due to their location underground and the highly visible ecological destruction that results from extracting them. However, the historical and current prominence of mining in the Gariep basin, the recent shift in focus to more sustainable mining practices, and the links between mining and other ecosystem services merit a place in this assessment. The important role mining plays in the local economy also means that it features significantly, in ways both positive and negative, in the constituents of human well-being in the basin.

Some one-third of the gold ever mined worldwide comes from the deposits of the Witwatersrand conglomerate reefs near Johannesburg (Sampat 2003). South Africa leads the world's production of numerous minerals, including gold, alumino-silicates, chrome ore, ferrochrome, platinum group metals (PGMs), vanadium, and vermiculite, but it is gold, diamonds, coal, and platinum production that are the backbone of the industry (African Development Bank 1993, COSATU/NUM 2001, Makwinzha *et al.* 2001). The bulk of this production occurs in the Gariep basin (Figure 2.22) (Hoadley *et al.* 2002). Mining contributes significantly to the South African economy. It provides 8.1 percent of its total GDP, as well as employment, infrastructure development, secondary industry development, export earnings - of which mining and minerals account for some 30 percent (Eskom 2003) - and gross fixed capital formation (10.7 percent) (African Development Bank 1993, Granville 2001, Makwinzha *et al.* 2001, Economic Advisory Unit of the Chamber of Mines 2002). Lesotho's total mineral production, mainly kimberlite diamonds, earns a comparatively modest US$ 0.5 million per annum (Lebesa 2003), but the South African mines have been a major source of employment for Lesotho.

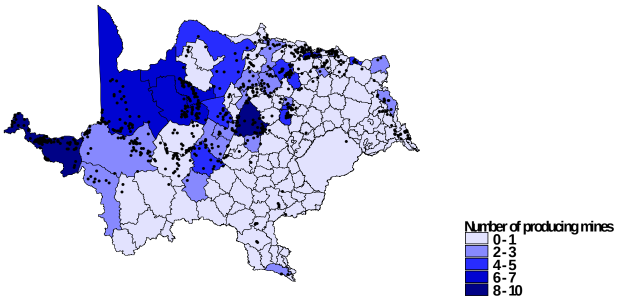


Figure 2.22 Number of actively producing mines per district. Exploited mineral deposits are indicated with black points.

The last few decades have been volatile ones for the South African mining industry. In the early 1990s, the industry stepped into the global business community after years of isolation imposed by apartheid sanctions. By the end of the decade, however, world prices for gold and other metals declined sharply, causing a reduction in operations and workforces. A corporate restructuring of the industry followed

(Makwinzha *et al.* 2001) along with a recognition that the survival of the industry would depend on changes in productivity and profitability (Granville 2001).

Despite the generation of considerable wealth by the industry, the majority of South Africans still live in poverty (COSATU/NUM 2001). Consequently, with international, national, regional, and local pressures, there has been a shift in the focus of the industry to improve the relationships between major and minor stakeholders, to encourage development, education and training, address safety needs and the issue of HIV/AIDS (Elias and Taylor 2001), and to improve environmental management. One objective of South Africa's Reconstruction and Development Programme (RDP) is to use mining as a vehicle to expand entrepreneurial development, black empowerment, and to stimulate employment and growth (Makwinzha *et al.* 2001).

Demand

The South African mineral industry is largely export-orientated, with a small domestic market for mineral commodities (Granville 2001, Makwinzha *et al.* 2001, Chamber of Mines 2002). It is therefore directly impacted upon by world trends and events such as apartheid sanctions in the 1980s, the Asian financial crisis in 1997, and the September 11 attacks in the USA in 2001 (Granville 2001), as well as swings in global markets. The contribution of mining as a proportion of GDP in South Africa peaked in 1980 due to high gold prices, but there has been a steep decline ever since. This is due to the contraction of the gold mining industry, weak commodity prices, increasing labour costs, decreased government revenue, and increased capital costs (African Development Bank 1993, Granville 2001, Makwinzha *et al.* 2001, Hoadley *et al.* 2002). The impacts have been felt widely, as evidenced by the economic decay of former mining towns and the loss of jobs by thousands of mineworkers.

However, the reduced dependency on gold in South Africa's total mineral sales, the long-term growth of coal, PGMs, and chrome and the prospects for further growth of non-gold minerals may halt a further decline in the role of mineral industries in the economy (Granville 2001, Hoadley *et al.* 2002). If income and employment generated in the basin through mining activities are an indication, then the mineral commodities most in demand are diamonds, gold, or coal, indicated by the municipalities with the highest levels of gross geographic product (GGP) from mining (Figure 2.23a) and employment in the mining industry (Figure 2.23b). Although only 3.6 percent of the Gariep basin's population is employed in the mining industry, many millions of people (including migrant labourers from Lesotho, Mozambique, and Swaziland, employees of secondary industries and their dependants) rely heavily on the mining industry for their livelihoods (Granville 2001, Makwinzha *et al.* 2001).

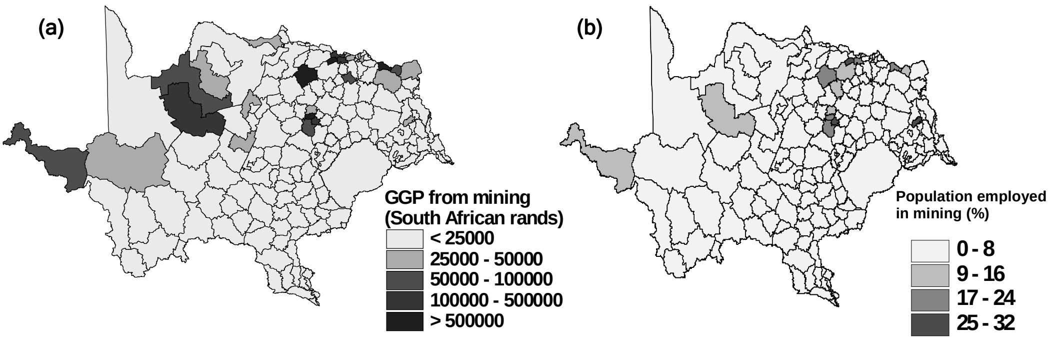


Figure 2.23 (a) Gross geographic product (GGP) per municipality earned by mining, in South African Rands; (b) Population employed in mining industry as a percentage of the Gariep basin's total population. *Source:* MDB 2001.

In terms of small-scale mining, current bias and opportunities appear to be in gold, diamonds, coal, industrial minerals, and minerals derived from pegmatite and construction materials (DME 2002, Mutemeri and Peterson 2002). In Lesotho, small-scale mining employs about 300 people, mainly in the quarrying of industrial minerals like clay, dolerite, sandstone, and river sand (Lebesa 2003). Despite the small scale of these operations, they can be surprisingly persistent, cause considerable surface disturbance, and are frequently not required to rehabilitate their operations to the same extent as corporate mining institutions. This is a classic example of landscape deterioration "by a thousand cuts," and the inability of authorities to regulate micro-industries adequately.

Access

New legislation governing access to mineral and mining rights has been passed since the restrictive policies of the apartheid government were lifted in South Africa in 1994 *(see Box 2.15)*. This is intended to shift the domination of the industry from the large mining houses to a mix of operations that includes a larger number of smaller-scale mines. South Africa's small-scale mining sector has been historically inhibited by these large mines, due to uneven access to minerals, a poor support system, the large development capital required to comply with national environmental, health, and safety standards, the lack of an appropriate institutional and legislative framework, and poor knowledge of project planning (Granville 2001). During the last ten years, more direct access to the region's mineral resources for the people living in the region has been promoted by nationalisation of mineral resources, the move towards 'people-centred' mining, sustainable and rural development programs, and increased beneficiation of minerals (Hoadley *et al*. 2002). These all present opportunities to increase employment, to promote a more equitable pattern of access to minerals, as well as to increase the indirect contributions of the mineral sector to the economy (Granville 2001). However, the environmental effects of these small-scale activities need careful regulation. Small-scale quartzite mining in the Bronberg region of Gauteng Province, along with urban development, is believed to have severe impacts on the sand-dwelling Juliana's golden mole *(Neamblysomus julianae)* (Maree *et al*. 2003).

Box 2.15 Legislation Promoting Change in the South African Mining Industry

- **Mineral and Petroleum Resources Development Bill (2002)**
  - Replaces the Diamonds Act (1986) and Minerals Act (1991) providing "for the recognition of the state as the custodian of the nation's mineral resources and for the development of the mineral wealth to its full potential" (Makwinzha *et al*. 2001). The main objectives are to redress past imbalances by promoting historically disadvantaged groups in the mining industry, focusing on vesting all mineral rights with the state, promoting the small-scale mining sector through new explorations, site development and creation of a stable economic environment. Keys to the transformation of the mineral industry are the social upliftment of communities impacted by mining operations, attracting investment and securing tenure, while making "changes with minimal disruption to mining industry and trust in SA industry" (Granville 2001).
  - Facilitates the Mine Health and Safety Act and the National Environmental Management Act.
- **Mine Health and Safety Act (1996)**
  - Provides the basis to protect the health and safety of persons involved in mining, to identify and eliminate hazards. Provides monitoring, enforcement, investigations, and inquiries to improve health and safety on mines, as well as promoting training, co-operation, and consultation on these issues in the mining industry between the state, employers, employees, and their representatives (see *http://www.acts.co.za/MHS/*, Makwinzha *et al*. 2001, Chamber of Mines annual report 2002).
- **National Environmental Management Act (1998)**
  - The South African Constitution (Section 24) specifies that "everyone has the right to an environment that is not harmful to their health or well-being" and for legislation and measures to guarantee that environment (South African constitution, Chapter 2: Bill of Rights, Section 24: Environment http://www.concourt.gov.za/constitution/const02.html#24).
  - Requires approved Environmental Management Programme Report (EMPR), (Granville 2001, Chamber of Mines annual report 2002) encouraging community participation in environmental management, a risk-averse approach, the "polluter-pays" principle, and integrated environmental management (Granville 2001).

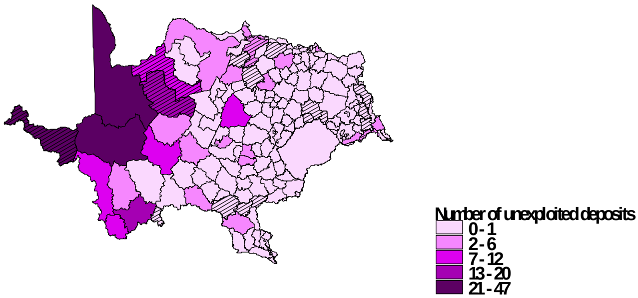


Figure 2.24 Number of unexploited deposits per municipality. Shaded municipalities have been identified for integrated rural development strategy nodes and potential poverty alleviation programs.

New government policies, the National Small-Scale Mining Development Framework, and recent domestic and foreign mineral investments all aim to develop and expand new mining activities and to couple these ventures with appropriate and integrated rural development programs. Their objective is to continue promoting the beneficiation derived from mineral deposits, especially those more suitable for small- or medium-scale mining operations (Granville 2001, Makwinzha *et al.* 2001, Hoadley *et al.* 2002, Mutemeri and Peterson 2002). The National Steering Committee of Service Providers to Small Scale Mining Industry (NSC) has identified deposits suitable for sustainable and integrated rural development initiatives. Additional unexploited mineral resources are scattered across the basin (Figure 2.24), while the potential also exists to discover new sites (Drechsler 2001, Makwinzha *et al.* 2001). The Free State, Northern Cape, and North West Provinces have the highest concentrations of active small-scale miners in the basin (Drechsler 2001). Within the Northern Cape, where the highest number of unexploited deposits lie, Richtersveld communities recently claimed a rich diamond-bearing area from the government as part of the national land restitution process.

Drivers of Change in Mineral Services

While in the past, both the benefits of mining and its impacts were largely the result of global forces and the practices of major mining corporations, much of the change in the sector is now being driven at the national scale. The new government policies designed to steer the growth of the industry, to promote private enterprise within a free-market system, and to increase attraction of foreign investment may precipitate much of the future development of the basin's mineral services (Granville 2001, Makwinzha *et al.* 2001). Policies aim to improve labour relations and rights, ownership issues, capital gains tax, black economic empowerment, environmental management, equity, and the growth and advancement of mineral beneficiation (DME 2002, Hoadley *et al.* 2002). At the same time, South Africa's entry into a global market is driving its move towards production technologies that require more educated, skilled labour in order to maintain its competitive position in the industry, continue to attract investment, and curb the effects of falling commodity prices, higher labour costs, and local ore depletion (Granville 2001).

There is now increasing emphasis around the world on alleviating dependence on minerals and making extraction of minerals more sustainable. In response to this emphasis, mining companies themselves have initiated efforts to research ways to make their operations more sustainable, with the Minerals and Sustainable Development Project being one example (Sampat 2003). The African Initiative on Mining, Environment, and Society (AIMES) of the Third World Network is a forum to unite civil society organizations that advocate mining issues in Africa.

Response Options for Managing Mineral Services

MINIMIZING IMPACTS OF MINERAL SERVICES ON ECOSYSTEMS

Interventions that reduce impacts of mineral extraction on ecosystems are certainly possible. Reclamation and rehabilitation of old mine dumps as well as minimising mining waste and pollution in current operations are important responses directed at managing the resource itself. Such responses may be costly and frequently need to be formalised in policies before they are adhered to. The adoption of sustainable and sensible extraction techniques is particularly important in the small- and medium-scale mining context where environmental integrity and poverty alleviation are closely interlinked *(see Box 2.16)*.

Box 2.16 Mining and Human Well-Being

The impacts of mineral extraction on health can be severe for communities near mining operations as well as ecosystems that they depend on. Asbestos pollution in particular has had devastating consequences for impoverished people in the Kuruman and Prieska areas, where entire school grounds are built on asbestos dumps, exposing those on the premises to air- and water-borne asbestos pollution. Rivers located near dumps act as conduits for secondary asbestos pollution, as fibres tend to clump along the banks and in dried-out riverbeds (Felix 1991).

Mineral services have the potential to reduce poverty and develop the economy through community-based projects aimed at building capacity and management skills in mining. These projects should focus on more effectively producing derived mineral commodities in a sustainable and diversified manner (Labonne 2002). However, development in the form of small-scale and particularly artisinal mining can, like large-scale mining, be economically, environmentally, and socially destructive unless properly organized (Granville 2001, Labonne 2002). For small-scale mining to successfully alleviate poverty and empower local communities, education about the importance of maintaining health, safety, and environmental standards and monitoring frameworks will be critical. So far, artisinal mining has usually not maintained these standards (Granville 2001). Large mining corporations could help with capacity building of inexperienced operators.

Even though the impact of mining can be alleviated by the responsible development of environmental guidelines, legislation, management, and development policies, the mining sector will inevitably continue to impact the environment by generating pollution and waste and consuming large amounts of water and energy. The export dependency of the sector also means that potential benefits of mineral services to human well-being are vulnerable to changes in global demand and laws affecting labour, safety, and environmental practices (Granville 2001).

One positive link between mineral services and human well-being concerns the mining industry's involvement in addressing the HIV/AIDS epidemic, which includes the enforcement of transparency about the disease and reducing discrimination in the workplace, and in some cases, the provision of anti-retroviral drugs to employees. Every mining company in South Africa is expected to have a sound policy and programme to deal with HIV/AIDS in place by 2004.

TECHNOLOGICAL INTERVENTIONS

Technological advances in the mineral industry have worked to reduce costs, extend the range of recoverable ores, improve productivity and safety, and decrease waste and pollution associated with mining activities and operations. While this has led to a decrease in demand for unskilled labour in previously labour-intensive mining operations, such technological innovation and development holds opportunities to continue extending the viability of mining for certain commodities, to slow the decline of others, and to continue improving health, safety, and productivity on mines (Granville 2001). As a result of such technological advancement and innovation, the few more highly-trained mine workers are able to live with their families near the mines more permanently and are slowly replacing the many migrant labourers of the past (Granville 2001). In the small-scale mining sector, improvements in production and extraction techniques are still necessary to lessen impacts on ecosystems.

Improvements in the application of information technology to mining – as well as information sharing - are increasingly important as more stakeholders enter the industry. The South African Council of

Geosciences, a parastatal organisation formed in 1993, produces maps and information regarding mineral deposits, prospects, and showings, including an electronic metallogenic map database.

The development of technologies for the beneficiation of minerals within South Africa is being addressed in a bill aimed at the growth and advancement of mineral beneficiation (Makwinzha *et al.* 2001). This is in response to the unnecessary export of raw mineral resources when possibly more foreign exchange could be earned by beneficiation, particularly pertinent if it can be utilised in the small-scale mining sector.

LEGAL, INSTIUTIONAL, AND ECONOMIC POLICIES

In response to the historical monopoly of the mineral industry by a few large companies and past racial discrimination, the move to state ownership of mineral resources in South Africa in 2002 is set to transform the mining industry. The Mineral and Petroleum Resources Development (MPRD) Bill places particular emphasis on the participation of previously disadvantaged persons in the mineral industry and the benefits they can receive (Chamber of Mines 2002). State ownership of resources will enable investment in new explorations, site development, and promotion of the small-scale mining sector, while protecting and promoting mining investment and assuring tenure of existing rights-holders. It also emphasises job creation and social development, provision of more funds to professional and special services such as rehabilitation of derelict mine dumps and implementation of environmental management programs, and social upliftment of communities affected by mining (Makwinzha *et al.* 2001, DME 2002, Chamber of Mines 2002).

The MPRD also calls for a broad-based socioeconomic empowerment charter "encouraging black economic empowerment and transformation at the tiers of ownership, management, skills development, employment equity, procurement and rural development". In order to facilitate the development of the small-scale mining sector, the Department of Minerals and Energy (DME) established the National Steering Committee of Service Providers to the Small-Scale Mining Sector (NSC). It aims to provide service delivery to the small-scale mining sector, and translate artisinal mining operations into operations that are more sustainable environmentally and economically (Makwinzha *et al.* 2001).

The MPRD Bill, by adopting the principles of the National Environmental Management Act (1998), must conform to national environmental policy and standards, which requires approval of environmental management programmes for prospecting organizations and mines (Chamber of Mines 2002). This government policy on environmental management takes a risk-averse approach and adopts the "polluter-pays" principle (Chamber of Mines 2002). The MPRD Bill requires that specific measures be taken to remedy impacts during and after the life of a mine (Chamber of Mines 2002). Mine health and safety legislation is relatively satisfactory but the implementation of this legislation still needs to be strengthened (Chamber of Mines 2002). The capacity of the Department of Minerals and Energy to utilise these legal instruments effectively is now being put to the test.

SOCIAL, BEHAVIOURAL, AND COGNITIVE RESPONSES

As minerals are a non-renewable service, their abundance will eventually decrease while the cost of extraction will increase. This problem is not unique to the Gariep basin, but because of South Africa's leadership in world mineral production, its effects may be more pronounced than in regions of the world with less dependence on mining. In truth, "dependence" on mining is fuelled to a great degree by the value that societies around the world place on mineral products and metals, and the ability of the mining industry to wield political power to keep these values high. Thus, a change in values could have significant consequences for this sector, but in the short term, it is not likely that the lustre of mineral products will diminish.

Greater societal awareness and environmental education have precipitated closer attendance by the public to mining activities and have prompted them to demand accountability. The mining industry has responded to some of these societal concerns, pledging to be more conscious of the environment and to act on its responsibilities to communities surrounding operations by lending support to small-scale mining and providing or subsidizing facilities such as schools and hospitals (Chamber of Mines 2002). Despite this trend and the fact that international interests and national policies encourage such involvement, it is not yet systematic (Chamber of Mines 2002).

2.7 Air Quality

Air quality and to ecosystems are linked in several key ways. Ecosystems provide a range of air quality and climate services; among them are sinks for pollution, atmospheric cleansing, atmospheric chemistry, and nutrient redistribution, all vital to human well-being and to many ecosystem components and processes. However, land-use activities that transform ecosystems, usually to obtain their services, alter air quality as well as climate. Land cover and land use are the direct drivers of air quality. Both natural (for example, rainfall patterns and soil fertility) and anthropogenic drivers (such as socioeconomic activities) determine largely the type of land uses occurring in specific areas. The variety of land cover types in the Gariep basin − ranging from shrubland, grassland, bushland, and cultivated areas to large residential and commercial areas (urban and rural) − and land uses, which include the combustion of biofuels, fertilizer use, and mining, quarrying, and manufacturing industries - affect air quality to varying degrees.

The main air pollutants include greenhouse gases such as (in order of magnitude) carbon dioxide (CO_2), carbon monoxide (CO), nitric oxides (NO_x), sulphur dioxide (SO_2), Volatile Organic Carbon (VOC) emissions, methane (CH_4), and nitrous oxide (N_2O). Carbon dioxide is the most important gas emitted in this area based on total amounts emitted on a yearly basis. While the African continent's contribution to global CO_2 emissions is only about 3.5 percent, South Africa is the single largest contributor to total CO_2 emissions in Africa (more than 40 percent), ranking it as the 15th largest emitter of greenhouse gases in the world (UNEP 2000). Most of these emissions in South Africa occur in the Gariep basin area.

Transport is a principal activity that contributes to air pollution in the basin, facilitated by the excellent road network throughout most of the Gariep basin. The transport sector (including airplanes, ships, trains as well as road vehicles) contributes more than 40 percent of South Africa's total nitric oxide and volatile organic carbon emissions. Road vehicles contribute the most to the total carbon dioxide, nitric oxide, and volatile organic carbon emissions from the transport sector (94 percent, 53 percent, and 89 percent respectively). Road vehicles also contribute to lead emissions, especially in urban areas. Veld fires, coal-fired power stations, manufacturing industries, mining, agriculture, as well as the burning of fuelwood and fossil fuels such as domestic coal, liquid petroleum gas, dung, and paraffin for household energy purposes cause air pollution (DEAT 1999).

Agricultural activities are the main contributors of methane and nitrous oxide emissions in the Gariep basin. Activities include farming with domestic livestock and using nitrogen fertilisers for crop agriculture. The methane emissions from manure handling of animals in feedlots are larger than from manure deposited on a rangeland, due to the anaerobic conditions typically associated with the former. Livestock raising technology is changing towards the greater use of feedlots for animal fattening.

The less industrialised parts of the Gariep basin have some of the lowest emissions in the country (as indicated by CO_2 and SO_2 emissions; see Figures 2.25a and b), while the highest emissions generally occur in urban, industrialised areas. Stable layers of air are frequent, persistent, and spatially continuous over southern Africa during the winter and summer seasons. Fine weather conditions over most of the Gariep basin area occur during most of the year and aerosols, trace gases, and other atmospheric material are trapped between the layers in the stable troposphere. Material trapped near the top of the inversion layer can be transported away from the source area over distances varying from 300 to 500 km per night. Emissions that occur in the Gariep basin are transported across local and national boundaries, and conversely, the Gariep basin is influenced by emissions that occur outside of its boundaries. Sulphur dioxide emissions remain relatively stable in the more industrialised parts of the Gariep basin, mainly because of the management of coal quality, greater efficiencies achieved in the combustion process, and a small degree of sulphur dioxide removal from the stack emissions.

An indicator of the health implications of air pollutants is the number of times when the guideline value has been exceeded over a given time period (long-term or short-term). Although average concentrations of the criteria pollutants such as sulphur dioxide, nitric oxide, tropospheric ozone, and respirable particulate matter fall within the South African as well as World Health Organization (WHO) guidelines, which tend to be more strict *(see Box 2.17)*, these are exceeded for certain periods of time at a household level, potentially affecting vulnerable individuals. Sulphur dioxide concentrations measured in some households exceeded international health guidelines by more than 10 times over a 24-hour period

(DEAT 1999). Concentrations of sulphur dioxide that are unacceptably high for humans are also likely to be damaging to plants, especially sensitive ones. Sulphur dioxide and nitric oxide are deposited in both dry and wet forms as acids, which, by corroding and changing soil and water acidity, may have negative long-term effects for ecosystem health. Sulphur dioxide has on occasion exceeded limits for short periods in Gauteng Province, but no conclusive evidence exists that these spurts have caused chronic damage to vegetation. Acidification of surface water also makes it less suitable for drinking, irrigation, and industrial uses (DEAT 1999).

Volatile organic carbon is not toxic itself, but combines with nitric oxide and carbon monoxide, in the presence of sunlight, to form "photochemical smog," which contains ozone and other gases toxic to plants and animals. This is particularly a problem in urban areas in the Gariep basin, mainly Gauteng. In rural areas, however, indoor air quality presents a problem in poorly ventilated housing where coal, dung or wood is burned in open hearths without chimneys (DEAT 1999). Data gathered for many sites in urban areas in the Gariep basin, especially those near industrial zones, show that the concentration of smoke particles in the air is often higher than the annual guideline (Van Zyl and Kruger 1998).

Particulate matter is also emitted in large amounts, especially in informal settlement areas where households are mainly dependent on the burning of fuelwood, dung, paraffin, and domestic coal for energy purposes. Emissions of respirable particulate matter together with emissions of carbon monoxide pose a serious health threat to people inhabiting poorly ventilated dwellings, especially the elderly, infants, and individuals with compromised immune systems, such as those suffering from HIV/AIDS. Since the energy sector is a major driver of air quality problems, a range of responses lie within the domains of energy policy and technology, discussed in Chapter 2.5. Of note is the introduction of a draft National Environmental Management: Air Quality Bill in 2003 to replace the Atmospheric Pollution Prevention Act of 1965, which was not able to involve provincial and local government effectively, lacked compliance and enforcement mechanisms, and did not foster transparent decision-making. The draft bill is far more comprehensive, enabling the establishment of national standards and proposing a regulatory framework for an air quality management planning and reporting regime and instruments to curb air pollution (DEAT 2003).

Box 2.17 How do South Africa's Air Quality Guidelines Measure up to the WHO's?

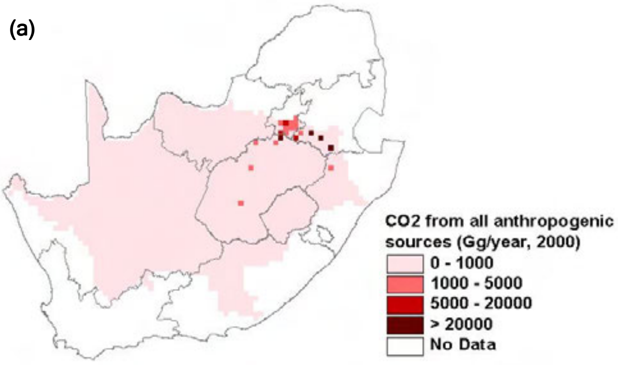
The following table provides a comparison of the WHO and South African guidelines, based on the Department of Environmental Affairs and Tourism (DEAT) recommendations, for some common air pollutants. While the averaging times for these guidelines vary, in most cases, South Africa's threshold guidelines are higher than the WHO's. The guidelines for pollutants not listed here must fall within threshold limit values recommended by the American Conference of Industrial and Governmental hygienists. A new bill introduced in South Africa in 2003 intends to catalyse the establishment of new guidelines.

It should be borne in mind that this table reflects averages only, and although average concentrations in the Gariep basin do normally fall within the South African as well as WHO guidelines, at household levels they are often exceeded in some areas.

Table A WHO and South African guideline values for ambient air quality.

Substance (Gaseous)	**Averaging Time**	**Ambient Air Quality Standards, in parts per billion (ppb)**	
Guidelines		WHO	South Africa
Nitrogen Dioxide	1 Hour	106	200
Nitrogen Dioxide	Annual	21	50
Ozone	1 Hour	-	120
Ozone	8 hour	61	-
Sulphur Dioxide	24 hour	48	100
Sulphur Dioxide	Annual	19	30
Substance (in suspended particulate matter)			
PM10	Annual	50	60
Lead (pb)	1 Month	-	2.5
Lead (pb)	Annual	0.5	-

(a)



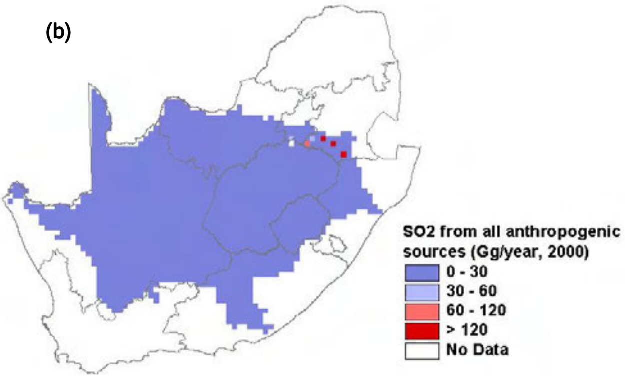


Figure 2.25 (a) Carbon dioxide emissions, in Gg CO_2 per 20 km^2 for the year 2000. One Gg equals one kiloton or $1x10^9$ grams; (b) Sulphur dioxide emissions, in Gg SO_2 per 20 km^2 for the year 2000. *Source:* CSIR 2003. *Notes:* Areas that are darkly coloured are most likely associated with industrial areas (e.g. SASOL, Eskom, metallurgical industries) that burn coal or diesel (with relatively high S contents). Although most of the industries do try to remove the S, SO_2 emissions persist, especially from the transport sector. In these areas, SO_2 is very likely to exceed the WHO guidelines, especially during winter, when there are low inversion layers as well as increased burning of domestic coal with high sulphur content.

2.8 Cultural Services

Many ecosystems in the Gariep basin have cultural significance, forming part of an individual, society's, or nation's identity. South Africa's Natural Heritage Act, as well as the World Heritage Convention, under which natural and cultural heritage sites have been established and afforded protection, recognise this formally. The uKhahlamba-Drakensberg Park, a World Heritage Site on the border between South Africa and Lesotho *(see Box 2.23)*, with its vast collection of San rock paintings, and the Cradle of Humankind site at Sterkfontein, near Johannesburg, are among the most well-known archaeological areas in the region.

While such heritage sites might be the most familiar icons of the cultural values of ecosystems and have garnered wide educational and tourism interest, numerous other, lesser-known cultural services exist, many of which do not occupy a physical place but are rather practices or traditions that are embedded in social customs. The cultures of many local people are interwoven with the ecosystems in which they live. Sacred pools and forests, taboos, rituals, belief systems, religion, and language centre around ecosystems and their services. People know that deteriorating ecosystems make them vulnerable, hence the current shift towards community-based natural resource management in many parts of the basin. Whether this shift will reap adequate benefits for ecosystems and people is yet unclear.

Local communities, and especially their older members, have considerable traditional ecological knowledge (Berkes and Folke 2002). This knowledge relates to ecosystem management (for example, maintaining sacred pools and forests), but also includes knowledge about medicinal plants and their properties. In the Fish River area, Xhosa tradition and identity is strongly founded on interactions with ancestors and the spiritual world *(see Box 2.18)*. In turn, there are strong links between the spiritual world and certain environmental features. Key among these are sacred pools, intact forests, medicinal plants, clan totems (usually specific animals), and ancestors' graves.

Land use pressures have posed threats to these sites in recent years, undermining cultural identity and spiritual harmony. Coupled with increasing urban contact, modernisation, and influences of other cultures, these pressures have made inroads into cultural beliefs and norms associated with use and abuse of landscapes. Much of the older generation perceives a decline in cultural identity and respect on behalf of the youth. In many instances, they use this to explain deterioration in the landscape, as the ancestors are believed to be disappointed or angry. A further threat to traditional knowledge stems from the loss of traditional intellectual property rights – particularly in the case of medicinal plants with pharmaceutical value − to more powerful forces who are able to patent this knowledge as their own (Downes 1996). However, with cooperation between communities, pharmaceutical companies, and research organizations, traditional ecological knowledge could contribute to rural poverty alleviation through profit-sharing agreements. Despite these threats, traditional knowledge, and associated cultural services and identities, have demonstrated a strong persistence (Hall and Fenelon 2004).

Importance of Scale in Assessing Cultural Services

Research on the values that some communities associate with ecosystems suggests that spatial relationships exist between the location of a community and the amount of value they perceive cultural services to have (Brown *et al.* 2002). This is related to the place-based theory (Norton and Hannon 1997) which maintains that human cultures place highest value on things that are closest to them in time and space. This appears to be is true for many communities, not only rural ones who maintain traditional customs.

Though it appears cultural services exist and have value in many places where people exist, the place-based theory would imply that an assessment of cultural services at a broad scale might underestimate the locally perceived values of such services. However, a broader-scale analysis enables a comparison of cultural services across local sites and the identification of general trends. Because cultural services may be distributed across large landscapes, it is imperative that these landscapes be managed for a variety of values, occurring at different intensities, over different scales of space and time (Brown *et al.* 2002). This requires an integrated social and biophysical science approach, as well as the recognition that communities themselves are heterogeneous. Both within and between communities, cultural values may interact in positive or negative ways.

For most rural people, cultural services are part of their daily reality, their livelihoods and identity. Some rural people define themselves by their connections to nature because their livelihoods depend upon it, and do not embrace nature only for particular rituals or ceremonies. Misunderstandings of the role of cultural services in rural livelihoods − including the romanticism sometimes perpetuated by distant western cultures − are a major challenge to appropriate recognition and management of cultural services.

Box 2.18 The Cultural Importance of Ecosystem Services to the amaXhosa People of the Eastern Cape

In the Great Fish River area, local Xhosa people place great cultural and utilitarian value on key resource patches such as mountains, forests in various stages of succession, and a variety of grazing lands. In many cases, the diversity of resource patches is the consequence of people interacting with the land, where, through a variety of induced disturbances these resource patches are created. The different types of resource patches provide a range of resources that satisfy villagers' basic needs. These include both practical, physical needs as well as cultural and spiritual needs.

Rituals and traditions are central to the culture and identity of Xhosa people. Key resource areas are fundamental to the performance of these rituals and include sacred pools, dense forests, and mountains. Each of these sites has particular rituals associated with it, with specific benefits. The most important of these sites are sacred pools. In the research area, these are typically places of still deep water, with water flowing above and below. They often have steep banks and are surrounded by particular species of trees and plants such as *Salix capensis*, which is regarded as the tree of the "river people", *Cyperus textiles,* and a variety of small plants and creepers such as *Tecomaria capensis*. The presence of these indicates the presence of the ancestors and the 'river people', mermaid-like creatures associated with the generation of water, rain, healing, and fertility of the land. These sites provide a place of direct communication with the spirit world where they can access blessing and health and provide thanks and veneration through the performance of particular traditions. They are therefore critical points in the landscape where culture in the form of traditions and connection with the ancestors is maintained.

