ACDI
African Climate &
Development Initiative

The Food-Energy-Water-Land-Biodiversity (FEWLB) Nexus and Local Economic Development in the Berg River Catchment: Framework and Description

Draft Research Report for submission to the Foreign and Commonwealth Office, South Africa

Stephanie Midgley, Mark New, Sichumile-Sanda Spelman,
Kashiefa Parker

African Climate and Development Initiative, University of Cape Town

June 2014

FOOD · ENERGY · WATER · LAND · BIODIVERSITY

Contents

Acronyms

ACDI	African Climate and Development Initiative, UCT
AFF	Agriculture, Forestry and Fishing sector
BRC	Berg River Catchment
BRIP	Berg River Improvement Plan
BWI	Biodiversity and Wine Initiative
CA	Conservation Agriculture
CCC	Confronting Climate Change project
CFR	Cape Floristic Region
CHEC	Cape Higher Education Consortium
CWD	Cape Winelands District
DEA&DP	Department of Environmental Affairs & Development Planning
DOA	Department of Agriculture
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
ERC	Energy Research Centre, UCT
FEWLB	Food, Energy, Water, Land and Biodiversity
GDPR	Regional Gross Domestic Product
GHG	Greenhouse Gas
GHS	General Household Survey
GIS	Geographical Information Systems
IDZ	Industrial Development Zone
IPM	Integrated Pest Management
IPP	Independent Power Producer
IWRM	Integrated Water Resource Management

MEA	Millennium Ecosystem Assessment
NDP	National Development Plan
NFEPA	National Freshwater Ecosystems Priority Areas
PV	Photovoltaic
REIPPP	Renewable Energy Independent Procurement Programme
SANHANES-1	South African National Health and Nutrition Examination Survey
SEI	Stockholm Environment Institute
SEZ	Special Economic Zone
TMG	Table Mountain Group (geological)
UCT	University of Cape Town
WC/WD	Water Conservation and Water Demand
WCD	West Coast District
WCWSS	Western Cape Water Supply System
WfW	Working for Water Programme
WMA	Water Management Area

List of Figures

List of Tables

Abstract

The Food, Energy, Water, Land and Biodiversity (FEWLB) Nexus approach provides a framework that captures the increasing demands on shared resources, and emerging constraints to local economic development and the Green Economy in stressed systems such as the Berg River Catchment (BRC) in the Western Cape Province.

The BRC is characterized by intensive agricultural production and processing for the local and export market, critical dependence of irrigation agriculture and urban users (including the Greater Cape Town Metropolitan area) on the highly managed water supply system, significantly transformed land and high rates of loss and threat to the exceptional biodiversity of terrestrial, riverine and estuarine ecosystems.

High rates of urban expansion and population growth demand strong economic growth and job creation, but this will only be possible and sustainable with careful consideration and analysis of resource needs and impacts, and possible trade-offs – the FEWLB Nexus can form the conceptual basis for the development of strategic integrated decision making tools.

In the BRC, agriculture has benefitted greatly from the use of land, water and biodiversity, but has also had negative consequences for these resources. The Nexus approach identifies numerous opportunities for this sector to contribute meaningfully to water quality improvement initiatives, clearing of alien invasive plants on farmland and riverbanks, protection of remaining valuable natural vegetation, use of conservation farming methods, more efficient water use practices, waste-to-energy (biogas) production, and wind/solar power generation for on-farm use and for the grid. In return, agriculture needs an assured supply and quality of water, and an assured supply of energy to sustain production for economic gain and food security.

The economically important food and agriculture-related manufacturing value chains are sensitive to supply and reliability of water and energy, and to water quality. Resource scarcity or instability of supply has knock-on impacts from production to the tertiary sector in the rural economy – and significant impacts on jobs. The fact that these sub-sectors have been specifically identified for growth and job creation potential in both District Municipalities (and across the Province) requires careful analysis of the Nexus inter-linkages.

Energy generation is low in the BRC but current (under construction and planned) wind and solar photovoltaic (PV) projects will eventually make a significant contribution to provincial energy demand. Agro-processing in the BRC is energy intensive and sensitive to supply and pricing instability. The Western Cape Water Supply System (WCWSS) comprises a complex network of infrastructure with a high reliance on energy for

treatment and pumping. Augmentation schemes planned for the next decade will be energy-intensive. Renewable energy can make an important contribution to the region, but site selection must consider land, agriculture and biodiversity impacts, and local component manufacture will require water.

Water supply is currently slightly greater than demand. Future demand growth will come from relentless urban expansion and population growth in BRC ‘hotspots’ and Greater Cape Town. In addition, the ecological reserve will be implemented over time, with implications for current water users, especially agriculture. Seasonal water flows through the system to the floodplain and estuary are critical for ecosystem productivity and biodiversity. The poor quality of river water in downstream areas of tributaries and where urban settlements and intensive agriculture occur near the river has negative impacts on all users and on biodiversity. Opportunities lie primarily in improving the water quality, increasing efficiencies of water use, further progress in Water Conservation and Demand Management (WC/WD) efforts, and development of additional sources of water sustainably and affordably (e.g. re-cycled water, groundwater).

Land for additional productive purposes is scarce and is also in high demand for urban and peri-urban development. Significant transformation of lowland vegetation has caused a number of vegetation types and plant species to become highly threatened.

Whilst some of the Nexus inter-linkages are well-known and reasonably well quantified, others require further research and quantification. For example, the energy “arm” of the Nexus is not well aligned with the other “arms” and the inter-linkages are poorly researched and quantified. Equally, although the value of biodiversity within the Nexus is acknowledged by most actors and the sector itself has a strong conservation research basis, some of the inter-linkages (often those loosely termed “ecosystem services” or “ecological infrastructure”) require further quantification and analysis.

Current plans and programmes typically address only parts of the Nexus, often with some success, but generally stop short of a Nexus-wide approach. One exception is the Berg River Improvement Plan (BRIP) which is conceptualized and structured in such a way that it has the potential to deliver a Nexus-relevant outcome.

1. Introduction to the FEWLB Nexus perspective

The Food, Energy, Water, Land and Biodiversity (FEWLB) Nexus project looks to inform decision making and project development to foster sustainable resource use and development within the Berg River Catchment (BRC) area. The project started in October 2013 and the first phase was funded by the British High Commission and the Cape Higher Education Consortium (CHEC). The African Climate and Development Initiative (ACDI) at the University of Cape Town (UCT) is implementing the project in collaboration with the Western Cape Department of Environmental Affairs and Development Planning (DEA&DP).

Nexus thinking is developing internationally in an attempt to understand and deal with the interdependencies which exist within complex natural and human systems (Hoff, 2011; Bazilian et al., 2011; Ringler et al., 2013; Davis, 2014; GWSP, 2014; Perrone and Hornberger, 2014; Von Bormann and Gulati, 2014). This is becoming increasingly important as societies begin to push against the planetary, regional and local boundaries of resource use, and emerging resource constraints become a limitation to economic development. Thus, an integrated systems-based consideration of food, water, energy, land and biodiversity is essential at multiple scales ranging from global to catchment scale. Resource-linked decisions which benefit some components of the Nexus can have negative impacts on other components. Nexus assessments need to consider both human well-being and environmental outcomes, and *benefits of Nexus-based decisions should be balanced and optimized across different sectors and human needs* and foster long-term cooperation. This also requires a focus on the future and additional resource constraints (e.g. water) and needs (e.g. energy) resulting from climate change (Louw et al., 2012; DEA&DP, 2014; Field et al., 2014).

There are numerous reasons why the implementation of the FEWLB Nexus approach is highly suited to local scale sustainable development planning and management, and in particular catchments and their management structures (Escobar, 2013; Lawford et al., 2013). Catchment landscapes are excellent examples of integration between water resources, land use and food production, and the energy required for economic activity. In addition, they often contain human settlements with associated resource uses and impacts, and in most cases are vital habitats for biological organisms and providers of essential ecosystem services. A catchment-scale perspective is important for the understanding and management of impacts, synergies and benefits, as shown by the Millennium Ecosystem Assessment (MEA) of 2005, and the water sector's Integrated Water Resource Management (IWRM) approach of the last 25 years or so.

The BRC represents an excellent example of an economically important regional system under high resource extractive pressure at the nexus of water quantity and quality, food production and energy supply, within the wider context of a rich biodiversity and intensive land use (DWAF, 2004). Pollution in the BRC is a cause of great concern especially to communities, farmers and industries in the various municipalities of the West Coast and Cape Winelands Districts (DEA&DP and DWA, 2011). In addition, there is increasing concern that the water will not be adequate in future to service the entire region – in particular, that the planned industrial development at Saldanha Bay (Wesgro, 2011) will be constrained by water availability unless the management of the resource is changed significantly. This is complicated by the high demand on Berg River water resources by the City of Cape Town and by intensive agricultural production and dependent secondary agro-industries. Water must also be allocated to the 'ecological reserve'[1] which provides critically important environmental and social services (DEA&DP and DWA, 2012; DWA, 2013).

In relation to government powers and functions, management of the Berg River system straddles all three spheres of government, involving local, provincial and national government responsibilities. Given the fact that the FEWLB nexus represents a complex system, cooperation between National Government, the Western Cape Provincial Government, District and Local Municipalities, and other Berg River stakeholders becomes increasingly important. A number of studies are already focused on the Berg River/Saldanha Bay area (e.g. Berg River Improvement Plan - BRIP), and this project seeks to add to and complement current research work, and show the way for future more in-depth research. Importantly, provincial and local economic and social development goals, with the strong provincial drive to implement the Green Economy (Provincial Government of the Western Cape, 2013), form the policy and investment framework within which the FEWLB approach should be located. A green economic development path can facilitate increased investment in new and expanded market opportunities that support a low carbon, resource efficient and socially inclusive economic pathway. This commitment to the green economy requires us to have a clear understanding of, for example, the flow of resources in the economy, or the impact of one resource on the sustainability of other resources – namely, the FEWLB nexus.

This report focuses on presenting a framework and description of the FEWLB Nexus for the BRC. The full argument towards the adoption of the Nexus approach in local economic development planning can be found in the accompanying document "Position Paper". A full "Systems Report" presents further detailed data and analysis of the FEWLB Nexus, as well as a policy review, stakeholder mapping and interviews, a literature database, and an inventory of the interactive spatial database (GIS maps) compiled for this project.

---

[1] The National Water Act (1998) states that: "The ecological reserve relates to the water required to protect the aquatic ecosystems of the water resource. The Reserve refers to both the quantity and quality of the water in the resource, and will vary depending on the class of the resource."

2. Overview of the Berg River Catchment

Biophysical description

The Berg River is located north/north-east of Cape Town, in the Western Cape Province of South Africa (Fig. 1). It arises in the mountains of Franschhoek and Drakenstein, winding its way northward within a relatively narrow channel past the towns of Paarl, Wellington, Hermon, Gouda and Porterville, before changing course to the west. In its lower reaches it passes the towns of Piketberg, Hopefield and Velddrif, before broadening into an estuary and discharging into St Helena Bay on the Atlantic Ocean. En route, the main stem of the river is joined by a number of tributaries, the bulk of the water arising in the mountains bordering the east of the catchment. The river is approximately 290 km long with a catchment area of nearly 9000 km^2.

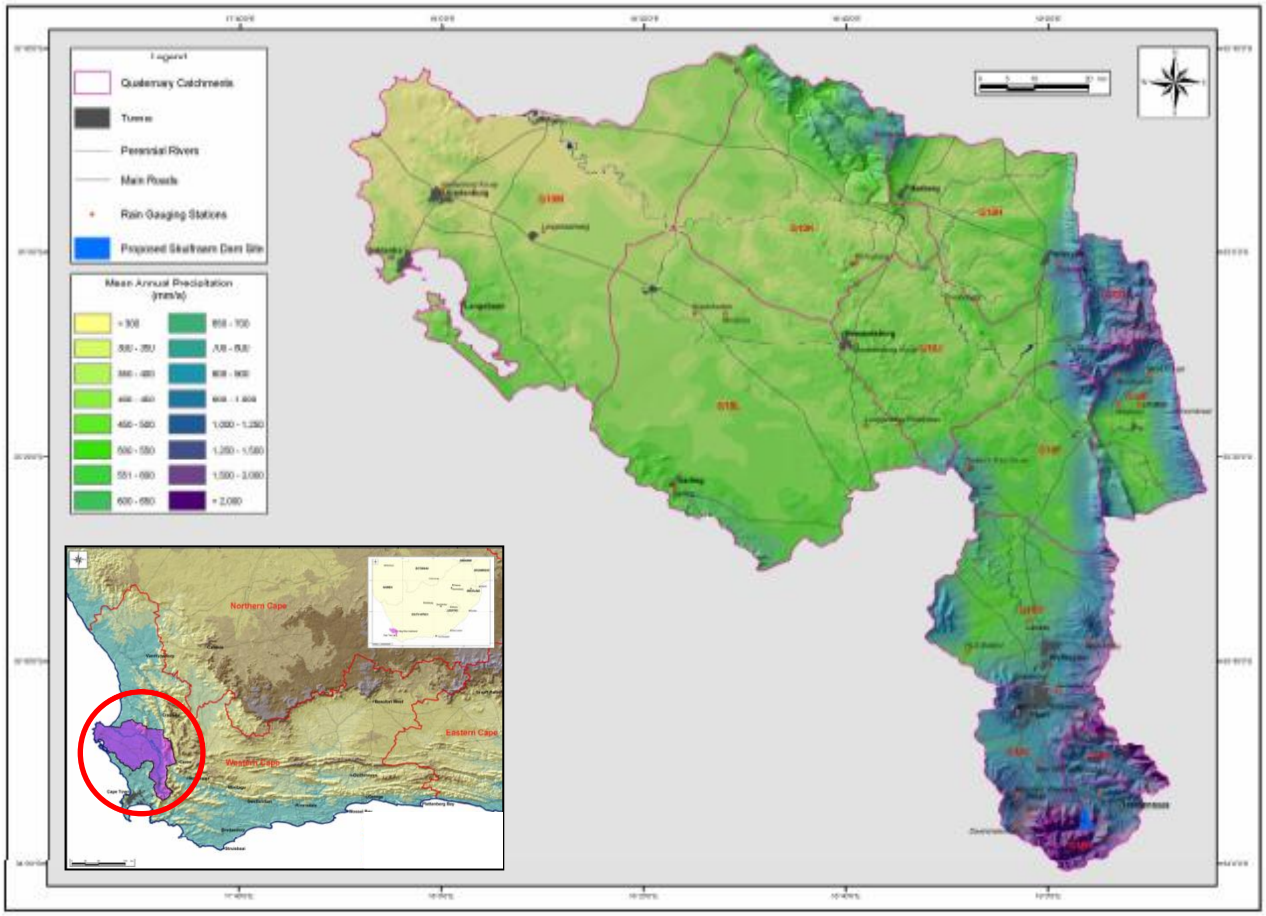


Figure 1 Locality and mean annual rainfall of the Berg River Catchment (BRC) and position of the BRC within the Western Cape Province (inset). Source: DWAF, 2007a.