Sacred pools also have a practical benefit, in that many people indicated that they never dry up. They consequently become very important water sources during times of severe drought. This relates to the many taboos associated with sacred pools where, for instance, the harvesting of medicinal and other useful plants surrounding a sacred pool is not allowed unless one is a diviner or *igqirha*. The vegetation surrounding sacred pools is therefore denser and provides a protective canopy, thus reducing the effect of evaporation.

The varieties of resource patches in the area are not only of cultural significance. They also supply over nine different types of building materials, more than forty medicinal plants, over ten species of fuelwood, a variety of cultural species, resources with an economic value such as prickly pear and aloe, game meat, honey, clean water, and forage of different densities, which obtain value at different times in the year and under different drought conditions. The table below summarises the results of a participatory ranking exercise for these resource types.

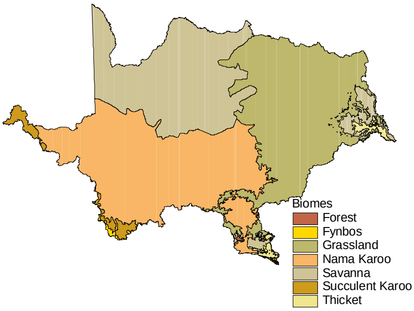
Ranking	Resource
1	Mountain water
2	Cultural species
3	Fuelwood
4	Livestock
5	Medicinal plants
6	Building materials
7	River water
8	Agricultural crops
9	imiFino (wild vegetables)
10	Honey
11	Wild fruits

Although the resource patches of dense vegetation and diversity have high environmental value, the villagers regard them as having limited utilitarian value. It is rather the disturbed forest patches and grazing lands that are of importance. However, the attachment of spiritual or cultural values to certain sites in the landscape places restrictions on harvesting resources − such as the taboos associated with sacred pools − and ensure that nodes of dense vegetation remain in the landscape. This could reflect the co-evolution of Xhosa people with their local environment, as these dense pockets of vegetation become important during times of crises, such as drought and fire.

2.9 Ecosystem Integrity

Box 2.19 Biodiversity of the Gariep in Summary

The Gariep contains all seven of South Africa's biomes, but is predominantly made up of the Savanna, Grasslands, and Nama Karoo biomes. These biomes are significantly different from one another in terms of their biodiversity composition, processes that threaten them, and conservation efforts. The table below contains a summary of the three major biomes and demonstrates the high numbers of species, including endemic and endangered species, recorded in the basin. The Grasslands biome is the most specious and threatened biome with most of the region's endemic and endangered species. The Savanna biome, the smallest of the three in the Gariep, is a species-rich biome with a fair number of endemic and endangered species. The Nama Karoo is a semi-arid biome with lower species richness but it contains substantial numbers of the region's endemic and endangered species.



Despite the fact that these biodiversity assets support the livelihoods of many South Africans and contribute to the economy, they are one of the most threatened in the world. South Africa contains the highest concentration of threatened plant taxa in the world (Cowling and Hilton-Taylor 1994) while 91 percent of the country falls within the UNCCD (1994) definition of "affected drylands". Land cover change is unevenly distributed in the basin with the Grasslands containing 28.77 percent transformed land, followed by the Savanna with 6.7 percent, and the Nama Karoo with only 1.48 percent. Invasions by alien species are another significant threat to the biodiversity of the Gariep basin. An estimated 8 percent of South Africa has been invaded by 161 alien plant species affecting all biomes in the region. Bush encroachment of indigenous plants affects over 33 percent of the basin, particularly the Grasslands.

*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)

Biome	Area (km^2)	*Species richness	**Endemic spp.	***Endangered spp.	ªProtected area	†Transformed area
Grasslands	215508.20	1377	144	112	2.7%	28.77%
Savanna	190645.90	1424	106	102	10.58%	6.7%
Nama Karoo	237147.45	979	99	73	1.28%	1.48%

Assessing Condition and Trends of Ecosystem Integrity

Ecosystem integrity refers to the ability of ecosystems to continue delivering the ecosystem services upon which human well-being depends *(Box 2.20)*. This is a complex issue to assess, and one for which no single proven method exists. Most assessments of ecosystem integrity to date have therefore focused on the condition and trends of one or more elements of a region's biodiversity as a proxy for ecosystem integrity. Biodiversity is an overarching term referring broadly to the variety of life on earth, and comprises a range of elements and concepts. Similar to freshwater, biodiversity is a crosscutting concept associated with different types of services. These include provisioning (in that biodiversity underpins the existence of a variety of species that have utilitarian value to people, such as for food or fuel), regulating (it helps to control climate or sequester carbon), supporting (it plays a role in soil formation and nutrient cycling), and cultural (it is attached to recreation opportunities, nature-based tourism, and sacred and aesthetic features).

SAfMA acknowledges biodiversity as a service, but also places biodiversity at a basic level depicted by the MA conceptual framework as the "life on earth" which underpins all ecosystem services. Although biodiversity may be directly linked to some services like fuelwood and medicine, its role is also far more fundamental in that it supports these services as well as most others. Biodiversity is linked to ecosystem services by the role it plays in governing ecosystem properties and processes (Ehrlich and Mooney 1983, Daily 1997, Naeem 2001, Loreau *et al.* 2002). Ultimately, all types of services are derived from ecosystem processes; the condition and trends of ecosystem services are inextricably linked to the condition and trends of ecosystems and their functions.

Biodiversity is a complex notion and therefore difficult to measure and assess in its entirety. Assessment includes measuring where biodiversity is, as well as identifying areas of endemism, rarity, and threat and how these all change over space and time. We can never directly observe or count all biodiversity in an area; thus, much use has been made of the hierarchical nature of biodiversity (Figure 2.26) and the fact that levels of the hierarchy might act as surrogates or substitute measures for other levels and therefore the entire hierarchy. It is assumed that to measure and assess the condition and trends of, for example, specific groups of species will indicate the condition and trends of all biodiversity in the region. This assumption, however remains largely unsupported and untested.

The hierarchy of biodiversity is organised from genes to ecosystems with several levels in between. The most common levels of measurement are the species and ecosystem levels, which are relatively easy to measure and at which data already exist in many regions of the world. The genetic level is the basic supporting level of the entire hierarchy; however, data on genetic composition are difficult and expensive to collect and are therefore not often employed in the measurement and assessment of biodiversity. The ability to measure biodiversity at levels between individual organisms and populations is also critical, as these are the levels that interact with the biophysical environment, and with each other, to produce the ecosystem services that humans both rely on and impact. Like the genetic level, these levels are difficult, costly, and time-consuming to measure, and are therefore largely data-poor.

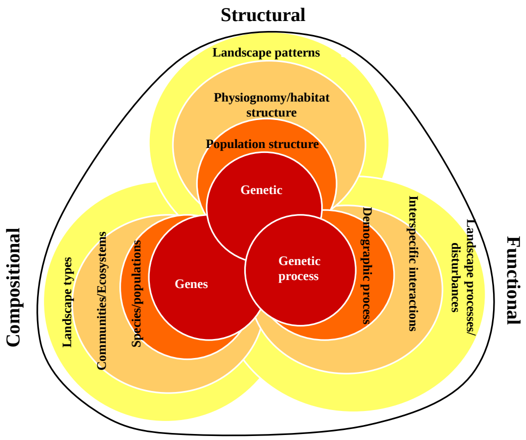


Figure 2.26 The nested hierarchy of biodiversity (Noss 1990).

Box 2.20 Key definitions

Ecosystem: A dynamic complex of plant, animal and micro-organism communities and their nonliving environment interacting as a functional unit *(Source:* United Nations 1992: Article 2).

Ecosystem Integrity: Ability of an ecosystem to provide services; more specifically, the maintenance of the structure and function of an ecosystem that enable service provision.

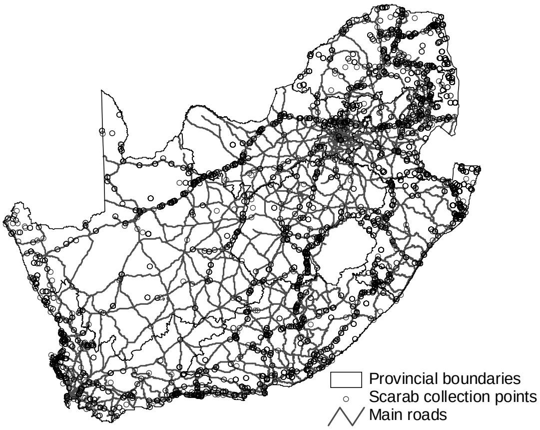
Biodiversity: (biological diversity) Overarching term referring broadly to the variety of life on earth, and comprises a range of components and concepts. While biodiversity is necessary for the delivery of all ecosystem services, it is not treated as a service itself within the MA.

Generally, species belonging to indicator taxa (groups that are well known and well surveyed) as well as endemic and threatened species (which are often most sensitive to ecosystem change) are commonly used measures to assess the condition of biodiversity in a region. More recently, collation of data on environmental variables and classifications of remotely-sensed imagery have resulted in several broad-scale measures such as vegetation types, ecosystems, and land classes. In principle, these can be used as surrogates of lower levels of biodiversity. Naturally, the appropriateness of any measure also depends on the scale at which the assessment takes place. Local-scale studies tend to use species inventories, while national and regional scales employ broad-scale measures like land classes due to biases and gaps in species data at this level.

There are mixed degrees of support for the assumptions of surrogacy. It is generally assumed that in measuring the composition and structure of biodiversity that the more data and levels of hierarchy assessed the more accurate and realistic the representation of biodiversity will be. However, the reality is that data are often only available for these surrogates. Therefore, we used surrogates in our assessment of biodiversity and ecosystem integrity, with a caveat that the results are limited because they are only representative of these elements and not of the entire regional biodiversity. In addition, as Figure 2.26 indicates, biodiversity also has a functional component (e.g. genetic mutations, population migrations, seed dispersal) that is thought to be related to the maintenance of the compositional and structural elements of biodiversity (e.g. species, land classes) as well as the ecosystem services under consideration. SAfMA is particularly interested in these functional aspects of biodiversity. There is, however, currently very little data on functional types or groups for an assessment at a basin scale. Biodiversity elements assessed in the Gariep are discussed below as well as the methods used to assess the elements, condition, and trends in ecosystem integrity.

Species

In this assessment of condition and trends of biodiversity in the Gariep basin, we relied heavily on species data, mostly for vertebrates. Species distribution databases at a broad scale are notoriously problematic due to sampling biases, unclear taxonomy, and a lack of data for the majority of the regions' species. We included distribution data for birds from the South African Bird Atlas Project (Harrison 1992), mammals from the Conservation Management and Assessment Program (Friedmann and Daily 2004), and butterflies, and scarabs from the Transvaal Museum, Northern Flagship Institute (Koch *et al.* 2000). At the time of this assessment, a frog atlas was being put together but was not available. The vertebrates are well-known and relatively well-sampled groups, while invertebrate data are very sparsely collected and reflect substantial sampling bias. Figure 2.27 illustrates the bias in collection effort for scarab beetles in South Africa. The collection points are concentrated along the road network, reflecting sampling effort rather than the actual distribution of scarab beetles in South Africa.



Plant species collected from across the whole of South Africa are kept in a significant database by the National Botanical Institute. However, previous attempts to use the data concluded that the nature of the database renders it almost impossible to use in an assessment because it focuses on many rare and unusual plants rather than on a representative sample. Some attempts have been made to refine the data for some regions of the country (Freitag *et al.* 1997, Reyers *et al.* 2000) and to use species of special concern. However, only now is there a national attempt to rationalise this database in the National Biodiversity Spatial Assessment. We thus relied mostly on bird and mammal data in this assessment.

These species of birds, mammals, and insects were used as indicator taxa; indicator taxa are well known and sampled groups of species whose distribution patterns and condition can be used to indicate patterns and conditions in other less well-sampled groups (Reyers *et al.* 2000). Data on endemism and threat were taken from various sources including Barnes (2000), Friedmann and Daily (2004), and expert opinion for the invertebrates.

These species distribution data were collected at a variety of scales ranging from point records with geographic coordinates (Figure 2.27) to grid cells of various sizes. The data were collated at the quarter-degree square (QDS) scale, which corresponds with the largest grid cell used for data collection. There are 1110 QDS in the Gariep basin, each with an area of approximately 625 square kilometres. We assessed the numbers of species, including endemic and threatened species, in each grid square in order to explore the spatial distribution of species diversity and threat in the region. Table 2.5 illustrates the species data used in the study.

Table 2.5 Description of the species data used in the study, including number of species, as well as the numbers of endemic and listed Red Data species per taxon. These latter categories show some overlap and thus species can fall into both categories.

Taxon	Number of species	Endemics	RDB
Birds	634	42	44
Butterflies	440	51	21
Mammals	188	20	24
Scarabs	258	65	37
Total	1520	178	126

Figure 2.28 illustrates the species richness per QDS for all taxa assessed. The east-west gradient in species richness is reflected in most taxa, which potentially reflects the moisture gradient in the region. The birds are a well-sampled taxa in this assessment and as such, their distribution patterns are a reliable indication of bird species richness within the Gariep. The butterflies are not well sampled in the region, but do show a concentration in the east. The mammals show a similar pattern. However, many of the mammals are constrained to or are only sampled in national parks. As such, their richness is often a reflection of the boundaries of protected areas such as the Kalahari Gemsbok National Park, a part of the Kgalagadi Transfrontier Conservation Area in the northwest of the basin. The scarab richness reflects the location of roads as is obvious from the linear nature of the grid cells with species records. Despite these shortcomings in the species data, we do form an idea that the eastern parts of the Gariep are richer in terms of species than the western parts.

Species richness, although an important measure of biodiversity in the region, provides very little information in terms of ecosystem integrity. The only way to use the data would be if a time series of species data per QDS existed (i.e. richness per QDS resampled every 10 years). This would provide trend data in species richness, which is helpful to infer integrity of various ecosystems. For example, species declines could be translated into decreases in integrity while increases in exotic or invasive species could be used to indicate decreases in integrity as well. Unfortunately, time series data for species are not available for this region for any of the taxa sampled, and thus species information has limited use in determining the ecosystem integrity of the region.

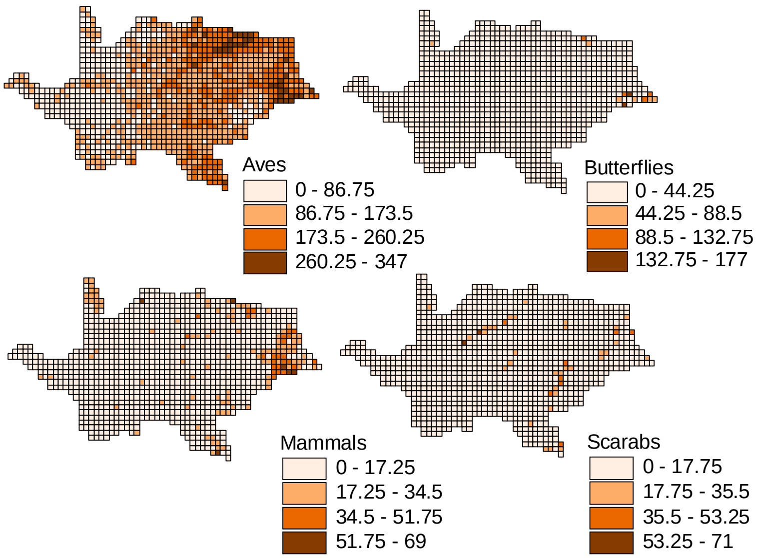


Figure 2.28 Numbers of species of each taxon per QDS in the Gariep basin. Insert on the next page shows the study region with protected areas in green, highlighting the Kalahari Gemsbok National Park, a part of the Kgalagadi Transfrontier Conservation Area.

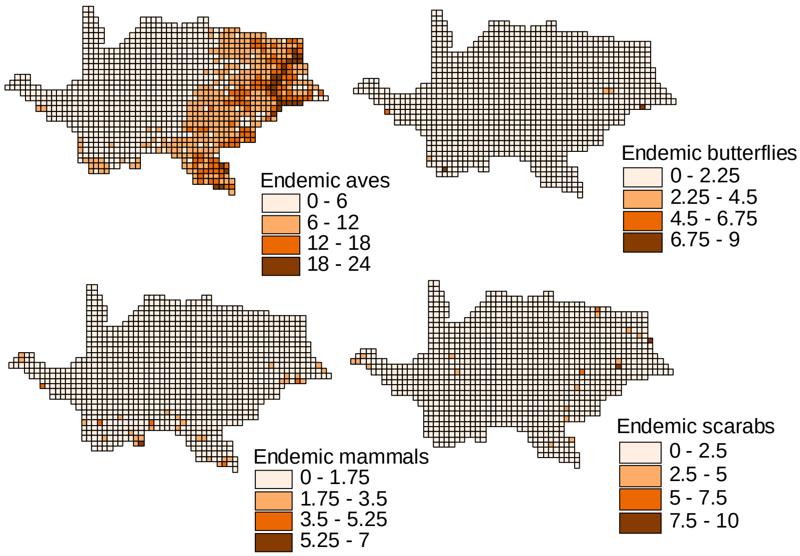


Figure 2.29 Numbers of endemic species of each taxon per QDS in the Gariep basin.

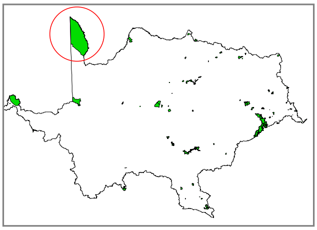


Figure 2.29 shows the numbers of endemic species per QDS for each taxon assessed. These figures reflect those in Figure 2.28, and because they have the same sampling problems, fall short as a measure of ecosystem integrity. Their only value is perhaps to illustrate regions of serious conservation concern, as they contain species not found outside of South Africa, and thus are important national priorities. The expected east-west gradient in richness is again obvious in the bird species. However, endemic species can often emphasise areas of importance not highlighted by richness patterns. Endemic species are useful to highlight biodiversity priorities, as these are often rare and unusual species occupying rare and unusual places (Reyers *et al.* 2000, Driver *et al.* 2003).

The final assessment of species distribution is illustrated in Figure 2.30 and shows the numbers of threatened species per QDS. These maps provide a first assessment of the ecological integrity of the region. The concentration of threatened species is often used to measure the condition of the biodiversity or ecosystem. The threatened species also appear to be concentrated in the east of the basin, particularly in the case of the birds. The invertebrate taxa have very few records for threatened species and as such are perhaps less useful for assessing ecological integrity. It is apparent that the patterns shown here are a reflection of those in the maps of species richness. One could therefore argue that the areas with many threatened species are just more species-rich than others and as such are not areas of declining ecological integrity. This highlights that caution should be exercised in interpreting such information. In fact, some of the areas with many species and many threatened species are within protected areas such as the Kalahari Gemsbok National Park and therefore should have an above average ecological integrity.

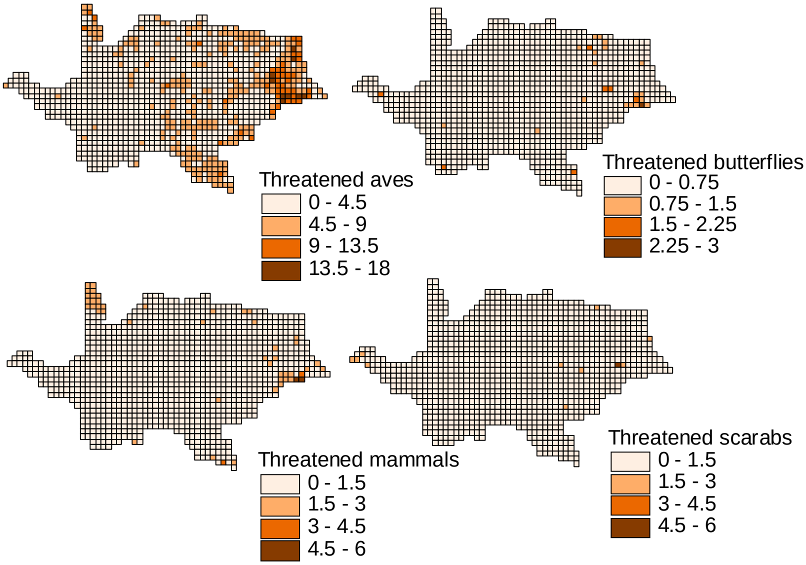


Figure 2.30 Number of threatened species of each taxon per QDS. Threatened species were compiled from Red Data Lists for the vertebrate taxa and were based on expert opinion for the invertebrates.

Conservation Value

The final component of the ecosystem integrity assessment using species data evaluated the conservation value of areas within the basin. Conservation value is a term that refers to the importance of a particular area in terms of its biodiversity. We use the notion of irreplaceability when assessing the biodiversity value of areas within the basin as a measure of conservation options lost if the site were to be converted or further degraded. High irreplaceability values indicate importance to the conservation targets of a region (Pressey 1999, Cowling *et al*. 2003a). Conservation targets can include numbers of localities of each species, the number of individuals or populations, or area of a habitat type. (Targets are discussed in more detail below in the section on ecosystems and in *Box 2.21)*. Thus if the conservation target of the Gariep basin represented all species in at least one locality, then an area with the only known record of a particular species is totally irreplaceable. If this area were to be degraded, it would not be possible to meet the target. We applied the notion of irreplaceability to the Gariep basin using species distribution data for mammals and birds. With the use of the software packages C-Plan (Pressey 1999) and ArcView 3.2 (ESRI 1998) irreplaceability surfaces of the basin were developed to identify areas of high biodiversity value, which could then be compared to data layers depicting threats and conservation status.

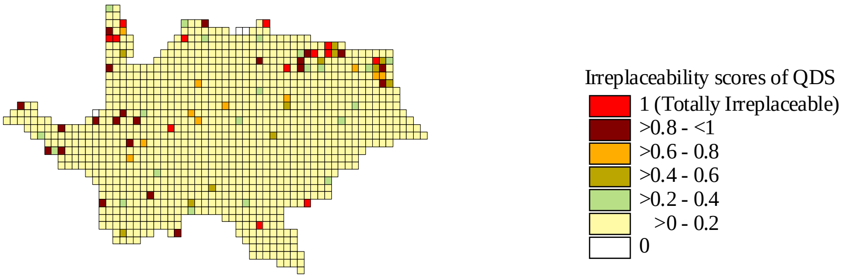


Figure 2.31 Irreplaceability values per quarter-degree grid square (QDS) range from 0 (low = many alternative options for the conservation of the specie found within the QDS) to 1 (high = no options for conservation of the biodiversity found in the QDS). This figure illustrates the irreplaceability values of the QDS in the basin based on the conservation target of one locality for each bird and mammal species

Box 2.21 Conservation Targets for Species

The setting of conservation targets is a controversial topic. There has been much debate on the targets for conservation planning units like ecosystems and habitats, but very little discussion has taken place on setting conservation targets for species. These targets are usually population level targets of minimum viable numbers of individuals for a population of a particular species. Kerley *et al*. (2003) discuss the setting of targets for mammals based on abundance information.

However, most conservation planning with species data relies on presence/absence data per planning unit or grid cell, which give no indication of abundances or occurrence per unit. Therefore, targets in these cases are really the number of localities, units, or grid cells for each species, which actually amounts to a certain amount of land per species. This is not really a useful target as the planning units such as QDS are often not viable implementation units. For this reason, most studies of this nature – including the National Biodiversity Spatial Assessment as well as this assessment - leave the target as a simple one grid cell per species. Once data on the actual distribution of species (e.g. point records), minimum population sizes, and habitat requirements of species are available, we can start to set meaningful targets for each species.

Figures 2.31 illustrates sites with high irreplaceability values in the Gariep. These sites contain species found nowhere else in the basin and are thus essential if only one representative of each species is required as a conservation target. Because several endemic and rare bird and mammal species occur in the basin the grid cells they inhabit are likely to be irreplaceable. The Highveld grasslands of the provinces of Mpumalanga and Gauteng are the most irreplaceable along with some regions in the Nama Karoo. Some of the irreplaceable QDS coincide with conservation areas such as Kgalagadi Transfrontier Conservation Area. The concentration of sites of conservation importance in the Grasslands is of concern due to the location of threats and absence of protected areas in the biome. The targets set for the analysis are low; if the goal was to represent more of the species' localities, the picture would change with more sites becoming irreplaceable.

Assessments such as these allow for effective land-use planning and analysis of trade-offs. Although this evaluation says very little about the integrity of ecosystems in the region and is thus of limited value in this assessment of integrity, it does highlight the ecosystems of critical importance to biodiversity in the Gariep. It is recognised that these irreplaceability values would change if protected areas were included in the assessment. The present assessment excludes protected areas from the calculations of irreplaceability and just examines the biodiversity value of the basin. However, species in protected areas can be excluded from the assessment as they are considered already represented and their targets are achieved. As the calculation of irreplaceability is an iterative process, as more protected areas are included and the species in them excluded from the analysis, the patterns of irreplaceability would change. Thus, the establishment of new protected areas would also change the current picture of conservation value.

This assessment of ecological integrity based on lists of species, endemic species, and threatened species is flawed due to sampling biases, taxonomic biases, and a lack of good threat data for species such as Red Data Lists. In addition, as pointed out above, these species assessments provide very little information on the integrity or health of ecosystems within the region. These data also represent only one timeframe and thus are not useful for inferring any trends. The species distribution data would have to be resampled for the basin to detect changes in species richness, endemics, and threat hotspots. Because this is unlikely in the near future we only have a measure of condition and not trends.

The assessment of ecological integrity in the Gariep attempted to evaluate other levels of the biodiversity hierarchy besides the species level, such as the lower levels of genes, individual organisms, and populations. However, as mentioned previously, there is very little information on these levels and their condition and trends for the whole Gariep basin. The higher levels of organisation, including the ecosystem level, formed a major component of our assessment of ecological integrity, because of information availability at these levels.

Ecosystems

It is generally agreed that an ecosystem, according to the definition of the Convention on Biological Diversity that has been adopted by the Millennium Ecosystem Assessment, is: *a dynamic complex of plant, animal and micro-organism communities and their nonliving environment interacting as a functional unit" (see Box 2.20)* (United Nations 1992: Article 2). However, very few ecosystem classifications or maps correspond with this definition at the scale of the Gariep basin. Broad-scale vegetation types (Low and Rebelo 1996) and broader-scale biomes have been defined, but do not necessarily correspond with the notion of an ecosystem as a functional unit. The newly developed VEGMAP (Mucina and Rutherford 2004) will in all likelihood address some of these concerns and is in fact being used as an ecosystem data layer in South Africa's National Spatial Biodiversity Assessment (a broad-scale assessment of regions of conservation concern in South Africa); however, it was not available at the time of this assessment.

The lack of a fine-scale classification of ecosystems is not unique to the Gariep and has been noted as a problem in the MA at both sub-global and global scales. The vegetation types of Low and Rebelo (1996) could potentially correspond with broad scale ecosystems and their condition thus could be an indicator of ecosystem integrity in the region. These units are defined as having "...similar vegetation structure, sharing important plant species, and having similar ecological processes". These units would have potentially been intact today, were it not for major anthropogenic land transformations such as agriculture and urbanisation. Monitoring and understanding land cover change, as a reflection of underlying land use change, are critical to the assessment of the condition and trends in biodiversity.

Land cover change is the greatest threat to biodiversity in the region, and therefore we assessed such changes in land cover within these ecosystems and their spatial implications for the region. Land cover data provide an indication of areas in their natural state, converted areas, and degraded regions (*see Box 2.22* for a summary of land cover in the Gariep) which are of use to identify the threatened status of the ecosystem. Remotely-sensed (satellite) data have made one of the most significant contributions to identifying and monitoring land cover change. Data acquired by Landsat and SPOT HRV are the primary sources for assessing land cover change at relatively high resolutions. This technology for measuring land cover is useful as an indication of the condition of ecosystems but requires subsequent resurveys to be able to reflect land cover change.

South Africa is currently being resurveyed and a new land cover map of the area will be available shortly based on remotely sensed images from the year 2000. This will then allow the identification of areas where rapid land cover change is experienced. At present, it is only possible to compare the situation as it appeared in 1996 when the last land cover survey was conducted (Thompson 1996) with what was potentially there before it was altered by industrialisation. The potential pre-industrial land cover can be inferred from a map of the extent of potential vegetation types (Low and Rebelo 1996).

Box 2.22 Land Cover in the Gariep

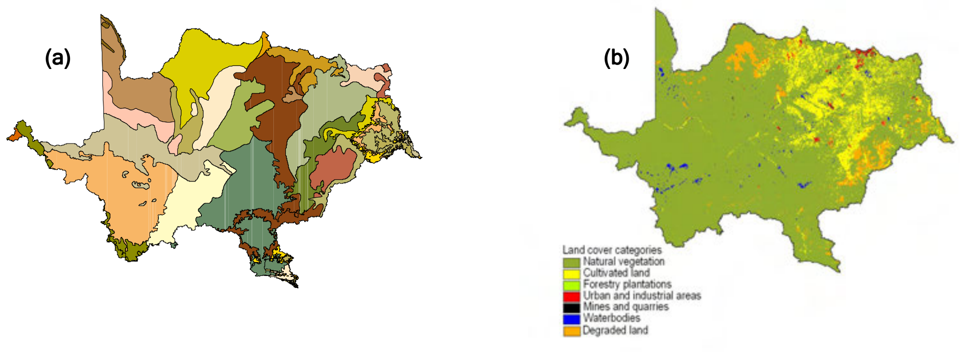
Based on an assessment of the 1996 Landcover data for South Africa (Thompson 1996, Figure 2.9.7b), about 84 percent of the Gariep basin remains in its natural state while 12 percent is transformed by other land uses. Of this, most has been changed through cultivation (93 percent), followed by urbanisation (four percent) and degradation through overgrazing and fuel wood removal associated with subsistence level livelihoods (four percent). This has resulted in over five percent of soils in the country being affected by water erosion and average soil loss of 2.5 tons per hectare, which is more than eight times the rate of soil formation.

These land cover threats are concentrated mostly in the Grasslands biome. This is the hub of economic activity in and in the Gariep as well as South Africa. The majority of people in South Africa live in this region, not only because of its agricultural potential, but also due to historical settlement related to its large coal deposits and the world's richest gold fields. Many areas suitable to afforestation by *Pinus* and *Eucalyptus* species occur within the Grasslands. The biome contains Gauteng Province, the major urban complex of South Africa. Some 150 000 head of cattle and 1.5 million sheep graze in the area (McAllister 1998). Grasslands also provide many traditional medicines, the value of which is estimated to exceed R 50 million annually.

The rest of the basin remains largely untransformed with only a small section of the Savanna degraded through overgrazing and fuelwood collection. However, while a large proportion of land in the Gariep is in a natural state, much of this land is fragmented and used for grazing. It is not possible to distinguish between all natural and disturbed grasslands with current satellite imagery. A more advanced satellite product is needed that reflects land uses and degradation, and which can verify the results of the interview-based study of land degradation by Hoffman *et al.* (1999) discussed in Section 2.4.

Reyers et al. (2001) assessed of the status of vegetation units (Figure 2.32). The areas with the highest concentrations of threatened vegetation types are in the eastern half of the region, falling largely within the Grasslands biome. Levels of transformation were compared against the transformation thresholds predicted by a geometric model developed by Franklin and Forman (1987). This work suggested that the most critical time for land planning and conservation is when between 10 and 40 percent of the landscape has been transformed or impacted upon. Regions showing greater than 40 percent loss of natural habitat (indicated in the two darker shades in Figure 2.32c) have already undergone significant ecological disruptions. Thus vegetation types falling between the 10 and 40 percent levels of transformation by urbanisation, cultivation, and plantations (the second lightest shade) and those with more than 40 percent transformation, recognised as critically threatened with low levels of ecosystem integrity, were highlighted as needing conservation attention. This work suggests that large tracts of the eastern region of the Gariep basin have low levels of ecosystem integrity, which has implications for the continued functioning of these eastern ecosystems and their provision of ecosystem services. These results are of concern, because, as highlighted in *Box 2.21,* this eastern grassland region is important for the provision of many ecosystem services.

Because these vegetation units are very broad and do not include functional components in the definition of their boundaries, it was decided in this assessment of ecosystem integrity in the Gariep basin to include some finer scale, functional ecosystem types in our assessment of ecosystem integrity. These data are not readily available in South Africa. There is the possibility of defining new units based on edaphic and climatic factors; however, the role of the SAfMA was not to create new data, but rather to assess existing data.



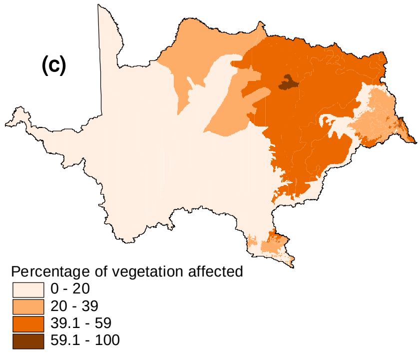


Figure 2.32 a) Vegetation types of the Gariep basin based on the definition and delineation of Low and Rebelo (1996); (b) broad land cover categories in the Gariep; and (c) location of threatened vegetation types (from Reyers *et al.* 2001). The vegetation types in darker colours have lost more of their original area to land cover change.

The Agricultural Research Council (ARC) has defined what are called “landtypes” for most of South Africa (Figure 2.33; excluding portions of the old “homelands” and Lesotho). Pedosystems are areas with uniform terrain and soil patterns (MacVicar *et al.* 1974, Land Type Survey Staff 1986). They are similar to land systems (Christian and Steward 1968, Lawrence *et al.* 1993), which have been extensively used as ecosystem units for conservation area evaluation at broad regional scales in Australia (Purdie *et al.* 1986, Pressey and Nicholls 1989, Pressey and Tully 1994). Climate zones (mapped at 1:250 000 scale) have been superimposed upon pedosystem maps to arrive at maps of landtypes covering the majority of South Africa (MacVicar *et al.* 1974, Land Type Survey Staff 1986). A landtype therefore delineates an area at 1:250 000 scale that displays a marked degree of uniformity with respect to terrain form, soil pattern, and climate. Landtype data were prepared by the Institute for Soil, Climate and Water (ISCW) of the ARC.