Administratively, the Berg River catchment intersects with two District Municipalities. The Cape Winelands District Municipality is positioned in the upstream eastern part of the catchment and the river and its tributaries pass through Stellenbosch, Drakenstein and Witzenberg Local Municipalities. Towards the west, the river passes through the hills and coastal plains of Swartland, Bergrivier and Saldanha Bay Local Municipalities, which form part of the West Coast District Municipality. It is a complicating factor that the hydrological basin boundaries do not align with administrative boundaries. The majority of the populations live in urban settlements.

Due to its position in a Mediterranean-type climate region, rainfall is concentrated during the cool winter months, with a steep gradient from the south-eastern upper catchment (>1200 mm per year) to less than 300 mm per year at the north-western estuary. Summers are dry and can get very hot, particularly on the more northerly interior plains at the foot of the mountains. Cooler conditions prevail in the mountains and along the windy coastline. The area is geologically diverse and includes Table Mountain sandstone, granite and Malmesbury shale, with extensive coastal sandy areas of recent geological origin. The combination of climate and soils results in patches of high fertility, but large areas of lower potential productivity suited only to rainfed farming.

This catchment is a significant water source on a regional level. The area is an integral part of the Western Cape Water Supply System (WCWSS), which focuses both on ensuring adequate water supply for the metropolitan area of Cape Town and surrounds, as well as supplying the needs of irrigators and some rural towns. Total natural runoff from the BRC amounts to 931 million m^3/annum, 45% of which is generated in three quaternary catchments near Franschhoek, and 70% in the Upper Berg (DWAF, 2007a).

The total water requirement from the WCWSS in 2012/13 was estimated at around 502.7 million m^3/a, of which 333.7 million m^3/a (66.4%) is used by urban areas, and 169.0 million m^3/a (33.6%) for irrigation (DWA, 2013). The existing yield is about 596 million m^3/a, meaning that the total water requirement is currently met by supply, thanks to the new Berg River Dam and the Water Conservation and Demand Management Programme.

Major users of the water within the catchment include irrigated agriculture (grapes and fruits), processing of agricultural produce, municipalities (urban water supply, wastewater treatment), and industry (mainly around Saldanha Bay and Paarl/Wellington). Water is abstracted primarily from surface water (57% of total water resource), although groundwater (8%) is used in some towns such as Porterville and Hopefield (DWAF, 2007a; DEA&DP and DWA, 2011) and by some farmers. Return flows from irrigation amount to about 8 million m^3/a (1.7% of total yield) and are limited to the Upper Berg. Urban return flows come from the Upper Berg and the Greater City of Cape Town and contribute 7.7% of total yield.

A few larger dams form part of the WCWSS. They are the Berg River Dam (completed in 2007) and Wemmershoek Dam, both in the upper catchment, the Voëlvlei Dam and the Misverstand Dam (Fig. 2). Substantial amounts of water (27% of the water resource) are transferred into the basin during the summer months from the adjacent Breede River catchment to supplement the water resource. Many hundreds of small private farm dams also provide an essential water resource for irrigated agriculture. Nevertheless, the Berg River system is under water stress and new water augmentation schemes will be required by 2022 in order to avoid deficits (DWA, 2013). New sources of water are likely to become increasingly costly.

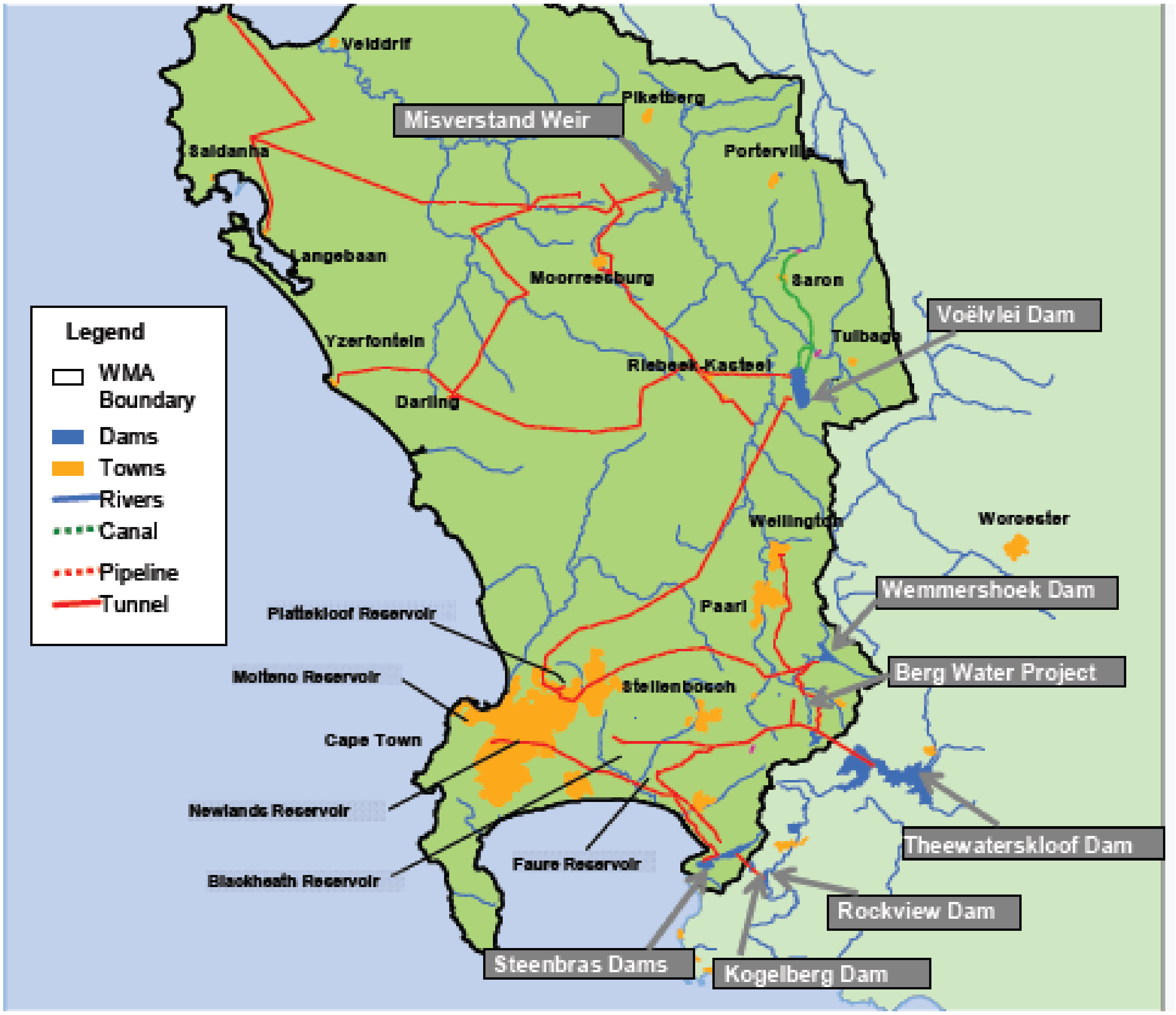


Figure 2 The Western Cape Water Supply System (WCWSS) within the Berg Water Management Area (WMA) showing transfer schemes into the Berg WMA and within the Berg WMA. Source: DWAF, 2007b.

Poor water quality has been identified as a major concern in the Berg River system (Görgens and de Clercq, 2005; de Villiers, 2007). The reasons range from agro-chemical runoff from intensive farming operations, and ageing and under-capacity waste water treatment facilities for burgeoning settlements, to a natural tendency towards high levels of salinity from tributaries underlain by shales of marine origin (DEA&DP and DWA, 2011). This pollution situation threatens the viability of export-driven agriculture and industrial processes in Saldanha Bay (e.g. steel production) which require water of a minimum quality standard.

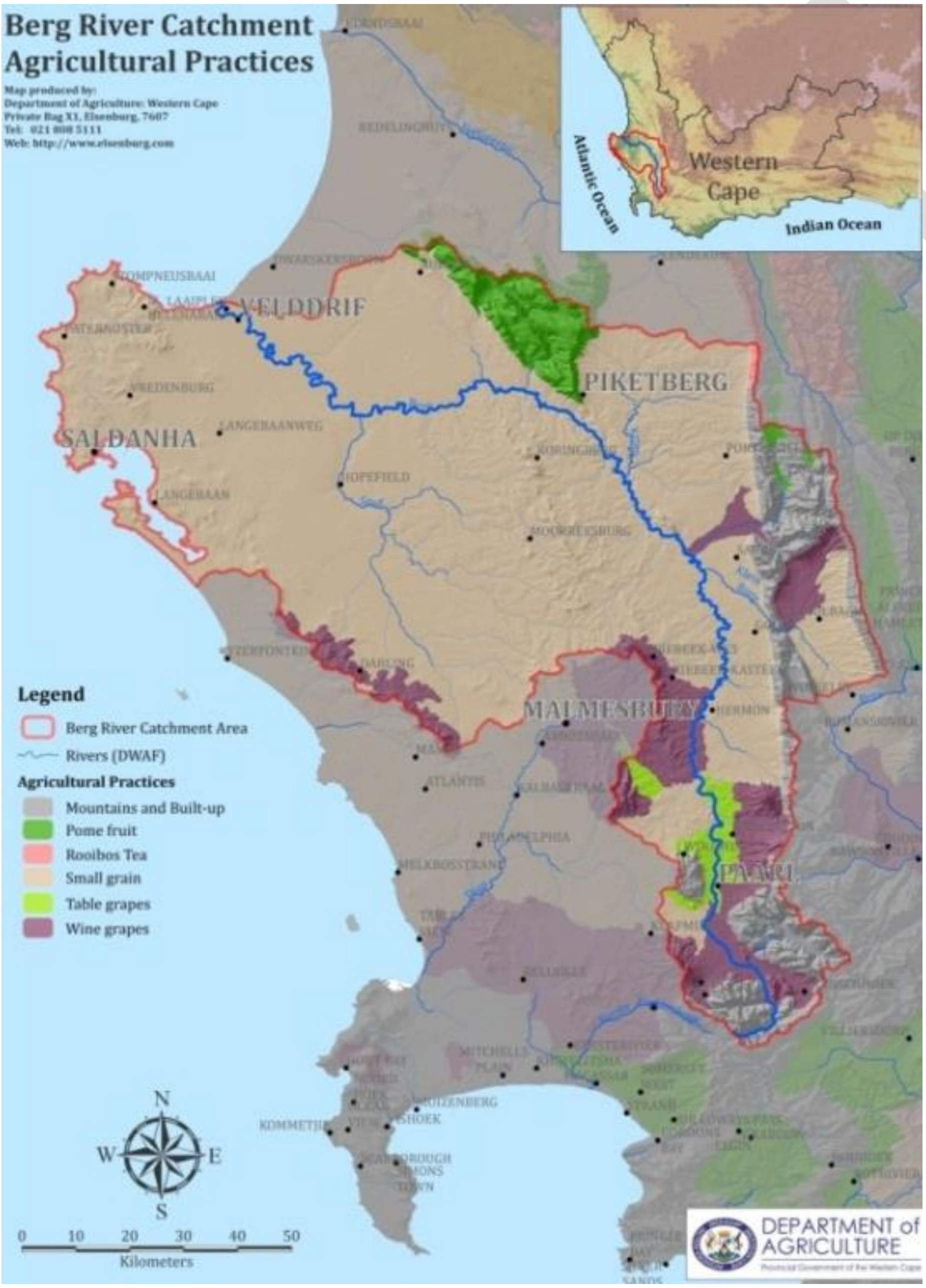


Figure 3 *Berg River Catchment agricultural practices. Source: Western Cape Department of Agriculture.*

Roughly sixty percent of the Berg River catchment area is agricultural, with primarily grapes and deciduous fruits being cultivated intensively in the eastern regions, and small grains (e.g. wheat, canola) and extensive livestock (cattle and sheep) dominating the drylands to the west (Fig. 3). Significant foreign revenue earnings flow from the export of fruits and wine/spirits, with most of the production being exported. Other products include vegetables, indigenous 'fynbos' flowers (e.g. *Protea*), olives, dairy products, pigs and poultry. Agriculture also drives much of the secondary economy in the form of fruit and vegetable processing, including canning, drying, juicing, and jam production.

Extensive land use change from natural fynbos and Renosterveld vegetation to agriculture and settlements has placed the rich biodiversity under threat (Fig. 4).

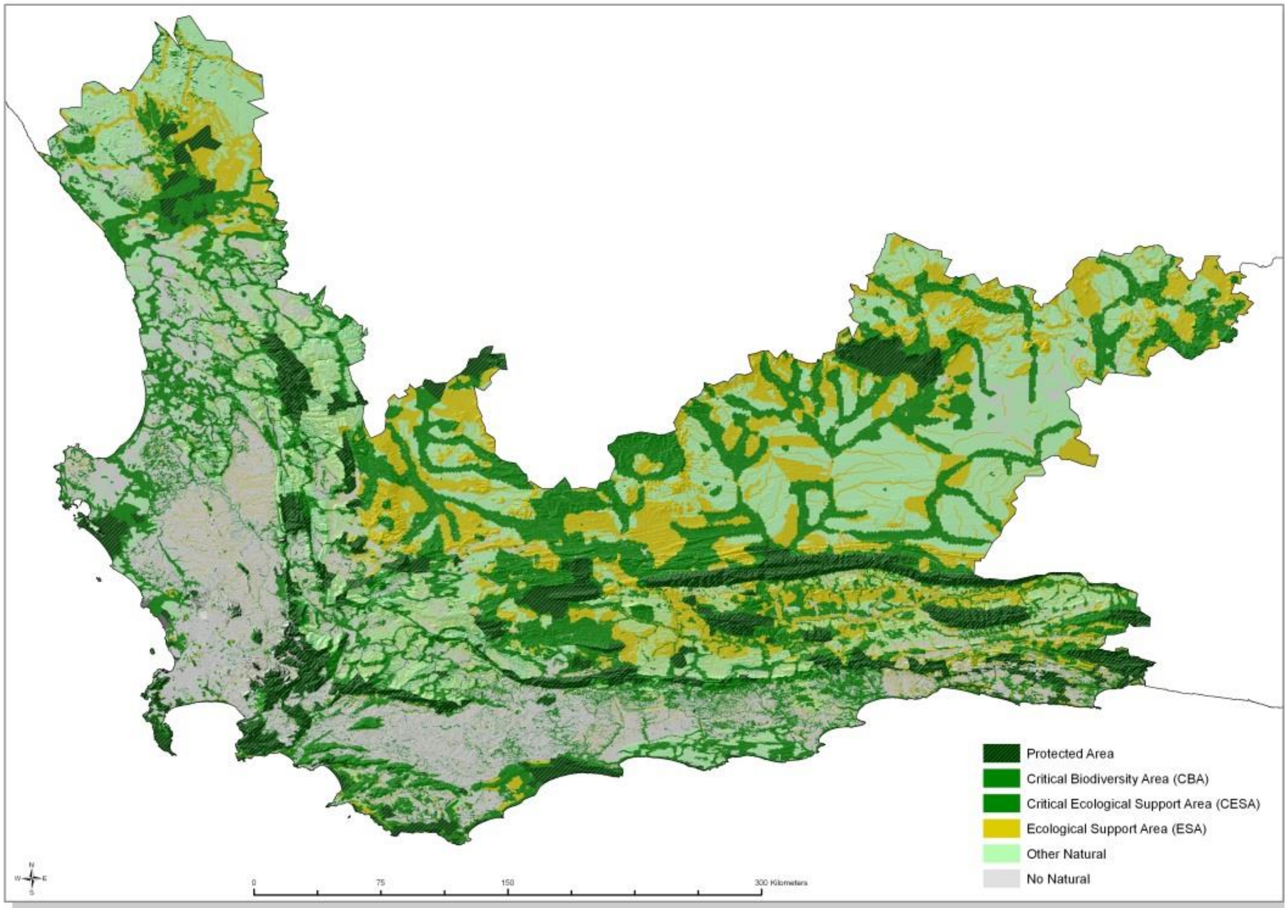


***Figure 4** Protected Areas, Critical Biodiversity Areas (CBAs), Critical Ecological Support Areas (CESA) and Ecological Support Areas (ESAs) of the Western Cape. Grey areas are not natural, meaning that they have been transformed into agricultural land. Source: Turner et al., 2012*

The area forms part of the Cape Floral Kingdom, the smallest of the six Floral Kingdoms in the world, but containing extraordinary high levels of terrestrial and aquatic biodiversity and endemism. This biodiversity 'hotspot' has immense intrinsic value for the healthy functioning of the ecosystems of the catchment, as well as having great economic value associated with wildflower harvesting and ecotourism. Conservation efforts have been aided by the proclamation of numerous protected areas, concentrated in the mountains and the West Coast area. The most significant threats are the encroachment of alien invasive plants and the rising risks of wildfires, as well as degraded river banks and wetlands (Turner et al., 2012). The Langebaan RAMSAR site serves to protect the rich biodiversity of the Lagoon and surrounding wetlands.

The BRC imports almost all its electricity requirements from the national grid through the utility ESKOM (DEA&DP, 2013). This energy is heavily coal-based, with a small nuclear and gas component. Electricity supply has been strained for a number of years and this has impacted on all users countrywide. Until new generation capacity up-country comes online, economic development, especially heavy usage associated with some industries envisaged for the Saldanha Bay area and elsewhere, could limit accelerated economic growth. Additional electricity is required to fully service the growing informal settlements in the area. Within the BRC, a few wind farms have been constructed but with small generating capacity, and solar power is expanding but at small scale.

Economy of the Berg River catchment

The economy of the BRC is inextricably linked to the economic powerhouse of the City of Cape Town Metropolitan District on its doorstep (Western Cape Government Provincial Treasury, 2013). The Cape Town Metro contributes close to three quarters of the real value added generated in the Western Cape Province and dictates the economic growth in the region. Moreover, most of the produce of the BRC makes its way into or through the city for distribution or export.

The BRC economy is primarily driven by the finance, insurance, real estate & business services sector (22.9%/25.6% contribution to provincial GDPR in Cape Winelands/West Coast) and the manufacturing sector (24.2%/17.7% contribution to GDPR in Cape Winelands/West Coast) (Western Cape Government Provincial Treasury, 2012a,b). The agriculture, forestry & fishing (AFF) sector is much larger in the West Coast (14.6% contribution), Cape Winelands (11.1% contribution) and Overberg (11.6% contribution) districts than in the remainder of the province, significantly higher than the provincial average of about 4%. The agro-processing industries (especially food & beverages) dominate the region's manufacturing sector, and manufacturing together with AFF (primary production) account for a combined contribution to GDPR exceeding that of finance & business services.

It is noteworthy that the AFF sector contributes disproportionately to employment, relative to economic value. In the Cape Winelands and West Coast Districts, 24.2% and 27.9%, respectively, of employment was in this sector in 2007, with 14.6% and 12.3%, respectively, in manufacturing which is strongly dependent on AFF (Western Cape Government Provincial Treasury, 2012a,b).

The BRC makes substantial contributions to the export offering of the Western Cape Province (Western Cape Government Provincial Treasury, 2013). The West Coast District (WCD) export basket is relatively concentrated, lacking diversity. Close to 90% of the region's export basket consists of agriculture & agro-processing exports (46%) and steel exports (44%). Within agro-processing, the beverages (mainly wine) share of total regional exports increased from 4% to 14% between 2005 and 2011. The share of steel exports has remained relatively stable over the 2000s, except for dipping quite sharply in 2011. On the import side, the importation of coal, mineral fuels (or oil) and petroleum products account for more than half of the region's goods import basket.

Cape Winelands District goods exports grew strongly over the 2000s – it increased from 11.4% of GDPR in 2000 (R1.5 billion) to 28% of GDPR by 2011 (R12.2 billion) - real growth of ca. 20% per annum. However, the region's export basket is concentrated – 94% of the basket consist of agriculture and associated processing exports, i.e. beverages (wine & fruit juices) 41%; agriculture (table grapes & fruit) 36% and food processing 17%. Slightly less than half of the region's import basket consists of manufactured products for the agriculture & processing sectors. It is also likely that most of the third largest import category, i.e. metals & machinery (15.4%) represent imports for the agriculture and processing industries.

The role of economic sectors varies widely within Local Municipalities: In Drakenstein, Stellenbosch, Swartland and Saldanha Bay, financial & business services and manufacturing form the economic backbone, contributing 45-55% to the local GDP. This is reflected in the intensity of energy use and the growth of settlements resulting from an influx of jobseekers. To illustrate this trend: the population of Drakenstein Local Municipality grew from 194,413 in 2001 to 251,262 in 2011. On the other hand, the AFF sector makes large contributions in Bergrivier (18.4% local GDP, 30.3% employment), Witzenberg (29.1% local GDP, 58.3% employment) and Swartland (14.3% local GDP, 27.1% employment), with slightly lower contributions of around 5-8% in Stellenbosch, Drakenstein and Saldanha Bay (employment: 12.7%, 16.7%, 20.4%, respectively). The manufacturing sector in Drakenstein and Stellenbosch (15.1% and 20.2% employment, respectively) is heavily dependent on AFF.

It is interesting to note that the best growth in recent years has been in the services sector, retail and wholesale, and construction in some areas (e.g. Stellenbosch), with tourism doing particularly well, especially in the Cape Winelands. However, growth in the AFF sector has stagnated or even contracted (e.g. Bergrivier). The developmental potential of a number of towns has come under pressure due to a shrinking agricultural sector. The manufacturing sector in Drakenstein has contracted with jobs shed on a large scale as long-established factories closed their doors or relocated/consolidated to other regions.

Provincial and regional economic development planning is guided by both national and provincial policies. The main focus is on job creation and the alleviation of poverty (Provincial Government of the Western Cape, 2010). Nevertheless, the local context within individual catchments also acts as a filter for what is feasible, given the mix of natural and human resource availability. In the case of the Berg River system, the proximity to the City of Cape Town and port facilities, and the extraordinary richness and sensitivity of ecosystems and the need to minimize further environmental degradation, are additional important influences (Provincial Government of the Western Cape, 2013).

The current drive is to increase exports across all sectors. Because of the current strength and comparative advantage of the food and beverages sector, this is an area seen as ripe for development to its fullest potential. Opportunities exist for further value addition and novel products suited to the climate.

Manufacturing growth is seen as very important since it can create jobs, especially within the West Coast Development Corridor and the 'regional motor' of Saldanha-Vredenburg. The proclamation of the Industrial Development Zone (IDZ) and Special Economic Zone (SEZ) in Saldanha is expected to help diversify and encourage the production of more sophisticated (higher value added) products. Three potential industrial clusters for the IDZ were identified during the Feasibility Study (Wesgro, 2011):

- A Renewable Energy Production and Manufacturing Cluster,
- An Oil Supply Base/Hub servicing the Oil and Gas Cluster and a Maritime Ship Building and Repair Cluster, and
- A Steel and Minerals Production and Manufacturing Cluster

In addition, an analysis of comparative advantage of the two district economies suggests that the AFF and agro-processing sectors should receive priority (Western Cape Government Provincial Treasury, 2013). The food value chain is not only economically important but is critically important for food security. The catering & accommodation (mainly tourism) value chain also presents a comparative advantage and employment creation potential in the Catchment and can be identified as a key growth area. There exists tremendous potential for the development of tourism, and especially ecotourism, across the Berg River catchment.

Social development

The BRC is experiencing rapid population growth and urbanization, an increasingly young population requiring care/schooling or looking for employment, and high density settlements particularly in the economically strong Stellenbosch (Franschhoek) and Drakenstein Local Municipalities, as well as in the industrial area of Saldanha Bay (Table 1). With the exception of Saldanha Bay, unemployment rates per Local Municipality are not as high as the national or provincial averages, although the youth everywhere are particularly disadvantaged.

Table 1 Socio-economic situation of the population of the six Local Municipalities (or parts thereof) which fall within the Berg River Catchment. Source: Statistics South Africa www.statssa.gov.za

	Stellenbosch	Drakenstein	Witzenberg	Swartland	Bergrivier	Saldanha Bay
Total population	155,733	252,262	115,946	113,762	1,897	99,193
Young (0-14) (%)	22.8	25.6	25.4	25	24.9	25.3
Working age (15-64) (%)	72.3	69.2	70.4	69.1	68.1	69.5
Elderly (65+) (%)	4.9	5.2	4.2	5.9	7	5.2
Dependency ratio (%)	38.4	44.5	42	44.7	46.9	44
Sex ratio	95.8	96.7	105.6	98.6	94.4	99.2
Growth rate* (%)	2.71	2.56	2.64	4.56	2.85	3.45
Population density**	187	163	11	31	13	49
Unemployment rate (%)	15.2	17.6	7.6	12.7	6.8	23.4
Youth unemployment rate (%)	21.5	24.6	9.9	17.9	9.6	30.4
No schooling aged 20+ (%)	3.1	3.3	6.6	6	6.4	2.4
Higher education aged 20+ (%)	17.3	11.8	5.8	9.5	7.7	9.3
Matric aged 20+ (%)	25.2	27.4	18.2	24.2	22.3	28.4
Number of households	43,420	59,774	27,419	29,324	16,275	28,835
Average household size	3.3	3.8	3.4	3.5	3.5	3.2

Female headed households (%)	34.6	33.6	28.9	28.5	31.5	30.4
Formal dwellings (%)	75.1	85.1	86.2	90.9	93.4	81.7
Housing owned / paying off (%)	35.6	46.3	34.5	52.3	46.4	62.1
Flush toilet connected to sewerage (%)	87.1	90.2	86.9	77.3	72.3	92.5
Weekly refuse removal (%)	87	86.1	69.9	76.1	67	96.6
Piped water inside dwelling (%)	72.4	80	78.8	80.6	83.5	80.2
Electricity for lighting (%)	92.9	95	93.4	97.8	94.9	97

*2001-2011

**Persons/km^2

Importantly, the averaged data for each Local Municipality masks the wide range of situations between the constituent Wards. According to the Census 2011 (Statistics South Africa), certain Wards representing recently established informal settlements with mostly first-generation migrants show unemployment rates of up to 60%, and a majority of households with a monthly income less than R3200. Thus chronic poverty and associated food insecurity are prevalent in such ‘hotspots’. These ‘hotspots’ were identified as Langrug (Franschhoek), Mbekweni (Paarl) – numerous Wards, parts of Darling-Moorreesburg and Malmesbury, and parts of Saldanha, Vredenburg and St Helena Bay.