The delineation of these landtypes approximates the scale of ecosystems in the Gariep assessment and includes some functional components in their definition due to the inclusion of climate, terrain, and soil in their delineation. There are 2138 different landtypes recognised in the Gariep basin. In a similar assessment to the one done by Reyers *et al.* (2001) on the vegetation types of South Africa, we assessed the land cover situation in each of the landtypes. However, we deviated from their technique and used one based on current work in South Africa and elsewhere that assesses the conservation status of the ecosystem (Cowling *et al.* 2003a). This method assesses the proportion of land in the ecosystem subject to some form of land cover change, which is then compared to the proportion of land required to represent a designated conservation target.

Figure 2.33 Landtypes of the Gariep basin as defined by the Institute for Soil, Climate and Water, Agricultural Research Council.

One of the most familiar conservation targets is the 10 percent set by the IUCN. However, this target has been highly criticised as being too low to guarantee the persistence of regional biodiversity (Soule and Sanjayan 1998). In addition, several conservation planners have argued that each ecosystem deserves a separate conservation target, depending on its sensitivity, rarity, vulnerability, and value. Several techniques have been developed recently to determine the conservation target for an ecosystem. These have included species area curve calculations (Pressey *et al.* 2003) as well as simple weighting formulae, which calculate a target based on the rarity and threat status of the ecosystem. In a similar fashion to Pressey and Taffs (2001) and Reyers (2004), we set conservation targets for each land type as:

$$TARGET = 10 * (1 + NR + VU)$$

where TARGET is the percentage of the original extent of each ecosystem, NR is the natural rarity of each ecosystem measured as (Am - Ai)/Am where Am is the area of the largest ecosystem in the region and Ai is the area of the ecosystem for which the target is to be set. NR ranges from 0 to 1. VU is a measure of threat facing the ecosystem, calculated as the suitability of that ecosystem to alternate land uses (i.e. dryland cultivation in the Gariep). The Institute for Soil, Climate and Water of the ARC determined the suitability values for each landtype. Although only based on suitability to one type of land use, this provides an adequate reflection of the vulnerability of that land type as there is large congruence between areas suitable to cultivation and afforestation (Wessels *et al.* 2003, Reyers 2004), which are the main land uses in the region. Suitability values for the landtypes range from 1 (very suitable) to 9 (unsuitable). These values were reclassified into three VU values of 1 (not suitable), 2 (moderately suitable), and 3 (very suitable) in a similar fashion to Pressey and Taffs (2001). TARGET could thus range from 20 to 50 percent, but in fact, values ranged from 21 to 33 percent of the original extent of the landtype.

We assess conservation status by calculating the proportion of the ecosystem remaining in a natural condition and then classify this value in one of four categories, which correspond with categories used in Red Data assessments. These categories include:

- *Not threatened* (NT) = more than 80 percent of the ecosystem remains in a natural state
- *Vulnerable* (VU) = between 60 and 80 percent of the ecosystem remains in a natural state
- *Endangered* (EN) = ecosystems with less than 60 percent natural area remaining and more than the area required by the conservation target

- *Critically Endangered* (CR) = ecosystems with less than the natural area required to meet the conservation target

These thresholds correspond closely with those used by Franklin and Forman (1987) and which are applied in Figure 2.31. It classifies ecosystems that are between 20 and 40 percent transformed and require some attention as *vulnerable*. Those that are more than 40 percent transformed are already experiencing some loss of ecological integrity with the accompanying loss of function and ecosystem service provision and are classified as *endangered*, signifying that they have lost so much land in natural condition that they can no longer meet the conservation targets set for them. *Critically endangered* ecosystems have a very low ecological integrity and are likely to be of serious concern to human well-being.

Figure 2.34 shows a breakdown of the landtypes as ecosystems and their conservation status. The figure shows that most of the ecosystems are *not threatened*; these ecosystems fall mostly within the western and central regions of the basin. Some nine percent of the ecosystems fall into the *vulnerable* category. These ecosystems have lost between 20 and 40 percent of their original extent to other land uses and require consideration in land use and conservation plans. Like those in the *endangered* and *critically endangered* categories, *vulnerable* ecosystems fall largely in the north-east of the basin.

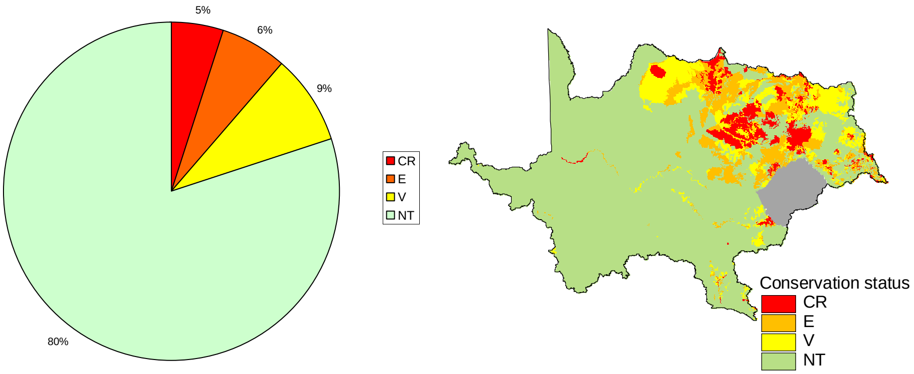


Figure 2.34 Conservation status of the landtypes of the Gariep: (a) Pie chart depicting percentage of ecosystems falling into each conservation status class and (b) spatial display of the ecosystems and their conservation status.

Those ecosystems that are *endangered* and *critically endangered* have lost more than 40 percent of their original extent and are experiencing loss of ecological function and ecosystem services. These results are in agreement with those shown in Figure 2.32 of the broader vegetation types and thus re-emphasise the importance of these eastern regions in planning frameworks and conservation decision-making. As highlighted in the previous sections, this region in the east is an important source of most of the water and food produced in the basin.

A second component of this assessment involves an examination of their protected area coverage. One of the most popular responses to declining ecosystem conditions is the establishment of protected areas for the *in situ* conservation of biodiversity. A measure of the protected area coverage in each land type would be a useful measure of the integrity of the ecosystem, assuming that protected areas actually improve and protect the integrity of ecosystems within their boundaries. In South Africa, this is a reasonable assumption where protected area establishment and management have had a good record. An assessment of protected area coverage therefore provides another measure of ecosystem integrity.

Based on data from Department of Water Affairs and Forestry (Figure 2.28 inset) we assessed the overlap of protected areas (provincial and national parks) with the various land types and in a gap analysis, compared the extent of protection with the conservation targets set for the conservation status assessment. Figure 2.35 illustrates a gap analysis, or a measure of how close the protected area coverage is to the conservation target. Regions in the north-west are very well protected, with more than

350 percent of the targets achieved for some landtypes in the region. The rest of the Gariep is poorly protected, with only 0 to 10 percent of the targets attained for the majority of the basin's ecosystems.

The formally protected areas are distributed unevenly between the three biomes of the Gariep. The Savanna biome is well-protected (10.6 percent) because the large national parks fall mainly with this area (10.6 percent). This coverage is due mostly to its biodiversity content and nature-based tourism potential. The Nama Karoo receives very little protection (1.3 percent) due to its lack of charismatic fauna and hence lower tourism appeal. The Grasslands contain mostly provincial parks and a World Heritage Site in the Drakensberg. These protected areas make up a very small percentage of the biome with only 2.7 percent of the Grasslands protected. These results reinforce the plight of the eastern ecosystems of the basin: they are rich in species, highly transformed, important for the provision of ecosystem services, and poorly protected.

Although the protected areas database used in this study is the most up-to-date available at the time of the assessment, shortcomings of the data include incorrect boundaries, missing protected areas, and differing levels of legislation and tenure for some of the protected areas. This realisation has led to the refinement of these maps by the National Biodiversity Spatial Assessment, but these data were not available at the time of this assessment. In addition, this database does not include Ramsar and Natural Heritage Sites *(see Box 2.23)*. The management and tenure of these areas is not perhaps on the same level as that in formal protected areas, but they do play a role in conserving ecosystems. Furthermore, these protected areas may no longer play a role in conservation as species begin to adjust their ranges and movements in response to climate change, as discussed in the next section.

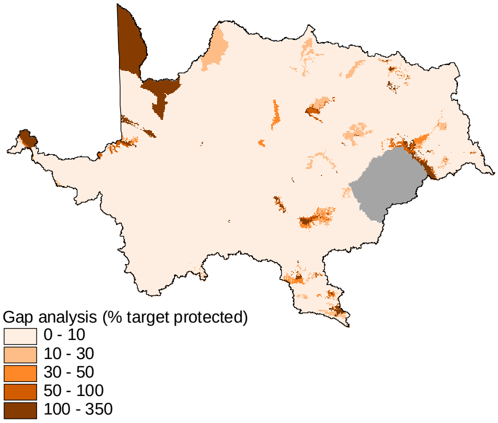
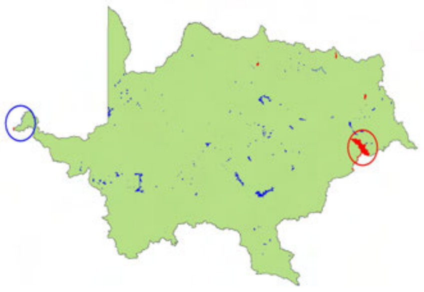


Figure 2.35 Gap analysis of the landtypes of the Gariep. The darker areas have protected area extents that meet or exceed the conservation target for the landtype. The areas of concern are the lighter landtypes where the protected areas cover very little of the landtype, not meeting the conservation targets of the ecosystems.



Box 2.23 Areas of Biodiversity Interest in the Gariep

The map shows the distribution of wetlands (in blue) and Ramsar Sites (in red) in the Gariep basin. (*Source*: van Riet *et al*. 1997). At the western end of the catchment sits the Orange River Mouth Wetland (circled in blue), a designated Ramsar Site and Important Bird Area that exemplifies the high degree of transformation that the Gariep River system has undergone. In 1995, the wetland was placed on the Montreux Record of sites considerably degraded by anthropogenic activities, which, in addition to being impacted by dams upstream, is close to diamond mining operations. Despite this, the Orange River Mouth Wetland remains unprotected, although plans are in development to declare the site a provincial nature reserve, and possibly an international conservation area under joint management with Namibia (Barnes *et al*. 2001). At the opposite end lies the uKhahlamba-Drakensberg Park (circled in red), a Ramsar Site and a World Heritage Site which forms part of a TFCA.

Drivers of Change in Biodiversity

The MA conceptual framework distinguishes between direct drivers of change in ecosystems, such as land use and land cover change, species introductions or removals, technology adaptation and use, external inputs (fertiliser use), harvest and resource consumption, climate change, and natural physical and biological drivers such as volcanoes. Indirect drivers, including economic, demographic, socio-political, scientific and technological, and cultural and religious change, in turn influence these direct drivers. South Africa has witnessed changes in many of these indirect drivers due to the democratic transformation in the country since 1994 (Wynberg 2002).

The shift to democratic rule has had significant implications for how the environment is viewed and managed. Ten years ago, conservation was a preservationist agenda serving the privileged elite, restricting community access and often resettling rural populations. The government policies of the time supported biodiversity conservation and resulted in threatened species programs, protected areas, management, and research development. However, these policies also ignored sustainable use, established protected areas on marginal land, and supported a non-integrated land use strategy with seventeen government departments sharing the responsibility for nature conservation.

The UNCED meeting in Rio de Janeiro in 1992, the democratisation of South Africa in 1994 and subsequent ratification of the Convention on Biological Diversity in 1995 had large implications for South African biodiversity. Seven policy processes were initiated in the environmental field and the nationally consultative process of the White Paper on Biodiversity as well as the subsequent National Environmental Management, Biodiversity and Protected Areas Acts began after 1994. With this change in government came the introduction of a bioregional approach to conservation, as hailed by organizations such as Cape Action for People and the Environment (C.A.P.E.), TFCAs, community-based natural resource management, conservation on private land, bioprospecting and biotechnology advances. Government funding cuts, and subsequent needs to privatise protected areas within the last ten years have been offset by increased donor interest, with GEF, UNDP, and UNEP donating R128 million between 1994 and 1999. These funds were intended to be catalytic or to provide for the incremental costs of particular initiatives that had succeeded, however. At the same time, research capacity has been decreasing, with taxonomist numbers in decline and a drop in research grants at universities, research facilities, and museums (Herbert 2001).

Box 2.24 Drivers of Land Cover Change

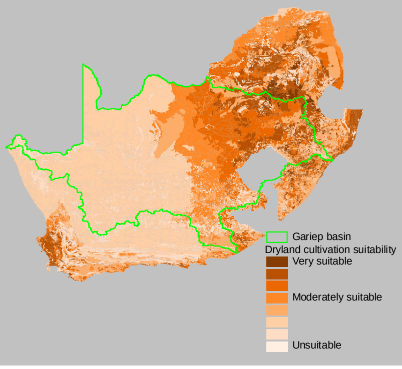
The current land cover situation in the Gariep is discussed in *Box 2.22*. The impacts of land cover change on biodiversity and ecosystem integrity are serious and often irreversible. These changes affect ecosystems by altering their composition, processes, and resilience to disturbance, but they also have important consequences for ecosystem services upon which humans depend (Kunin and Lawton 1996, McCann 2000). Land use planning in South Africa has historically been poor, driven by political processes rather than biophysical characteristics, with inefficiencies, inequities, and environmental degradation resulting. The almost total transfer of land in most regions of South Africa from government to private ownership is possibly unique in the annals of European colonisation. The state by the mid-1930s had lost control over natural resources, which in countries such as Australia and the United States were retained by the authorities because of their unsuitability for agriculture (Christopher 1982). In effect the absence of state interest in land through a leasehold system has led to a strong demand for land and an attempt to make a living in areas highly unsuitable for farming.

Biggs and Scholes (2002) provide a detailed assessment of land cover change in South Africa between 1911 and 1993. Their study focused on cultivation and afforestation as agents of land cover change. Another form of land use which has not been studied in much detail in the Gariep is urbanisation. Not much of the region is urbanised and very little is known of the historic trends in urbanisation. However, the portion that is transformed is in the already threatened northeastern highveld region. The impacts of urbanisation on ecosystem integrity are also serious; as with cultivation and afforestation these land cover changes result in areas where the structure and species composition are completely or almost completely altered. Biggs and Scholes (2002) showed that during this time period the cultivated land in South Africa more than tripled, while area under timber plantations increased more than tenfold in the former white areas. Area under cultivation increased until the 1960s where it reached a plateau and began to show increased variability due to sporadic cultivation of marginal land. Population growth and rising affluence have been important factors contributing to increases in food production. This increased demand has been met initially through the expansion of land under cultivation and later through technological changes which increased yields per hectare. These technological changes include higher yield cultivars, pesticide, irrigation, and inorganic fertilizer use.

Most of the expansion in agricultural land happened before the 1960s and was concentrated in the wetter eastern and extreme southern parts of the country and thus the impacts on ecosystems (such as habitat loss) have been disproportionately borne by these regions (e.g. the Highveld grasslands and southern fynbos). The impacts of the extensification of land under production are well studied in South Africa and incorporated into conservation planning and ecosystem management plans in the regions. On the other hand, the impacts of agricultural intensification are not as well known. These effects include pesticide build-up, fertilizer runoff, siltation of water bodies, extraction of limited water resources for irrigation, and other impacts associated with land degradation. These impacts can have as or even more serious implications for regional ecosystem integrity and as such should be included in land use planning and ecosystem management.

The area under afforestation increased after World War 2, but still only covered 1.5 percent of the country by 1995. This increase was driven by the demand for mine support timber, construction timber and an international pulp market. Forestry occurs mainly along the grasslands escarpment in the east of the Gariep.

How land cover might change in the future is uncertain. It appears that the conversion of natural areas into cultivated land has stabilised. The expansion of afforested land is less certain, but is likely to be influenced by the development of drought-resistant species and the economic benefits and job creation potential of the forestry industry. However, afforestation is very water demanding and in a water-limited country like South Africa this is a problem. The spread of urban areas including informal settlements and resultant peri-urban sprawl is difficult to predict, while the expansion of rural population centres is even less certain.



These impacts of democracy and other processes on environmental issues, together with the associated changes in the indirect drivers in South Africa, have led to significant alterations in the main drivers of ecosystem integrity change. In South Africa, current drivers of change in ecosystem integrity include land use/cover change, species introductions, and climate change. *Box 2.24* describes the broad land use changes that have taken place in South Africa and in the Gariep over the past century highlighting the historic expansion of land use into previously natural areas followed by a slowing of conversion rates and a focus rather on the intensification of land use practices. Thus, although land area conversion has slowed down, the impacts of external inputs have increased. Another form of land cover change is degradation, which includes areas that have a very low vegetation cover in comparison with the surrounding natural vegetation cover and are typically associated with rural population centres and subsistence level farming, where fuelwood removal, overgrazing, and subsequent soil erosion were excessive (Thompson 1996). Very little information is available on degradation of ecosystems in South Africa besides the Hoffman *et al.* (1999) product mentioned in Section 2.4. This is an important gap in data for use in ecosystem assessments. In addition to the conversion of land to alternate land uses, the combined effects of degradation and fragmentation - 46 percent of the grasslands biome occur in patches of less than two square kilometres (Neke and du Plessis 2004) - has had serious implications for ecosystem integrity. Eberhard (1990) has predicted that the combined effects of deforestation and subsistence agriculture will totally denude natural woodlands in communal areas by 2020.

The impacts of alien invasive species, as described in *Box 2.25,* highlight the impacts on ecosystems and the implications of this driver for ecosystem integrity and service delivery in the Gariep, especially in the north east of the region. The third major driver of change, climate change, may cause flagship protected areas in the region to lose many of their species (Erasmus *et al.* 2002, van Jaarsveld and Chown 2001) and may cause a reduction in biomes by 35-55 percent (WWF 2001). Coarse-scale climate change models predict that the climatic conditions that are currently associated with the Succulent Karoo biome will no longer exist by 2050, because of anthropogenic enhancement of CO_2 levels. If a strong relationship is assumed between plant and animal distributions and these broad-scale climatic correlates of biome distribution, it is reasonable to expect that there will be severe disruptions of the region's biota over the coming decades (Rutherford *et al.* 1999, Foden 2002). In addition to the direct impacts of climate change on ecosystems, Duke and Mooney (1999) point out that most of the important elements of global change are likely to increase the prevalence of biological invaders.

Box 2.25 Invasive Alien Species in South Africa

Like many countries, South Africa faces a particular challenge in terms of invasive alien species. These are plants, animals, and microbes that have been introduced from other parts of the world, and have often displaced indigenous species. It is widely accepted that invasive alien species are the single biggest threat to South Africa's biological diversity (Preston 2003). The impacts of alien invasive species on biodiversity are complex, with effects at all levels of the biodiversity hierarchy from the individual to ecosystem, and therefore have consequences for ecosystem services (Townsend 2003). Most work in South Africa on alien invasive species has focused on invasive alien plants (IAP). These plant species have very significant impacts on the ecological integrity of natural systems and consequently human livelihoods. IAPs use 2.4 percent of the basin's water resources (Section 2.3), reduce farming productivity, intensify flooding and fires, cause erosion, transform rivers, silt up dams and estuaries, impact water quality, and can ultimately lead to the extinction of indigenous plants and animals.

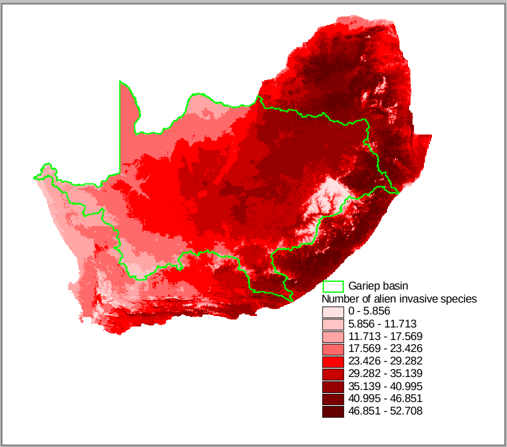
Documented evidence of the impacts of alien invasive species on some ecosystem services exists. These impacts can be measured as qualitative or quantitative changes in ecosystem service delivery (Simon and Townsend 2003) or through economic valuations of the impacts of particular species on ecosystem service production (Zavaleta 2000, Turpie *et al.* 2003). Turpie *et al.* (2003), in a study of the effects of alien infestation in the Cape Floristic Region of South Africa, showed that current total losses of ecosystem services in the fynbos due to alien plant species are almost 700 million Rands per annum. These values are mainly realised in the informal sector and are not accounted for in national accounting systems.

In a recent study of South Africa's most invasive alien plant species, scientists determined regions in South Africa which were suitable for these plant species and thus where these species could spread to. The north-eastern parts of the Gariep basin are highlighted as being suitable for invasion by many of these species and are in fact some of those most suitable areas for IAPs in the country.

Statistics

- Invasive alien plants have become established on over 10 million ha of land in South Africa.
- 750 tree species and 8000 herbaceous species have been introduced into South Africa.
- 1000 introduced species are naturalised, 200 are invasive.
- 84 species are from South and Central America, 14 from North America, 30 from Australia, 29 from Europe, 36 from Asia.
- 45 percent of species from Australia have become important pests.
- Invasive alien plants threaten 55 percent of the Red Data-listed plants in the country (Versveld *et al.* 1998).
- Invasive alien plants threaten insect diversity (McGeoch 2002).
- Up to 60 percent of endemic freshwater fish are threatened by introduced alien animal species.
- Over the next 20 years, the cost of controlling invasive alien plants in South Africa is estimated to be R600 million a year.
- Left uncontrolled, invasive alien plants are expected to double within 15 years.

Source: http://www.dwaf.gov.za/wfw



Responses

In 1995, the then-Minister of Water Affairs and Forestry, Professor Kader Asmal, initiated the *Working for Water* programme. This program has seen exceptional budget increases – from R25 million in 1995/6 to R442 million in 2003/4. It has provided training and employment opportunities for upwards of 20,000 people, mostly the poor and marginalised. Over one million hectares of land have been cleared of invasive alien plants during the past eight years (Preston 2003). However, invasive alien plants are still spreading and growing at a faster rate than the programme is clearing them.

There is a particularly strong bond between *Working for Water* and the protected areas of South Africa, where invasive alien species present one of the greatest threats to their role in conservation. The program has come under criticism for not being sufficiently flexible in prioritizing emerging weeds (controlling them before they get out of hand), its lack of a clear mandate and authority, its use of "incentives" rather than "disincentives", its failure to optimise the necessary public and private partnerships, and weaknesses in its planning, systems, structures and general management (Preston 2003). The recent development of the Biodiversity Bill, and in particular the thematic area of the National Biodiversity Strategy and Action Plan (NBSAP) which focuses on alien invasive species, has promised a step forward for *Working for Water* and other efforts to contain the damage of invasive alien species. The establishment of the Secretariat of the *Global Invasive Species Programme* within South Africa has further given the cause a further boost.

Response Options for Maintaining Ecosystem Integrity

Responses for managing ecosystems and maintaining ecosystem integrity include protected area establishment and management, goals and approaches for sustainable use, management of invasive alien species, reintroductions, rehabilitation and recovery programs, metapopulation management, and the inclusion of biodiversity issues in agriculture and other forms of land-use planning (mainstreaming).

Despite the many challenges to the maintenance of ecosystem integrity, some positive trends in the environmental arena are apparent in the region. The responses noted above, many unfathomable in the recent past, are quickly gaining ground. They demand time and resources, however, and their benefits are often felt over a much longer time scale than their costs. The average politician or decision maker may be reluctant to implement these responses after evaluating the costs and benefits; however, through processes like this assessment and other sector-specific evaluations such as alien invasive impacts (Turpie *et al.* 2003), stakeholders are becoming increasingly aware of the risks of allowing ecosystem integrity to continue its downward spiral. As stakeholders gain an increased awareness of the importance of maintaining ecosystem integrity, these responses become possible, as stakeholders are in a position to exert an influence on the decision-making process.

Biodiversity awareness is on the increase in the region and thus many policies are being developed for the management of these drivers and their impacts, which may serve to strengthen legislative powers for biodiversity conservation. South Africa's international convention commitments and an active National Department of Environment Affairs and Tourism have driven many of these policy processes. The White Paper on Biodiversity Conservation and Sustainable Use was the precursor to new legislation in the form of a National Environmental Management Act, which has subsequently passed two additional acts on Protected Areas and Biodiversity. These pieces of legislation propose several frameworks and action plans to streamline and prioritise the conservation of biodiversity. They are well thought out, contain many new ideas and approaches, and should hopefully aid the cause of conservation. These national processes include the National Biodiversity Strategy and Action Plan (NBSAP) and a parallel National Spatial Biodiversity Assessment, mentioned several times above. Both of these processes aim to be completed by the end of 2004 and should provide a National Biodiversity Framework from which to start assessing and managing the conservation and sustainable use of biodiversity in the country. The National Spatial Biodiversity Assessment will also hopefully focus the conservation efforts in the region on the areas identified as most urgently requiring conservation attention (Figure 2.36).

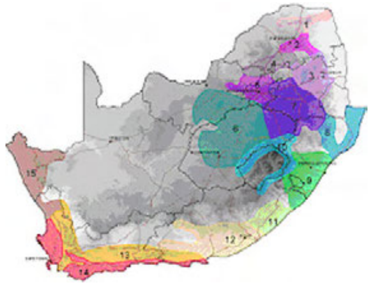


Figure 2.36 Draft priority areas of South Africa identified by the National Spatial Biodiversity Assessment.

However, concern exists that the economic value of some land use practices will undermine some of the policies' aims and objectives. In a country where about a quarter of the population lives below the poverty line, immediate economic benefits associated with certain land uses easily derail the opportunity to achieve long-term benefits of biodiversity conservation. However, new incentives, such as the rates reduction of land managed for conservation, are promising. These and other economic incentives are valuable techniques for promoting conservation particularly on private or communal land. Of course, care must be taken that these incentives are appropriately applied and monitored.

The last ten years have seen the addition of 155 000 hectares of protected land countrywide, with plans to increase this level of protection from the current six to eight percent within the next ten years. However, this will not improve the biodiversity situation unless done in a systematic way through the identification of areas most in need of conservation. The establishment of protected areas in South Africa has a history of inefficiency and inequity, and the realisation that this approach could lead to ineffective conservation coincided with a similar realisation globally in the 1980s and led to the development of systematic conservation procedures in the country (Lombard *et al*. 1997). These procedures focus on the use of spatial biodiversity data to efficiently identify areas requiring protection in order to conserve national or regional biodiversity (see Margules and Pressey 2000 for a review). The effectiveness of these techniques in some areas of the country has been exemplified in, for example, the Cape Floristic Region (Cowling *et al*. 2003a), Succulent Karoo (Driver *et al*. 2003), and Subtropical Thicket (Cowling *et al*. 2003b). In fact, the techniques have been so successfully applied that South Africa has become a world leader in the area of conservation planning (Balmford 2003). Still, obstacles and problems associated with the techniques exist, particularly in the phase between the identification of land for conservation and its effective conservation. It appears that implementing these "optimal" reserve systems remains a major obstacle that needs to be traversed. However, new approaches in the use of off-reserve conservation of the areas identified as important to biodiversity are helping to overcome this.

This form of conservation moves away from the use of formal protection of areas with removal of people from land. Not only is this type of approach important in a country where people still live off natural resources found in protected areas, it is also of value as more than 80 percent of the country is owned by private land owners and thus not readily available for formal protection. Many new schemes now exist to involve landowners in the conservation of biodiversity found on their land. In addition, many attempts are being made to involve communities living around protected areas in the management and benefits of the area. These Community Based Natural Resource Management (CBNRM) approaches and their value in conservation and community upliftment are still topics of hot debate. Communities living near protected areas are often very poor and have not yet found ways of converting the natural resources around which they live into economically beneficial products without undermining the ecological integrity of the area. Many studies justify the conservation of an area as being more economically beneficial than utilising the area for some other land use. However, this is mostly through paper profits rather than real benefits to the rural poor. Even so, it is becoming increasingly clear to conservationists and other development workers that communities will not conserve a resource if benefits accruing from it cannot be demonstrated in more tangible forms than has been the case in the past. As a result, the idea of conserving natural resources by using them more appropriately is gaining ground. Economic gains from such commercialisation programs will hopefully encourage communities to appreciate natural resources and promote their subsequent conservation.

In addition to new techniques for identifying and establishing conservation areas, the management practices of protected areas have also changed. The focus of conservation has shifted from the preservationist approach of protecting the status quo of charismatic vertebrates to the maintenance of natural processes and the biodiversity these processes support (Reyers *et al.* 2002, Rouget *et al.* 2003). Thus, the establishment and management of protected areas are more dynamic and efficient.

The regions shown in Figure 2.36 classified as national conservation priorities require fine-scale planning, assessment, and conservation management. The areas of overlap with the basin are in the north-eastern region of the basin and include areas 5, 6, 7, 10 with some overlap in the far west with area 15. This assessment has highlighted the north-eastern region repeatedly due to its wealth of biodiversity, large contribution to the provision of ecosystem services, suitability to other land uses, and threatened status. Priority area 15 is also identified in this study due to its overlap with the Ramsar Site and Important Bird Area of the Orange River Mouth Wetland.

Working against the favour of the Gariep are its lack of tourist appeal and the global hotspot status of other areas in South Africa. Many of the country's conservation initiatives focus on areas outside of the Gariep basin, including bioregional plans such as Cape Action for People and the Environment (C.A.P.E.), the Succulent Karoo Ecosystem Plan (SKEP), the Subtropical Thicket Ecosystem Plan (STEP), and the KwaZulu-Natal Conservation Value Assessment. It is therefore not surprising that the Gariep has had few of these approaches applied, few new protected areas identified, and attracted little conservation NGO interest. On the other hand, it could be argued that Savanna regions of the basin are already well protected due to the presence of charismatic megafauna in this biome. Small portions of the basin, which coincide with the Succulent Karoo and Subtropical Thicket, are taken in account by the bioregional plans in these biomes. This leaves the Grasslands and Nama Karoo biomes as areas of concern. Some conservation work has already begun in these parts. These include the establishment of a grasslands forum through the Gauteng Department of Agriculture, Conservation, and Environment (DACE) in order to coordinate conservation efforts in the Grasslands, most of which fall in the Gariep basin. This National Grasslands Initiative has developed a scoping report and now waits for funding to appoint a coordinator to take the initiative forward. WWF-South Africa, DACE, and the National Botanical Institute are the organisations responsible for this process. Other initiatives include the establishment of a TFCA in the Drakensberg escarpment, Ramsar Wetlands, and World Heritage Sites, which address the protection of cultural services in addition to biodiversity conservation.

In the Nama Karoo, it could be argued that because land use pressures are reasonably low (even grazing pressure is declining relative to the 1960s and 1970s) and ecosystems are little transformed and mostly functional, this region is not high on the conservation agenda of the basin. Additionally, although large tracts of untransformed land in the biome mean that many opportunities exist to create massive areas to protect migratory ungulates, this may negatively influence livestock enterprises and the economic activity that these support. The lack of a priority area in the Nama Karoo based on the outputs of the National Spatial Biodiversity Assessment further strengthens the case against immediate conservation action in the region.

Outputs of the conservation plans in the Grasslands, Succulent Karoo, and Subtropical Thicket will identify areas requiring conservation. Effective conservation of this basin, known as the "heartland" of the country is gaining momentum. It will however require new and innovative approaches, as traditional formal protected areas are not an option in a region so suitable to alternative land uses that appear more lucrative. The conservation and management of land within the Gariep will have to be dynamic and adaptive due to the large numbers of people living on the land and utilising natural resources. Due to the importance of agriculture in the basin, one of the more appealing responses to maintaining ecological integrity would be to include biodiversity issues into agricultural practices. Some work has already been done on this in regions of the Gariep where areas important to biodiversity are highlighted and avoided in the extensification of land under agriculture. These are often areas marginally suitable to agriculture that are not sustainable (Wessels *et al.* 2003). An ideal approach would be to manage land for conservation as well as agriculture; however, the Gariep is not only extensively cultivated but is also intensively farmed, making the persistence of biodiversity in those landscapes less likely. It is therefore more suitable to suppose that conservation and cultivation will not necessarily be possible in the same area, but that the planning of what happens where on the landscape is important.

An innovative response is the transboundary conservation concept through the use of TFCAs. Several such areas are either existing or proposed in the Gariep basin and their potential benefits could be large. However, the role these areas play in conservation and development is still unclear and care must be exercised in their future development as it could potentially exacerbate previous *ad hoc* land allocation practices. Another new direction in biodiversity conservation involves intellectual property rights, a controversial and rapidly changing issue that has an important impact on national economies. Amendments on patent laws on plants and bioprospecting of plant-based drugs from the less developed and plant-rich nations are intended to protect the interests of all parties. However, these amendments still favour the developed nations when it comes to property rights of botanical materials, and South Africa will be required to prepare well-drafted patent laws for these products (George and van Staden 2000). In addition, the owners of the original material and knowledge must also benefit from the plant products and engineered flora.

These frameworks, initiatives, and policies will only be of value if supported by sensible agricultural, land reform, and development policies in the region. The continued population growth within the area and increased levels of urbanisation and migration into the area as well as the increased demand for ecosystem services need addressing to protect these valuable and threatened biological resources upon which all people in the basin depend. It is hoped that an assessment such as this one will help to bring about changes in policies and attitudes to biodiversity and ecosystem integrity, with recognition of the role that ecosystems play in delivering services and supporting human well-being.

Providing information to stakeholders is one way to influence behavioural change. Other responses include establishing effective and accountable institutions to drive and manage change, and identifying and implementing incentives for individuals and organisations to embrace change. The Working for Water Programme (*Box 2.25)* is an example of a program that successfully changed the way people view and deal with alien invasive plants by highlighting the impacts these plants have on ecosystem integrity, ecosystem services, and ultimately, human well-being.