Numerous households in these hotspots and to some extent on farms do not yet have access to safe water inside the dwelling or regular refuse removal, and lack of sanitation is still prevalent here. Municipalities struggle to deal with the backlog for housing and basic services in the face of continuing in-migration, combined with constrained budgets. For example, the Saldanha Bay Municipality experienced a growth rate of nearly 53% from 2001 to 2011 as the total number of households increased by approximately 10,000 households. In many Municipalities, existing bulk water and waste infrastructure has not been able to cope with these growth rates, and increased capacity is only now gradually coming online as budgets make provision for upgrades and new infrastructure.

Food security

Both the General Household Survey (GHS) of 2012 and the South African National Health and Nutrition Examination Survey (SANHANES-1) (HSRC and MRC 2013) found that, although food insecurity is lowest in the Western Cape across all provinces, it is still high at 21.3% and 16.4%, respectively (the difference is attributable to varying methodologies and definitions). According to the GHS (Statistics South Africa, 2013) only 3.6% of households in the province were involved in agricultural production, the lowest nationally. Also, 44.2% of households practicing agriculture in the Western Cape used it as a leisure activity, by far the highest nationally, and 43.6% used it as an additional source of food. Household food production focused primarily on fruit and vegetable crops. As a result of the high percentages of food purchasing in poor, rural areas, food intake is mainly related to cost and availability at outlets. Food prices were found to be higher in rural than in urban areas while wages were lower in rural areas. As a result the regularity of which food products are purchased largely depends on income quantity and frequency.

Social grants are critical as enablers of food purchasing in unemployment/poverty 'hotspots' such as Langrug (Franschhoek), Mbekweni (Paarl) and Saldanha Bay. Many households are vulnerable to food inflation and price spikes. Malnutrition and stunting in children is also more prevalent in indigent households.

3. A FEWLB Nexus Framework for the Berg River Catchment

During this study, a Framework to describe and populate the FEWLB Nexus for the BRC was developed. It is broadly based on the well-known Water-Energy-Food Security Nexus Framework developed by Hoff and co-workers (Hoff, 2011) which is centred on water supply security, energy security and food security, all connected to available water resources. The Stockholm Environment Institute (SEI) subsequently developed a framework centred on food, energy and environment, connected centrally to available land and water resources (Davis, 2014). It conceptualizes land and water as critical resources used in energy, food and environmental systems. It allows for more explicit identification and analysis of the direct and indirect (via land and water) linkages between the three systems and gives environment an important and equal role to food and energy.

This framework is suited to developmental contexts where land issues are as important as water issues and the nexus is thus able to capture problems of land use change. It is also relevant to situations where economic development in biodiverse or vulnerable ecosystems can lead to significant habitat losses and pollution. This was deemed to be highly relevant for the BRC since land use change and the resulting loss of biodiversity and environmental integrity are as pertinent as challenges related to the quantity and quality of water. This framework was thus adapted and the term FEW Nexus broadened to include Land and Biodiversity (FEWLB Nexus).

The broader framework in which the FEWLB Nexus Framework is embedded reflects the national (South Africa) and provincial (Western Cape) development context and key drivers of change (Fig. 5).

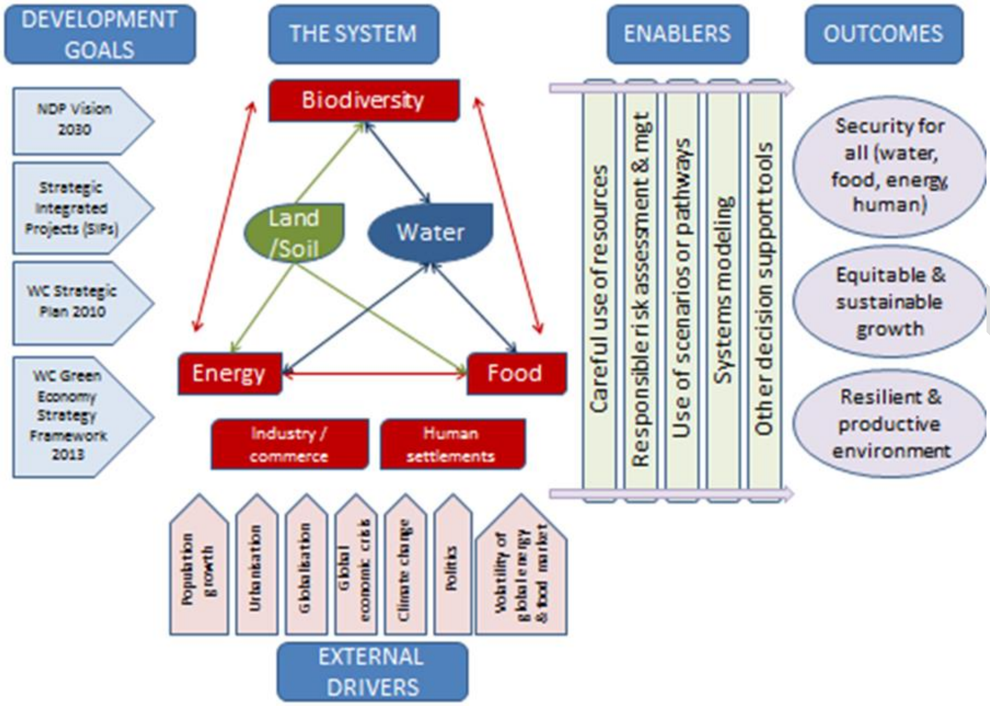


Figure 5 Diagrammatic representation of the broader FEWLB Nexus Framework for the Western Cape Provincial context

In Fig. 5, national and provincial development goals provide the decision making strategy and guidance. The imperative is to achieve inclusive economic growth, job creation and a reduction in poverty, whilst reducing environmental risks and ecological scarcities (the Green Economy).

The external drivers range from global risks (climate change, market volatility and the global economic crisis which continues to impact the economy of the Western Cape) to national and provincial trends around urbanization and population growth, and the urgent need for social and economic development of the poor. Globalisation presents both opportunities and challenges, and politics and governance is always a key factor to consider in the Western Cape.

The 'Enablers' represent possible tools and approaches which can help decision makers to take action and achieve the desired outcomes. In the middle is the system itself, a complex web of inter-linkages representing the stocks and flows that exist between agriculture/food, energy, biodiversity, land and water.

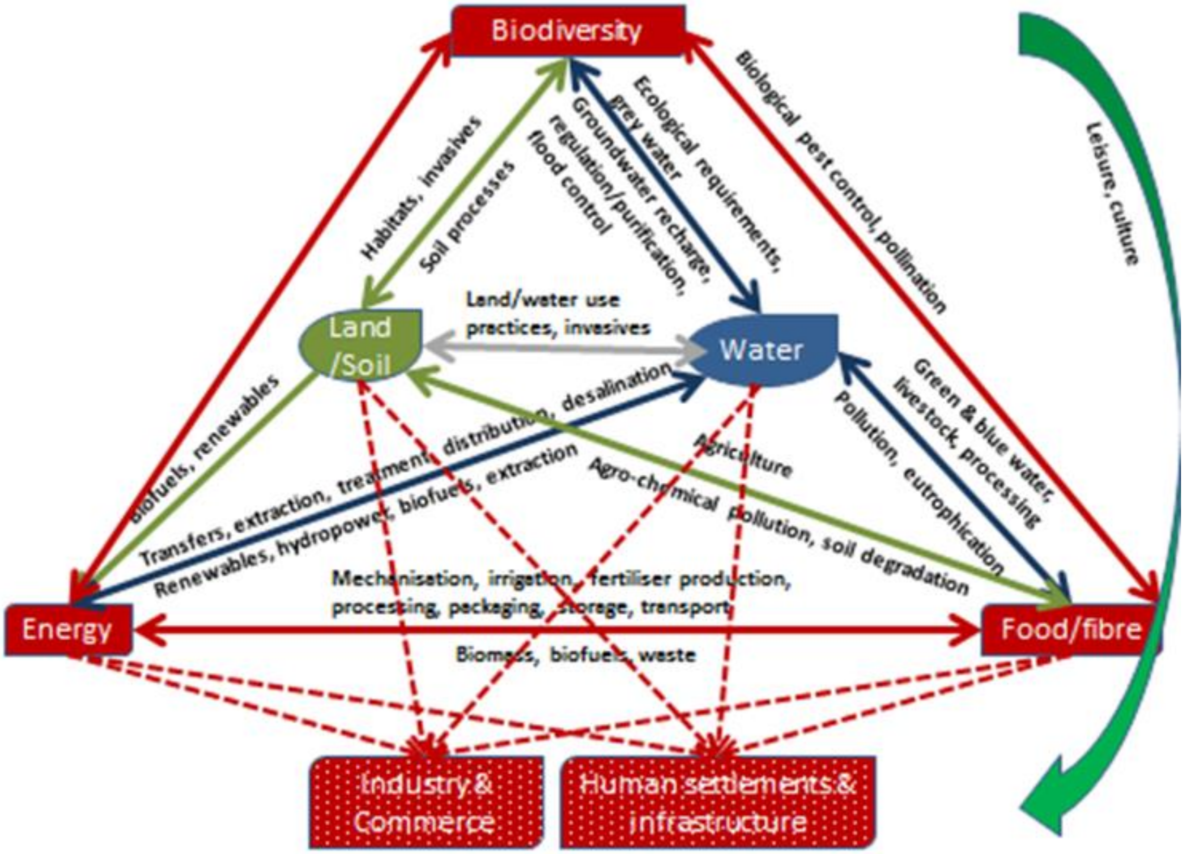


Figure 6 The central part of the FEWLB Nexus Framework for the Western Cape Provincial context

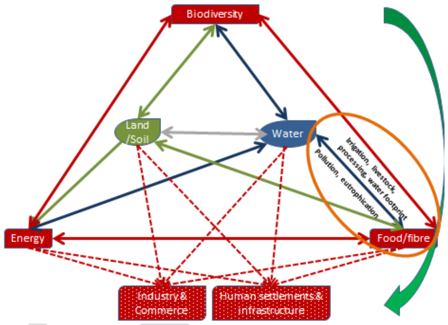
Next, the 'System' Framework in the centre of Figure 1 was analysed in more detail and the possible inter-linkages identified (Fig. 6). The central FEWLB system is also linked to industry/commerce and human settlements and infrastructure, since these sectors compete directly for FEWLB resources and play a key role in decision making around resource allocation for social and economic development. The value of biodiversity and ecosystems for human leisure, well-being (including cultural activities), and economic development of the tourism sector across the Berg River Catchment is explicitly identified by the green arrow.

Energy use is the most important source of greenhouse gas (GHG) emissions, which are resulting in global climate change. Over time, this component of the Nexus will thus have significant impacts on the whole 'system', through changes in hydrological and nutrient cycles and seasonalities, and increasing frequencies and intensities of extreme climate events. In this context, GHG emissions from land use and agriculture will result in feedbacks, which are likely to be mostly negative on balance of current evidence and exacerbate resource constraints and the stress nexus.

The Framework shown in Fig. 6 can be applied to any spatial unit, with potential theoretical linkages possible between all the components. In the following sections, we summarise the key inter-linkages as experienced in the Berg River Catchment, focusing primarily on the central part of the Framework: food, energy, water, land and biodiversity. The broader context (socio-economic and development) will be incorporated into section 5, for a discussion of the application of the Nexus approach in local decision making and economic planning.

4. FEWLB Nexus in the Berg River Catchment

4.1 Water for agriculture and food security; impacts on water



KEY FACTS

- Irrigated crop production uses 50-60% of the allocated water supply in the BRC part of the Western Cape Water Supply System, and 36% in the whole WCWSS;
- Around 50% of the irrigation requirement in the Berg WMA lies outside of the WCWSS system (farm dams and run of river);
- Agricultural water use growth has been capped at 2% per annum;
- Water use of crops ranges from 8000-10000 m^3/ha/annum (deciduous and citrus fruit, wine grapes), 7100 m^3/ha/annum (potatoes), 3600 m^3/ha/annum (fynbos flowers), to 3000 m^3/ha/annum (vegetables);
- Water quality decreases in a downstream direction, with fairly good water quality in the headwaters of most of the rivers, but pollution where the rivers pass through urban settlements and areas of intensive agriculture.

Agriculture is a major consumer of water in the BRC. Intensive irrigation is practiced in the Upper Berg and parts of the Lower Berg (north of the river between Piketberg and the Atlantic Ocean) (Fig. 7). Irrigated crops include wine and table grapes, deciduous fruit (primarily plums and other stone fruit), citrus fruit ('easy peelers', lemons and limes), olives, 'fynbos' flowers, potatoes and other vegetables, as well as pastures and fodder. Water is also used for livestock rearing (cattle, sheep, pigs, chickens) and agro-processing (e.g. wineries, canning, abattoirs, dairies).

Figure 7 Areas under irrigation in the Berg Water Management Area. Source: Green Cape, based on Department of Agriculture, Western Cape

The Mediterranean climate means that rainfall is received in winter, when the water requirements are at their lowest. Thus, irrigation farmers are highly dependent on water supplies from the Western Cape Water Supply System (WCWSS), which consists of six large dams and a number of smaller dams and weirs. Water use for irrigation in the WCWSS for 2012/13 was estimated at 169 million m^3/a out of a total water use of approximately 503 million m^3/a (thus 36%) (DWA, 2013). However, other catchments in the Berg WMA (especially the Steenbras River) provide a high proportion of water to the Greater Cape Town area, and proportional water use for irrigation in the BRC is greater than 50% (DWAF 2007b, Fig. 8). Hundreds of small farm dams on private land and direct abstraction from rivers also contribute significantly to farmers' water supplies, particularly in the upper catchment.