The value of education and communication cannot be overstated in promoting the maintenance of ecosystem integrity. The inclusion of environmental issues in school curricula and effective communication of the value of intact ecosystems to people are crucial steps for effecting positive behavioural change in future generations.

Box 2.26 Biodiversity and Communities

At the local level, protected areas provide useful benchmarks for biodiversity. In the Great Fish River area, communal areas have fewer plant and arthropod species, but more reptile and insect-eating bird species, than neighbouring protected areas, while the protected area has more frugivorous and arboreal birds than the communal areas (Fabricius *et al.* 2003). In addition, protected areas are much less fragmented than communal land.

For communities, biodiversity is important at the landscape and species levels, the latter being so because of the widespread use of goods from the local environment within daily livelihoods. At Sehlabathebe, a key facet is the increasing fragmentation of the mountain grasslands by human habitation and cultivation. Overgrazing by livestock is also perceived to be a significant problem, resulting in increased silt loads in streams, soil erosion, and invasive shrubs, accompanied by changes in grass sward composition and impacted sponge areas. The national park offers some protection for endemic species.

In the Fish River, overall ecosystem integrity has declined over the last decades, of which respondents are keenly aware. This is a result of several factors, the key one being a rapid increase in human populations, largely because of the enforced resettlements during the apartheid era. This reduced the area of land available for land-based activities of arable cropping, grazing, and collection of wild products. By 1990, approximately 40 percent of the land area was under residential settlements and roads. This subjected unsettled areas to heavy utilisation pressures. As such, much of the woody vegetation has been removed completely or markedly opened up. The area under gully erosion increased four fold. The resistant, unpalatable, dwarf shrub *Pteronia incana* has invaded grazing lands. In reasonably intact areas, local communities potentially use more than 120 plant species for multiple purposes. However, differing land uses favour different species. In comparison with the Fish River Reserve, 20 percent of useful plants found there are not evident in the communal areas, yet 11 percent of useful plants in the communal lands were absent from the reserve. Overall, there was a higher abundance of useful plants in the reserve. Similar findings were found with respect to reptiles and arthropods, namely communal lands had lowered species richness, but nonetheless supported some species not found in neighbouring land uses. Therefore, at a landscape level, a diversity of land uses and management objectives is necessary to promote species richness.

The Richtersveld National Park (RNP) is renowned for its plant species richness, especially of endemic succulent species. The diversity of plants in mountainous terrain is significantly higher than that on the plains. Generally, footslopes and mountains have on average at least twice as many plant species per 100 square metre plot than plains (Hendricks *et al.* 2003c). A significant driver behind the proclamation of the RNP were the threats to this endemic flora through perceived overgrazing as well as sale of succulents to collectors. With the establishment of the RNP under joint management control of the South African National Parks and the local community, the magnitude of both these perceived threats is likely to have decreased. There has been no investigation of the effects of unscrupulous collecting. The effect of grazing is most prominent around stockposts and watering points, with reduced vegetation cover and hardy pioneers replacing plant species sensitive to grazing. These effects decrease away from these point sources, up to a distance of approximately 800 metres. However, the total impact is relatively small with only one stockpost per 500 hectares. The large-scale earthworks associated with diamond mining in the RNP are perhaps more significant an impact on species distributions and richness. On the Namibian side, however, the declaration of restricted mining areas has been a major factor in conserving biodiversity and ecosystem integrity because of the limits such declarations place on settlement and land use.

2.10 Ecosystem Services in an Urbanising World: Gauteng Province

It is projected that by 2030, three-fifths of the world's population will be urban (UNPFA 1999). The Gariep basin is already ahead of the global trend, with approximately 64 percent of its 14 million residents making their homes in urban areas. By comparison, 54 percent of South Africans were living in cities in 1999 (Stats SA 2003). Lesotho is a more rural nation, with an urban population making up 28 percent of the total in 2000 (World Health Organization 2002a).

Urban populations are highly dependent on ecosystem services. In effect, urbanites trade resource-based livelihoods for industrial and service-based ones, thus relying on networks to deliver the ecosystem services they need and that cannot be produced in urban areas. As cities grow, these urban-rural linkages are redefined, and can have tremendous effects on both the supply of and demand for ecosystem services that extend far beyond city limits. In less developed nations, the effects of urbanisation are often more profound, as it quickly takes priority over alternative forms of land use in the proximity of cities, even where productive croplands occur (Lambin *et al.* 2001). In addition, the prospect of employment in cities induces permanent or circulatory migration, with people flowing out of rural areas and a proportion of their wages flowing back in as remittances to relatives who stay behind.

Gauteng Province, the southern half of which lies within the Gariep basin, exemplifies the urban transformation process. It is the smallest province in South Africa (17,010 square kilometres; 1.4 percent of the total land area of the country) and contains 8.8 million people (20 percent of the national population, the second highest proportion of all the provinces). Perhaps most telling, the population of Gauteng increased by 20 percent between 1996 and 2001, outstripping the national growth rate by a factor of two; meanwhile, population in some of the more rural provinces declined significantly during this period (Stats SA 2003).

Gauteng forms the integral economic hub of South Africa - and the greater southern African region - contributing 36.5 percent of the national GDP. It has an urbanisation rate of 94 percent and a population density of 375 people per square kilometre, an order of magnitude higher than the country's average. Like most urban areas, Gauteng consumes greater amounts of ecosystem services than it produces, particularly food and water.

The effects of urbanisation on biodiversity can differ radically from that of other forms of land use such as cultivation. As Gauteng Province lies mostly within the Grasslands biome, it contains many endemic and severely threatened species, formally protected only in a modest reserve network. Nonetheless, the Gauteng Department of Agriculture, Conservation and Environment (DACE) maintains an extensive database on conservation features and threats in the province, which contributes to policy processes.

Gauteng's Agricultural "Footprint"

Gauteng provides only 0.3 percent of South Africa's total agricultural income and profit (Stats SA 2002) but is a major agricultural market. An analysis was conducted of the food volumes produced and consumed in Gauteng compared to South Africa as a whole (Figure 2.37). For most food types, annual production for Gauteng is well below four percent of the national production. The exceptions are pork and chicken, of which Gauteng comprises between 17 and 20 percent of the national consumption, probably due to the fact that neither space nor rangeland is a major requirement for farming these animals. Interestingly, Gauteng reportedly consumes 60 percent of South Africa's dairy products. Much of this, however, is redistributed to other areas in the country as butter, cream, cheese, and yoghurt.

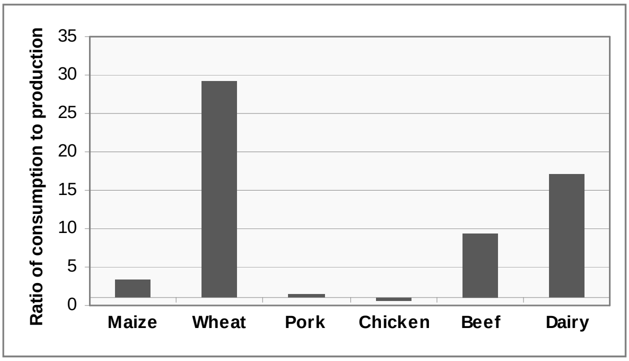


Figure 2.37 Ratio of Gauteng's consumption to its production of six food types. Only chicken, with a ratio of 0.66, is produced in excess of consumption. Wheat has the largest "footprint": Gauteng consumes nearly 30 times the amount produced within the province. *Sources*: Agriwriters 2003, De Villiers 2003, IFAP 2003, South African Government Online 2002a, 2002b, South African Grain Information Services 2002, Stats SA 2001.

The Gauteng Water Cycle

Johannesburg, the urban nucleus of Gauteng, is one of the few major cities not built on a navigable watercourse, and was instead developed around the fledgling gold mines that were founded in the late 19th century (Figure 2.38). Gauteng is in fact a water-scarce province, with a mean annual precipitation of only 655 mm per year. The scarcity is intensified by the high levels of urbanisation, mining, and industry that require vast quantities of water, much of which is imported into the province from the Lesotho Water Highlands Project. These activities, however, also contribute substantial return flows of water, which results in keeping inputs of water roughly equal to the outputs. Table 2.6 indicates the inputs and outputs of water in Gauteng. On average, 58.3 percent of urban water use returns to the water supply. Mining returns 254.9 percent of the water used, due to the required pumping of groundwater to prevent the mines from flooding. There is a relatively small surplus of 213.94 million cubic metres of water in Gauteng; this does not include water stored in dams and groundwater resources that have effectively been allocated.

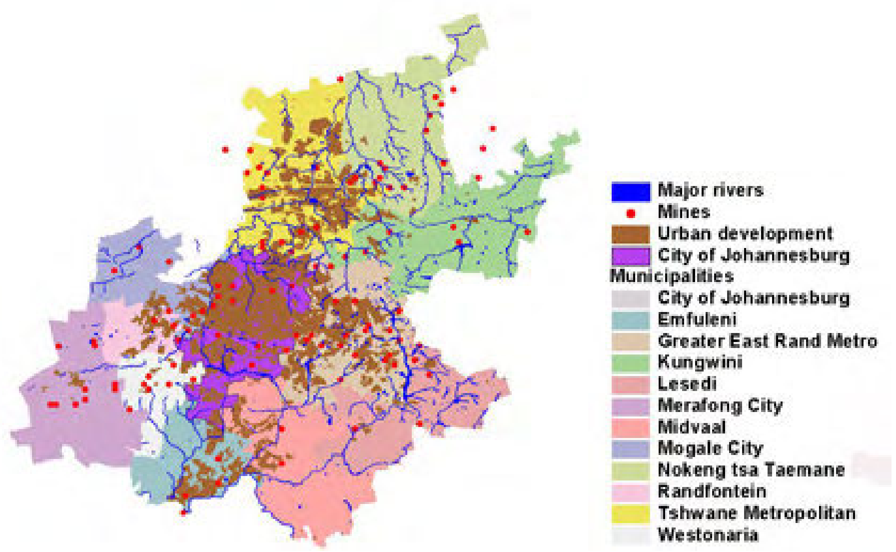


Figure 2.38 Location of urban development, mines, major rivers, and municipalities in Gauteng Province.

Table 2.6 Water balance for Gauteng Province. *Source*: Water Situation Assessment Model (WSAM).

Outputs	Volume of water (Mm^3)	Inputs	Volume of water (Mm^3)	Balance (Mm^3)
Water exports	993.02	Water imports	916.14	
Water use by: **Irrigation**	283.84	Return flows from: Irrigation	27.12	
Urban	929.36	Urban	541.74	
Mining	53.55	Mining	136.50	
Strategic bulk	74.97	Groundwater	64.90	
Rural	57.97	Mean annual runoff	1054.18	
Other bulk	73.20			
Forestry	0.01			
Alien vegetation	25.11			
Totals	2526.64		2740.58	213.94 (surplus)

Much of the water that flows through Gauteng is high in salts and heavy metals due to mining and industry. While mining is a major contributor to the province's GDP, it has significant impacts on ecosystems and health. These include acid mine drainage, with pH levels downstream of some mines reaching 2.2 to 2.5 over the period of a year (City of Johannesburg 2001, Holgate 2002). A pH below 4.0 presents a severe danger to human health (DWAF 1996a). Very acidic water also dissolves heavy metals from the surrounding rock and causes surface water contamination.

The Upper Klip River is one location in Gauteng where mine pollution is severe (Table 2.7). Heavy metal concentrations are in most cases well above twice the acute levels, indicating a significant negative impact on aquatic ecosystems (DWAF 1998, Oryx 2000). Another major indicator of mine pollution is the sulphate concentration in rivers. In the Upper Klip River, there are instances of the SO_4 levels reaching maximum levels of 22 445 mg/l, orders of magnitude higher than the maximum level of 600 mg/l considered acceptable (Holgate 2002, City of Johannesburg, 2001).

Many Gauteng residents live in low-cost housing and informal settlements, most of which do not have water-borne sewerage. As many of these settlements occur along the rivers, surface water resources are heavily impacted. To add to this, the rapid urbanisation and increased population density has resulted in the sewer system being under capacity, particularly in the inner city where the apartment blocks house as many as 20 people per apartment. This causes blockages and sewerage spillages into the stormwater system and ultimately into the rivers. The primary problem is the level of faecal pollution, indicated by faecal coli (a group of gut-dwelling *Escherichia coli* found in warm-blooded animals associated with disease in humans), which is often found in association with other diarrhoeal-causing bacteria such as cholera. The acceptable limit for faecal coli is 130 per 100 ml. At many monitoring points for water quality, the faecal coli levels reach the millions, with one point registering a massive 11 million faecal coli per 100 ml. This is not uncommon and poses a significant health threat to people who are exposed to such highly contaminated water (City of Johannesburg 2001, Holgate 2002).

Table 2.7 Average levels of heavy metal concentrations found in the Upper Klip River, 1995 to 1999. *Source*: City of Johannesburg 2001.

Constituent	Average Concentration	Recommended Levels for Aquatic Ecosystems		
		Target	*Chronic*	*Acute*
Cadmium (µg/l)	10	<0.25	0.5	6
Copper (µg/l)	20	<0.8	1.5	4.6
Arsenic (µg/l)	70	<10	20	130
Zinc (µg/l)	190	<2	3.6	36
Manganese (µg/l)	18010	180	370	1300
Iron (mg/l)	3.01	0.0-0.1	0.3-1.0	>1.0

Wetland Services in Gauteng

The Klip River catchment with its widespread reedbeds of *Phragmites australis* clearly illustrates the filtering functions of wetlands. Table 2.8 shows levels of faecal coli and ammonia recorded in 2000 at monitoring points upstream and downstream of wetland areas. This suggests that 2 km of watercourse with large segments of instream reedbeds is capable of assimilating up to 98.6 percent of the faecal coli present and up to 55.8 percent of the ammonia (nitrates). An additional 2 km reduces the faecal coli by an additional 96.1 percent and ammonia by 50 percent (City of Johannesburg 2001, Holgate 2002).

Table 2.8 Reduction of faecal coli and ammonia due to wetland filtering. *Source*: City of Johannesburg 2001. *Notes*: The maximum faecal coli concentration considered acceptable is 130/100 ml. The maximum ammonia concentration considered acceptable is 0.03 mg/l.

Monitoring point	Faecal coli (per 100 ml) mean (maximum)	Ammonia (mg/l) mean (maximum)
Point 1a (upstream)	150 818 (330 000)	16.5 (42.0)
Point 1b (2 km downstream)	573 (2 300)	7.3 (14.5)
Point 2a (upstream)	41 864 (330 000)	1.7 (5.8)
Point 2b (2 km downstream)	564 (2 600)	0.8 (4.5)
Point 2c (4 km downstream)	22 (200)	0.4 (1.0)

Urban biodiversity

The urbanisation of Gauteng Province during the past century and a half has had serious consequences for its biodiversity. DACE has a comprehensive database on the condition and trends of biodiversity in the province. In an attempt to contain urban development and protect rural areas from urban sprawl, an urban edge has been delineated, outside of which no further urban development may occur (Figure 2.39). This urban edge spreads over about 20 percent of the province and is already developed significantly. Not only is the province dealing with the impacts of urban development on biodiversity, but the Highveld grasslands of the province are also suitable for cultivation, with 16 percent of the province supporting crop production.

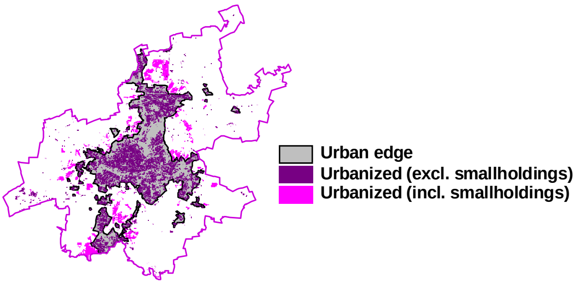


Figure 2.39 Extent of Gauteng's urbanisation and urban edge. *Source:* Fairbanks *et al.* 2000.

It is estimated that only about 30 percent of Gauteng Province is in a natural (and highly fragmented) state. This figure is probably an overestimate of natural land cover as it is based on a national landcover database, which does not distinguish between untransformed and secondary grasslands that were once ploughed for cultivation but are now recovering grasslands. This is an important distinction, however, because a grassland will never recover to its previous state after being transformed; grass may regrow but plant diversity associated with that grassland is irrevocably lost (van Wyk, *pers. comm.*). DACE has begun ground-truthing the areas classified as "natural," and initial field surveys indicate that only 50 percent are actually natural.

With only 60 percent of the province in a natural state (albeit a very fragmented one), the thresholds of ecological integrity and function are very close to being reached (Franklin and Forman 1987, Reyers *et al.* 2001). Only 1.7 percent of the province falls into provincial protected areas, with another 4.6 percent in private and municipal reserves, natural heritage sites, bird sanctuaries, and protected natural environments. These levels are far below the 10 percent target recommended by the Convention on Biological Diversity. Roads and other urban infrastructure make up a significant portion of the province (14.3 percent and 54.3 percent respectively within the urban edge). Over 77 percent of the grasslands, of which Gauteng is a major part, occur in fragments of less than 10 square kilometres, of which 46 percent occur in fragments less than 2 square kilometres (Neke and du Plessis 2004). This poses potential problems for habitat connectivity, meta-population dynamics, and related ecosystem resilience.

The province has a large number of threatened wetlands, of which about only eight percent fall within protected areas, while 80 percent are within the urban edge. In addition, almost 32 percent of urban perennial streams are denuded of riparian vegetation. The province is also significantly degraded by invasions of alien plants and animals (Figure 2.40b). The highest numbers of threatened species coincide with the urban edge (Figure 2.40c). Some native species have increased in abundance, possibly because of increased habitat diversity, and the presence of gardens and green spaces. The Grey Go-away Bird, Rameron Pigeon, and Black-collared Barbet are common indigenous bird species that have expanded their ranges as the result of urban development and associated planting of trees, for example.

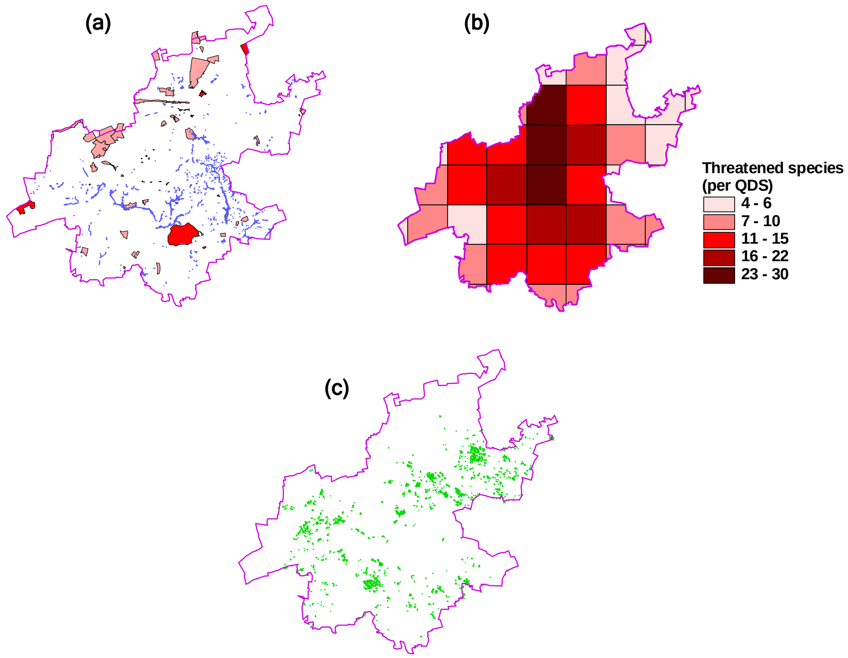
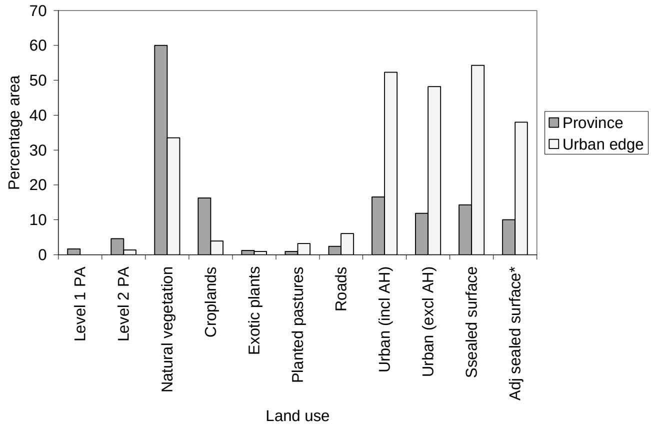


Figure 2.40 Biodiversity in Gauteng: (a) Distribution of wetlands illustrating provincial (red) and private nature reserves (pink); (b) Total number of threatened species per quarter degree grid square; (c) Areas (in green) that are invaded by alien plant species. *Source:* Gauteng Nature Conservation 2003, SAPIA (Henderson 1998).

Figure 2.41 illustrates the percentage of land in different landcover classes in Gauteng Province and within the urban edge, highlighting the predominance of urban and other artificial areas. An average of 179 square metres of vegetated open space is available per urban resident in Gauteng. Roads significantly threaten biodiversity in the province, with impacts including habitat fragmentation, noise and chemical pollution, road kills, construction effects, and increased behavioural modifications in wildlife. Road density is 1.7 hectares per square kilometre in rural areas and 5.5 hectares per square kilometre within the urban edge. Road zone effects (Reyers *et al.* 2001) impact on more than half the natural habitat in the province, and on almost ninety percent of the natural habitat within the urban edge.

Judging by the number of invasive species and species threatened by urbanisation in the province (see Figure 2.42b), from plant, vertebrate, and invertebrate surveys in the region (Gauteng Nature Conservation 2003), the problem of invasive species is significant. An analysis of invaded areas using the Southern African Plant Invaders Atlas (SAPIA) database (Henderson 1998) shows that 17 percent of invaded areas contain more than ten invasive plant species, 15 percent contain between five and ten invasive plant species, while 68 percent of invaded areas contain less than five invasive plant species.

(a)



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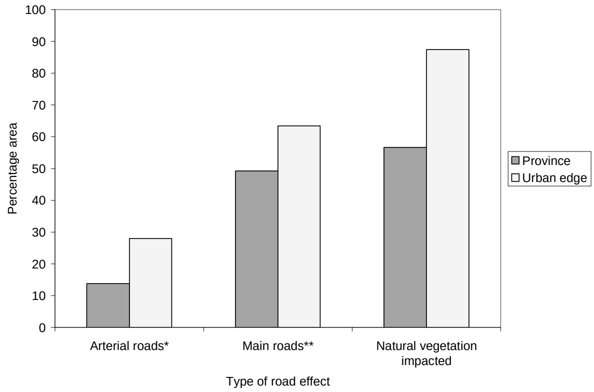


Figure 2.41 Land cover in Gauteng Province showing (a) the percentage cover of various land uses within the province and within the urban edge and (b) road effects on the province and the urban edge. Categories are not mutually exclusive and thus will not total 100 percent. *Sources:* Landcover 2000 (Fairbanks *et al*. 2000), Gauteng Nature Conservation 2003, Chief Directorate: Department of Surveys and Mapping 2003. *Notes:* (a) PA = protected areas. Level 1 = provincial nature reserves, i.e. protected areas with strong legislative and institutional protection; Level 2 = municipal nature reserves, natural heritage sites, bird sanctuaries, protected natural environments, private nature reserves. (b) * Adjusted sealed surface = subtraction of 30 percent to account for all untarred roads in rural areas and gardens/landscaped areas in residential areas; no GIS data available to verify this. * 500 m buffer; ** 200 m buffer;

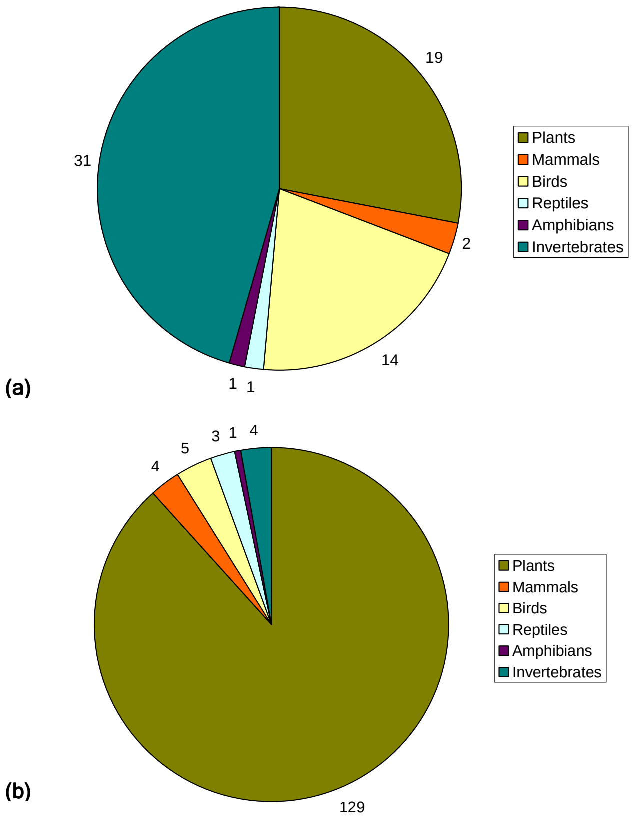


Figure 2.42 Number of species per taxonomic group occurring in Gauteng which are (a) threatened by urbanisation and (b) invasive species. *Sources*: (a) Gauteng Nature Conservation 2003; (b) SAPIA (Henderson 1998).

Box 2.27 A Survey of Urban Backyards

Despite the images cities evoke of concrete and high-rises, many urban yards provide ecosystem services to city dwellers. In Gauteng, residential yards and gardens can be refugia of biodiversity, as well as plants used for food, decoration, or other purposes. The large income gap in Gauteng is reflected in the diversity of its neighbourhoods, and the nature and purpose of plants grown in yards also vary. To see if socioeconomic differences are expressed in terms of yard or garden plant composition, an investigation was carried out in the city of Pretoria in Gauteng's Tshwane Municipality. Each yard surveyed was defined as belonging to a wealthy residence, a middle-income residence, a township, or an informal settlement. Measurements were made of the proportion of each yard covered by hard surfaces, vegetated surfaces, water, alien plants, and indigenous plants, and the use or purpose of the plants (e.g. for food, decoration) was noted.

It was discovered that:

- Wealthy residents have the largest yards, averaging 1230 square metres, middle-income yards average 373 square metres, townships yards average 241 square metres, and yards in informal settlements average 46 square metres.
- The fraction of the area covered by hard surfaces, water, evergreen plants, plants used for decorative purposes, and grass was not significantly different between socioeconomic households.
- People from informal settlements and townships use a larger portion of their yards for food than for decorative purposes.
- In informal settlements, basic needs seem to be a key determinant of yard use. One inhabitant, asked to comment about the relationships between residents of informal settlements and biodiversity, maintained that although they do not intentionally introduce alien plants, they do clear vegetation that creates a hindrance to finding shelter.

Source: Zondo 2003.

CHAPTER 3

Trade-offs and Decision-making

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 be a contentious and sometimes conflict-ridden process. Trade-offs in the southern African context typically are made against the backdrop of particular pressures that arise from the need to achieve social and economic development goals while securing ecosystem functions. In the Gariep basin, the challenge of making trade-offs is intensified by the need to reverse past discrimination in South Africa that prevented the majority of the population from fully realizing or gaining access to the benefits provided by ecosystem services.

Choices may have to be made between: 1) different services (representing different livelihoods or means of procuring economic benefits); 2) reaping benefits of ecosystem services now and reserving them for future use (related to the issue of inter-generational equity); 3) meeting the needs of society and of ecosystems (related to 2, because society is usually concerned first and foremost with its present needs, and secondarily with its future needs, or the needs of others); 4) the provision of social and economic benefits and the maintenance of human well-being (frequently expressed as the provision of these benefits to one population in one time or place at the expense of the well-being of another).

Part of the difficulty surrounding such situations owes to the fact that they almost universally boil down to a trade-off between values of different stakeholder groups. An upstream industry may value the Gariep system as a sink for wastes; downstream, tourists may enjoy the Gariep River for recreational purposes, commercial irrigators may focus on the importance of water from the river to cultivate crops for local sale and export, and pastoralists in the Richtersveld may value the grazing lands along the river's banks. As noted at the beginning of Chapter 1, while the values of some services can be expressed in monetary terms, others cannot. In addition framing a question of ecosystem services only as an economic issue has several shortcomings.

So how should these situations be dealt with? We suggest that making trade-offs and their implications (ecologically, socially, and economically) transparent to decision-makers can assist the process of choosing between various options and the likely consequences of making alternative choices. Informed decision-making about such trade-offs requires specificity about the temporal and spatial scales of interest, and necessitates the ability to answer the following questions: Do potential future impacts on ecosystem services have a bearing on current decision-making? Over what period will impacts occur? Does the alteration in ecosystem services affect human well-being far away from the intended ecosystem change (e.g. through downstream effects or atmospheric transport)? Do impacts cross administrative or ecosystem boundaries?

A number of techniques have been developed to evaluate trade-offs. Below we present three approaches as case studies of trade-offs between different aspects of the three core service clusters assessed in SAfMA: water, food, and biodiversity or ecosystem integrity. The first addresses trade-offs between two ecosystem services, food production and water, using a model-based approach. The second illustrates a classification framework proposed by the Water Act for allocating multiple water services to provide for the needs of people as well as ecosystems. The third demonstrates the use of a GIS-based method to evaluate trade-offs between food production and biodiversity. Finally, we look at ways to deal with multiple trade-offs simultaneously, with reference to the examples discussed.

3.1 Trade-offs between Services: Water and Food Production

Water and food production are two ecosystem services that sustain the lives of people as well as a host of other species. Water and food are intrinsically connected. Water is essential to the production of major cereal crops. In fact, in the arid environment of much of the Gariep basin, water is a major limiting factor of production. Efforts to increase the productivity of agricultural water use by both commercial farmers and smallholders are thus of paramount importance and must aim to improve not only the economic efficiency of irrigation ("crop per drop") but also the equity of irrigation, as indicated by "jobs per drop" or number of people or livelihoods dependent on a given quantity of water (Kamara and Sally 2002).

The policy dialogue model, PODIUM, is a decision support tool developed by the International Water Management Institute (IWMI) to assess policy options related to national level cereal-based food security and water availability (Kamara and Salley 2002). Based on macroeconomic assumptions, the model provides an analytical framework for assessing water and food demand in 2025 resulting from population growth and changing diets. In particular, it focuses on four uncertainties: 1) population growth; 2) options for meeting food security by expanding irrigated area; 3) increasing the efficiency of irrigation water use or yield improvements; and 4) the impact of increasing the daily water allocation per capita for basic human needs.

About 60 percent of South Africa's potentially utilizable water resources are already developed; this is referred to as its *degree of development*. Beyond a 80 percent degree of development (i.e. in which 80 percent of water resources are developed, with 20 percent remaining to meet environmental reserve requirements), the country will experience *physical water scarcity*, at which stage few or no options for further water resource development are likely to exist (Kamara and Sally 2002). A country experiences *economic water scarcity* if the growth in total diversions – by development of additional storage, conveyance, and regulation systems – exceeds 25 percent of its 1995 levels (Seckler *et al*. 1998). Economic water scarcity is thus an indicator of a country's ability to make investments in water development and associated infrastructure required for sufficient water provision. By IWMI's calculations, for example, Lesotho will be economically water scarce in 2025, but will not experience a physical water scarcity.

Below some findings from the application of PODIUM to South Africa by Kamara and Sally (2002) are highlighted concerning the first three uncertainties noted above. Table 3.1 reveals that population growth in line with the UN's high-growth estimate for 2025 (resulting in a population of approximately 48 million people) will lead to threatened food security (production < 0 tons) if water utilisation, irrigation efficiencies, and crop yields remain stable.

The implications for developing additional irrigated area as a way to alleviate food deficits are presented in Table 3.2. According to the model, an increase of about 40 percent increase in irrigated land area (equalling about 1.778 million ha of total irrigated land area) would be needed to achieve surplus food production if current yield levels and the trade balance remain unchanged. To achieve such a large increase is highly unlikely, and would require significantly large investments.

Table 3.1 PODIUM Results: Implications of Population Growth on Water and Food Demands (2025). *Source:* PODIUM Model Estimations 2002 (Kamara and Sally 2002).

Population 2025 (million) [d]		**Water development and food security indicators**		
Variant	**Predicted**	DOD (%)[a]	Growth (%)[b]	Food Security [c]
Low	**39.96**	67	28	2.0
Medium	**43.77**	68	29	0.73
High	**47.52**	69	31	-0.51
Constant	**49.21**	69	32	-1.08
UN-ECA	**66.90**	72	40	-6.96
Agricultural water productivity (crop per drop): 1.18 kg/m^{3}ET				

[a] Degree of Development (percent of potentially utilisable water resources)

[b] Growth in total water diversions to agriculture, domestic and industrial uses (percent)

[c] National level food security: surplus (+) and deficit (–) in million tons

[d] Projections: UN Population Division and the Economic Commission for Africa (ECA)

Table 3.2 PODIUM Results: Implications of Increasing Irrigated Area for Water and Food Situation (2025). *Source:* PODIUM Model Simulations 2002 (Kamara and Sally 2002).

Increase in net irrigated area (2025 million ha; current 1.27)			**Water resources development And food security indicators**		
Annual %	Total %	Actual Area	DOD (%)[a]	Growth (%)[b]	Food Security [c]
0.32	10	1.377	59	13	-0.23
0.47	15	1.461	61	16	-0.18
0.61	20	1.524	63	20	-0.14
0.75	25	1.588	65	23	-0.10
0.88	30	1.651	67	27	-0.05
1.13	40	1.778	71	34	0.03
Agricultural water productivity (crop per drop): 1.18 kg/m^{3}ET					

[a] Degree of Development (percent of potentially utilisable water resources)

[b] Growth in total water diversions to agriculture, domestic and industrial uses (percent)

[c] National level food security: surplus (+) and deficit (–) in million tons

A third set of options involves using agricultural water more efficiently by improving the effectiveness of irrigation systems. The PODIUM model was used to investigate the implications of increasing irrigation efficiency from 55 through 65 percent (under flood systems), to 75 and 80 percent (under sprinkler systems) for degree of development and total diversions (Table 3.3). Thus, an increase in the efficient use of irrigation water from 55 to 60 percent would reduce the degree of development by 4 percent and total diversions by 9 percent.