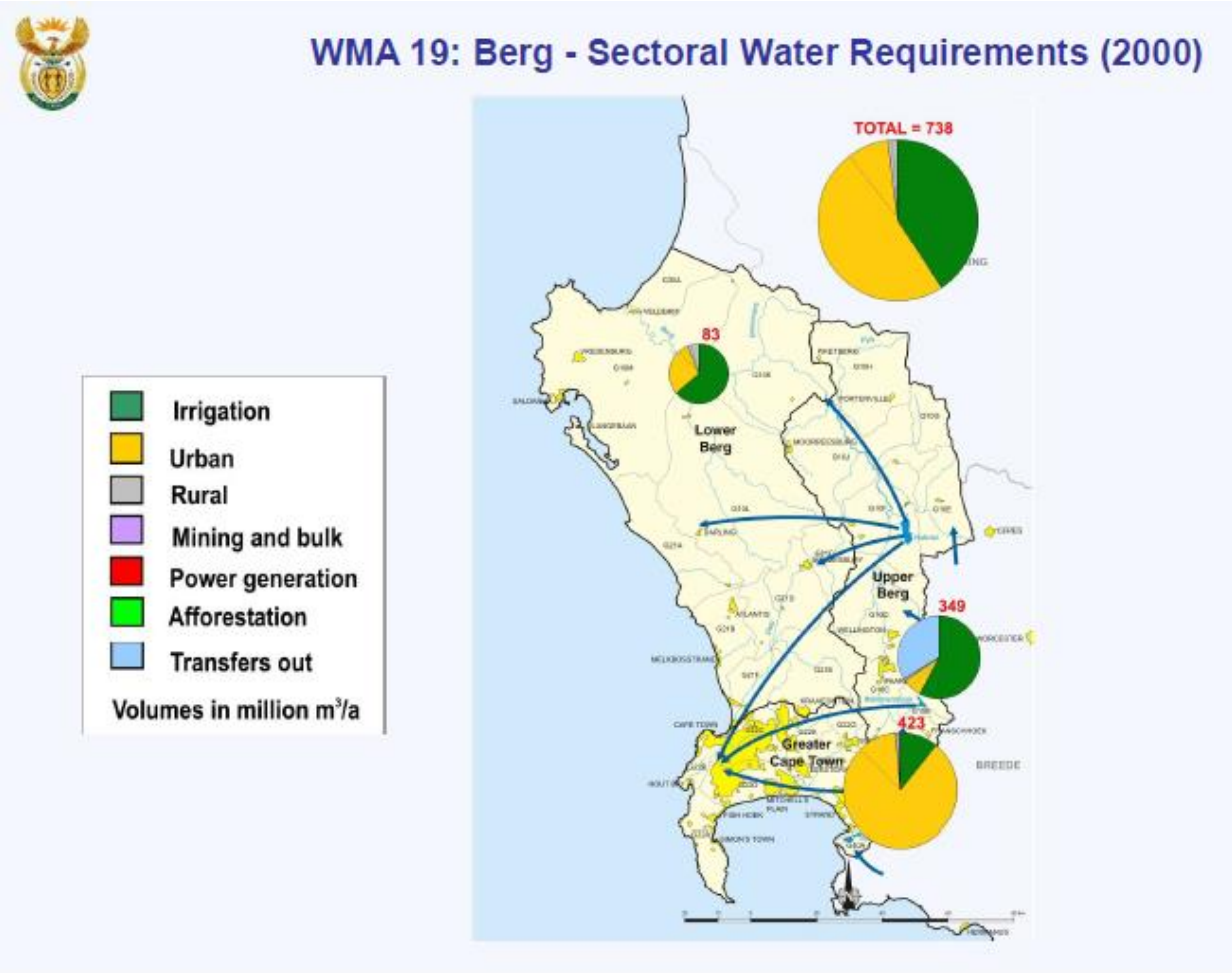


Figure 8 Berg Water Management Area sectoral water requirements in 2000. Source: DWAF, 2007b.

In order to balance water supply and demand in the WCWSS, the Department of Water Affairs has placed a cap on agricultural water use from this system, with only minimal growth (2%) factored into the Water Reconciliation Strategy (Fig. 9). However, since around 50% of the irrigation requirement in the Berg WMA lies outside of the system (farm dams and run of river), this is more difficult to monitor and control. The DWA's Water Conservation and Demand Management (WC/DM) Strategy is also being applied to agriculture and has contributed to "freeing up" water in the system.

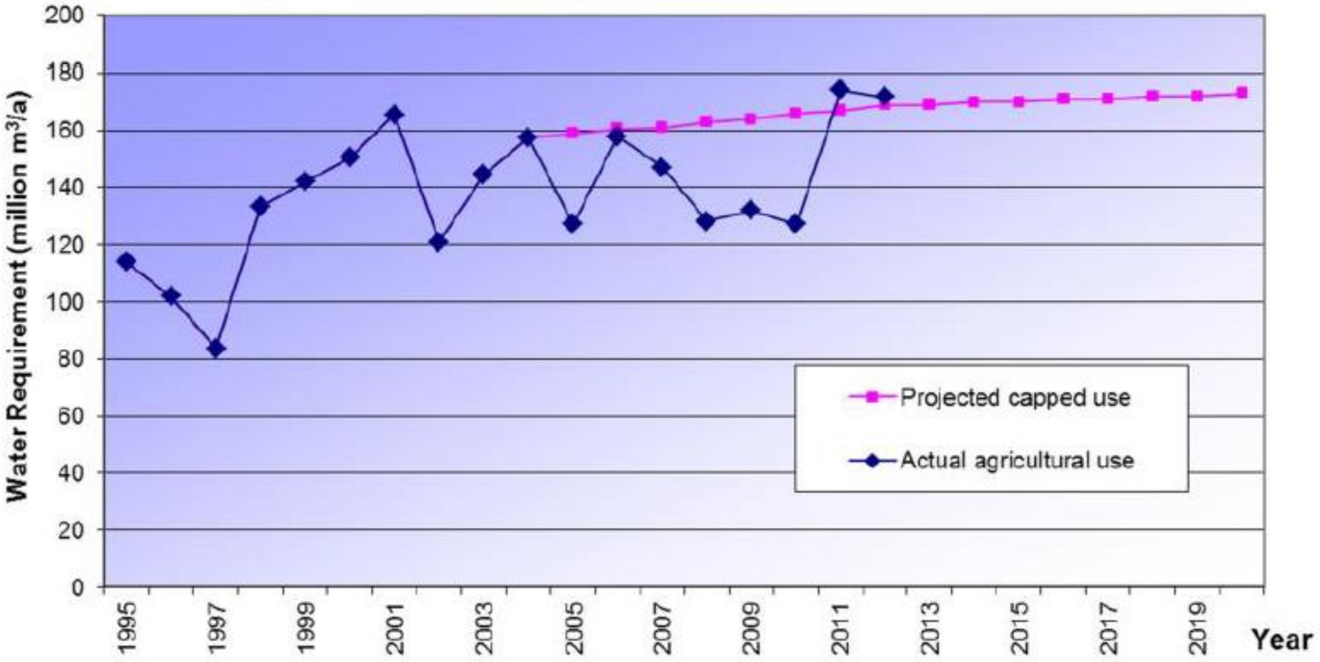


Figure 9 Historic agricultural water requirement from the WCWSS. Agricultural use has been capped. Source: DWA, 2013.

Most farmers have introduced effective water conservation measures to obtain the maximum yield from this scarce resource in the face of capped future allocations. This often includes changing to water-efficient drip irrigation systems for orchards and vineyards, although this is not always feasible and many farmers still opt for micro irrigation systems. Irrigation efficiencies have been greatly improved, but there is still room for efficiency gains through more precise scheduling and more efficient pumping technologies. A study on deciduous fruit orchards in the winter rainfall area shown that many farmers tend to over-irrigate their orchards (Volschenk et al., 2003). Currently, water use of apple trees in a commercial orchard in the Western Cape is about 10,000 m^3/ha/annum, with some farmers aiming for 8,000 m^3/ha/annum. With a mean yield of 50-80 tonnes/ha, this amounts to between 100 (best case) and 200 (average) m^3/tonne. The fruit industry has made increasing water use efficiencies an industry priority and detailed studies are underway on water use by high performing fruit orchards.

There are also economic reasons for this effort: At a national level, water purchases account for 0.7% of the current (2011) expenditure incurred within farming operations (Statistics South Africa, 2011). The average apple or pear farmer in South Africa budgets approximately R2150 per hectare of orchard for water costs (Hortgro, 2012). This amounts to 4.1% of costs per ha for a non-bearing orchard, and 1% for a bearing orchard. A table grape grower spends approximately R1400 per 4.5kg equivalent carton of table grapes for export (SATI, 2012). This is 1.1% of his total production cost. Future changes in water pricing could have significant impacts on irrigation farming.

An innovative demonstration project named FruitLook was launched in 2011 with the purpose of using satellite observations to assist grape and fruit farmers in optimizing their irrigation and fertilization scheduling on a weekly basis (www.fruitlook.co.za). The web-based system provides information on nine parameters per plot, such as evapotranspiration deficit, crop factor, biomass growth, biomass water use efficiency and nitrogen content. The pilot no-cost FruitLook service was funded by the Department of Agriculture, Western Cape, with support of the Department of Agriculture, Forestry and Fisheries, HortGro and the Integrated Applications Promotion program of the European Space Agency (ESA). It is now being commercialised.

The water footprints of key crops in the BRC are highly variable since they depend on rainfall, climate, soil type and water availability at a local (farm) scale. Here, one needs to distinguish between green water (rainfall), blue water (abstracted from surface or ground water for irrigation), and grey water (water that has been polluted by human activity, or more specifically as "…the amount of water needed to dilute pollutants emitted to the natural water system during the production process to the extent that the quality of the ambient water remains beyond agreed water quality standards" (Hoekstra and Chapagain, 2008). For the BRC, green water is the primary supply for the production of winter small grains, pasture and feed production, livestock rearing and rooibos tea production (Baleta and Pegram, 2014).

Irrigated citrus and stone fruit orchards and wine grape vineyards have a similar water requirement (on a per tonne basis per annum) compared to pome fruit (apple and pear) orchards (Pegasys, 2012; CCC, 2013). Table grapes have a slightly higher requirement. Wine grape vineyards are irrigated in the eastern parts of the catchment (Franschhoek, Drakenstein), but are not generally irrigated in the western parts (Swartland). Other horticultural crops such as olives and fynbos flowers have a lower irrigation requirement. Fynbos flowers use about 3600 m^3/ha/annum, or 40-50% less than for deciduous fruit, with 57% under drip irrigation (Kotze, 2011). Some pastures and fodder production are irrigated using overhead systems. Vegetables (other than potatoes) have a water requirement per tonne of about one-third that for fruit crops (Pegasys, 2012).

Potatoes grown in the Sandveld (north-western part of the BRC and further north up the West Coast) are irrigated using centre pivot systems fed with groundwater (Archer et al., 2009). The area planted to potatoes every year is estimated at 6591 ha for the whole Sandveld with the majority of fields left fallow or planted with other crops in a rotational system. Total water use is about 46.9 Mm^3/annum or 20% of annual groundwater recharge, and translates to water use of approximately 7100 m^3/ha/annum.

Irrigation farmers require assurance of water supply for current and future timeframes, considering the planning frame of 20-30 years for these crops. They also require assurance of minimum water quality standards to meet the strict requirements of the export market. The levels of certain pollutants in the water have at times and in certain areas already exceeded the minimum requirements of the European Union, the main recipient of produce from the region. This was immediately dealt with, but the risks remain high, and market share could be irretrievably lost, which would be disastrous for the sector and its employees.

Water quality in the Berg River catchment varies between and within the individual tributary systems (Fig. 10). The general trend is one of decreasing water quality in a downstream direction, with fairly good water quality in the headwaters of most of the rivers, but pollution becoming problematic where the rivers pass through urban settlements and areas of intensive agriculture.