Table 3.3 PODIUM Results: Irrigation Efficiency and Water Resources Development. *Source:* PODIUM Model Simulations 2002 (Kamara and Sally 2002).

Increase in Irrigation Efficiency (%)	55	60	65	70	75	80	85
Degree of Development (%)	71	67	63	59	57	54	52
Total Diversions (%)	36	27	20	14	8	4	0

In summary, at the country level, expanding irrigated area in isolation of other interventions is not likely to improve food security significantly. On the other hand, modest increases in irrigated area and improvements in efficiency are feasible and do not imply the need to allocate large amounts of water to the agricultural sector. Research and investments need to continue into both technical and institutional options to improve irrigation efficiency, intensification possibilities, and yield enhancing alternatives in both irrigated and rainfed agricultural production (Kamara and Sally 2002), as well as opportunities to produce less water-intensive crops and to increase imports of grain through “virtual water” schemes. The scope and scale of this analysis, which focuses only on cereal production at the national level, may obscure key trends that would emerge in studies of other crops or specific catchments. Work is commencing to expand the PODIUM model so that it may accommodate analyses of additional crops and finer-scale data.

3.2 Trade-offs between Utilisation and Protection of Water Services

Competition for water services exists in several dimensions. Users compete spatially for water, with upstream users influencing water that flows to downstream users, and water pollution induces further competition when polluters displace the effects of their activities to other parts of the basin. Trade-offs also exist between the use of surface water and groundwater abstraction, typically in rural areas where groundwater is a key resource. Competition for water is also temporal, whereby modifications to increase the quantity or reliability of water supplies in the short term may compromise the quality of water in the long term (although increased quantities can result in localized improvements in quality), and ultimately threaten aquatic ecosystem integrity. Inter-generational equity introduces another type of competition, between the water users of the past, the present, and the future.

In another sense, trade-offs between the different services provided by water revolve around sectoral competition for limited supplies, a fact that carries various social and economic connotations. Water is needed for different purposes: urban and rural domestic use, irrigation, mining, industry, power generation, afforestation, biodiversity, and ecosystems. Most of the major sectors of water use in the Gariep basin have unique spatial distributions, but they all withdraw water from what is essentially a common, limited source. While past developments have enabled a high level of assurance of most of these sectors' requirements, it is uncertain how well these needs will continue to be met in the future without compromising the ability to meet the reserve.

With sustainability a major goal of water management, trade-offs must be made in such a way to safeguard the future capacity of ecosystems to continue functioning. The Water Act recognizes both the conservation significance and economic value of water resources, and that varying levels of impacts on water resources must be tolerated in order to provide services, but must not exceed these levels. Some water resources will require greater protection because they support endemic or threatened biota, or provide runoff to a protected area. Other resources would require less protection because they perform a vital economic role by supporting the water demands of an urban area or absorbing industrial wastes.

Table 3.4 illustrates a framework to classify South Africa's water resources that enables a balance between the protection and utilisation of water services (Mackay 2000). For each water resource, typically a quaternary catchment or river reach, a letter from "A" to "F" designates an ecological management to indicate its ecological condition. Resources in Class A are mostly natural, resources in Class D heavily modified, and resources in Classes E and F seriously or critically modified to the point that their functioning may be impaired irreversibly. Management would strive, where possible, to restore resources in Classes E and F to Class D or better. Very low levels of risk would be tolerated for Class A resources, while increasing levels would be acceptable as resources approach Class D. These designations are decided upon systematically by a group of stakeholders who have knowledge of the system to be classified. Clearly, these designations are site-specific, and some quite uncertain, due to the lack of knowledge about relationships between hydrological flows and ecological variables. While this classification system acknowledges that some water resources must be sacrificial "workhorses" in order to allow others to remain pristine, it also provides for suggested improvements of resources that can lead to a reclassification upward.

The application of this framework to the Gariep basin in Figure 3.10 illustrates the configuration of present ecological management classes based on local studies and models, and of attainable classes that indicate the restoration potential of the catchment in the next five years. Table 3.5 indicates the area of the basin in each of these classes. Until this framework is implemented and tested, it is difficult to pinpoint the exact balance needed between protection and utilisation in order to achieve ecological, social, and economic development goals, and in practice, may only be found through a process of trial and error. The current human reserve requirements are already a contentious issue, with the World Health Organization and others maintaining that a daily minimum of 50 litres per capita, rather than the current 25, is much more conducive to securing health benefits. This level of service provision is unlikely to be possible unless directly provided to homes or yards (World Bank 1992), which will require significant financial support and infrastructure investment. Twenty-five litres is considered sufficient for one person's drinking, cooking, and personal hygiene, but is usually inadequate for irrigation of even subsistence crops (Mackay 2003). However, with careful and committed management, it should be possible for people to have more water for basic use and to meet the ecological reserve requirements, though this will require re-allocation of some water from irrigation, for example, to more economically efficient uses.

Table 3.4 Proposed framework for setting ecological resource quality objectives on the basis of a classification system (adapted from Mackay 2000). Class A affords the highest level of protection of resources and would be least amenable to many forms of utilisation, while class D affords the lowest level of protection but allows utilisation that is more intensive. Classes E and F are not included, as these are considered unacceptable and would be managed according to the rules for resources in class D.

PROTECTION ↕ UTILIZATION

Class	Water quantity	Water quality	Instream habitat	Riparian habitat	Biota
A	Natural variability and disturbance regime. Allow negligible modification.	Negligible modification from natural. Allow negligible risk to sensitive species. Must be within Aquatic Ecosystems Target Water Quality Range (TWQR)[1].	Allow negligible modification from natural conditions. Depends on the instream flow and quality objectives which are set.	Allow negligible modification from natural conditions. Control of land uses in the riparian zone.	Negligible modification from reference conditions should be observed based on the use of a score or index such as the South African Scoring System (SASS).
B	Set instream flow requirements to allow only slight risk to especially intolerant biota.	Use Aquatic Ecosystems TWQR and Chronic Effect Value (CEV) to set objectives which allow only slight risk to intolerant biota.	Allow slight modification from natural conditions. Depends on the instream flow and quality objectives which are set.	Allow slight modification from natural conditions.	May be slightly modified from reference conditions. Especially intolerant biota may be reduced in numbers or extent of distribution.
C	Set instream flow requirements to allow only moderate risk to especially intolerant biota.	Use Aquatic Ecosystems TWQR, CEV and Acute Effect Value (AEV) to set objectives that allow only moderate risk to intolerant biota.	Allow moderate modification from natural conditions. Depends on the instream flow and quality objectives which are set.	Allow moderate modification from natural conditions.	May be moderately modified from reference conditions. Especially intolerant biota may be absent from some locations.
D	Set instream flow requirements that may result in a high risk of loss of intolerant biota.	Use Aquatic Ecosystems TWQR, CEV and AEV to set objectives that may result in a high risk of loss of intolerant biota.	Allow a high degree of modification from natural conditions. Depends on the instream flow and quality objectives which are set.	Allow a high degree of modification from natural conditions.	May be highly modified from reference conditions. Intolerant biota unlikely to be present.

1 See DWAF 1996b for an elaboration on Target Water Quality Range, Chronic Effect Value, and Acute Effect Value.

Because the Water Act emphasizes efficiency and achieving the optimal allocation of water with a pricing system, comparing the relative economic values of alternative water uses (and non-use) has merited much interest in the region in recent years. A suggested framework for the economic analysis of different combinations of water utilisation and protection has been applied to the Crocodile River catchment in Mpumalanga Province (Mander *et al*. 2002).

This framework defines three types of water uses, or "activities:" Type 1 activities affect water resources as externalities, and include forestry and dryland agriculture. Type 2 activities are abstractive; that is, they withdraw water from the catchment, and may also return polluted water to the catchment; these include domestic use, irrigation, mining, and industrial use of water. Type 3 activities are those that depend on in-stream flow and water quality, such as conservation, tourism, recreation, and the provision of ecosystem services. These activities carry different economic and ecosystem values, which will depend in part on the robustness or sensitivity of ecosystems in a given catchment. An illustration of how trade-offs in a catchment can be optimised through increased efficiency is given in Figure 3.2. It demonstrates the "unevenness" of trade-offs in robust and sensitive systems. The value of allocating more water to Type 1 and 2 activities in a sensitive system may be offset by a greater loss to Type 3 activities, while the value of allocating more water to Type 3 activities in a robust system may be offset by a greater loss to Type 1 and 2 activities.

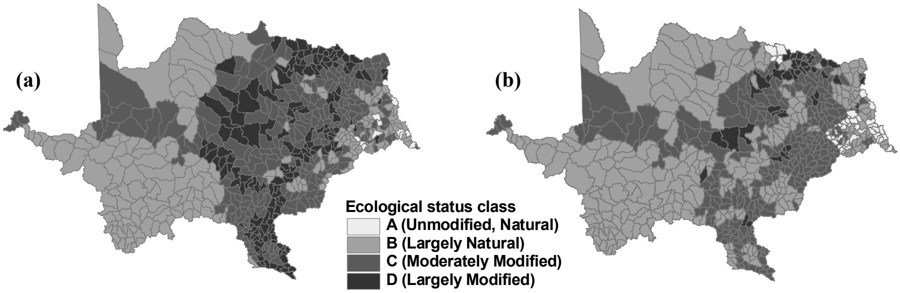


Figure 3.1 (a) Present and (b) attainable ecological management classes. *Source:* WSAM.

Table 3.5 The area of the Gariep basin (in square kilometres and as a percentage of total area) in each ecological management class under present and attainable configurations shown in Figure 3.1.

Area of basin in class	Present (km²)	Present (% of total)	Attainable (km²)	Attainable (% of total)
A	4102	0.6	16 406	2.4
B	295 999	43.3	390 336	57.1
C	250 198	36.6	201 662	29.5
D	132 619	19.4	74 513	10.9

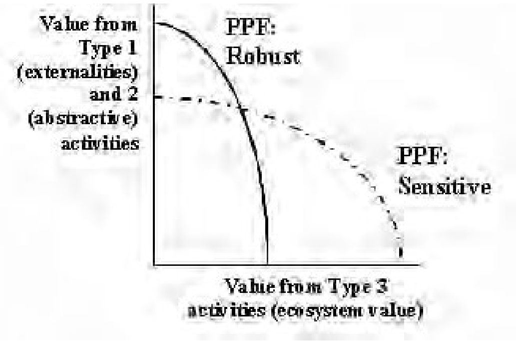


Figure 3.2 Production possibilities frontier (PPF) for water resources in an ecosystem, or the possible combinations of output that can be attained for a given set of inputs, in terms of the allocation of water to Type 1 or 2 activities (externalities or abstractive) vs. Type 3 activities (to the environment) for robust and sensitive ecosystems. *Source:* Mander *et al*. 2002.

3.3 Trade-offs between Land Use and Biodiversity

Land-use planning requires knowledge of the impacts of various decisions on other components of the landscape. A decision to afforest an area cannot be taken without knowledge of the impacts it can have on the provision, regulation and maintenance of ecosystem services (e.g. water, food production, and carbon storage) and biodiversity.

In a similar fashion to the assessment of ecosystem integrity (Chapter 2.9), we used the notion of irreplaceability (Pressey 1999) to assign comparable values to areas of land, based on a variety of ecosystem services and biodiversity. Irreplaceability is a measure of how important the features that an area contains are to the achievement of a stated goal. The idea of irreplaceability originated in the field of conservation planning where the biodiversity features contained in an area are evaluated to determine how important that area is to the achievement of a conservation goal. This concept is applicable to ecosystem services in a similar way. The availability of maps of ecosystem services has allowed us to investigate the amount of a service produced annually in an area. Irreplaceability requires a target or goal in order to calculate an area's importance or contribution to that target. Some ecosystem services have readily available targets, such as Recommended Daily Allowances (RDA) for protein and calories, which when multiplied by the number of people who rely on these services, results in a target amount for the basin. The services investigated in this fashion included calorie and protein production. As more data become available for other ecosystem services, they too can be included in the assessment.

Food production was divided into two components: calorie and protein production from cereal crops and livestock. It is acknowledged that there are other sources of protein and calories like vegetables and fruit, but little data exist on these crop types in the Gariep basin. This analysis is therefore limited to the calories and proteins from meat and cereals. Cereals are responsible for 54 percent of calories consumed by people and 57 percent of the protein requirements. This analysis thus assigned the remainder of calorie and protein requirements to meat production (i.e. 46 percent of caloric and 43 percent of protein requirements). The area of each quarter degree square (QDS) under cultivation was calculated. It was then extrapolated to provide the tons of each type of cereal produced per quarter degree grid cell. These tons could then be converted into calories and grams of proteins. Meat production was based on the number of livestock units in each QDS. Each livestock unit could then be converted to grams of protein and calories. Table 3.6 shows the total available calories and protein from cereals and livestock in the basin. The amounts required by the Gariep population (i.e. target) of both proteins and calories were calculated from the RDA per person for each, multiplied by the population. Both an upper and a lower target were calculated for each service in order to investigate the implications of different policies. Table 3.7 illustrates the per capita values of these upper and lower targets, as well as the discrepancy between male and female requirements. Targets were set based on an assumed 50:50 sex ratio in the basin. The total targets were then broken down into the amount required from cereals and from meat. These amounts were determined from the percentage breakdown above (i.e. 54 percent calories from cereals, 57 percent proteins from cereals, and the remainder from meat).

Table 3.6 Total calories and protein produced by cereals and meat in the basin. Upper and lower targets for calories and protein are also illustrated. These targets are then split into the proportion of the target met by cereal and meat production respectively.

Service	Total produced by cereal	Total produced by livestock	Total	Lower target	Upper target	Cereal lower target	Cereal upper target	Meat lower target	Meat upper target
Calories (cal)	1.8×10^{13}	4.4×10^{12}	2.3×10^{13}	12.0×10^{12}	15.0×10^{12}	6.5×10^{12}	8.1×10^{12}	5.5×10^{12}	6.9×10^{12}
Protein (g)	4.5×10^{11}	6.6×10^{11}	1.1×10^{12}	3.3×10^{11}	4.0×10^{11}	1.9×10^{11}	2.28×10^{11}	1.4×10^{11}	1.7×10^{11}

Table 3.7 Per capita amount of calories and protein for upper and lower targets for males and females.

	Male	Female	Source
Calories - lower	2350	1740	FNRI*
Calories - upper	2840	2250	FNRI*
Protein – lower	56	56	SA's RDA**
Protein – upper	73	63	FNRI*

* Food and Nutrition Research Institute (FNRI), recommended energy and nutrient intakes (RENI), 2002

** South African Recommended Daily Dietary Allowances (RDA) for labelling purposes, Act 54 of 1972, G.N.R. 1130/1984

As is obvious from Table 3.6, the total calories and protein produced in the basin exceed the requirements of the basin by at least an order of magnitude. This is not surprising as the basin is the source of most of South Africa's cereal and meat (Chapter 2), providing cereal for 70 percent of South Africa and a surplus for livestock (20 percent of total production) and export (50 percent of total production). There is also three times as much meat in the basin than is required by the population. These service values per QDS were inserted into the irreplaceability calculation. However, because the Gariep more than meets its own caloric and protein requirements the irreplaceability values of the QDS were all very low. The targets were therefore modified to include the requirements of 70 percent of South Africa's population (the estimated number of people that rely on the Gariep's food production - in essence another 30 percent of the population), another 20 percent of cereal for food for livestock and an additional 50 percent 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 3.3a illustrates that irreplaceability values for most QDSs are still low for the amended upper targets for protein and calorie production. However, this is not an indication that targets are easy to meet in the basin but rather that many combinations of sites could meet those aims, as irreplaceability is a measure of options for meeting targets. However, the sites with high values are excellent sources of the services and as such should be incorporated into any decisions made on land use. The areas highlighted are better at achieving the targets than those not highlighted, but are not essential as none of them is totally irreplaceable. The chances are high that if these highlighted sites were not available for food production, it would require several areas to replace just one of these high production ones. The upper and lower targets do not change the picture dramatically as the difference between the final targets is small compared with the size of the target. The irreplaceability surface using combined species and vegetation targets as discussed in Chapter 2.9 is represented by Figure 3.3b.

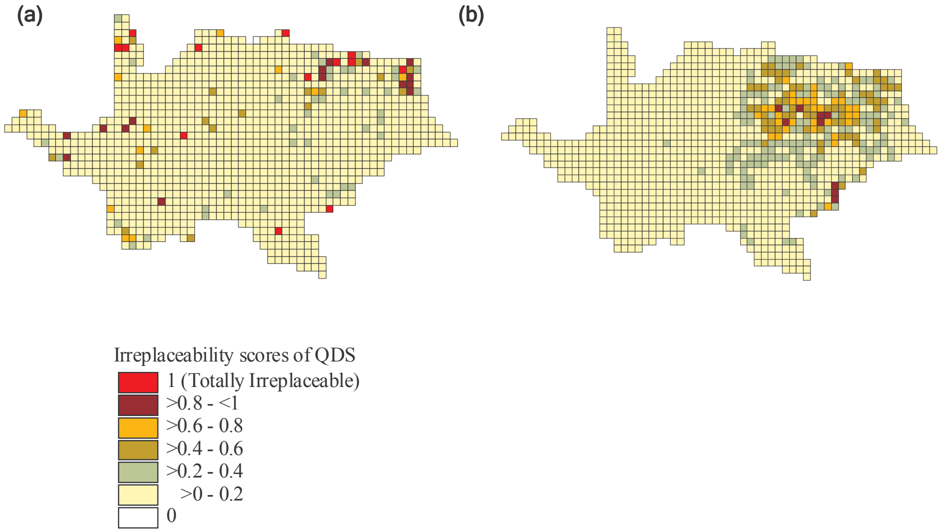


Figure 3.3 Irreplaceability maps for the Gariep basin based on upper targets for (a) biodiversity and (b) proteins and calories. Irreplaceability values range from 0 (very low importance for target achievement and many options for this cells substitution with another cell to achieve target) to 1 (totally irreplaceable, if this cell were not included in the provision of services, the targets for those services would not be met).

There is some congruence between areas important to calorie and protein production and biodiversity in the eastern portion of the basin, yet overall, the conflict between areas important to biodiversity and food production appears to be very low. However, this analysis is very preliminary and the targets are basic. Biodiversity targets were set very low while the food production targets need refinement. In addition, the irreplaceability analysis highlights areas important to target achievement but does not illustrate final target achievement. This would happen as decision makers chose grid cells for uses like conservation or cultivation and thus excluded them from other uses. In addition, the landscape of the Gariep is not a blank canvas as assumed in this assessment, as some areas are already cultivated and conserved. These factors would significantly influence the irreplaceability surfaces produced, and thus must be included in future iterations as these data become available.

One alternative to the irreplaceability assessment of protein and calorie production illustrated above is to use the potential production of all areas in the Gariep rather than the actual production used in the current assessment. This would add value to a planning framework for land use as it would highlight areas best suited to food production rather than areas currently in use. While new policies have replaced much of the inappropriate land-use planning in South Africa in the past, its legacy remains in the current patterns of land use. These do not necessarily lend themselves to the most beneficial and efficient harnessing of ecosystem services (Reyers *et al*. 2000). However, as data on potential production are not available for the entire basin, this assessment uses current production figures. This approach can be applied to potential values in much the same way, once these data become available.

The grid cells with high values for each service are illustrated in Figure 3.4. These are cells with an irreplaceability greater than 0.4. Land use trade-offs can then be further explored in those grid cells where there is conflict between conservation goals and ecosystem service supply. It must be noted that trade-offs need not be absolute. Some ecosystem services are more amenable with one another and with biodiversity than others are. For example, biodiversity conservation can take place in the same area as grazing (Pressey 1992, Scholes and Biggs 2004). This will obviously be limited to low-intensity of these uses; in other words, commercial-scale grazing on unplanted pastures would not be considered amenable with biodiversity conservation. This means that an area can be used for crop agriculture while still maintaining much of its biodiversity, through, for example, the implementation of corridors, retention of wetlands, and other key habitats. Similarly, areas allocated for conservation could still support a viable small stock industry without compromising biodiversity and services. It is important that ecologically sustainable land use management is never compromised. The secret to successful land-use planning in areas where multiple objectives are pursued is to give preference to compatible or more appropriate land-uses.

The trade-offs in the Gariep basin between biodiversity and food production are not fully understood and elucidated by this approach. Work is ongoing within the basin to improve these models of trade-offs using simulated annealing algorithms and opportunity costs.

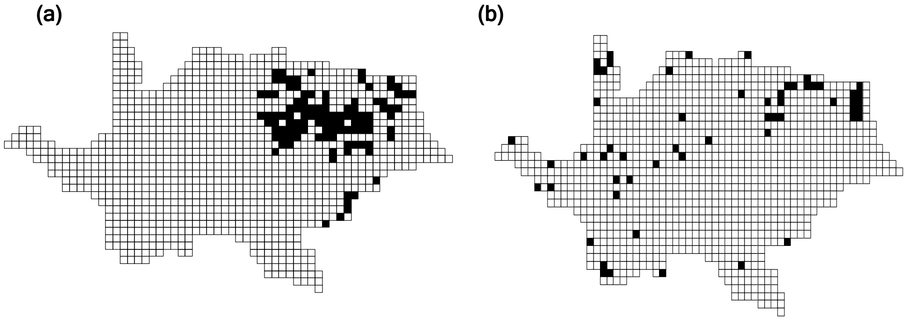


Figure 3.4 Grid cells with irreplaceability values of more than 0.4 illustrating areas of importance to the provision of (a) food and (b) biodiversity conservation.

3.4 Summary: Assessing Trade-offs

The examples presented here represent a small sample of the growing number of approaches used to confront complex decision-making problems. In the Gariep basin, these examples demonstrate that it is, in principle, possible to address societal and ecosystem needs simultaneously, that the land use requirements for biodiversity conservation and food production can be determined, and that appropriate land-use decisions are possible to achieve multiple objectives, sometimes even in the same area. Furthermore, a switch to more intensive production systems is feasible when land for extensive production becomes limiting and access to markets is adequate. However, managers must take care to work across sectors and spatial and temporal scales, which thus far, has not always been common practice.

How can the different approaches presented here be integrated in a way that they effectively communicate options and trade-offs to decision-makers? The Millennium Ecosystem Assessment Working Group on Condition and Trends uses graphical depictions of the trade-offs in ecosystem services associated with alternative policy options to provide useful input to decision makers (Daily 2000, Balvanera *et al.* 2001). Such depictions can take various forms, including the “spider diagram” approach, which depicts hypothetical trade-offs among ecosystem services associated with a policy decision

(Figure 3.5). Comparison of the ecosystem services available before and after the decision is made, allows a decision maker to account for the full suite of ecosystem services affected by the conversion.

We could therefore take the outputs of the PODIUM model, the production possibilities frontiers for water use, and the irreplaceability maps of biodiversity and convert them to such diagrams. This would involve more precise data sets and validation with stakeholder groups, but would resemble the hypothetical example below.

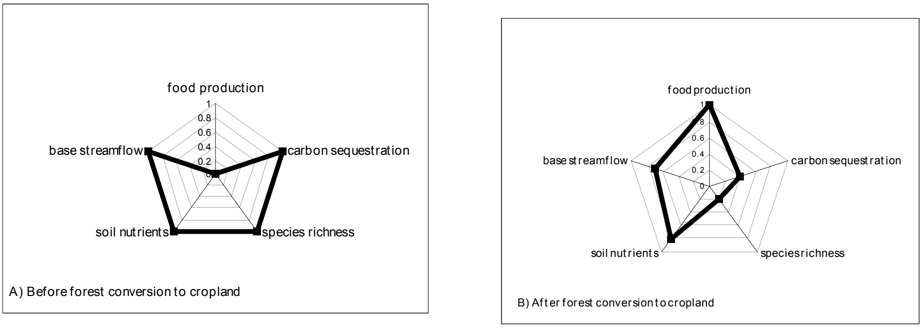


Figure 3.5 Hypothetical trade-offs in a policy decision to expand cropland in a forested area. Indicators range from 0 to 1 for low to high value of service. The values of the indicators vary according to the spatial and temporal scales of interest. Adapted from Millennium Ecosystem Assessment (first review draft, 2004b).

CHAPTER 4

Looking Ahead: Drivers, Scenarios, and Responses

4.1 Drivers of Change in Ecosystems and their Services

We need a solid grasp of the various driving forces, or *drivers*, that operate in the system to understand current trends in supply and demand of ecosystem services, the consequences for ecosystems and human well-being, and to be able to contemplate the directions these trends might take in the future. In the context of the Millennium Assessment, a driver is any natural or human-induced factor that directly or indirectly causes a change in ecosystem services. There is a distinction between direct and indirect drivers. A direct driver unequivocally influences ecosystem processes and can therefore be identified and measured to differing degrees of accuracy. An indirect driver operates more diffusely, often by altering one or more direct drivers. Its influence is established by understanding its effect on direct drivers (Millennium Assessment 2003). These are also referred to as primary and proximate drivers, and are often used to describe situations in which a human intent (primary driver) is linked with physical actions (proximate driver) (Millennium Assessment 2003).

In Chapter 2, we discussed drivers of change in the specific ecosystem services. Many direct drivers such as land-use and impoundment are traceable to another set of indirect drivers that create the conditions for them to happen. For example, population growth in the Gariep basin is an indirect driver of change in ecosystem services (Figure 4.1). Little growth occurred up until 1800, with expansion starting in the 19th century with the arrival of Europeans and continuing at a steady pace during the 20th century. This in turn spurred the industrial expansion in the region that began in the mid-1900s and catalysed a wave of dam construction and other developments *(see Box 4.1)*.

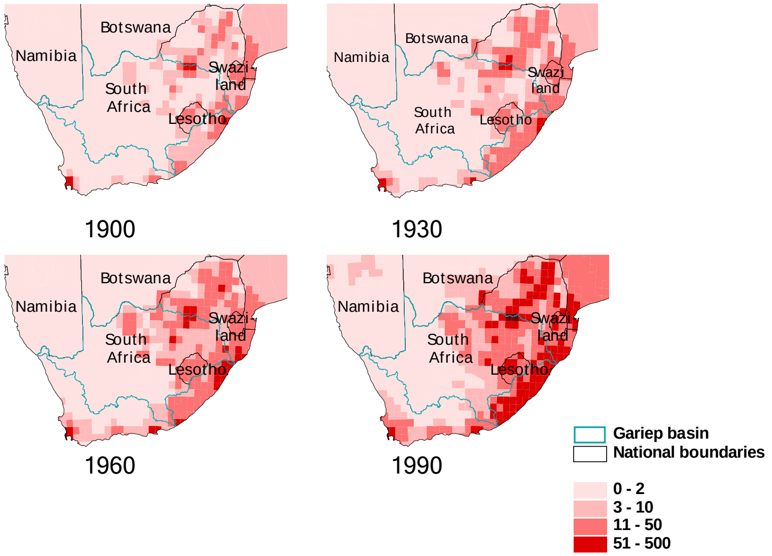


Figure 4.1 Indirect driver: Demographic change in the Gariep basin. Estimated historical population density of the basin and surrounding regions, 1900 – 1990. *Source:* Klein Goldewijk (2001).

We identified six categories of indirect drivers in the Gariep basin (Table 4.1): 1) governance change, 2) demographic change, 3) economic change, 4) climate change, 5) social/cultural change and 6) large-scale interventions on behalf of government, the private sector, or other relevant institutions. There are, of course, numerous examples of ways in which these drivers defy categorization as indirect or direct; every driver that is identified can be traced back a step in the chain of causality to another driver. Climate change, for example, may operate as a direct driver that is a product of one or more indirect drivers. Governance, economic or social/cultural change can cause demographic change. Furthermore, a consensus on driver identification can be difficult to achieve due to differences in perspectives about system dynamics, no single one of which is "correct". In consultation with the Gariep Basin User Advisory Group, we chose to focus on the direct and indirect drivers we see as being the most descriptive of pertinent changes in ecosystem services and human well-being.

Such an exercise of driver identification must consider the role of scale − both spatial and temporal. A change in ecosystem services observed at the basin scale may be attributable to a shift in national government policy. Other factors may drive change at the local scale, while change might not even occur at all. The Gariep local assessments identified a different set of drivers, some of which are consistent with the basin-scale drivers and some of which are not relevant to the basin. These were divided further into generic drivers that operate in all of the local assessments as well as specific drivers at each of the local-scale sites (Table 4.2).

Furthermore, drivers may interact; for example, when a new leadership takes power that passes novel trade regulations, or when economic change occurs after a change in governance. On the other hand, economic change may result from climate change, where warmer temperatures precipitate the collapse of an important agricultural sector. The interaction of drivers over space and time can either exacerbate or cancel out the effects that each would be expected to have when considered in isolation.

Box 4.1 Direct Drivers: A Timeline of Transformation of Gariep Basin Rivers

1800s: Korana people farm on Gariep River banks; Europeans build first irrigation scheme at Upington
1872: First dam constructed in Gariep basin
1880: Gold discovered in Johannesburg; water demands of the region begin to increase
1912: Passage of South Africa's Irrigation and Conservation of Water Act lays foundation for future water allocation; reserves surplus water for private property owners, and establishes irrigation boards
1928: Department of Irrigation conceives idea of Orange River Development Project, but considered too costly
1943: Annual flow of Gariep River reaches 62-year high of 25,472 million cubic metres[†]
1950s: First survey of water resources of Basutoland (now Lesotho) undertaken to assess viability of water exportation to South Africa
1956: South Africa passes Water Act no. 54 to accommodate needs of industrial expansion
1962-3: Political climate enables Orange River Development Project to win approval; poor planning results in delays and a quadrupling of initial budget
1971: Gariep Dam completed; storage capacity (5341 million cubic metres) equal to roughly one-third of Gariep basin's total runoff
1975: Orange-Fish Tunnel begins to deliver water from Gariep River to Eastern Cape Province
1978: Vanderkloof Dam completed, the highest (108 metres) in South Africa
1986: Treaty signed to implement Lesotho Highlands Water Project (LHWP) after 8 years of negotiations
1992: Annual flow of Gariep River reaches 62-year low of 818 million cubic metres[†]
1995: Katse Dam – at 185 metres, the highest in Africa - completed in Lesotho's Maloti Mountains
1998: South Africa's Water Act no. 36 declares water a human and environmental right; first LHWP water is released

Sources: Chutter *et al*. 1996, World Commission on Dams 2000, Thompson *et al*. 2001, DWAF 2002b, Metsi Consultants 2003, DWAF 2003a.

[†]Based on annual flow records from 1935-1997; mean flow for period was 6980 million cubic metres.

Table 4.1 Indirect (primary) drivers of change in the Gariep basin.

Driver	Explanation	Mechanisms of change in ecosystem services and human well-being
1. Governance Change	Change in the structure, role or effectiveness of national, regional, and local government and its consequences for devolution of authority to sub-national bodies, participation of citizens, access to information, transparency, conflict resolution, checks and balances, and environmental management. Also entails change in the role of private sector rather than government in provisioning public goods, security, and regulation.	The way in which rules and laws are made and enforced affects the supply of, management of, or access to ecosystem services and human well-being. For example, when a government (or private investor) builds better roads, there is improved access to markets and hence an adoption of more sustainable agricultural practices, and improved access to and quality of education and healthcare.
2. Demographic Change	Change in size and structure of the population, such as population size and rate of change over time (birth and death rates), age and gender structure of a population, household distribution by size and composition, spatial distribution (urban versus rural and by country and ecosystem), migration patterns, and level of educational attainment, prevalence of HIV/AIDS.	Demographic change may entail an increase in population, which decreases the per capita availability of food, fuel, water, and a wide range of ecosystem services. Demographic change also drives changes in greenhouse gas emissions, and hence human-induced climate change. When coupled with growing income and other factors such as urbanisation and market development, population growth increases the demand for food and energy, with negative consequences for ecosystems and human well-being.
3. Economic Change	Change in global economic growth and its distribution by country, sector, community and individual, which in turn may be caused by international trade, capital flows, technology and political change.	The growth rates of an economy and employment frequently result in a higher demand for services, although as incomes rise a shift may be observed from locally produced to imported products. The degree of inequality in the ownership of resources, trade and capital flows, and subsidies and taxes also impact on change in demand and consumption of ecosystem services, land use patterns, resource extraction, water diversion and pollution, biodiversity losses, changes in greenhouse gas emissions and hence human-induced climate change.
4. Climate Change	Regional increase in temperature and associated changes in precipitation, increasing aridification, increases in extreme weather events such as heat waves, floods, and droughts and associated fires and pest outbreaks.	Changes in temperature and precipitation can directly, or indirectly, by changing land cover and land-use, result in shifts in supply and quality of ecosystem services due to altered flow regimes and crop production, biodiversity loss, and increased invasive species introductions.
5. Social and Cultural Change	Change in values, beliefs, outlooks or desires of a (usually substantially large or influential) segment of society; change in lifestyles.	Social and cultural change affects attitudes towards, perceptions and use of ecosystem services and links to human well-being; it may also affect attitudes that result from other drivers, such as economic change, which in turn cause changes in the ways ecosystem services are used.
6. Large-scale Interventions	Once-off (and typically, infrequent but influential) actions by government or private sector that lead to large shifts in land cover and land-use.	These “surprise” interventions can change supply of, management of, or access to ecosystem services, with implications for human well-being. These include the authorization of large dam construction, irrigation schemes, protected areas, and land tenure policies.

Table 4.2 Generic local-scale drivers, common to the three sites, but with varying degrees of change.

Generic drivers	Description of trend
Demographic change	Low change: skewed population consisting of old and young people; small increase in total population size High change: large rural depopulation; skewed population consisting of old and young people; economically active population reduced
Large scale interventions	High-handed: interventions that have no benefit to local people and take useful land and resources away forcefully Community-friendly interventions: local capacity building and fair benefit flows
Macro-economic change	Real positive growth: (4-5 percent) with reduced Gini coefficients/inequality ratios No economic growth Negative growth / economic contraction
Policies	Reasonable policies are implemented. Reasonable policies are not implemented or poorly implemented with no or little external and government support. Policies are abused.
Value system change	High materialism: People become more materialistic, and strive towards short-term, material benefits rather than longer-term intangible benefits Limited materialism: Some individuals or groups emerge that advocate for longer-term benefits and a less materialistic approach
Infrastructural change	Infrastructural growth: Infrastructure such as telephone connections, electricity, reticulated water, and condition of roads gradually increases. Access to services improves. Infrastructural stagnation/decline
Climate and weather patterns	It becomes warmer and drier.