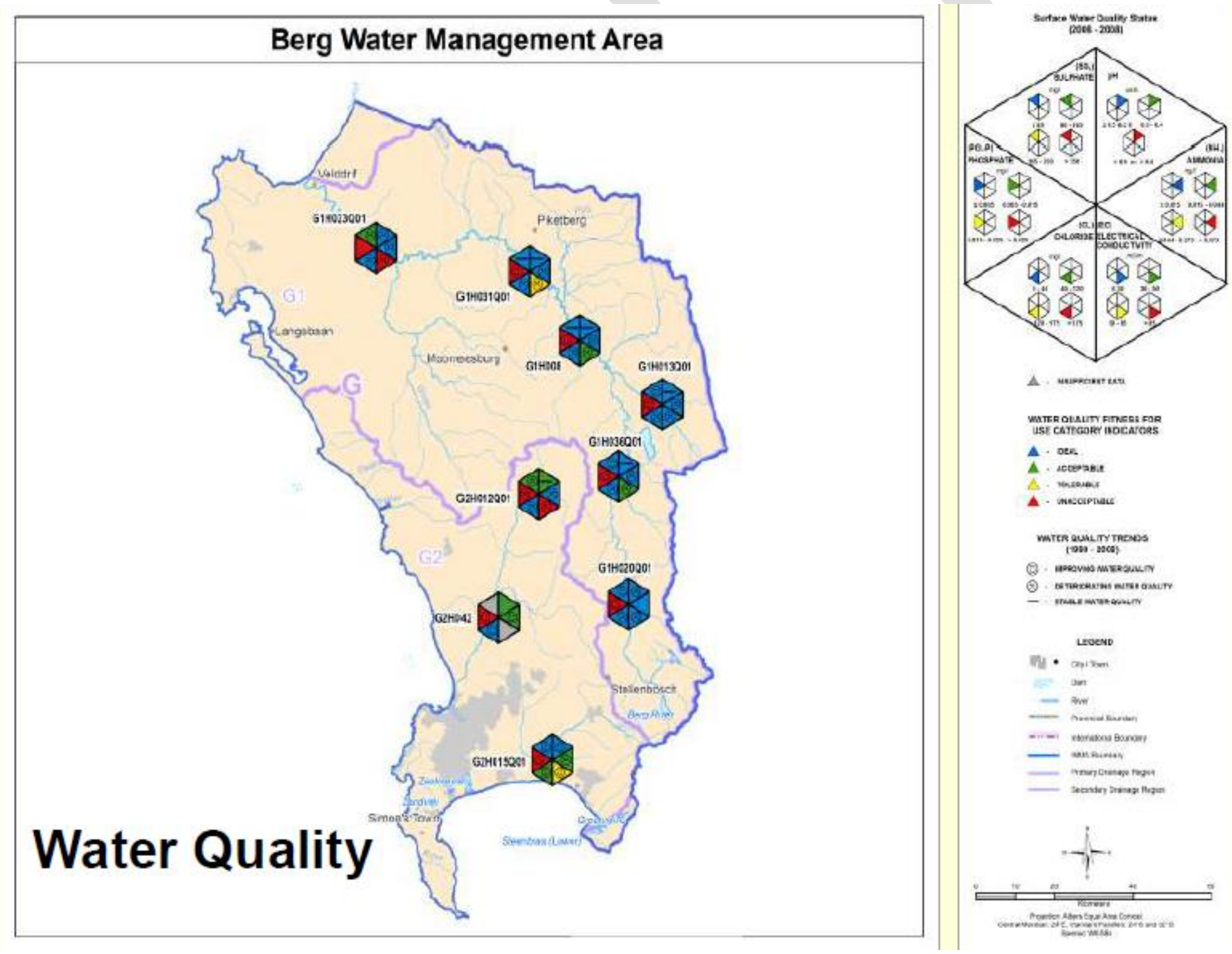


Figure 10 Water quality in the Berg River catchment. Source: DEA&DP and DWA, 2011

The main sources of pollution are agricultural activities (river modifications, water over-abstractions, runoff return flows from irrigated soils, discharge of inadequately treated winery effluent and piggery waste), polluted urban storm water, discharge from wastewater treatment works causing nutrient enrichment, runoff from informal settlements which tend to have poorer sanitation services, and loss of indigenous vegetation and alien encroachment along the river (DEA&DP and DWA, 2011). Many of the lower Berg River tributaries are underlain by Malmesbury shales of marine origin and therefore have naturally high salinity concentrations. The shales coupled with agricultural return flows introduce elevated salinities in the middle and lower reaches of the Berg River. This constrains the types of crops that can be grown.

The livestock sub-sector also both impacts on water quality of the Berg River Catchment, and is itself highly sensitive to water quality problems. Large dairies are found clustered around Malmesbury, Vredenburg and Piketberg, with smaller ones elsewhere across the Swartland and in the Drakenstein Municipality (Paarl/Wellington). The Malmesbury and Drakenstein areas also host large chicken farms (for meat and eggs) and commercial piggeries. Water is sourced from the Berg River system, and treated effluent returned to it. As with crops, a minimum water quality is required for livestock in order to meet hygiene standards and prevent disease outbreaks.

Various initiatives and projects are underway to address the water pollution concerns, notably the Berg River Improvement Plan (BRIP) (DEA&DP and DWA, 2012). The objectives of the BRIP are to (i) reduce the negative impact from Municipal urban areas, particularly informal settlements and wastewater treatment works; (ii) reduce the negative impact of agriculture on the Berg River's water quality to acceptable levels; (iii) ensure sustainable resource use efficiency and ecological integrity.

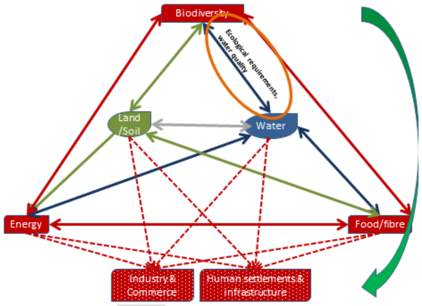
Future risks:

- Water supply in the system is reduced due to climate change and/or catchment mismanagement;
- Increasing water resource constraints lead to higher pricing;
- Water becomes unsuitable for agriculture due to unacceptably low quality;
- Water allocations to agriculture are diverted to environmental, urban and industrial demands;
- Crop water needs rise due to climate change (warming leads to greater evapotranspiration);
- Switching to high performance orchard systems in order to remain competitive could require more water;
- Effective water-based climate change adaptation options for agriculture are not implementable;
- Resource poor farmers and new entrants are unable to access water licenses and cannot achieve viability and livelihood security.

Key opportunities

Further irrigation efficiency achievements, focus on crops with lower water demand, improved understanding of the wider socio-economic value of water through the various arms of the agri-food value chain, effective water quality improvement programme.

4.2 Water for biodiversity and ecosystems



KEY FACTS

- 10% of the Berg Water Management Area is a freshwater ecosystem priority area, and more than 60% of river length in the BRC contains critically endangered or endangered ecosystems;
- Of the four indigenous fish species in the Berg River system, one is locally extinct, one is critically endangered, and the other two are near threatened;
- The Berg River floodplain is 5500 ha in extent and supports 127 species of water birds;
- The Berg River estuary supports 250 resident bird species and numerous migrants, 30 fish species, and a very high abundance of invertebrates;
- Dams and water abstraction have reduced freshwater inflow into the Berg River estuary by 30%.
- Biodiversity-dependent livelihoods, economic and recreational activity, particularly fishing and tourism, are important in the upper and lower reaches. Of the ca. 90,000 urban residents in the floodplain and estuary settlements, the majority is employed in these sub-sectors, and subsistence fishing contributes to their food security.

Economic activities associated with the estuary have historically been fisheries-based (commercial fishing, fish processing factories and boat repair facilities), subsistence line-fishing, but have recently expanded to include tourism and recreation (e.g. fishing.

Plants and animals

The Berg River Catchment falls within the western part of the Cape Floristic Region (CFR), a floral kingdom comprising some 9000 species. A key feature of the CFR is that 68.8% of its plant species is confined to this region, the highest for any Mediterranean region. Species richness is driven by a combination of infertile soils and a range of geological and moisture gradients which produce a complexity of habitats. Numerous plant species in the BRC are listed as endangered or threatened.

Furthermore, the rivers and their riparian zones provide habitat and migration routes for many animals such as Cape clawless otter, water mongoose and bushpig (DWAF, 2004). Other animals dependent on the river system are frogs (the giant rain frog is near endangered) and birds. The terrestrial bird diversity of the region is threatened primarily by habitat destruction and degradation including riparian zones.

The River system

The National Freshwater Ecosystems Priority Areas study (Nel at al., 2011) found that more than 60% of river length in the Berg River Catchment contains critically endangered or endangered ecosystems. Very few rivers in the BRC are in a natural or good condition (DWAF, 2004). Generally, the good to natural sites are the tributaries of mainstem rivers (Fig. 11).

The Freshwater Priority Areas and Fish Sanctuaries within the Berg River catchment include the upper Berg and Wemmers, upstream of the Berg River Dam and Wemmershoek Dam, respectively; the upper Klein Bergh tributary near Tulbagh, and the Vier-en-Twintig tributary in the Groot Winterhoek range; as well as the Platkloof and Boesmans tributaries in the southern Piketberg. The NFEPA Freshwater ecosystem priority area map for the Berg Water Management Area indicates that 10% of the WMA area is priority area.

Wetlands in the Klein Berg catchment, the southern Piketberg and the upper end of the Berg estuary, and the estuary itself are also Priority Areas. Approximately 87% of Western Cape wetlands are categorised in a moderate to heavily modified condition, and wetlands continue to be lost or impacted through development, drainage, cultivation, human-induced erosion or invasive alien plants.

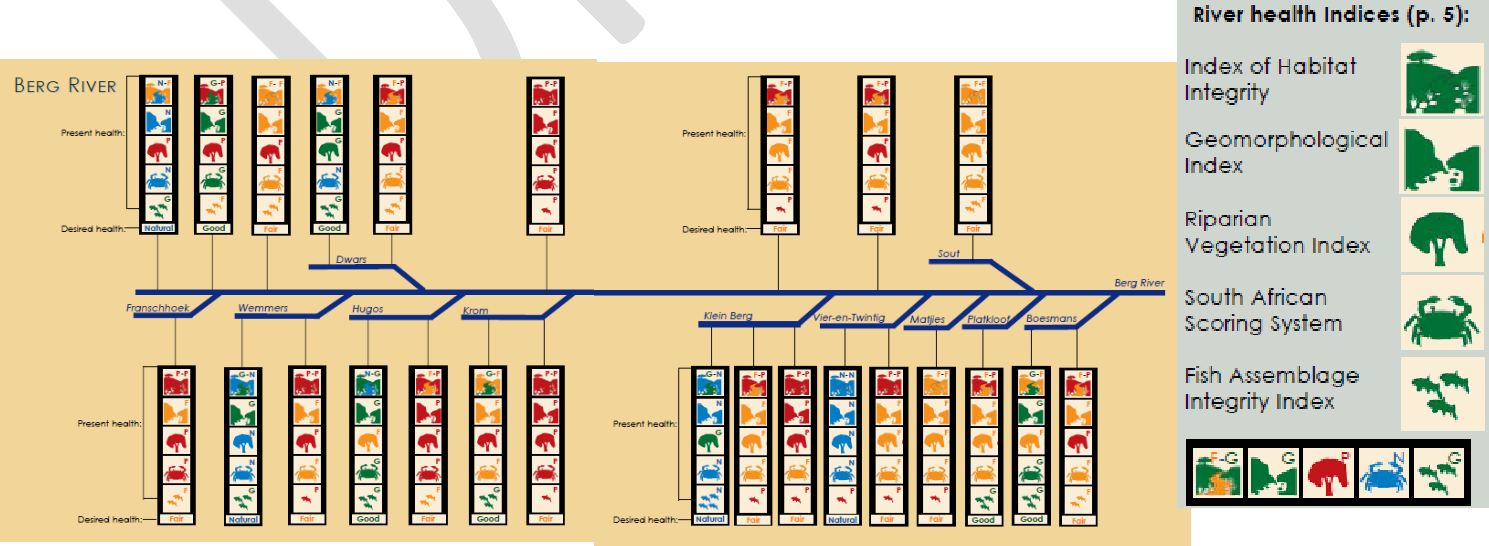


Figure 11 State of the Berg River and its tributaries. Source: DWAF, 2004.

Four indigenous fish species have been recorded in the Berg River system, the Berg River redfin (*Pseudobarbus burgi*), Cape galaxias (*Galaxias zebratus*), Cape kurper (*Sandelia capensis*) and Berg-Breede witvis (*Barbus andrewi*) (DWAF, 2004). Indigenous fish in the Berg River mainstream and perennial tributaries were once naturally abundant. Today, witvis are extinct in the Berg River, the Berg River redfin is critically endangered, and the other two species mentioned above are near threatened. The upper reaches of the Berg River and a handful of tributaries are the last refuge areas where indigenous fish are still relatively abundant. A project to re-establish the witvis has recently been implemented.

Invasive alien fish, as well as reduced water quality, degraded riparian zones which provides shade, shelter and food for fish, and extensive rates of abstraction have impacted severely on the indigenous fish populations in the Berg River system, particularly the mainstream and lower reaches of tributaries. Intensive use of agro-chemicals, the transfer of inferior quality water from Theewaterskloof Dam into the Berg River in summer, and pollution from human settlements have reduced water quality and negatively impacted on indigenous fish. Excessive water abstraction from certain tributaries (e.g. Boesmans, Hugos, Dwars and Vier-en-Twintig rivers) further reduce habitat quality and diversity for smaller species. This results in repeated recruitment failure and the eventual localized extinction of indigenous fish.

The floodplain

The extensive floodplain of the Berg River (about 5 500 ha), above the estuary, is unique in the south-western Cape. Evaporation on the floodplain is three times more than the rainfall. Thus, the floodplain and the surrounding communities rely on floods originating higher up in the catchment for their existence (DWAF, 2004). It is thus essential that environmental flow releases are made to ensure the future existence and viability of this locally unique ecosystem.

The floodplain acts as flood buffer, water filter, fish nursery (e.g. flathead mullet), it provides food and shelter for many bird species, and is a major centre of biological activity in the river ecosystem. During periods of high water, the floodplain acts as a natural sponge, which stores and releases floodwaters slowly. It improves water quality by providing fresh water to the wetlands and backwaters, diluting salts and nutrients and generally improving the overall habitat health. In addition to filtering out pollutants, floodplain trees and plants also prevent bank erosion and provide shade, which reduces water temperatures.

The floodplain supports at least 127 species of water birds, of which 85 are observed regularly, 31 are of regional significance, 25 are of national importance and 5 are listed as red data species. Migratory birds from Europe and northern Asia use the floodplain as feeding grounds during summer. A number of large heronries occur within the Berg River floodplain. Riparian reedbeds, sedge pans and burrows near open pans also provide breeding habitat for a large diversity of bird species.

Many floodplain species are dependent on the winter rainfall regime and winter flooding for survival. For example, floods trigger breeding in water birds and fish as food availability increases, while seedlings of a number of floodplain plants establish during flood events. Terrestrial grazers and browsers are attracted to the floodplain at the end of the wet season when rich alluvium deposits activate new growth.

Any development that alters the seasonal flow pattern (e.g. construction of large in-stream dams on the Berg River and water abstraction) reduce the frequency and intensity of flooding of the Berg River floodplain, while agricultural and urban encroachment further damage the floodplain. This can severely impact on the breeding behaviour and performance of water birds. Lack of flushing during floods gradually results in increased salinity levels in floodplain soils affecting the whole ecosystem.

The Estuary

Estuaries are unique habitats where rivers interact with the sea to varying degrees. The extent of seawater penetration and whether an estuary mouth will be open or closed depends strongly on river flow. The salinity regime and mouth status of an estuary in turn, govern the nature of the habitats on which most estuarine biota depend.

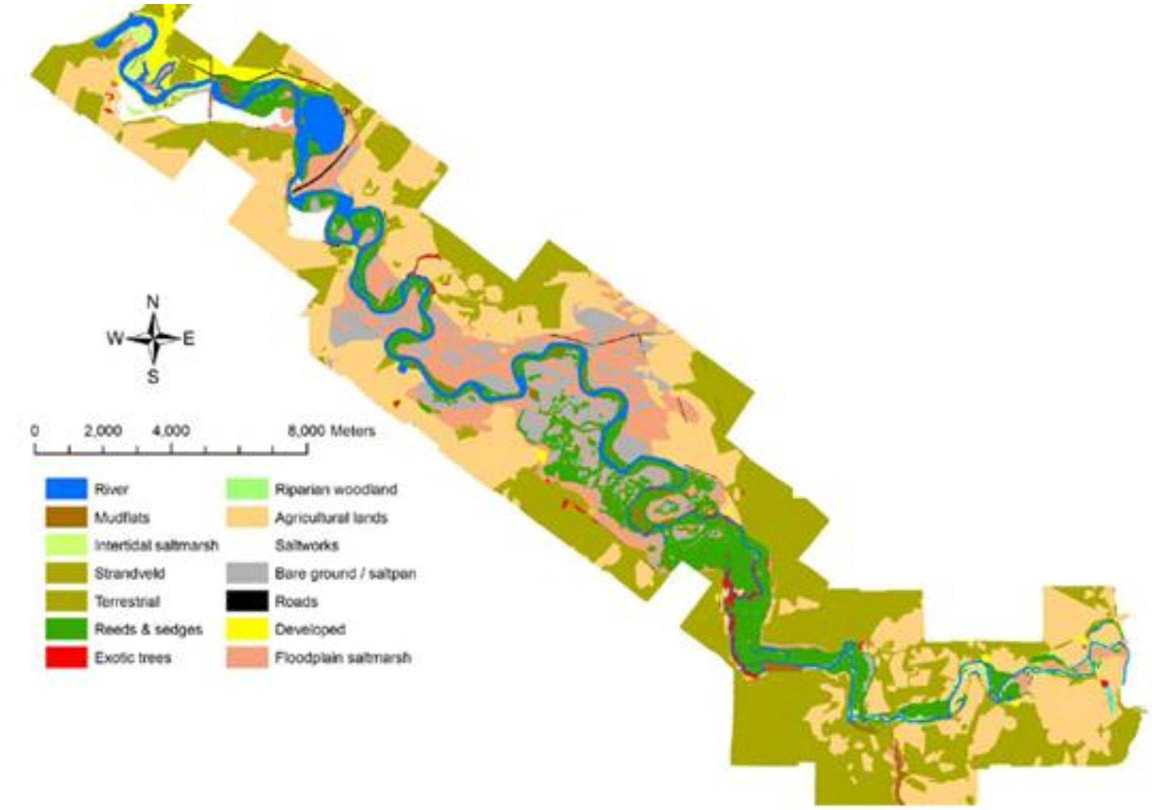


Figure 12 Distribution of plant communities along the length of the Berg River Estuary. Source: Anchor Environmental Consultants, 2008

The mouth of the Berg River estuary is kept permanently open by a constructed channel and dredging. The estuary reflects strong seasonal patterns. River inflow during winter creates more turbid, freshwater-dominated conditions, with limited saline intrusion near the mouth. During summer, the estuary becomes marine-dominated with less turbid saline waters penetrating up to about 40 km from the mouth. Upwelling during these summer months is a typical feature along the West Coast when colder, nutrient-rich seawater is introduced into the estuary. This seasonal variability drives the ecology of the estuary.

The Berg River Estuary is South Africa's second most important estuary in terms of national conservation importance for estuarine birds, fish, invertebrates and vegetation (Fig. 12). Despite extensive human activity, the system is still particularly important for birds because it supports large populations of both resident species and Palaearctic migrants. The floodplain and the Berg River Estuary are known collectively as the Lower Berg River Wetlands and are listed as an Important Bird Area (Ramsar Convention).

The estuary is one of the few suitable habitats along the west coast for migratory birds. Migratory waders on the East Atlantic, Mediterranean and Middle East flyways (with South Africa as the southerly end-point) use the estuary as a feeding ground. In addition, the estuary supports approximately 250 resident bird species, representing 50% of the species of the South-Western Cape in the area.

Nearly 80% of the Western Cape coastal fish species have been recorded in the Berg River Estuary and floodplain. Of these fish, some are entirely estuarine or partially dependent on the estuary and floodplain. Over 30 fish species have been recorded, including six estuarine residents, eleven euryhaline migrants (e.g. flathead mullet), seven marine migrants and six freshwater species. Due to the scarcity of suitable sheltered habitats along this stretch of coast, west coast floodplains and estuaries are of tremendous local importance to fish, particularly as nursery areas.

Invertebrates are an important food source for bird and fish in the estuary. The system supports an extremely high abundance of invertebrates, including polychaete worms, mud prawns and sand prawns. Dense stands of indigenous reeds and sedges, and the third largest saltmarsh in the Cape in the lower reaches of the estuary, provide food and habitat for estuarine fauna.

The following factors pose threats to the Berg River estuary:

- Dams and water abstraction in the catchment, which have reduced freshwater inflow to the Berg River Estuary by 30%;
- Erosion in the catchment due to agriculture and siltation of sensitive areas in the estuary;
- Loss and destruction of natural habitat, especially saltmarsh destruction and bank erosion in the estuary;
- Overexploitation of living resources, especially estuarine fish;
- Deterioration in water quality from factory wastewater discharges, harbour activities, and agricultural return flow.

Overall, the Berg River estuary is very highly exposed to fishing impacts, highly exposed to pollution, moderately exposed to changes in flow and habitat loss, and also feels the pressure of bait collection (Turner et al., 2012). For individual ecological components, “Hydrodynamics” was rated “excellent” but all other components were rated “fair” and the overall ecological category was a “D” (with “A” being the best).

Thus, ecosystem functioning and biodiversity are inextricably linked to the river system along its whole length, and the ecological water requirements (the ‘reserve’) are entrenched in the Water Act. In highly managed systems, where natural flow has been highly altered by dams and other infrastructure, environmental flow releases should be made regularly in order to maintain ecosystem health. Until the completion of the Berg River Dam in 2007, no environmental releases were made from the Wemmershoek Dam supplying the City of Cape Town, or from the numerous farm dams in the Berg River valley. Limited compensation releases are made from the Voëlvlei Dam and from Misverstand Dam in the Lower Berg River. However, the ecological Reserve requirement of the Berg River downstream of the Berg River Dam was built into the design and operational rules for the scheme. The ecological reserve on dams constructed prior to the Berg River Dam will only be phased in after 2022 or when a new augmentation intervention has been put in place. The environment and conservation sector is concerned that current releases are insufficient (Haiden et al., 2014).

A key consideration for the water-biodiversity inter-linkage is that biodiversity and healthy ecosystems directly support the businesses, livelihoods and food security of many inhabitants in the BRC. Biodiversity-dependent economic and recreational activities, particularly fishing and tourism, are important in both the upper and lower reaches of the catchment. In terms of livelihoods, of the ca. 90,000 urban residents in the floodplain and estuary settlements, the majority is employed in fisheries and tourism, and subsistence fishing contributes to their food security.

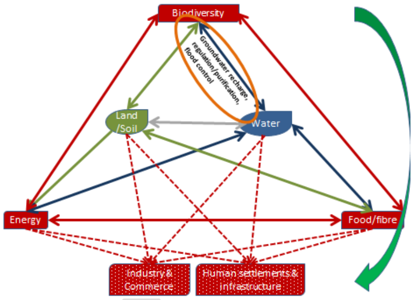
Future risks

- The ecological reserve (environmental flow releases) is not fully implemented due to pressure of water demand elsewhere;
- Water supply in the system is reduced due to climate change and/or catchment mismanagement;
- Climate change impacts ecosystems through rising evapotranspiration and general drying, changes in rainfall seasonality and peak water flows, salinization of the floodplain through sea level rise;
- Siltation; destruction of riparian zones, wetlands, the floodplain and estuary; alien plant and animal species – current threats are not managed;
- Further deterioration of water quality.

Key opportunities

Implementation of the ecological reserve, successful floodplain/estuary management, effective water quality improvement programme.

4.3 Biodiversity and ecosystems for water security



KEY FACTS

- The mountain reserves managed by Cape Nature in the upper Berg provide at least 35% of the runoff into the Berg River;
- Alien invasive plants cover ca. 155,000 ha across the Berg WMA;
- Each mature plant uses 250 litres of water per day; aliens in riparian zones result in a reduction in surface water runoff of about 87 Mm^3/annum.
- Clearing about 6500 ha of alien vegetation provided an additional 5 million m^3 per annum of water.

The inter-linkages between biodiversity and ecosystems and water security can best be described with reference to the concept of ecosystem services. These are generally classified as provisioning, regulating, supporting and cultural services.

Provisioning services

Healthy ecosystems make for productive catchments. By far the most important sub-catchments in the Berg River system are in the mountains and hills of the Upper Berg, characterised by fynbos vegetation. The highest volume and best quality water comes from pristine fynbos catchments. The mountain reserves managed by CapeNature in the upper Berg provide at least 35% of the runoff into the Berg River. These catchments have in the past been heavily infested with invasive alien tree species, but clearing programmes (Working for Water, Cape Nature, and Department of Agriculture) have already made significant inroads and "freed up" water flows previously intercepted and transpired by the invasive trees. Nevertheless, aliens remain an extensive problem (Fig. 13) and comprise in excess of 155,000 ha across the Berg WMA (DWAF, 2007b).

At least 109 terrestrial alien plant species have been found in the fynbos. Rooikrans (*Acacia cyclops*) is the most extensive in the Strandveld while eucalypts (*Eucalyptus camaldulensis*), long-leafed wattle (*Acacia longifolia*) and black wattle (*Acacia* *mearnsii*) prevail along river courses where they can form dense thickets. Other aliens include cluster pines (*Pinus pinaster*), and silky hakeas (*Hakea sericea*) in the mountainous areas.

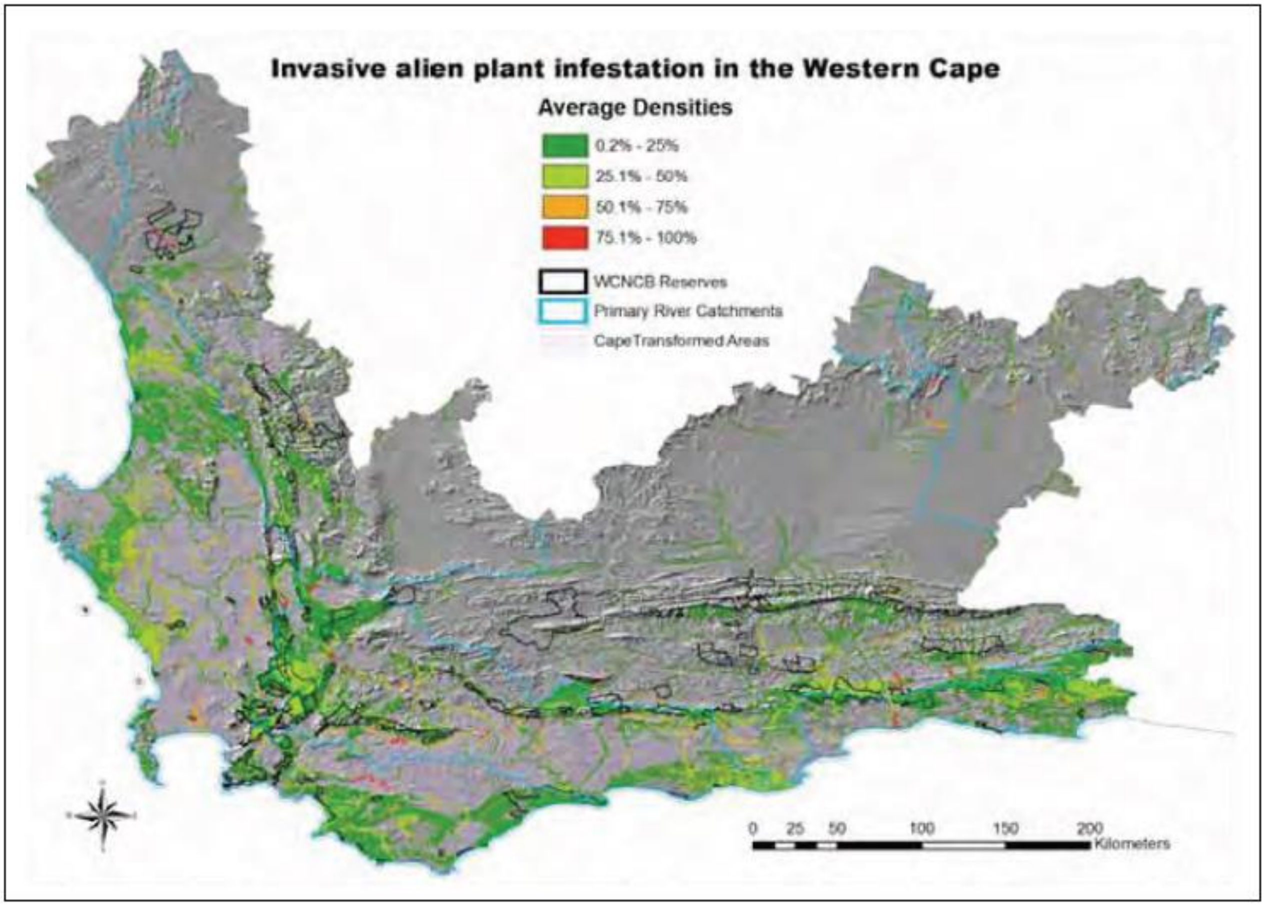


Figure 13 Invasive alien plant infestation in the Western Cape (adopted from Kotzé et al., 2010). Source: Turner et al., 2012.