Table 4.3 Local-scale drivers that are specific to each site.

Richtersveld	Sehlabathebe	Great Fish River
Local level institutional change	International donor priorities and sentiments	Availability of water through the transfer schemes
Agreements and infrastructure	Governance: traditional vs. conventional values	Credibility and legitimacy of leadership
Water availability from the Gariep	Lawlessness e.g. stock theft	Access to key resource areas or patches
Access to key resource areas	Irrigation schemes	Exceptionally high levels of HIV/AIDS
Transfrontier park		

4.2 The Gariep Basin in 2030: Envisioning the Future with Scenarios

Scenarios are plausible visions of alternative pathways to the future, and the consequences for various aspects of life on earth. Scenarios differ from forecasts, projections and predictions, all of which relate more closely to the "probable" rather than the "possible" (Peterson *et al*. 2003). *Scenario planning* is a useful, structured way to stimulate thinking and debate about future events or trends, and to make explicit our uncertainty about these. It can be particularly informative when dealing with complexity in a system like the Gariep basin, in which numerous biophysical, socioeconomic, political, and cultural factors interact in ways that are not well understood or easily controlled.

The Gariep basin scenario planning exercise aimed at gaining insight into the uncertainties and potential surprises that may affect the basin, its ecosystems and their services, and the well-being of its inhabitants to the year 2030, given different outcomes for the future. To construct a meaningful set of scenarios for this region, we first explored the wealth of existing scenarios previously produced for the region. Many of these involved several years of research and workshops with a broad spectrum of society. We also investigated the feasibility of adapting elements of the global scenarios being developed by the Millennium Assessment to the Gariep basin.

After reviewing these two bodies of scenarios literature, we chose to pursue development of a unique set of scenarios for the basin, with input from the Gariep Basin User Advisory Group (UAG) as well as the SAfMA teams working at the regional and local scales.

Overview of Scenario Planning for the Region

The objectives of scenario planning may be varied. Building consensus and stimulating dialogue are among the main reasons for using scenarios, as was the case with the Mont Fleur Scenarios, perhaps the most influential of scenario planning exercises in the region *(see Box 4.2)*. In other situations, where the need exists to analyse quantitatively future trends, the purpose may be to develop tools to create scenarios and thereby enable projections.

Box 4.2 What will South Africa be like in 2002?

This was the question asked by the Mont Fleur Scenarios, developed in the early 1990s to explore possible outcomes of South Africa's transition to democracy. These scenarios posed four alternative futures in which majority rule takes hold with varying degrees of success and sets the country on a new political and socioeconomic course:

- *Ostrich* – No settlement reached and minority rule continues.
- *Lame Duck* – Transition slow and indecisive.
- *Icarus* – Transition rapid, but new government pursues unsustainable policies.
- *Flight of the Flamingos* – New government adopts sustainable, democratic policies.

This undertaking was considered a remarkable achievement on several counts: it illuminated the potential opportunities and pitfalls at stake, focused public attention on previously unfamiliar issues, and engendered an interdisciplinary network of politicians, businesspeople, academics and others interacting around a common challenge, of which perceptions were broadened or even changed.

Source: Kahane 1992. A follow-up set of scenarios entitled "South Africa 2014: Boom or bust?" has been published (Mail & Guardian 2003).

Scenario exercises and tools developed to address issues in the region are generally of two types: qualitative integrated approaches that focus on socioeconomic and political change, such as those completed at Mont Fleur, and quantitative sectoral efforts. The former type follows the Shell/SRI International model of scenarios based on the qualitative integration of political, economic and social elements of possible future worlds (Peterson *et al.* 2003). Typically, the latter type is designed around a particular issue, such as the environmental effects of the Lesotho Highlands Water Project, or future projections for achieving specified goals, such as meeting water requirements. In both instances, these are typically developed at the national rather than basin scale.

We reviewed a number of scenario exercises[1] but found that, in most cases, they would have limited applicability for our purposes. Those of the political nature did not describe implications for ecosystems, and those that were more sector-specific, while useful for pursuing questions relating to specific services, or analysing trade-offs, did not allow for the integration of the full range of ecosystem services, human well-being and their drivers of change. The global Millennium Ecosystem Assessment scenarios, on the other hand, are capable of such integration, but their applicability to the dynamics occurring at the scale of the Gariep basin was uncertain, and required an attempt at translation.

Scaling Down the Future: From Globe to Basin

A number of global scenario archetypes have been identified based on clusters of driving forces, such as economic and geopolitical forces, and social issues (Gallopín 2002). Four of these archetypes were adopted for the global MA scenarios: *Market Forces* and *Policy Reform* see a continuation of current processes and forces. *Fortress World* and *Local Learning* describe a world driven by a global economy, but an unmanageable one in which poverty climbs and institutions collapse. *Value Change* marks a significant shift in values, with an emphasis on sustainability and community. Table 4.4 gives a classification of the global MA scenarios, and scenarios in development in three SAfMA studies.

Table 4.4 Classification of the MA global scenarios, the SAfMA regional scenarios, the Gariep basin scenarios, and the Gariep local assessment scenarios into five scenario archetypes.

Scenario archetype	MA Global scenarios	SAfMA regional scenarios	Gariep basin scenarios (this study)	Gariep local assessment scenarios
Fortress World	Order from Strength		Fortress World	
Local Resources	Adapting Mosaic	African Patchwork	Local Learning	Stagnation
Market Forces	Global Orchestration Technogarden		Market Forces	Green Engineering
Policy Reform		African Partnership	Policy Reform	Betterment
Value change	Rosy			

[1] In addition to Kahane (1992), these included Tucker and Scott (1992), the Foresight scenarios of the Department of Arts, Culture, Science and Technology (now DST) (DACST 1996), Metsi Consultants (2002) and Schlemmer (2002).

These archetypes were interpreted for the Gariep basin to explore their potential applicability to the region during the next 30 years. Our analysis was limited to four scenarios. We discarded the fifth archetype, *Value Change*, because we considered it unlikely for the Gariep basin during the next 30-year period, and therefore not especially informative.

Table 4.5 Bifurcations of key uncertainties and their demographic consequences under four scenarios: FW = Fortress World; LL = Local Learning; MF = Market Forces; PR = Policy Reform; √√ = exceptional, √ = good; X = poor or non-existent; L = low, M = medium, H = high.

Key Uncertainty						**Demographic Consequence**			
	Political, Economic and Social Environment					**Population**			HIV/ AIDS Mgmt
	National Govern- ance	Local Govern- ance	National Economic Growth	Distribution of Wealth	National Social/ Environ- mental Policy	Births	Deaths	Urbanisa- tion	
FW	X	X	X	X	X	H	H	Increasing	X
LL	X	√	X	√	X	M	H	Constant	X
MF	√	X	√	X	X	M	M	Increasing	√
PR	√	√	√	√	√	L	L	Increasing	√√

Scenarios tend to be most effective if designed to address a few key uncertainties. We chose to develop scenarios for the Gariep basin around bifurcations, or branches, of several important, yet uncertain, elements (Table 4.5): the strength and effectiveness of national government, the strength and effectiveness of local government, national economic growth, wealth distribution, and national social and environmental policy. These have unique implications for demographic trends (i.e. birth rate, death rate, and urbanisation) and management of HIV/AIDS, which we define as one or more of the following: a cure for HIV/AIDS, widespread, equitable provision of treatment, and improved care for those living with HIV/AIDS and their dependents *(see Box 4.3)*.

Box 4.3 What Role for Climate Change and HIV/AIDS in an Uncertain Future?

Two key uncertainties in the Gariep basin revolve around climate change and HIV/AIDS. What is certain is that by 2030, these two forces will have already changed life in the basin in perhaps significant ways.

Between 1990 and 2050 climate change is expected to raise temperatures by 2 to 5 ˚C, and decrease precipitation in the basin, which may threaten food production, water supplies, and biodiversity – although certain crops and species may thrive in some regions (IPCC 2001). For this exercise, we assume that current trends in climate change will continue during the 30-year period, and that due to lag effects these will not differ drastically between the four scenarios. However, the management of the impacts of current climate change, as well as of human activities likely to lead to future climate change, will differ between scenarios. Under *Policy Reform*, legislation governing activities that contribute to greenhouse gas emissions will be strictly enforced by national, provincial, and local governments. Under *Market Forces*, incentives will exist in some sectors to reduce emissions and more businesses will adopt environmentally friendly practices in general, but this will not occur on a broad scale, and legislation will be slow to materialize. Under *Fortress World* and *Local Learning*, the weakening of central government and the economy will have mixed results: industrial activity will decline, but will be highly unregulated, and measures to curtail greenhouse gas emissions will not be adopted.

HIV/AIDS afflicted approximately 26 percent of South Africa’s population (DOH 2003) and 31 percent of Lesotho’s in 2001 (UNAIDS and WHO 2002). It has been suggested that HIV/AIDS will reduce the South African adult population by in excess of 2 million by the year 2030 (Goldblatt *et al*. 2002). This has implications for demographics, the economy, ecosystem services, and human well-being, perhaps the most notable of which will be a loss of human capital, diversion of government resources, and increasing dependency burdens. One of the questions demanding attention in this regard relates to the stage the epidemic has to reach for it to exhaust the capacity of a society to continue functioning. The ability to keep producing food, for example, is not necessarily degraded when its producers are infected but is devastated when they develop full-blown HIV/AIDS (Harvey 2003).

Demographics influenced by HIV/AIDS are not likely to differ greatly between scenarios, but the consequences of that change for ecosystem services in human well-being will diverge. For example, we would expect to see differences under the four scenarios in the administration of treatment, of care for those with HIV/AIDS and their dependants, and in the ability of government institutions (and food producers) to meet more specific and often greater demands for ecosystem services, such as adequate water and food. Furthermore, the capacity for preventing future HIV/AIDS transmission will also differ under the scenarios. We have implied that HIV/AIDS management will be poor in a *Fortress World* or under *Local Learning*, as the national government will play a limited role in providing the necessary framework and resources to deal with the disease. However, the role of international agencies in helping to curtail the transmission of HIV/AIDS and administer treatment to existing patients under these scenarios should not be overlooked.

4.3 Scenario Storylines

In what follows, we present the four scenario storylines and their consequences for ecosystem services and human well-being.

Fortress World

Key Features of the Fortress World

Drivers
- Collapse of national governance
- Economic collapse
- Weak civil society

Ecosystem Services
- Illegal, unregulated exploitation
- Widespread degradation
- Ineffective service delivery
- Some sources of pollution decline, but are highly unregulated

Human Well-being
- Elites live in security enclaves, depend on imports
- Poor become increasingly impoverished

Following the collapse of governance in 2014, long predicted by some, South Africa sinks into a state of political turmoil and economic decline, reminiscent of the situation that began more than a decade earlier in neighbouring Zimbabwe. This has a negative impact on ecosystems throughout the Gariep basin and the well-being of the entire population, driving many with the means to emigrate from the region. The elites who stay – which include corrupt government officials, exploitative multi-national concerns and warlords – manage to survive in security enclaves and are frequently dependent on imported commodities. The poor majority has no voice in government and is forced to be self-reliant in an impoverished and hostile landscape. There is a notable absence of civil society networks in this disrupted society.

This compromises the ability of the rural poor to survive against a variable and arid climatic regime, and many seek employment in cities. The illegal and unregulated exploitation of minerals by corrupt officials and warlords provides sufficient income to prop up dysfunctional regimes. There is no effective service delivery to the majority of the population; ecosystem services are degraded and unsustainably exploited. There is also no effective enforcement of protected area legislation, and the poor resort to poaching and harvesting of resources in reserves. One positive upshot for ecosystem integrity and human well-being is that the reduction in industrial activity decreases associated air and water pollution. Most gains are offset by the government's failure to extend electricity and water services to people who instead put increasing pressure on the limited biofuels and water supplies they can access.

Ecosystem services in urban areas suffer the most. Here there are sharp declines in the quantity and quality of water, energy, food, biodiversity, and air quality shared among its 12 million residents, many of whom are unemployed and undernourished. Mineral extraction, financed by private and foreign investors, increases. The welfare of the elites takes a downward turn, though slight in comparison to the steep decline of that of the poor population, which lacks the resources and options of the wealthy.

Population declines in rural regions have some surprising consequences for ecosystem services. In the Great Fish River, for example, air quality improves slightly due to the reduction in manufacturing that occurs here in the wake of economic decline. However, as in the urban areas, there is a differential decrease in the human well-being of the elites who are somewhat buffered from the changes in their surroundings, and the poor, who are not. The conditions of ecosystem services in the arid western part of the basin are compromised but less so here than in the other regions because of its tradition of self-reliance.

However, only modest levels of mineral exploitation are profitable, and in the absence of beneficiation and community mining projects, local benefits do not materialize. In the basin's commercial farming areas, once known as its "grain basket", food production suffers, as agricultural investments are designed to secure benefits for the wealthy few rather than the poor masses. With cutbacks in industry and energy production, particularly coal-burning, degradation of biodiversity and air quality continues only at slight levels. With no policies enforced to manage these services, they show no signs of improving. With the severe cuts in energy and food, the basin's poor suffer substantially, while the well-being of the elites is somewhat reduced.

While Lesotho's government remains stable, it is deeply wounded by events beyond its borders. In 2017, South Africa defaults on its royalty payments for the Lesotho Highlands Water Project, and many of the benefits once provided to Lesotho under this arrangement are eroded. Migrant workers seeking work in South African industries are increasingly turned away. The only hope is for positive political change, or an international intervention.

Local Learning

Key Features of Local Learning

Drivers
- Weak national governance
- Weak economy
- Strong civil society
- Community-driven land-use practices
- Strong reliance on informal sector

Ecosystem Services
- Poor service delivery
- Over-harvesting of resources
- Crop failures common
- Encroachment on protected areas

Human Well-being
- Increased mortalities from water-borne diseases and indoor pollution
- Conflict and violence caused by lack of access to resources

Ineffective national governance, corruption and economic mismanagement across most of the basin keep poor people impoverished. Low economic growth rates and declining foreign trade and investment exacerbate the economic marginalization of South Africa and Lesotho. However, strong civil society networks encourage local infrastructure development, with service provision dependent on community initiative.

The rural population, growing steadily and faced with a declining resource base for subsistence farming, becomes increasingly locally organized and self-reliant. The remnants of commercial agricultural are sufficient to feed the urban markets until 2030 but are expanded onto lands that are more marginal. This has devastating environmental consequences. Agricultural diversity provides some resistance to pest outbreaks though crop failures are common, as droughts occur more frequently due to climate change. The conditions for the urban poor deteriorate rapidly due to the absence of a resource base and a lack of service delivery. A declining and impoverished infrastructure isolates the rural poor. However, local tourism initiatives that emphasize conservation do spring up in places, and catch the eye of international NGOs who proceed to lend them support.

Most local authorities are unable to make the promises of the free basic water and electricity programs a reality, and mortalities from water-borne disease and indoor pollution increase. Poor environmental standards become prevalent, and waste products are dumped onto poor communities across the basin. This results in deteriorating water and air quality, increased soil erosion and untreated sewerage. Lack of access to water, land, and mining rights increasingly causes local tensions and conflict across the basin.

In the absence of a strong central government and market mechanisms, all regions look locally to obtain the services they need. Their welfare varies: while there is less ambitious development of resources, there are also lower levels of pollution, producing only moderate declines in water quantity and quality region-wide. The sparsely populated arid west manages to maintain its energy, food, and biodiversity at constant levels. Small declines in energy occur in all other regions. Food production drops drastically in the Great Fish River, where the effects of climate change, land degradation and a reduced labour force because of HIV/AIDS curb the capacity of the remaining arable land to feed its growing population.

In the urban centres, reduced economic activity means a slight, but not severe, deterioration in water, energy, food, biodiversity, and air quality, while the output of the minerals industry slowly increases, still fuelled by foreign investment. For its affluent inhabitants, life is slightly worse; it is much worse for the poor. The arid west elites maintain their well-being at constant rates, while the poor in this region are slightly worse-off. In the grain basket, many who rely on a now-reduced agricultural income experience a lower sense of well-being, regardless of their affluence. Lesotho, recognizing the need for economic independence from South Africa, embarks on a program to reform its agricultural productivity, but needs international assistance. The local discovery of a plant endemic to the Lesotho grasslands with high pharmaceutical value piques foreign interest in Lesotho. This calls attention to the need for more formal conservation of this biome, as well as stronger legislation to protect intellectual property rights.

Market Forces

Gauteng continues to expand as the industrial heartland of the basin. As rural living conditions deteriorate the rural poor flock to the rapidly expanding peri-urban areas to find employment. Water and air pollution caused by poorly regulated coal power generation and increased industrial effluent lead to a higher prevalence of water-borne diseases and infant mortality rates among the poor. Insufficient health service delivery compounds this and leads to a declining life expectancy for the poor across the basin. Mining activities expand across the area and are largely exploitative of the available human capital and the environment. The combination of mining, commercial agriculture, and cheap labour supports most visible economic activity. Income disparity increases. Due to a lack of emphasis on social services, no great strides are made in improving the well-being of the poor, but they do benefit marginally from the trickle-down effects of a growing economy, particularly in urban areas where most wealth is concentrated.

Key Features of Market Forces

Drivers
- Strong economy facilitated by national governance framework
- Lack of wealth distribution
- Weak local governance
- Weak social and environmental policies

Ecosystem services
- Expansion of mining activities
- Increased development of water resources
- High levels of water and air pollution
- Erratic agricultural production
- "Development before conservation"

Human Well-being
- Inadequate health service delivery
- Decreased food security for poor
- Increased income disparity, though marginal benefits accrue to urban areas

South Africa's entry into free trade agreements pushes agricultural production toward exports, such as grapes along the Gariep River, and results in a reduction of grain production in the basin. Meanwhile, the effects of climate change result in increased temperatures and variable rainfall, and the lack of a clear policy framework for climate change decreases household food security for subsistence farmers and the rural poor, especially in the arid west. Farming on increasingly marginal lands promotes soil erosion, and reduces water quality through siltation. Water is also increasingly impounded and diverted to be used by industry, urban and commercial agriculture. Poor enforcement of environmental legislation negatively affects biodiversity conservation. Societal values largely favour developmental initiatives over conservation concerns.

In the urban areas, an emphasis on economic growth stimulates production of food, energy, and minerals, but increased demands for water place pressure on limited resources. Economic and industrial growth, without policies to govern their environmental, social, or health implications, results in declining water quality, biodiversity, and air quality. Human well-being remains constant for elites and poor alike, due to the combined effects of increases in some services and reduction of others. The Great Fish River does not fare as well, and watches its entire ecosystem services decline due to an ineffective distribution of the social grants on which they depend. This results in a sharp decline in human well-being of the poor section of the population, and a slight reduction for the elites. The arid western region performs better: though it receives fewer of the benefits of national economic growth, the population's reliance on local ecosystem services is a buffer against the associated declines in biodiversity and air quality. Water is an exception, as upstream abstraction from an already-taxed water supply leaves less water of adequate quality for this region. The elites experience a slight improvement in their well-being, owing mainly to the continued investments in mineral resources. Due to its links to Gauteng, the grain basket mirrors somewhat its patterns of economic growth, but food production increases only slightly as the economic climate favours the services, manufacturing, and trade sectors over agriculture. Human well-being remains constant for both elite and poor members of the population. In Lesotho, environmental problems as a result of the water transfer scheme, notably siltation, begin to ignite conflict between residents and farmers who are affected, and champions of economic growth, who believe that extending the LHWP is crucial to development of Lesotho's economy. The number of migrant workers reaches an all-time high but the cumulative effects of HIV/AIDS during the past thirty years are severe.

Policy Reform

A strong commitment in South Africa and Lesotho to good governance and regional peace and security is finally emerging. The region attracts increased foreign investment and a fair trade environment promotes its global competitiveness. In the Gariep basin, this leads to responsible expansion of industrial investment together with socially and environmentally responsible governance. Improvements in infrastructure, health, education, and service delivery are supported by a vibrant technology sector.

Key Features of Policy Reform

Drivers
- Effective democratic governance
- Strong, globally-linked economy in a balanced trade regime
- Significant poverty reduction
- Substantial investments in health, education, and ICT sectors

Ecosystem Services
- Intensification of agriculture
- Strengthening of protected areas
- Tariff system and catchment management encourage efficient use of water

Human Well-being
- Improved food security
- Improved access to water and energy

Consequences of the new policies for ecosystem services are mixed. Intensified agricultural practices support high economic growth with the rapid adoption of genetically modified organisms (GMOs), irrigation, pesticides, and fertilizers in the basin. This meets with some resistance from small farmers unable to invest in these inputs and health and environmental advocates, yet organic farming practices are also on the rise. Overall, productivity is boosted, and the expansion of agriculture onto marginal land is prevented. Food security across the basin improves. Pressures on water supplies increase, but an effective system of water tariffs, together with the establishment of catchment management agencies now ensures that users are accountable for their abstractions. Cash crops are widely produced by commercial farmers who trade in a global economy but due to past biodiversity losses the genetic stock is impoverished. This marginalizes small growers except for those linked to designer markets, such as organic farmers. Climate change increases crop vulnerability to pests and diseases and droughts and floods occur more frequently. Intermittent food shortages occur, but do not threaten food security in the basin. Increased wealth drives agricultural production towards meat production. Intensive livestock production - batteries and feedlots, for example - becomes more common across the Gariep. A drive toward more intensive meat production leads to an expansion of game farming operations in the basin, and creates a link between protected areas. Reduced pressure for land means a more positive outlook for conservation in general. Biodiversity and environmental education are high on the agenda of policymakers, and the concept of ecosystem services becomes widely familiar.

A growing proportion of the energy needs of the urban and wealthy population in the basin are derived from alternative power sources (e.g. solar and nuclear) but coal still dominates as the most important source of energy production. Growing mining and industrial activities reduce water and air quality. Water purification costs increase and water scarcities south of the Zambezi become a potential source of regional conflict. However, the environmental legal framework is fundamentally sound and adequately enforced, enabling regional cooperation to mediate resource-related tensions.

The conditions of ecosystem services in the urban areas improve slightly, with the exception of biodiversity, in which exceptional recovery from past degradation is not observed during the 30-year period, but further declines are slight rather than steep. The already good level of well-being of elites increases slightly, while the poor benefit more significantly under policies with the equitable distribution of services such as water, electricity, and health care at their core. The Great Fish River also experiences improved access to most services, particularly energy, but air quality continues to decline due to lag effects of new policies to curb pollution. The positive effects of the new policy shifts are less dramatic in the arid western regions, where water quantity only remains constant. Large investments in energy seen elsewhere in the basin do not occur in this sparsely populated area, but access improves slightly as the national grid is extended and more solar power projects come online in the Northern Cape. Biodiversity and air quality remain constant, and exploitation of minerals increases steeply. Well-being improves slightly for both elites and poor. In the grain basket, reforms of the agriculture sector, including support for organic farming, results in improvements in all services except biodiversity, still recovering from many decades of severe impacts.

Lesotho becomes a hot tourism destination, owing in part to the great success of the Drakensberg-Maloti Transfrontier Conservation Area and foreign investment in infrastructure. Yet the pressures from the rapid influx in tourist numbers challenge the capacity of park managers, while some local residents feel that they do not benefit from these conservation initiatives.

Scenarios across Scales: A Sensitivity Analysis

One of the challenges in scenario development regards the treatment of exogenous conditions and their potential influence on the scenarios. The problem of defining the bounds of the "fortress" in a *Fortress World* illustrates this well. At the global scale, the fortress separates powerful, well-off nations or regions from destitute ones. By this definition, South Africa and Lesotho are, to a large degree, outside the fortress. At the basin scale, the fortress separates members of the basin population. The question this raises is whether a *Fortress World* in the basin implies that the whole globe is also a *Fortress World*, or whether an alternative scenario might be conducive to a basin *Fortress World*. A second challenge we acknowledge is that a single, simplified scenario is unable to describe the whole suite of dynamics occurring at any scale, which instead is characterised by a combination of different elements of many different scenarios.

The effects of global and regional drivers of change, their interactions, and the strength of their impact on ecosystem services in the basin is highly dependent on the connectedness of the basin to the region or globe and its resilience to change in exogenous forces. This connectedness, and hence resilience, seems to vary between scenarios. We expect, for example, that if a *Market Forces* scenario dominates the global economy, a basin-scale *Fortress World* would be highly exploitable by external forces, increasing the vulnerability of governance, the economy, and society. The population would be likely to increase and urbanise, with little regard for ecosystem capacity to provide services, and ultimately generating negative feedbacks at a higher level and perpetuating the *Fortress World* situation. Conversely, if a *Policy Reform* scenario takes global prevalence, international pressure may mount to take punitive measures against the basin states that are not practicing good governance and an externally led effort to reform a *Fortress World* in the basin states might be possible.

Because of the convergence between scenarios at the SAfMA regional, basin, and local scales, we can explore these challenges by examining the sensitivity of scenarios at the basin scale to alternative combinations of scenarios occurring at both the broader and finer scales. Examples of how the two scenarios that correspond roughly to the *Local Learning* scenario - the *African Patchwork* scenario at the SAfMA regional scale and the *Stagnation* scenario at the local scale – might affect the basin are shown in Box 4.4.

This comparison of scenarios highlights the cross-scale nature of political and environmental security. It will be difficult to achieve *long-term* security in the basin, for example, while there are high levels of instability at the regional scale or massive poverty at the local community scale. Despite this, interpretation of the *African Patchwork* scenario for the Gariep basin indicates that at the national scale, some level of disconnectedness from other nations is desirable, as heavy dependence on external resources increases a nation's vulnerability to changes in the stability of its neighbours. The *Stagnation* scenario, however, suggests that highly impoverished communities are dependent on external resources in the form of government support, and have little recourse to escape poverty without intervention. A key difference is that the *Local Learning* basin-scale scenario assumes that civil society networks will function independently of the central government and that these will play an essential role in accessing ecosystem services and improving human well-being. If this is true, the *Local Learning* scenario for the basin perhaps overestimates the ability of local communities to devise innovative solutions to benefit from ecosystem services in the absence of any institutional or financial support. *Local Learning* also does not consider the importance of the acceptance of interventions by communities in order for these to succeed.

In addition to enabling the identification of linkages between scales, comparing scenarios at different scales can provide a first-cut reality check on storylines and identify features that may need more development.

Box 4.4 Scenarios Across Scales

Zooming out: African Patchwork in the SAfMA region

Key drivers:

- Governance: Weak, ineffective states in most countries – but democracy and good governance take hold in some countries; regional fragmentation; ongoing localised military conflicts drain resources, damage infrastructure and impede the provision of services; little investment in health and education
- Economy: Low economic growth rates and declining foreign investment lead to the increased economic marginalization of Africa; informal sector dominates

At the regional scale, the Gariep might be one of the more successful "patches" in the *African Patchwork*, perhaps surrounded by less successful ones. This would result in high levels of immigration to the Gariep basin states from other nations. Heightened competition for water would be a particular problem. If the Gariep itself is "patchy," with South Africa being a more successful patch and Lesotho an unsuccessful one, the basin's water supply could be endangered; however, this could motivate South Africa to lend support to Lesotho and thus rebuild the nation.

We could also hypothesise a situation in which South Africa, succumbing to a *Fortress World* scenario, becomes one of the more unstable nations in the patchwork, while neighbouring Lesotho, Namibia, and Botswana all become more stable and achieve increased economic growth. Under this scenario, many rural South Africans (commercial and subsistence farmers and those in the tourism and mineral industries) may try to move their operations elsewhere. With climate change making conditions in the arid west increasingly inhospitable for farming and unattractive to tourists, Lesotho, Zimbabwe, and Mozambique may appear more favourable for relocation. Gauteng's numbers might decline, with urbanites re-establishing themselves in other African cities, and many others fleeing further afield.

The implications of such a patchwork are firstly that in an unstable political climate, states will have to be much more independent in order to survive. This may lead to better management of some shared services, such as water, in the realization that the instability of other SADC nations will continue to inhibit regional sharing or cooperative production of services for some time. Secondly, countries that succeed in this environment will be confronted with a growing number of unemployed and asylum-seeking individuals from beyond their borders. This will place increasing pressure on those countries' resources and conflict is likely to emerge even in relatively stable, peaceful societies.

Zooming in: Stagnation in Rural Communities

Key Drivers:

- Governance: Democracy prevails, but policies are not implemented; large-scale interventions are implemented in a heavy-handed manner
- Economy: Negative or zero economic growth; there are no prospects of employment; human lives and values in the cities are cheap and people migrate back to rural areas.

At the community scale, much depends on the extent to which national economic growth and policy implementation trickles down to the local level, especially in the more isolated rural areas. This scenario illustrates a situation in which this does not happen, and any investment in communities comes merely as a by-product of outside interventions, typically designed to reward benefactors. These interventions may yield no benefit to the communities at all, and sometimes are simply destructive, undermining community structures.

Rural communities are increasingly impoverished throughout the Gariep basin, leading to rapid deterioration of ecosystem services and human well-being, with people managing to survive off resources of a more marginal quality than ever before but pushing many ecosystems beyond a reversible threshold. The notion of a "protected area" rings hollow in this environment, as the desperation of the neighbouring communities drives them to encroach unabashedly on these areas. While social capital in the form of bonds and networks between community members is important, the prevailing levels of poverty and lack of options keep birth rates very high, seeming to dictate the fate of successive generations. Ultimately, when a crisis arises, bonds break down, and the conflict that emerges is of significant proportions to affect stability on a broader scale, which finally alerts those at a higher level of power.

Negligence on the part of national governments will saddle them with an enormous burden in the decades to come, even when economic growth picks up and action taken to uplift their people from poverty. Many more will need to be uplifted, while fewer ecosystem services will be available with which to sustain them.

Preparing for the Future

We conclude the scenarios analysis by stressing that this is a first attempt to introduce the concept of scenario planning in the context of ecosystem services and human well-being in the Gariep basin, and to stimulate thinking about possible futures. These scenarios should not be treated as predictions for the future of the Gariep basin. They are simply an exploration of the consequences for the future of the basin's ecosystem services and human well-being given certain conditions. As such, a statement of the relative likelihood of these futures cannot be made here.

Certain elements of these scenarios describe the situation in the Gariep basin today. The more developed parts of the basin represent a *Market Forces* world with an active economy but limited distribution of wealth. The *Local Learning* scenario is generally applicable in the more rural areas of the basin where traditional authority still prevails and service delivery is relatively poor. The division of elites and poor, indicative of a *Fortress World,* is evident in the wealthier parts of the basin, although this has not been accompanied by a collapse of national governance and the economy. Finally, the *Policy Reform* scenario shows signs of emergence in certain sectors where economic and social policy interventions are beginning to succeed.

Thus, a careful look at the basin now, combined with a reflection on its history and an understanding of drivers of change across multiple scales, are likely to serve as the best preparation for what may come. In future iterations, a set of scenarios could also consider the types of responses that would be likely to take place and how they might feed back on key processes.

4.4. Response Options in Alternative Futures

As the examples discussed throughout this report illustrate, many responses involve a combination of typologies. Interventions designed to manage the state of an ecosystem often are part of a broader policy measure, or are closely linked to educational and outreach efforts, for example. In most cases, a course of action will be needed that includes several types of responses that complement each other and serve multiple objectives. A response with very specific or short-term goals is not as likely to succeed because it ignores the complex web of relationships between different aspects of the ecosystem or populations. In the past, technological responses have often been constructed and implemented in this way, with unintended and often negative consequences emerging later.

Responses that address policy and institutions, responses directed at improving ecosystems and their capacity to deliver services, and responses that emphasize education are usually key ingredients in successful ecosystem and resource management. Technology and economic instruments often play an important role, but may not be successful in the long term unless embedded in a larger program of sustainability. Technological responses in particular have a dangerous ability to mask problems - and to disregard their root causes - rather than solve them (Berkes *et al.* 2000). However, technological responses can demonstrate great success when they improve human well-being in the short term, and decrease the dependency of people on any particular component of ecosystems by simultaneously increasing their options over the long term.

At the same time, few of the types of responses mentioned can be implemented in isolation. Policy and institutional measures that are not socially acceptable or economically favourable do not guarantee success, nor do interventions to improve the state of ecosystems and service provision that fail to distribute their benefits equitably, or responses that improve education but do not empower people to act on it.

The nature of the response 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 be influenced by existing circumstances. It can be helpful to explore this issue under a set of alternative scenarios such as those sketched in this report.

Feasibility of Responses under Alternative Scenarios

Which types of responses will be feasible given the adaptive capacity of ecological, social and management systems? We have to think about the political, economic, and social context in which responses will be shaped and executed. In Table 4.6 we indicate which responses are most likely to be adopted under the assumptions of our four scenarios. Under *Policy Reform* we assume a higher capacity to utilise multiple responses, including legal and policy responses, than under other scenarios. However, some additional considerations need to be borne in mind. As revealed by the cross-scale comparison of scenarios discussed earlier, the level of regional stability will limit the adoption and success of responses in the Gariep basin. In addition, responses at the basin scale must recognize the importance of and variation in local-scale conditions that will likewise enable or constrain adoption and success. The significance of scale in choosing among responses cannot be overemphasized. Too often, responses suffer from a scale mismatch – spatial or temporal (Redman and Kinzig 2003). The outcome of a response made under these conditions is that it often has unintended effects.

Box 4.5 Local Responses to Ecosystem Change

People at the three local assessment sites cope with ecosystem change through strategies to reduce their risk. They become seasonally and spatially mobile and flexible, and invest in landscape diversity rather than monoculture. They also diversify the household labour force, and invest in formal education. People also 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. They may rely on rumours or superstition to forecast but their desire to predict is high. People also 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 a more important role in their lives than before, and may be a mix of Christianity and African Traditional Religion. People also gather often frequently for oral communication.

Another strategy is to adapt management practices. People try new enterprises such as eco-tourism, 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.

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, as well as proactive in optimizing opportunities and minimizing risks to sustainable livelihoods. Coping strategies and adaptation common to the three sites include:

- A diversity of livelihood strategies
- Temporal flexibility in the livelihood portfolio
- Internal stratification
- Links to urban centres
- Multiple landscapes and environments; multiple resources and species from each environment
- Resource and species substitution
- Secure water resources
- Mobility
- Nurturing social and kin networks

Table 4.6 Which responses in which future?

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

CHAPTER 5

Adding it up: A Synthesis

5.1 The Big Picture

By providing services, ecosystems underpin and sustain the livelihoods of human beings, societies and economies. The links between ecosystem services and human well-being are complex, as the harnessing of services does not always benefit people, and sometimes has detrimental effects. This assessment resolved to examine these relationships by using measures of demand and supply. However, while a demand and supply approach may be able to identify some of the physical barriers to deriving benefits from ecosystems; it does not consistently capture the actual impediments to service delivery. Many situations exist in which supplies of a service are adequate, but human-well being demands remain unsatisfied. This is particularly true in a region such as the Gariep basin with a history of inequality.

We suggest that a useful synthesis of condition and trends of ecosystems and human well-being in the Gariep basin entails an examination, more specifically, of: 1) the ability of services to meet human well-being requirements, including the capacity of ecosystems to continue producing services, and 2) ecosystem service "hotspots" that either are key areas of service production, produce an irreplaceable (unique) service, or may be sources or locations of conflict or potential conflict in the near future.

Table 5.1 depicts four components of the ability of provisioning ecosystem services to fulfil the basic requirements for human well-being: adequate supplies, effective distribution, associated health impacts, and the capacity of ecosystems to continue providing the service. In some cases, it is indeed a shortage of the service that results in its failure to satisfy minimum human well-being requirements, for instance, when demand for fuelwood (perhaps because of population growth) outstrips the capacity of existing resources. In other cases, a service is not provided because distribution channels are ineffective or non-existent. Still in others, benefits from the service come at a cost to human welfare. This is illustrated by mineral services: while mining provides an ecosystem service of value to some members of the population by generating revenue and providing jobs, it involves processes that generate widespread negative effects on human health that, at least for some, outweigh its benefits. Pesticides used to improve the efficiency of food production may be harmful to humans and livestock, as may water works that alter natural ecosystem characteristics. Lastly, unsustainable use of ecosystem services can compromise the capacity of the ecosystem to continue to provide services, threatening the well-being of future generations.

The wealth of relationships between ecosystems and human well-being extends beyond the provisioning services. As a regulating service, good air quality is vital to health. As noted in Table 5.1, inappropriate energy policies that create externalities are a cause of decreasing air quality, and unacceptable levels of air quality present a threat to health. Preservation of cultural services is essential to good social relations, and where such services also have a utilitarian value, may also be essential to achieving the material minimum for well-being. Cultural services may also be important to health, security, and freedom and choice. In some cases, of course, ecosystem services may be replaceable or substitutable; that is, alternative options exist to meet a specific need. While water and air have no true substitute, food and energy come in different forms, and switching between them is often a crucial human well-being survival strategy.

Figures 5.1a − h depict ecosystem service and human well-being "hotspots," which include: irreplaceable areas for food production (able to supply caloric and protein requirements) and biodiversity, areas in which water requirements are approaching available surface water supply, areas in which groundwater is high in salinity, municipalities in which one quarter or fewer of households have access to electricity from a local authority, municipalities with significant mining activity, and a synthesis map of several key services. Each service has a unique spatial pattern. The eastern and north-eastern regions of the basin, for example, are highly irreplaceable for the provision of food, while the eastern and south-eastern regions produce high levels of surface water runoff.

Table 5.1 Ability of provisioning services to meet human well-being requirements.

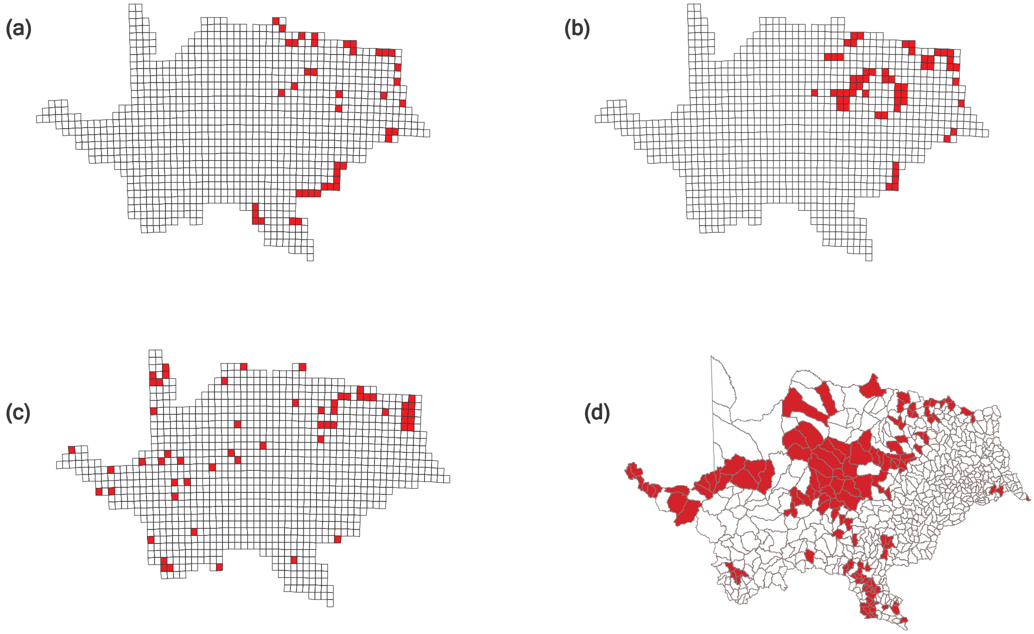
	Food	Water	Energy Services	Mineral Services
Adequate supplies?	Basin can supply 50 percent more dietary energy and three times more dietary protein than needed.	Limits of current supply may be reached by 2025; climate change could exacerbate scarcity.	Fuelwood becoming increasingly scarce; coal supplies adequate for long-term (300 years). Investment in other energy sources and technologies remains limited.	Supplies abundant, but exploitation depends on economic viability.
Effective distribution?	Social inequality and disparity in income distribution make some sources of protein and energy unaffordable.	Free basic water to be granted to all but infrastructure is lacking. Some 5 million people still obtain water from rivers and springs and 16 million lack sanitation; others cannot afford to pay for additional water.	About 70 percent of South Africa electrified; 50 percent in rural areas; three percent of Lesotho. Connections remain unaffordable to many residents; environmental and social externalities not reflected in costs.	Largest benefits rarely accrue to those who bear the cost of mining's externalities.
Implications for health?	Source of water and air pollution. Uses superfluous amounts of water, causes land degradation. Fertilizers, pesticides, GMOs may have negative effects on health.	Pollutants in untreated water lead to potentially lethal water-borne diseases; infrastructure alters natural characteristics of water bodies and their regulating processes.	Coal-burning produces high carbon dioxide and sulphur dioxide emissions, affecting air quality; contributes to greenhouse gas emissions.	By-products of mining affect air and water quality; extraction creates excessive ecological disturbance, which interferes with ecosystem function and biodiversity.
Capacity of ecosystems to continue producing service?	Will require technological inputs to improve production; land degradation and climate change pose potential problems.	Will require implementation of resource protection measures and ecological reserve.	High capacity to produce coal and renewable sources; supply of fuelwood will depend on sustainable management.	High capacity for 30-year timeline.

These regions also largely coincide with areas of high biodiversity value, and in some cases with areas with high water stress, mines, and poor air quality. These regions must therefore be planned for carefully in order to deliver ecosystem services without compromising ecosystem integrity. The high levels of agriculture and urbanisation are well-known concerns in the basin and have impacted on the ecological integrity of this region already (Fairbanks *et al*. 2000, Reyers *et al*. 2000) with most of the indigenous grasslands of the region under severe threat.

In addition, the arid western region of the basin could be a potential area of conflict. This is important to highlight, as it is not an area that receives a lot of attention in land use and biodiversity planning initiatives (with the exception of the Succulent Karoo). This area is a source of mineral wealth and contains several irreplaceable biodiversity sites due to the concentration of many endemic species. However, it is also vulnerable to water scarcity, surface and groundwater quality problems, and desertification, all of which may be amplified by climate change. The region is further hampered by its low level of development, exemplified by the low percentage of households connected to the electricity grid who must obtain energy from other sources. On the other hand, it is less vulnerable to threats associated with high levels of development. The coincidence of these features suggests that if this area is not well managed, the implications for biodiversity, ecosystem services, and human well-being in the area could be severe.

Key resource areas: hotspots at the local level

The community assessments revealed that the patchy distribution of ecosystem services enables local people to cope with and benefit from ecosystems in environments that, from a distance, appear extremely hostile. In the Great Fish River, people walk up to three kilometres to obtain fuelwood and construction materials in particular landscapes, known for their ability to provide these goods. These landscapes are often abandoned when they are over-harvested, to be revisited several years later once they have recovered. Inaccessible, distant, or policed areas serve as refugia for genetic stocks of highly preferred fuelwood and kraalwood species such as *Ptaeroxylon obliquum* (sneezewood) and *Olea europeae* var *africana* (wild olive). Certain medicinal plant products such as the bark of slow-growing trees are confined to the interiors of large forests, where they are protected by taboos that permit only ordained herbalists or healers to access them. Animal resources such as honey and wildlife are also restricted to the most remote and dense forest and woodland patches, where only the most skilful hunters can find them. Fountains and streams represent key resource areas for water security during times of crisis, for example when government authorities fail to maintain water infrastructure.



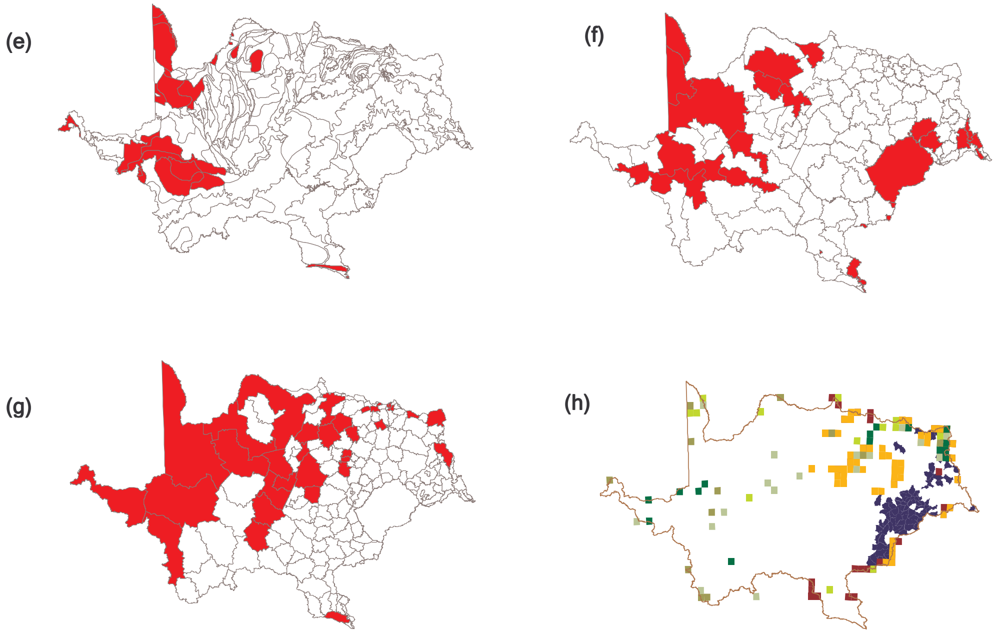


Figure 5.1 Ecosystem service and human well-being "hotspots:" Areas of the Gariep basin with high levels of service provision, unique services, or in which service provision or human well-being may be of concern. (a) Grid cells with irreplaceability values of more than 0.5 illustrating areas of importance to the provision of upper targets of protein, (b) calories, and (c) biodiversity conservation; (d) Quaternary catchments in which surface water requirements are 60 percent or more of availability; (e) Geohydrological units in which groundwater salinity (TDS) is above 2400mg/l; (f) Municipalities in which electricity is supplied by a local authority to 25 percent or fewer of households, and (g) with 2 or more producing mines or exploited deposits. (h) 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).

These water sources depend on the maintenance of even smaller critical areas such as wetlands and sacred pools. At an even finer resolution, individual plants, especially trees, are mapped in social memory as key collection points for honey, fruit, bark, or walking sticks, or for their spiritual value during critical times such as traditional ceremonies.

In the Richtersveld, the Gariep floodplain is a key resource area for fodder, shade, and water for people and livestock during the hot dry summer months. The Gariep also acts as a key source of drinking water all year round, and people use it to complement their protein by fishing or hunting for bushmeat. The Gariep floodplain is also a key resource area for tourism and mining, and is therefore a highly contested area with claims made by all the main stakeholders. Further inland, fountains and wells are hotspots for the survival of pastoralists, while minute quartzite outcrops are biodiversity hotspots for endemic succulents, but are also used by people and animals to escape the mid-day heat because they are slightly cooler than the surrounding landscape. In Sehlabathebe, small forest patches represent key resource areas for water and fuelwood, and small pockets of deeper soils in sheltered areas are reserved for vegetable production.

The overlap of areas with high levels of ecosystem services or areas of concern does not imply conflict, but the management of such areas will require an integrated, multiple-use approach in which different stakeholders are represented. True "hotspots" may exist where technical, institutional, or ideological barriers constrain the implementation of such an approach.

Implications for Decision-Making

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. The experience gained in this assessment indicates that the responses most likely to succeed in problems related to ecosystem services and human well-being will:

1) ***Recognise 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) ***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 the knowledge of and consultation with stakeholders.

3) ***Strive to create synergies.*** Where trade-offs must be made, decision-makers must consider and make explicit the consequences of all options. Tools such as those described in this report can assist decision-makers in visualising, understanding, and communicating the issues at stake.

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.

5) ***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 asymmetric ecosystem service benefits, reduced adaptability, and responsiveness. Collectively these asymmetries increase the vulnerability of disenfranchised communities. However, 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.

6) ***Acknowledge uncertainty and enhance adaptive capacity.*** Given the complexity of social-ecological systems, it is seldom if ever possible to fully understand the structure or functioning of a system to be able to reliably predict the outcome of an intervention or response. In choosing responses, we must understand the limits to our knowledge, and we must expect the unexpected.

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 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.

Decision-makers, whether they are ecosystem users, managers, or governments, must design responses that can meet the challenges noted in this assessment. 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.

5.2 Epilogue: Lessons learned from a Multi-Scale Integrated Assessment Approach

One objective of this assessment was to determine whether such an exercise could actually be carried out, and whether the information and capacity to analyse it in the way proposed by the MA Conceptual Framework exist. In general, the Gariep basin is an information- and data-rich region of southern Africa. In particular, many South African and Lesotho government departments, NGOs, and industries have made large volumes of information freely available on the internet. This is promising, but major knowledge gaps remain, with the most obvious deficiencies relating to our understanding of ecological process and function, particularly the links between biodiversity pattern and process, and the relationships between ecology and hydrology. We are also plagued by the nearly universal difficulty of integrating the natural and social sciences, where great gains clearly stand to be made (Redman and Kinzig 2003). However, knowledge of ecosystems has evolved rapidly during recent decades, and will hopefully keep up the pace.

An important lesson learned from this process relates to the role of an assessment in plugging information gaps. Often at the conclusion of an assessment (and this one is no exception), as many new gaps are identified as old ones filled. While such a realisation may be frustrating, it can help to reframe questions and refocus research efforts so that they can address the most pressing concerns in light of these gaps.

Furthermore, there is inherent, and necessary, bias in assessments of this nature. Even an integrated assessment can only address a limited number of issues, a multiple-scale assessment can only include a limited number of levels, and most assessment designs can only accommodate a limited number of viewpoints, perspectives, and epistemologies. On balance, the larger SAfMA does span a reasonable breadth of issues, scales, and types of knowledge. Within the Gariep assessment itself, this “bridging” is done through the community studies, which reflect a rich body of local knowledge about ecosystems and their functioning.

5.3 Conclusion: Decisions for the Future

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.

A more general but important achievement for this assessment process to strive for 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 in the Gariep basin 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, so that effective decision-making can continue into the future.

LITERATURE CITED

Acocks, J.P.H., 1988: Veld types of South Africa. *Memoirs of the Botanical Survey of South Africa*, 57.

African Development Bank, 1993: *Economic integration in southern Africa*. Volume 3, Oxford Ltd, Oxford, Great Britain, 401 pp.

AGAMA Energy (Pty) Ltd, 2003: *Employment Potential of Renewable Energy in South Africa*. Earthlife Africa and WWF Denmark, Johannesburg. 59 pp.

Agriwriters, 2003: Available at http://www.agriwriters.org.za/farm_industries.htm.

Ainslie, A., 2003: The Southern African Millennium Ecosystem Assessment local level assessment scoping report: The mid-Great Fish River area. Unpublished report, Rhodes University, Grahamstown. 45 pp.

Ayensu, E., D.R. Claasen, M. Collins, A. Dearing, L. Fresco, M. Gadgil, H. Gitay, G. Glaser, C. Juma, J. Krebs, R. Lenton, J. Lubchenco, J.A. McNeely, H.A. Mooney, P. Pinstrup-Andersen, M. Ramos, P. Raven, W.V. Reid, C. Samper, J. Sarukhán, P. Schei, J.G. Tundisi, R.T. Watson, and A.H. Azkri, 1999: International ecosystem assessment. *Science*, 286, 685-686.

Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farber, R.E. Green, M. Jenkins, P. Jefferies, V. Jessamy, J. Madden, K. Munro, N. Myers, S. Naeem, J. Paavola, M. Rayment, S. Rosendo, J. Roughgarden, K. Trumper and R.K. Turner, 2002: Economic Reasons for Conserving Wild Nature. *Science*, 297, 950-953.

Balmford, A., 2003: Conservation planning in the real world: South Africa shows the way. *Trends in Ecology and Evolution* 18, 435-438.

Barnes, K.N., D.J. Johnson, M.D. Anderson and P.B. Taylor, 2001: South Africa, In *Important Bird Areas in Africa and Associated Islands: Priority Sites for Conservation*, *BirdLife Conservation Series No. 11*, L.D.C. Fishpool and M.I. Evans (eds.), Pisces Publications and BirdLife International, Newbury and Cambridge, UK, 793-896.

Barnes, K.N. (ed.), 2000: The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland. Birdlife South Africa, Johannesburg.

Basson, M.S., P.H. van Niekerk and J.A. van Rooyen, 1997: *Overview of water resources and utilisation in South Africa*. DWAF report P RSA/00/0197, 72pp.

Basson, J., 2003: Energy Policies and Practices. Pp. 33-47. In *Towards a Just South Africa: The Political Economy of Natural Resource Wealth,* D. Reed and M. de Wit (eds.), WWF Macroeconomics Programme Office, Washington D.C. and CSIR, Pretoria.

Behr, J. and J.A. Groenewald, 1990: Commercial game utilization on South African farms. *Agrekon,* 29, 55-58.

Berkes, F., J. Colding and C. Folke, 2000: Rediscovery of Traditional Ecological Knowledge as Adaptive Management. *Ecological Applications*, 10(5), 1251-1262.

Berkes, F. and C. Folke, 2002: Back to the future: Ecosystem dynamics and local knowledge, In *Panarchy: Understanding Transformations in Human and Natural Systems*, L. Gunderson and C. S. Holling (eds.), Island Press, Washington D.C., 121-146.

Beukes, E.P., 1990: Thoughts on development in the new South Africa. In: *Development, employment and the new South Africa*, Beukes, E.P., W.J. Davies, R.J.W. van der Kooy and L.A. van Wyk (eds), pp. 41 – 56.

Biggs, R. and R.J. Scholes, 2002: Land-cover changes in South Africa 1911-1993. *South African Journal of Science*, 98, 420-424.

Biggs, R., E. Bohensky, C. Fabricius, T. Lynam, A. Misselhorn, C. Musvoto, M. Mutale, B. Reyers, R.J. Scholes, S. Shikongo and A.S. van Jaarsveld, 2004: *Nature supporting people: The southern African Millennium Ecosystem Assessment*. CSIR, Pretoria, South Africa.

Boonzaier, E., 1996: Local responses to conservation in the Richtersveld National Park, South Africa, *Biodiversity and Conservation*, 5*,* 307-314.

Braune, E., Manager: Information Programmes, Department of Water Affairs and Forestry. Personal Communication.

Breytenbach, M.C. and T.I. Fenyes, 2000: Maize and wheat production trends in South Africa in a deregulated environment. *Agrekon,* 39, 293-305.

Brown, G.G., P. Reed and C.C. Harris, 2002: Testing a place-based theory for environmental evaluation: an Alaskan case study. *Applied Geography,* 22, 49-76.

Brown, K., 2002: Water scarcity: forecasting the future with spotty data. *Science*, 297, 926-927.

Central Statistical Service 1970-1993: Agricultural Census, CSIR, Pretoria.

CGS, 2001: *Digital metallogenic map of the Republic of South Africa and the kingdoms of Lesotho and Swaziland*. Council for Geosciences, Pretoria, South Africa.

CGS, 2002: *Poverty Alleviation Program – Potential mining projects South Africa, Lesotho and Swaziland*. Council for Geosciences, Pretoria, South Africa. Available at http://www.geoscience.org.za/poverty.

Chamber of Mines, 2002: Annual Report 2002, Chamber of Mines, South Africa. Available at http://www.bullion.org.za.

Chief Directorate: Department of Surveys and Mapping, 2003.

Chiuta T.M., P. Johnson and R. Hirji, 2002: Water Resources and the Economy. In *Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa* Hirji, R., P. Johnson, P. Maro and T.M. Chiuta (eds.), SADC, IUCN, SARDC, World Bank: Maseru/Harare/Washington DC.

Chown, S.L., B.J. van Rensburg, K.J. Gaston, A.S. Rodrigues and A.S. van Jaarsveld, 2003: Energy availability, species richness and human population size: conservation conflicts at a national scale. *Ecological Applications*, 13, 1233-1241.

Christian, C.S. and G.A. Steward, 1968: Methodology of integrated surveys. In *Proceedings of the Toulouse conference on aerial and integrated studies*. UNESCO, Paris, 233-280.

Christopher, A.J., 1982: *South Africa*. Longman Press, London.

Chutter, F.M., R.W. Palmer and J.J. Walmsley, 1996: *Environmental Overview of the Orange River*. Orange River Development Project Replanning Study. DWAF report PD 00/00/5295, 193 pp.

Chutter, F.M., 1998: *Research on the rapid biological assessment of water quality impacts in streams and rivers*. Report to the WRC, Environmentek CSIR, WRC Report 422/1/98.

City of Johannesburg (COJ), 2001: *Surface Water Quality Summary for the Period December 1999 to November 2000*. CoJ, January 2001.

COSATU/NUM, 2001: *COSATU/NUM initial submission on mineral development draft bill*, Submitted to the Department of Minerals and Energy on 30 March 2001, Pretoria, South Africa, 24 pp.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton and M. van den Belt, 1997: The value of the world's ecosystem services and natural capital. *Nature*, 387, 253-260.

Cowling, R.M. and C. Hilton-Taylor, 1994: Patterns of Plant Diversity and Endemism in South Africa: an Overview. In: *Botanical Diversity in Southern Africa*, Strelitzia 1, Huntley, B.J. (ed.), National Botanical Institute, Pretoria, pp 31-52.

Cowling, R.M. and P.W. Roux (eds.), 1987: The Karoo biome: a preliminary synthesis. Part 2. Vegetation and history. *South African National Scientific Programmes Report* 142. CSIR, Pretoria.

Cowling, R.M., K.J. Esler, and P.W. Rundel, 1999: Namaqualand, South Africa – an overview of a unique winter-rainfall desert ecosystem, *Plant Ecology*, 142, 3-21.

Cowling, R.M., R.L. Pressey, M. Rouget, G.I.H. Kerley, A.T. Lombard, 2003a: A conservation plan for a global biodiversity hotspot - the Cape Floristic Region, South Africa. *Biological Conservation*, 112, 191-216.

Cowling, R.M., A.T. Lombard, M. Rouget, G.I.H. Kerley, T. Wolf, R. Sims-Castley, A. Knight, J.H.J. Vlok, S.M. Pierce, A.F. Boshoff and S.L. Wilson, 2003b: *A conservation assessment for the Subtropical Thicket Biome*. TERU REPORT 43, Terrestrial Ecology Research Unit, University of Port Elizabeth, South Africa.

CSIR, 2002: RSA Historic Landcover Dataset. Council for Scientific and Industrial Research, South Africa.

Daily, G.C. (ed.), 1997: *Nature's services: societal dependence on natural systems*. Island Press, Washington DC, 392 pp.

De Lange, A.O., van Averbeke, A, Sonandi, A, Lesoetsa, T.E., Witbooi, W and Mei, P., 1994: *Mid-Fish River Zonal Study: A Description and Analysis of the Soils and Climate and the Agricultural Land Use Systems*. The Agricultural and Rural Development Research Institute, University of Fort Hare, Alice, South Africa.

De Villiers, P. 2003 : *Milk Producers Organisation* (MPO), personal communication. November 2003

Dent, M.C., S.D. Lynch, and R.E. Schulze, 1987: *Mapping mean annual and other rainfall statistics over Southern Africa*, University of Natal, Pietermaritzburg.

DACST, 1996: Foresight Synthesis Report: Dawn of the African Century. Department of Arts, Culture, Science and Technology, Pretoria, 93 pp.

DEAT, 1999: National State of the Environment Report, Department of Environmental Affairs and Tourism, Pretoria, South Africa.

DEAT, 2003: Memorandum on the Objects of the National Environmental Management: Air Quality Bill. Department of Environmental Affairs and Tourism, South Africa. Available at http://www.environment.gov.za/HotIssues/2003apr22/airQualityBill_22032003.html.

Department of Water Affairs, 1986: *Management of the Water Resources of the Republic of South Africa*. Department of Water Affairs, Pretoria.

Desanker, P., D. Kwesha and D. Gumbo, *in preparation. Ecosystem Services in the Zambezi River Basin*. Zimbabwe Forest Commission, Harare, Zimbabwe.

Dickens, C.W.S. and P.M. Graham, 2002: The South African Scoring System (SASS) Version 5 Rapid Bioassessment Method for Rivers. *African Journal of Aquatic Science,* 27, 1- 10.

DME, 2002: Department of Minerals and Energy Annual Report 2002, Department of Minerals and Energy, Pretoria, South Africa, 104 pp.

DOE, 2002: *Strategic Plan for the Department of Education (2002-2004).* Department of Education, South Africa.

DOH, 2003: National HIV and Syphillis Antenatal Sero-Prevalence Survey in South Africa: 2002. Department of Health, Pretoria, 15 pp.

Downes, D.R. 1996: Global trade, local economies, and the Biodiversity Convention, In *Biodiversity and the Law*, W.J. Snape and O.A. Houck (eds.), Island Press, Washington, D.C., 202-216.

Drechsler, B., 2001: *South Africa CH5, Small-scale mining and sustainable development within the SADC region*, Mining, minerals and sustainable development in South Africa research Topic 1, Harare, Zimbabwe, 98-112 pp.

Driver, A., P. Desmet, M. Rouget, R. Cowling and K. Maze, 2003: *Succulent Karoo Ecosystem Plan*, Biodiversity Component, Technical Report. Cape Conservation Unit, Report No CCU 1/03, Botanical Society of South Africa, Claremont, South Africa.

Duke, J.S. and H.A. Mooney, 1999: Does global change increase the success of biological invaders? *Trends in Ecology and Evolution,* 14, 135-139.

DWAF, 1996a: South African Water Quality Guidelines: Volume 1: Domestic Use, Second Edition. Department of Water Affairs and Forestry, Pretoria, South Africa, 214 pp.

DWAF, 1996b: South African Water Quality Guidelines: Volume 7: Aquatic Ecosystems, Second Edition. Department of Water Affairs and Forestry, Pretoria, South Africa, 161 pp.

DWAF, 1997a: White Paper on a National Water Policy for South Africa. Department of Water Affairs and Forestry, Pretoria. Available at http://www.dwaf.gov.za/Documents/Policies/nwpwp.pdf.

DWAF, 1997b: *South Africa's National Forestry Action Plan.* September 1997. Department of Water Affairs and Forestry, Pretoria South Africa. Available at http://www.dwaf.gov.za/Forestry/Forestry%20Policy/Nfap.htm.

DWAF, 1998: The National Water Act, No. 36 of 1998. Department of Water Affairs and Forestry, Pretoria, South Africa.

DWAF, 1999: The Raw Water Pricing Strategy. Department of Water Affairs and Forestry, Pretoria South Africa.

DWAF, 2000a: Economic Information System, Department of Water Affairs and Forestry, Pretoria South Africa.

DWAF, 2000b: Policy and Strategy for Groundwater Quality Management in South Africa. Department of Water Affairs and Forestry, Pretoria, South Africa. 44 pp.

DWAF, 2002a: *Proposed First Edition of the National Water Resources Strategy*, 59 pp. Department of Water Affairs and Forestry, Pretoria South Africa.

DWAF, 2002b: Report No. P09000/00/0101. Middle Vaal Water Management Area: Water Resources Situation Assessment. Stewart Scott Consulting Engineers. Department of Water Affairs and Forestry, Pretoria South Africa.

DWAF, 2003a: Hydrological Information System, Department of Water Affairs and Forestry, Pretoria South Africa [online] http://www.dwaf.gov.za/hydrology/cgi-bin/his/cgihis.exe/station.

DWAF, 2003b: Working for Water Annual Report 2000/2001, Department of Water Affairs and Forestry, Pretoria South Africa [online] http://www.dwaf.gov.za/wfw/AnnualReports/WFWANNUA.pdf

DWAF, 2003c: Water Use Charges for Government Water Schemes and Water Resource Management Charges, Department of Water Affairs and Forestry, Pretoria South Africa

DWAF, 2003d: Trophic Status of South African Impoundments. National Eutrophication Monitoring Programme. Department of Water Affairs and Forestry, Pretoria South Africa [online] http://www.dwaf.gov.za/iwqs/eutrophication/NEMP/default.htm.

DWAF, 2004: "A Decade of Delivery" Department of Water Affairs and Forestry, Pretoria South Africa [online] http://www.dwaf.gov.za/Communications/Articles/Minister/2004/TENYEARSOFDELIVER%20ARTICLE.doc.

Eberhard, A. A., 1990: *Energy Consumption Patterns and Supply Problems in Underdeveloped Areas in South Africa*. Development South Africa, 7, 335-346.

Eberhardtt, R. and G. Pegram, 2000: *The water sector: A position paper*. Macroeconomics and Sustainable Development in Southern Africa. Development Bank of South Africa, Midrand, South Africa.

Economic Advisory Unit of the Chamber of Mines, 2002: South African Mining Industry Fact Sheet 2002, Chamber of Mines, South Africa. Available at http://www.bullion.org.za/MiningEconomics&Stats/Eco%20Pdf's/minfactsheetfinal-2002.pdf.

Ehrlich, P.R. and H.A. Mooney, 1983: Extinction, substitution and ecosystem services. *BioScience*, 33, 248-253.

EIA, 2002: South Africa country analysis: In Brief, Energy Information Administration. Available at http://www.eia.doe.gov/emeu/cabs/safrica.html.

Elias, R. and I. Taylor, 2001: *HIV/AIDS, The mining and minerals sector and sustainable development in Southern Africa.* Mining, minerals and sustainable development in South Africa, Johannesburg, South Africa, 110 pp.

Erasmus, B.F.N., A.S. van Jaarsveld, S.L. Chown, M. Kshatriya and K.J. Wessels, 2002: Vulnerability of South African animal taxa to climate change. *Global Change Biology*, 8, 679-693.

Erasmus, L. and A.S. van Jaarsveld, 2002: Exploring policy interventions for sustainable development in South Africa: A modelling approach. *South African Journal of Science*, 98, 3-8.

ERI, 2001: *Preliminary Energy Outlook for South Africa*. Energy Research Institute, Department of Mechanical Engineering, University of Cape Town, Rondebosch, South Africa. 78pp.

Eskom, 2003: Company Information. Available at http://www.eskom.co.za..

ESRI, 1998: *Arc and Grid Command References*. Environmental Systems Research Institute, Redlands, California.

Fabricius, C. 1997. The Impact of Land Use on Biodiversity in Xeric Succulent Thicket, South Africa. Ph.D Thesis, University of Cape Town, Cape Town, South Africa.

Fabricius, C., M. Burger and P.A.R. Hockey, 2003: Comparing biodiversity between protected areas and adjacent rangeland in xeric succulent thicket, South Africa: arthropods and reptiles. *Journal of Applied Ecology*, 40, 392-403.

Fairbanks, D.H.K., M.W. Thomson, D.E. Vink, T.S. Newby, H.M. van den Berg and D.A. Everard, 2000: The South African Land-cover Characteristics Database: a Synopsis of the Landscape. *South African Journal of Science*, 96, 69-82.

Falkenmark, M. and C. Widstrand, 1992: *Population and Water Resources: A Delicate Balance*. Population Bulletin. Population Reference Bureau.

Felix, M., 1991: Risking Their Lives in Ignorance: The Story of an asbestos-polluted community. In: *Going Green: People, politics and the environment in South Africa*, Cock, J. and E. Koch (eds.), Oxford University Press, Cape Town, South Africa. 36 pp.

Foden, W., 2002: A demographic study of *Aloe dichotoma* in the Succulent Karoo: Are the effects of climate change already apparent? MSc. thesis, University of Cape Town, Cape Town, South Africa.

Franklin, J.F. and R.T.T. Forman, 1987: Creating landscape patterns by forest cutting: ecological consequences and principles. *Landscape Ecology*, 1, 5-18.

Freitag, S., A.S. van Jaarsveld and H.C. Biggs, 1997: Ranking priority biodiversity areas: an iterative conservation value-based approach. *Biological Conservation*, 82, 263-272.

Friedmann, Y. and D. Daily (eds.), 2004: *Red data book of the mammals of South Africa: a conservation assessment*. CBSG Southern Africa, Conservation Breeding Specialist Group (SSC/IUCN), Endangered Wildlife Trust, South Africa.

Gallopín, G.C., 2002: Planning for resilience: scenarios, surprises and branchpoints. In *Panarchy: Understanding Transformations in Human and Natural Systems*, L. Gunderson and C. S. Holling (eds.), Island Press, Washington D.C., 361-392.

Gandar, M., 1994: *An investigation of prices, pricing criteria and distribution networks for fuelwood in selected areas of South Africa*, Biomass Initiative Report PFL-COM-01, Department of Mineral and Energy Affairs, Pretoria, South Africa, 68pp.

Gauteng Nature Conservation, 2003. GIS Database.

Geffen, N., 2004: *Why Rian Malan is wrong about AIDS*. Noseweek. February 2004.

George, J. and J. van Staden, 2000: Intellectual property rights: plants and phytomedicines - past history, present scenario and future prospects in South Africa. *South African Journal of Science*, 96, 433-443.

Godfrey, L., M. Claassen, C. Todd, V. Smakhtin, M. du Preez, and R. Stassen, 2002: *South Africa State of the Environment Report. Volume 1: Inland Waters*. Department of Environmental Affairs and Tourism, Pretoria, South Africa, 95 pp.

Goldblatt, M., S. Gelb and G. Davies, 2002: *Macroeconomics and Sustainable Development in Southern Africa: Synthesis Report of South African Study*. Development Bank of South Africa. Midrand, South Africa, 88 pp.

Granville, A., 2001: *Baseline survey of the mining and minerals sector, MMSD Research topic 6*, Mining, Minerals and Sustainable Development Southern Africa, Johannesburg, South Africa, 109pp.

Hall, T.D. and J.V. Fenelon, 2004: The Futures of Indigenous Peoples: 9-11 and the Trajectory of Indigenous Survival and Resistance, *Journal of World Systems Research*, x(1):153–197.

Harrison, J.A., 1992: The South African Bird Atlas Project: Five years of growth. *South African Journal of Science,* 88, 410-413.

Harvey, P., 2003: *HIV/AIDS: What are the implications for humanitarian action? A Literature Review*. Humanitarian Policy Group, Overseas Development Institute, 75 pp.

Haupt, C.J., 2001: *Water resources situation assessment: Groundwater resources of South Africa*. Department of Water Affairs and Forestry, Pretoria, South Africa. 21 pp.

Henderson, L., 1998: Southern African plant invaders atlas (SAPIA). *Applied Plant Sciences*, 12, 31-32.

Hendricks, H.H., 2003a: Semi-nomadic pastoralism and the conservation of biodiversity in the Richtersveld National Park. Unpublished manuscript, South African National Parks, Kimberley, and University of Cape Town, Cape Town, South Africa.

Hendricks, H.H., 2003b: Scoping report on a baseline assessment of the relationships between ecosystems and human well-being in the Richtersveld National Park, Northern Cape, South Africa. Unpublished report, Rhodes University, Grahamstown, South Africa. 35 pp.

Herbert , D., 2001: Museum Natural Science and the NRF: Crisis Time for Practitioners of Fundamental Biodiversity Science. *South African Journal of Science*, 97, 168-172.

Herold, C.E., 1992: Umfula Wempilo Consulting. Personal Communication.

Herold, C.E., A. Görgens, and H.R. van Vliet, 1992. The influence of atmosphere deposition on the Vaal Dam. In:*Proceedings of the Water Week Conference,* Pretoria, South Africa. 11pp.

Herold, C.E. and J.J. Rademeyer, 2000: *Water utilisation in the Vaal River system: the current situation, influences and expected trends*. Paper presented at Vaal 2000 Conference. 13 pp.

Heyns, P., 2004: *Achievements of the Orange-Senqu River Commission in Integrated Transboundary Water Resource management*. Paper presented at the General Assembly of the International Network of Basin Organisations, Martinique, French Antilles.

Hilton-Taylor, C. and A. le Roux, 1989: Conservation status of the Fynbos and Karoo biomes. In B.J. Huntley (Ed.) *Biotic Diversity in Southern Africa: Concepts and Conservation,* Oxford University Press, Cape Town, 202-223.

Hirschowitz, R, W. Sekwati and D. Budlender, 2001: *South Africa in transition: Selected findings from the October household survey of 1999 and changes that have occurred between 1995 and 1999/ Statistics South Africa*. Pretoria: Statistics South Africa, pp 71.

Hoadley, M., D. Limpitlaw, A. Weaver, 2002: *Volume 1. The report of the regional MMSD process*, Mining, minerals and sustainable development in South Africa, Johannesburg, South Africa, pp. 86.

Hoffman, M.T., S.W. Todd, Z.M. Ntshona and S.D. Turner, 1999: *Land Degradation in South Africa*. National Botanical Institute, Cape Town, Available at http://www.nbi.ac.za.

Hohls, B.C., M.J. Silberbauer, A.L. Kühn, P.L. Kempster and C.E. van Ginkel, 2002: *National water resource quality status report: inorganic chemical water quality of surface water resources in South Africa: the big picture*. Report No. N/0000/REQ0801. ISBN No. 0-621-32935-5. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa, pp 96.

Holgate, C.J., 2002: *Rapid Assessment of the Upper Klip River Catchment.* Unpublished report. UNCHS, Nairobi Kenya.

Holling, C.S., and L.H. Gunderson, 2002: Resilience and adaptive cycles. Pages 25-62 *in* L. H. Gunderson and C. S. Holling (eds.) *Panarchy: Understanding Transformations in Human and Natural Systems,* Island Press, Washington, D.C., USA.

HSRC, 2004: *Food security in South Africa: Key policy issues for the medium term*. Human Sciences Research Council, Pretoria, South Africa.

Hughes, D.A., 2001: Providing hydrological information and data analysis tools for determination of ecological instream flow requirements for South African rivers. *Journal of Hydrology*, 241, 140-151.

Hughes, D.A. and P. Hannart, 2003: A desktop model used to provide an initial estimate of the ecological instream flow requirements of rivers in South Africa. *Journal of Hydrology*, 270, 167-181.

Huntley, B., R. Siegfried and C. Sunter, 1989: *South African environments into the 21st century*. Human and Rousseau Tafelberg, Cape Town.

IFAP, 2003: Available at http://www.ifap.org/canberra/Meat/MF311.htm.

IPCC, 2001: *Climate Change 2001. Impacts, Adaptation and Vulnerability, Section, Hydrology and Water Resources*, Report of Working Group II of the Intergovernmental Panel on Climate Change. Available at http://www.ipcc.ch.

Jurgens, N., 1985: Konvergent Evolution von Blatt- und Epidermismerkmalen bei blattsukkulenten Familien. Berichte der Deutschen Botanischen Gesellschaft 98: 425-446.

Kahane, A., 1992: *The Mont Fleur Scenarios*. Deeper News. 7(1). Available at http://www.gbn.org.

Kamara, A. and H. Sally, 2002: *Water for food, livelihoods and nature: simulations for policy dialogue in South Africa*. Third WARSFA/ Waternet Symposium; Arusha; October 2002.

Kerley, G.I.H., R.L. Pressey, R.M. Cowling, A.E.F. Bosho, R. Sims-Castley, 2003: Options for the conservation of large and medium-sized mammals in the Cape Floristic Region. *Biological Conservation,* 112, 169-190.

King, J. and D. Louw, 1998: Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. *Aquatic Ecosystem Health and Management,* 1, 109-124.

Kirsten, M. and M. Sindane, 1994: The informal sector and small business: a South African case study. In: *Prospects for progress - critical choices for southern Africa,* M. Venter (ed.), 164-174.

Klasen, S. 2002. *The costs and benefits of changing in-stream flow requirements (IFR) below the Phase 1 structures of the Lesotho Highlands Water Project.* Lesotho Highlands Development Authority, Maseru, Lesotho. Available at http://www.sametsi.com/LHWP/ifr.htm.

Klein Goldewijk, K., 2001: Estimating global land use change over the past 300 years: The HYDE database. *Global Biogeochemical Cycles,* 15(2), 417-434.

Koch, S.O., S.L. Chown, A.L.V. Davis, S. Endrödy-Younga and A.S. van Jaarsveld, 2000: Conservation strategies for poorly surveyed taxa: a dung beetle (Coleoptera, Scarabaeidae) case study from southern Africa. *Journal of Insect Conservation,* 4, 45-56.

Kunin, W.E. and Lawton, J.H., 1996: Does biodiversity matter? Evaluating the case for conserving species. In *Biodiversity: A biology of numbers and difference*, K.J. Gaston (ed.), Chapter 11. Blackwell Science Ltd, Oxford, UK.

Labonne, B., 2002: Commentary: Harnessing mining for poverty reduction especially in Africa, *Natural Resources Forum*, 26, 69-73.

Lambin, E.F. and 25 others, 2001: The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change*, 11, 261-169.

Land Type Survey Staff, 1986: Landtypes of the map 2730 Vryheid. *Memoirs of Agricultural Natural Resouces of South Africa*, 7.

Langenhoven, M.L., P. Wolmarans, P.L. Jooste, M.A. Dhansay, and A.J.S. Benadé, 1995: Food consumption profile of the South African adult population. *South African Journal of Science*, 91, 523-528.

Lawrence, C.J., R.J. Byard and P.J. Beavan, 1993: *Terrain Evaluation Manual*. HMSO, London.

Lebesa, L.N., 2003: *Report prepared for the Gariep Basin Millennium Ecosystem Assessment as Lesotho's contribution on the Ecosystems in Lesotho*, Department of Agricultural Research, Maseru, Lesotho, 33 pp.

Lesotho Bureau of Statistics/Ministry of Agriculture, 2001: *Lesotho Agricultural Situation Report (1996/9 – 1998/99)*, Maseru, Lesotho.

Lesotho Bureau of Statistics, 2002a: Gross Domestic Product and Gross National Income (1982 - 2002), Bureau of Statistics, Maseru, Lesotho. Available at http://www.bos.gov.ls.

Lesotho Bureau of Statistics, 2002b: *Lesotho Demographic Survey, 2001*. Vol. 1, Bureau of Statistics, Maseru, Lesotho. Available at http://www.bos.gov.ls.

Lesotho Department of Energy, 2002: *Energy Policy Framework for Lesotho*. Maseru, Lesotho.

Lesotho Government, National Environment Secretariat 2000: *Biological Diversity in Lesotho: a Country Study*. Maseru, Lesotho.

Lesotho Meteorological Services, 2000: *National report on Climate Change*. Ministry of Natural Resources, Lesotho Government, Maseru, Lesotho.

Lesotho Vulnerability Assessment Committee/SADC FANR Vulnerability Assessment Committee, 2002: *Lesotho Emergency Food Security Assessment Report*. Maseru, Lesotho.

Lombard, A. T., R. M. Cowling, R. L. Pressey and P. J. Mustart, 1997: Reserve selection in a species-rich and fragmented landscape on the Agulhas Plain, South Africa. *Conservation Biology*, 11, 1101-1116.

Loreau, M., S. Naeem and P. Inchausti (eds.), 2002: *Biodiversity and Ecosystem Functioning: Synthesis and Perspectives*. Oxford University Press, Oxford.

Low, A.B. and A. Rebelo, 1996: *Map of the Vegetation of South Africa, Lesotho and Swaziland*. Department of Environmental Affairs and Tourism, Pretoria.

Lurie, M., 2000: Migration and AIDS in southern Africa: a review. *South African Journal of Science*, 96, 343-347.

Lynam, T., A. Sitoe, B. Reichelt, R. Owen, R. Zolho, R. Cunliffe and I. Buerinofa. 2004. *Human well-being and ecosystem services: an assessment of their linkages in the Gorongosa – Marromeu region of Sofala Province, Mozambique to 2015.* University of Zimbabwe, Harare, Zimbabwe.

Mackay, H., 2000: *Moving towards sustainability: The ecological Reserve and its role in implementation of South Africa's water policy*. Proceedings of the World Bank Water Week Conference, Washington, April 2000. Available at http://www.thewaterpage.com/aq_eco_main.htm.

Mackay, H., 2003: Water policies and practices. In *Towards a Just South Africa: The Political Economy of Natural Resource Wealth,* D. Reed and M. de Wit (eds.), WWF Macroeconomics Programme Office, Washington D.C. and CSIR, Pretoria, 49-83.

MacVicar, C.N., D.M. Scotney, T.E. Skinner, H.S. Niehaus and J.H. Loubser, 1974: A classification of land (climate, terrain form, soil) primarily for rainfed agriculture. *South African Journal of Agriculture Extensions*, 3, 21-24.

Mail & Guardian, 2003: *South Africa 2014: Boom or Bust?* 12 Dec. 2003. Available at http://archive.mg.co.za.

Makwinzha, T.P., P. Mwape, N. van Averbeke, 2001: *South Africa's Mineral Industry General Review*, Part One, Department of Minerals and Energy, Mineral Economics Directorate (Minerals Bureau), Mineralia Centre, Pretoria, South Africa. 202 pp.

Malan, R., 2003: *Apocalypse when?* Noseweek. December 2003/January 2004.

Mander, M., D. Cox, J. Turpie and C. Breen, 2002: *Incorporating economic considerations into quantification, allocation and management of the environmental water reserve*. WRC Report No. 978/1/02. Water Research Commission, Pretoria. 80 pp.

Maree, S., G. Bronner, C. Jackson and N. Bennett, 2003: The conservation of golden moles (Afrosoricida; Chrysochloridae) with emphasis on the status of *Neamblysomus julianae* in South Africa. *Afrotherian Conservation,* Newsletter of the IUCN/SSC Afrotheria Specialist Group, 2, 4-6.

Margules, C. R. and R.L. Pressey, 2000: Systematic conservation planning. *Nature*, 405, 243-253.

McAllister, 1998: *Grasslands – who needs them?* Available at http://www.sawac.co.za/articles.

McCann, K.S., 2000: Review article: Global patterns in biodiversity. *Nature*, 405, 220-227.

McGeogh, M., 2002: Insect Conservation in South Africa: an Overview. *African Entomology*, 10, 1-10.

MDB, 2001: SA Explorer. Municipal Demarcation Board. Available at http://www.demarcation.org.za/old/saexplorer/saexhome.html.

Metsi Consultants, 2002: *Lesotho Highlands Water Project Final Report: Summary of Main Findings for Phase I*. Development Report No. LHDA-678-F-001. 122 pp.

Mkhabela, S., 2002: Farm size and soil loss: prospects for a sustainable agriculture in KwaZulu-Natal. *Agrekon*, 41: 135-146.

Millennium Ecosystem Assessment, 2003: *Ecosystems and human well-being: a framework for assessment*. Island Press, Washington, D.C.

Millennium Ecosystem Assessment, first review draft, 2004a: Chapter 5: Food. In: Responses Working Group Assessment Report.

Millenium Ecosystem Assessment, first review draft, 2004b: Chapter 3: Analytical Approaches for Assessing Ecosystem Condition and Human Well-being. In: Condition and Trends Working Group Assessment Report.

Milton S.J., R.I. Yeaton, W.R.J. Dean, and J.H.J. Vlok, 1997: Succulent Karoo. In *Vegetation of Southern Africa*. R.M. Cowling, D.M. Richardson, and S.M. Pierce (eds.), Cambridge University Press, Cambridge, 131-166.

Mucina, L. and M.C. Rutherford, 2004: *Vegetation map of South Africa, Lesotho and Swaziland: an illustrated guide*. National Botanical Institute, Cape Town, South Africa.

Mutemeri, N. and F.W. Peterson, 2002: Small-scale mining in South Africa: Past, present and future, *Natural Resources Forum*, 26, 286-292.

Naeem, S., 2001: How changes in biodiversity may affect the provision of ecosystem services. In: *Managing Human Dominated Ecosystems*, Hollowell (ed.), Missouri Botanical Garden Press, St. Louis, 3-33.

NDA, 1997: Food Security Policy for South Africa: A Discussion Document. Agricultural Policy Unit, Department of Agriculture and Land Affairs, Pretoria, South Africa. Available at http://www.nda.agric.za/docs/Foodsecurity/foodsecurity.htm.

Neke, K. and M. du Plessis, 2004: The threat of transformation: Quantifying the vulnerability of grasslands in South Africa, *Conservation Biology*, (18)2, 466-477.

Norton, B. and B. Hannon, 1997: Environmental values: a place-based approach. *Environmental Ethics*, 19(3), 227-245.

Noss, R.F., 1990: Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology,* 4, 355-364.

Noss, R.F. and A.Y. Cooperrider, 1994: *Saving nature's legacy: protecting and restoring biodiversity*. Island Press, Washington D.C.

Oryx Environmental and Newtown Landscape Architects, 2000: *An open space framework for the Klip Spruit River Corridor, its tributaries and the adjacent open land*. Southern Metropolitan Local Council, August 2000.

Pahl-Wostl, C., H. Hoff, M. Meybeck and S. Sorooshian, 2002: The role of global change research for aquatic sciences. *Aquatic Sciences,* 64, iv-vi.

Palmer, A.R. and A.M. Avis, 1994: *The description, mapping and evaluation of recent change in the contemporary vegetation patterns. Mid-Fish River Zonal Study.* Land and Agriculture Policy Centre, Pretoria, 54 pp.

Peterson, G.D., G.S. Cumming and S.R. Carpenter, 2003: Scenario planning: A tool for conservation in an uncertain world. *Conservation Biology*, 17(2), 358-366.

Pressey, R.L. and A.O. Nicholls, 1989: Application of a numerical algorithm to the selection of reserves in semi-arid New South Wales. *Biological Conservation,* 50, 264-278.

Pressey, R.L., 1992: Nature conservation in rangelands: Lessons from research on reserve selection in New South Wales. *Rangelands Journal*, 14, 214-226.

Pressey, R.L. and S.L. Tully, 1994: The cost of ad hoc reservation: A case study in western New South Wales. *Australian Journal of Ecology*, 19, 375-384.

Pressey, R.L. and K.H. Taffs, 2001: Scheduling conservation action in production landscapes: priority areas in western New South Wales defined by irreplaceability and vulnerability to vegetation loss. *Biological Conservation*, 100, 355-376.

Pressey, R.L., 1999: Application of irreplaceability analysis to planning and management problems. *Parks*, 9, 42-51.

Pressey, R.L., R.M. Cowling and M. Rouget, 2003: Formulating conservation targets for biodiversity pattern and process in the Cape Floristic Region, South Africa. *Biological Conservation*, 112, 99-127.

Preston, G., 2003: *Invasive Alien Plants and Protected Areas in South Africa*. Presentation to World Parks Congress, Durban, South Africa.

Purdie, R.W., R. Blick and M.P. Bolton, 1986: Selection of a conservation reserve in the Mulga biogeograpgic region of south-western Queensland, Australia. *Biological Conservation*, 38, 369-384.

Reader, J., 1998: *Africa: A Biography of the Continent*. Penguin Books, London. 803 pp.

Redman, C.L. and A.P. Kinzig, 2003: Resilience of past landscapes: resilience theory, society and the *longue durée*. *Conservation Ecology*, 7(1), 14. Available at http://www.consecol.org/vol7/iss1/art14.

Revenga, C., J. Brunner, N. Henninger, K. Kassem and R. Payne, 2000: *PAGE Freshwater Systems*. World Resources Institute, Washington D.C. 65 pp.

Reyers, B., A.S. van Jaarsveld and M. Krüger, 2000: Complementarity as a biodiversity indicator strategy. *Proceedings of the Royal Society, London (B)*, 267, 505-513.

Reyers, B., D.H.K. Fairbanks, A.S. van Jaarsveld and M. Thomson, 2001: Priority Areas for Conserving South African Vegetation: a Coarse Filter Approach. *Diversity and Distributions*, 7, 77-96.

Reyers, B., D.H.K. Fairbanks and A.S. van Jaarsveld, 2002: A multicriteria approach to reserve selection: addressing long-term biodiversity maintenance and land use planning. *Biodiversity and Conservation*, 11, 769-793.

Reyers, B., 2004: Incorporating potential land-use threats into regional biodiversity evaluation and conservation area prioritisation. *Biological Conservation*, 118, 521-531.

Rogers, K., 1998: Managing science/management partnerships: a challenge of adaptive management. *Conservation Ecology*, 2(2). Available at http://www.consecol.org/vol2/iss2/resp1.

Rogers, K., D. Roux and H. Biggs, 2000: Challenges for catchment management agencies: lessons from bureaucracies, business and resource management. *Water SA*, 26(4), 505-511. Available at http://www.wrc.org.za.

Rosen, S., J.L. Simon, D.M. Thea and J.R. Vincent, 2000: Care and treatment to extend the working lives of HIV-positive employees: calculating the benefits to business. *South African Journal of Science*, 96, 300-304.

Rouget, M., R.M. Cowling, R.L. Pressey and D.M. Richardson, 2003: Identifying the spatial components of ecological and evolutionary processes for regional conservation planning in the Cape Floristic Region. *Diversity and Distributions*, 9, 191-210.

Rutherford, M.C. and R.H. Westfall, 1986: Biomes of southern Africa - an objective categorization. *Memoirs of the Botanical Survey of South Africa*, 54, 1-98.

Rutherford, M.C., G.F. Midgley, W.J. Bond, L.W. Powrie, R. Roberts and J. Allsopp, 1999: *Plant Biodiversity: Vulnerability and Adaptation Assessment: South African Country Study on Climate Change*. National Botanical Institute, Claremont, South Africa, pp. 1-59.

Sampat, P., 2003: Scrapping Mining Dependence. In: *State of the World 2003*, L. Starke (ed.), Worldwatch Institute/W.W. Norton and Company, Inc., New York, 110-129.

Schlemmer, L., 2002: *The distribution of South Africa's population, economy and water usage into the long-term future*. Mark Data (Pty) Ltd., Eric Hall and Associates report to the Department of Water Affairs and Forestry, Pretoria. 262 pp.

Scholes, R.J. and R. Biggs, 2004: *Ecosystem services in southern Africa: A regional assessment*. CSIR, Pretoria, South Africa. 60 pp.

Schoonraad, P.J. and P.A. Swanepoel, 2004: *Evaluation report: Pilot implementation of "Basa Mama" as method of igniting a coal fire*. Nova, Pretoria.

Seckler, D., U. Amarasinghe, D. Molden, R. de Silva and R. Barker, 1998: *World Water Demand and Supply, 1990 to 2025: Scenarios and Issues*. Research Report No. 19, International Water Management Institute (IWMI), Colombo, Sri Lanka.

Sellschop, J.P.F. and G.F.R. Ellis (eds.), 2003: The Royal Society of South Africa Workshop on the Pebble Bed Modulator Reactor. *Transactions of the Royal Society of South Africa*, 56, 1-150.

Simon, K.S., and C.R. Townsend, 2003: Impacts of freshwater invaders at different levels of ecological organisation, with emphasis on salmonids and ecosystem consequences. *Freshwater Biology*, 48(6), 982-994.

Shackleton C., I. Grundy and A.T. Williams, 2003a: Use of South Africa's woodlands for energy and construction. Woodlands for energy and construction - Shackleton *et al*. Natal University Press. ISBN: 1869140508.32pp.

Shackleton, C.M., G. Guthrie, J. Keirungi and J. Stewart, 2003b: Fuelwood availability and use in the Richtersveld National Park, South Africa. *Koedoe,* 46, 1-8.

Shackleton, C., C. Fabricius, A. Ainslie, G. Cundill, H. Hendricks, S. Matela, and N. Mhlanga, 2004. *Southern African Millennium Assessment: Gariep Basin Local Scale Assessments.* Rhodes Univerity, Grahamstown, South Africa.

Snaddon, C.D., M.J. Wishart and B.R. Davies, 1998: Some implications of inter-basin water transfers for river ecosystem functioning and water resources management in southern Africa. *Aquatic Ecosystem Health and Management*, 1, 159-182.

Soulé, M.E. and M.A. Sanjayan, 1998: Conservation targets: do they help? *Science*, 279, 2060-2061.

South Africa Government Online, 2002a: "Agriculture and Land Affairs." Available at http://www.gov.za/yearbook/2002/agricland.htm.

South Africa Government Online, 2002b: "The Land and its People." Available at http://www.gov.za/yearbook/2002/landpeople.htm.

South African Grain Information Services, 2002: Available at http://www.sagis.org.za.

Stats SA, 1997: *Living in Gauteng: Selected findings of the 1995 October Household Survey*. Statistics South Africa, Pretoria. Available at http://www.statssa.gov.za/Products/Publications/LivingIn(AllFiles)/Living%20in%20Gauteng.pdf

Stats SA, 2001: Human Development Index – 1980, 1991 and 1996, Statistics South Africa, Pretoria, 27pp.

Stats SA, 2002: Report on the survey of large- and small-scale agriculture. Statistics South Africa, Pretoria.

Stats SA, 2003: Census 2001. Statistics South Africa, Pretoria. Available at http://www.statssa.gov.za/SpecialProjects/Census2001/Census2001.htm.

Stewart, J., 2003: *Fuelwood in the lower Gariep Basin: the current situation and potential futures*. Honours dissertation, Rhodes University, Grahamstown. 33 pp.

Stiglitz, J.E., 2003: *Globalization and its discontents*. WW Norton and Company, New York.

Stokes, C.S., 2003: *Measuring Impacts of HIV/AIDS on Rural Livelihoods and Food Security*. Sustainable Development Department, Food and Agriculture Organization of the United Nations, Rome.

Thompson, H., C.M. Stimie, E. Richters and S. Perret, 2001: *Policies, legislation and organizations related to water in South Africa, with special reference to the Olifants River basin*. Working Paper 18 (South Africa Working Paper No. 7). Columbo, Sri Lanka: International Water Management Institute.

Thompson, M., 1996. A standard land-cover classification scheme for remote sensing applications in South Africa. *South African Journal of Science*, 92, 34-42.

Topouzis, D., 2003: *Addressing the Impact of HIV/AIDS on Ministries of Agriculture: Focus on Eastern and Southern Africa.* Joint FAO/UNAIDS Publication. Food and Agriculture Organization of the United Nations, Rome.

Tricarico, A., 2002: The Lesotho Highlands Water Project: Massive Dams for Massive Disasters. Reform the World Bank Campaign, Italy. Available at www.bankwatch.org/publications/issue_papers/2002/eib-ip-lesotho.pdf.

Townsend, C.R., 2003: Individual, population, community and ecosystem consequences of a fish invader in New Zealand streams. *Conservation Biology*, 17, 38-47.

Tucker, B. and B.R. Scott, 1992: *South Africa: Prospects for a successful transition*. Nedcor – Old Mutual. Juta and Co., Ltd., Kenwyn, South Africa.

Turpie, J.K., B.J. Heydenrych and S.J. Lamberth, 2003: Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation Strategies. *Biological Conservation*, 112, 233-251.

Turton, A., 2003: *The hydropolitical dynamics of cooperation in Southern Africa: A strategic perspective on institutional development in international river basins*. African Water Issues Research Unit (AWIRU) paper, Pretoria. 20 pp.

UNAIDS and WHO, 2002: *Aids Epidemic Update*. UNAIDS and WHO, Switzerland.

UNCCD, 1994: *Elaboration of an International Convention to Combat Desertification in Countries Experiencing Serious Drought and/Or Desertification, Particularly in Africa*, United Nations Convention to Combat Desertification, pp. 1-58.

UNDP, 2001: *Human development report 2001*, United Nations Development Programme, Oxford University Press, Oxford.

UNDP, 2003: *Human Development Report 2003*, United Nations Development Programme. Available at http://www.undp.org/hdr2003.

UNEP, 2000: Global Environmental Outlook 2000. Available at http://www.unep.org/Geo2000/english/0058.htm.

UNPFA, 1991: Population, Resources and the Environment: The Critical Challenges. United Nations, New York.

UNPFA, 1999: Six billion: A Time for Choices. The State of World Population 1999. United Nations, New York.

Urban-Econ Development Economists, 2000: *Economic Information System*, study prepared for the Department of Water Affairs and Forestry, Urban-Econ, Pretoria.

van den Bovenkamp, W., 2002: *Providing energy for development and protecting the climate: can South Africa combine these goals?* Unpublished MSc thesis, University of Utrecht. 81 pp.

van Horen C., 1996: *Counting the social costs: Electricity and externalities in South Africa*. UCT Press

van Jaarsveld, A.S. and S.L. Chown, 2001: Climate change and its impacts in South Africa. *Trends in Ecology and Evolution*, 16, 13-14.

van Onselen, C., 1997: *New Babylon: Essays in the Social and Economic History of the Witwatersrand, 1886-1914.* Ravan Press, Johannesburg.

van Riet, W.P., J. Claassen, T. van Rensburg, L. van Viegen and L. du Plessis, 1997: *Digital Environmental Potential Atlas for South Africa*. Department of Environmental Affairs and Tourism, Pretoria.

van Tienhoven, A.M., 1999: *Status of Air Pollution in South Africa*. Stockholm Environment Institute report. Available at www.sei.se/rapidc/pdfs/AirPollAfrica.pdf.

van Wyk, B. H.G.W.J.: Schweickerdt Herbarium, University of Pretoria. Personal communication.

van Zyl, B.R. and R. Kruger, 1998: *Climatic Change and Variability in Southern Africa*. Oxford University Press, Cape Town.

Versveld, D., D.C. le Maitre and R.A. Chapman, 1998: *Alien Invading plants and Water Resources in South Africa: A Preliminary Assessment*. Water Research Commission, Pretoria.

Vink, N. and J. van Zyl, 1998: Black disempowerment in South African agriculture: a historical perspective. In: *The agricultural democratisation of South Africa*, J. Kirsten, J. van Zyl, and N. Vink (eds.), Africa Institute for Policy Analysis/Francolin Publishers, Stellenbosch, 61-70.

Vink N., J.F. Kirsten, and J. van Zyl, 1998a: Favouritism in Agricultural Policy and Support Services. In: *The agricultural democratisation of South Africa*, J. Kirsten, J. van Zyl, and N. Vink (eds.), Africa Institute for Policy Analysis/Francolin Publishers, Stellenbosch, 71-82.

Vink N., J.F. Kirsten, and J. van Zyl, 1998b: Synthesis and an agenda for the empowerment of black farmers. In: *The agricultural democratisation of South Africa*, J. Kirsten, J. van Zyl, and N. Vink (eds.), Africa Institute for Policy Analysis/Francolin Publishers, Stellenbosch, 245-252.

Vogel, C. and J. Smith, 2002: The politics of scarcity: conceptualizing the current food security crisis in southern Africa, *South African Journal of Science,* 98(7/8), 315-317.

Von Willert, D.J., B.M. Eller, M.J.A. Werger, E. Brinckmann, and H.D. Ihlenfeldt, 1992: *Life Strategies of Succulents in Deserts with Special Reference to the Namib Desert*, Cambridge University Press, London.

Walmsley, J., M. Carden, C. Revenga, F. Sagona and M. Smith, 2001: Indicators of sustainable development for catchment management in South Africa: Review of indicators from around the world. *Water SA*, 27(4), 539-550. Available at http://www.wrc.org.za.

Walmsley, J., 2002: *Overview: Sustainability indicators for catchment management in South Africa*. Water Resource Commission, Pretoria, 25 pp.

Walters, C., 1997: Challenges in adaptive management of riparian and coastal ecosystems. *Conservation Ecology*, 1(2), 1. Available at http://www.consecol.org/vol1/iss2/art1/index.html.

Watson, M., Senior Specialist Engineer, Sub-Directorate: Water Resource Planning Systems, Directorate: Systems Analysis, Department of Water Affairs and Forestry. Personal Communication.

Webley, L.E., 1992: The history and archaeology of pastoralist and hunter-gatherer settlement in the north-western Cape, South Africa. PhD. Thesis, University of Cape Town, Cape Town.

Wessels, K.J., B. Reyers and A.S. van Jaarsveld, 2003: Identification of potential conflict areas between land transformation and biodiversity conservation in eastern South Africa. *Agriculture, Environment and Ecosystems*, 95, 157-178.

Westley, F., S.R. Carpenter, W.A. Brock, C.S. Holling, and L.H. Gunderson, 2002: Why systems of people and nature are not just social and ecological systems. In *Panarchy: Understanding transformations in human and natural systems*, L. Gunderson and C.S. Holling (eds.), Island Press, Washington D.C., 103-119.

WHO, 2002a: *Basic Indicators 2002 Health Situation in the WHO African Region*. World Health Organization, Brazzaville.

WHO, 2002b: *The World Health Report 2002 - Reducing Risks, Promoting Healthy Life*. World Health Organization, Switzerland.

Williams, A.T. and B.J. Dickson, 1996: *Synthesis Report of the Biomass Initiative.* Chief Directorate Energy, Department of Mineral and Energy Affairs, Government of South Africa.120pp.

Williams, A.T. and C. Shackleton, 2002: Fuelwood use in South Africa: Where to in the 21st century? *Southern African Forest Journal*, 196, 1-7.

World Bank, 1992: *World Development Report 1992: Development and the Environment*. Oxford University Press, New York.

World Bank, 1996: *World Development Report*. Washington, D.C.

World Commission on Dams, 2000: *Orange River Development Project, South Africa*. Case study prepared as an input to the World Commission on Dams, Cape Town. Available at http://www.dams.org.

WRI, 2000: World Resources 2000-2001: People and Ecosystems: The Fraying Web of Life. World Resources Institute, Washington, D.C.

WWF, 2001: The Heat is on: Impacts of Climate Change on Plant Diversity in South Africa. World Wide Fund for Nature, National Botanical Institute, Cape Town, pp 1-9.

Wynberg, R, 2002: A Decade of Biodiversity Conservation and Use in South Africa: Tracking Progress from the Rio Earth Summit to the Johannesburg World Summit on Sustainable Development. *South African Journal of Science*, 98, 233-243.

Zavaletta, E., 2000: The economic value of controlling an invasive shrub. AMBIO, 29, 462-467.

Zondo, L., 2003: *Gauteng Urban Area Millennium Ecosystem Assessment*. Unpublished M.Sc. data. University of Natal, Pietermaritzburg, South Africa.

For more information contact:
Prof Albert S. van Jaarsveld
Faculty of Science
Stellenbosch University
Private Bag X1
Stellenbosch
7600
South Africa
Tel: +27 21 808 3071
Fax: +27 21 808 3680
asvanj@sun.ac.za

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