In 1998, alien vegetation infestation in the Berg River catchment was estimated to be 101,882 ha, or 11.5% of the total catchment area. Working for Water cleared a "condensed area" of about 6507 ha of alien vegetation within the Berg Water Management Area (surface area of 1.3 million ha, including the Berg River catchment and Cape Town). This clearing is calculated to have provided an additional 5 million m^3 per annum of water to the environment and potentially to water users. There remains an urgent need to clear the extensive stands of eucalypts lining the Berg River. Each mature plant has been calculated to utilise 250 litres of water per day. In the Berg WMA, alien infestations along the riparian zones result in a reduction in surface water runoff of some 87 Mm 3 /a (DWAF, 2007b).

Research has shown that by clearing the riparian zone of a river, approximately 50% of the run-off can be returned to the river. Alien invasive clearing could potentially increase the water supply in the Berg River system by about 0.5% (DEA&DP and DWA, 2011). System-wide, this does not appear to be significant, but locally the improved hydrological flows could be highly significant for ecosystems at that scale.

Invasive alien plants are the second largest threat after habitat loss to conserving ecosystems and biodiversity in the Western Cape (Turner et al., 2012). Not only do they threaten natural resources, but can impose enormous costs on industries such as agriculture and forestry. The direct effects of aliens, such as less available water, and competition with indigenous species for light and nutrients, are exacerbated by wildfires which lead to much hotter fires due to increased fuel loads leading to increased damage which may even extend to the underlying soil. Wildfires in invaded areas are very difficult to control and may run into formal plantations and even farms and settlements.

Other forms of land use change, and in particular the transformation of natural vegetation to farmland, also causes significant changes to hydrological processes. For example, the destruction of Renosterveld in the middle catchment, and replacement with small grains, has led to serious salinization of some of the soils and run-off channels (de Clercq et al., 2010), and rising salinity of flows into the Misverstand Dam.

Regulating services

The regulating services of ecosystems in the BRC with respect to water flows and quality are numerous. They include:

- Flood attenuation – reduction of the amplitude and velocity of flood waters by wetlands, river banks and flood plains, thus reducing downstream damage;
- Groundwater recharge – differential recharge to groundwater relative to surrounding vegetation types;
- Dry season flows – moderating the seasonality of downstream flows;
- Drought mitigation;
- Water purification - breaking down of organic solid waste; interception and breakdown of nutrients from agricultural return flows; detoxification, dilution and transport of pollutants;
- Critical breeding, feeding or watering habitat for populations of fish, amphibians, reptiles, birds, mammals and invertebrates – these in turn keep the river water biota in balance and pests and diseases at acceptable levels.

Wetlands and riparian zones play a central role in regulating services and there has been an increasing focus on the conservation and rehabilitation of these areas (Turner et al., 2012). Although detailed data for the BRC are not available, the NFEPA study showed that 13% of Western Cape wetlands are in an AB or intact condition, 34% are in a C or moderately modified condition, and the remaining 53% are in a D, E, F or Z condition, meaning they are heavily or critically modified. Thus, approximately 87% of

Western Cape wetlands are categorised as being in a moderate to heavily modified condition, and wetlands continue to be lost or impacted through development, drainage, cultivation, human-induced erosion or invasive alien plants (Turner et al., 2012).

Wetlands are extremely diverse in terms of water source (groundwater, rainfall, surface flow, or a combination of these) and permanence (temporary or permanent). They also vary in chemical properties. In sandstone fynbos vegetation, wetlands often occur on peat soils with a high organic carbon content, and the water is stained brown by the tannins. When such wetlands are cleared the peat is destroyed, leading to severe riverbank erosion, loss of land, and damage to infrastructure. Along the West Coast, wetlands often take the form of seasonal shallow (usually saline) pans, often surrounded by farmland and easy to overlook during cultivation.

Cultural services

The diverse landscapes of the Berg River Catchment and the river itself offer a wide range of opportunities for tourism and leisure: hiking and fishing in the pristine high mountains of the upper catchment, agri-tourism on the wine farms of Franschhoek, the Drakenstein and parts of the Swartland, luxury resorts and self-catering camp grounds along the river, the spring wild flowers along the West Coast, water sports at Langebaan Lagoon, and world class birding at Langebaan Lagoon and the Berg River Estuary.

The estuary, located at the mouth of the river, is also the well-known finishing point for the Berg River Canoe Marathon. The Marathon is an annual 240 km race from Paarl to the harbour town of Veldrift. The race has taken place since 1962 and takes place during the winter month of July over a four day period, when the river is typically fast-flowing.

The increasing interest in and development of these activities and lucrative tourism offerings can add impetus to the call for habitat and biodiversity conservation, with positive feedbacks to river health and functioning.

Future risks

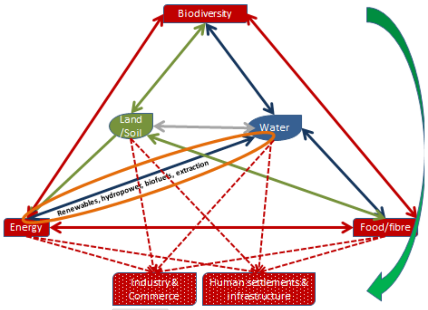
- Runaway invasive alien infestation possibly driven by climate change, leading to reduced runoff;
- Climate change driven changes in plant community structure leading to hydrological changes (surface and ground water) and possibly increasing fire frequencies;
- Further land use changes leading to hydrological alterations (surface, ground);
- Further degradation of wetlands, riparian zones and flood plains, with increasing flood damage, especially if accompanied by more intensive rainfall due to climate change;

- Loss of water flows during the dry season and during droughts owing to loss of flow regulation;
- Exceedance of the system's capacity to deal with waste and pollutants leading to rapid deterioration of water quality and "dead zones".

Key opportunities

Focus on the conservation and rehabilitation of ecological infrastructure – especially riparian zones, wetlands, flood plain; winning the war on aliens; leveraging opportunities for leisure and tourism development to benefit biodiversity and ecosystem health.

4.4 Water for energy security



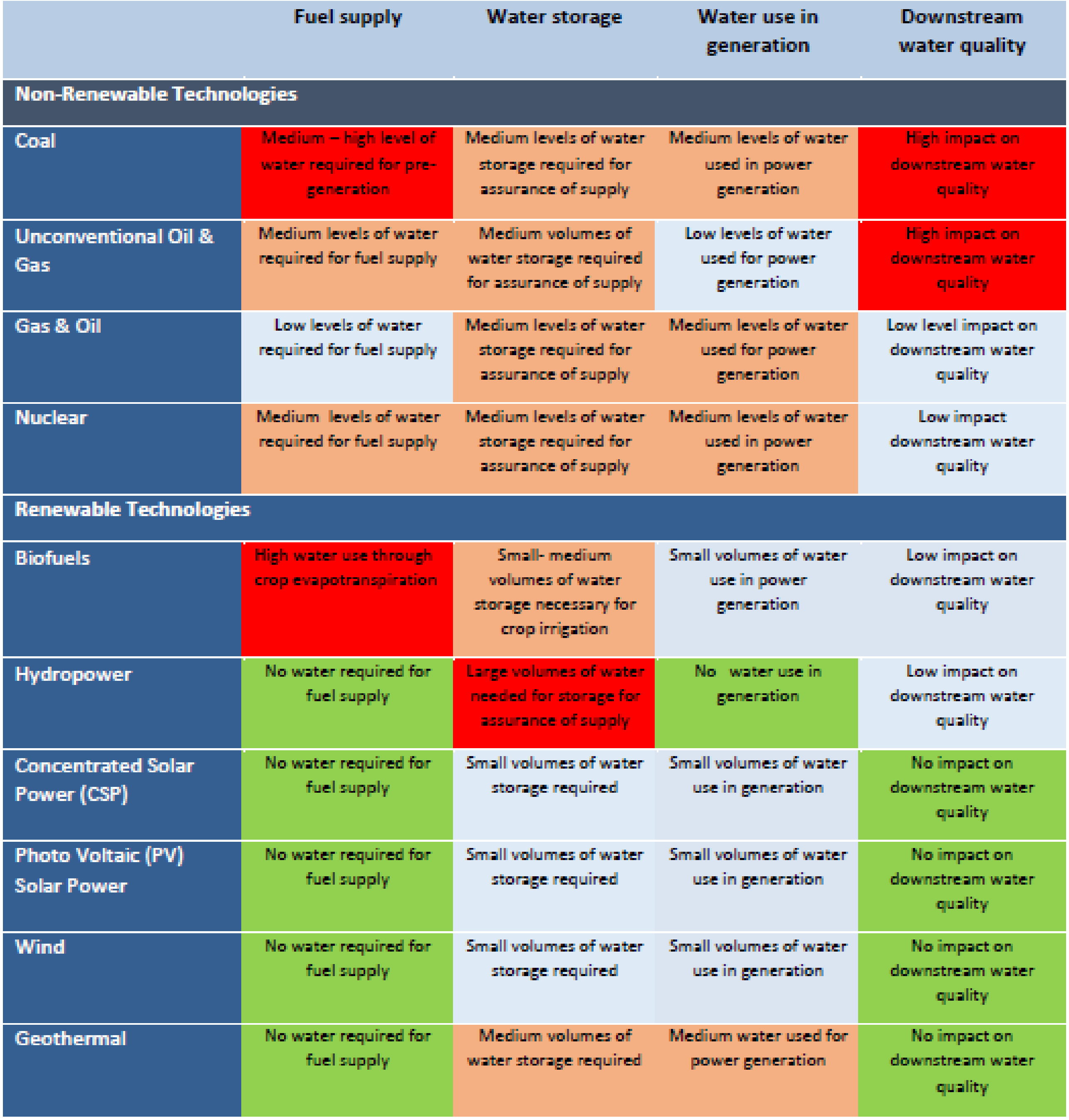
KEY FACTS

- Only wind, solar and biogas power generation facilities occur in the BRC area and additional wind and solar generation capacity is under construction or planned;
- Water is used in the abstraction and production of raw materials for solar/wind farms and in the manufacture of the components and infrastructure. These currently take place outside the BRC but are planned for the Atlantis and Saldanha areas which draw water from the WCWSS;
- On-site wind energy generation in the BRC currently requires no water;
- Solar PV (276-1957 litres/MWh) and wind energy (170-324 litres/MWh) exhibit the lowest demand for water and the highest efficiencies of water use for power generation (coal: 1284-194428 litres/MWh).
- Biogas generation does require water but the amount varies depending on the type and scale of operation - in the case of cattle manure the requirement is about 40 liters for every 40 kg of manure (daily mean per cow) which generates 26 MJ of biogas. Thus the water demand for power generation is about 5538 litres/MWh.
- An important feedback is the mitigative power of transitioning to local renewable energy technologies with a vastly reduced carbon footprint. This will, in the longer term, contribute towards reducing the negative impacts of climate change on water availability expected in the BRC.

National and provincial energy generation planning does not foresee any conventional fossil fuel-based plants, any hydropower plants, or any biofuel projects in the catchment in the foreseeable future. However, wind and solar generation is supported through the Renewable Energy Independent Procurement Programme (REIPPP) of the Department of Energy. Therefore, the main linkage of concern here is the projected water use of renewable (wind, solar) energy development. There is also potential for biogas plants.

The energy generation capacity in the BRC consists of two small wind farms at Klipheuwel (3.2 MW) and Darling (5.2 MW) and the full-scale operational Hopefield wind farm (66 MW), with the West Coast One wind farm near Vredenburg (90 MW) under construction. There are also numerous small scale off-grid rooftop solar (photovoltaic, PV) installations, a smaller (5 MW) solar PV park near Darling, and a medium solar PV park near Aurora (10 MW) and one off-grid biogas facility attached to a large dairy near Malmesbury.

During energy production water is used in the abstraction and production of raw materials for plant infrastructure, in the making of the components, and the building of power generating infrastructure. The water is either consumed or recycled and discharged at various stages of the energy production process. A study by ERC (ERC, 2013) concluded that solar PV and wind energy exhibit the lowest demand for water and the highest efficiencies of water use for power generation. The impacts on downstream water quality should also be taken into consideration (Figure 14).



	Fuel supply	Water storage	Water use in generation	Downstream water quality
Non-Renewable Technologies				
Coal	Medium – high level of water required for pre-generation	Medium levels of water storage required for assurance of supply	Medium levels of water used in power generation	High impact on downstream water quality
Unconventional Oil & Gas	Medium levels of water required for fuel supply	Medium volumes of water storage required for assurance of supply	Low levels of water used for power generation	High impact on downstream water quality
Gas & Oil	Low levels of water required for fuel supply	Medium levels of water storage required for assurance of supply	Medium levels of water used for power generation	Low level impact on downstream water quality
Nuclear	Medium levels of water required for fuel supply	Medium levels of water storage required for assurance of supply	Medium levels of water used in power generation	Low impact downstream water quality
Renewable Technologies				
Biofuels	High water use through crop evapotranspiration	Small- medium volumes of water storage necessary for crop irrigation	Small volumes of water use in power generation	Low impact on downstream water quality
Hydropower	No water required for fuel supply	Large volumes of water needed for storage for assurance of supply	No water use in generation	Low impact on downstream water quality
Concentrated Solar Power (CSP)	No water required for fuel supply	Small volumes of water storage required	Small volumes of water use in generation	No impact on downstream water quality
Photo Voltaic (PV) Solar Power	No water required for fuel supply	Small volumes of water storage required	Small volumes of water use in generation	No impact on downstream water quality
Wind	No water required for fuel supply	Small volumes of water storage required	Small volumes of water use in generation	No impact on downstream water quality
Geothermal	No water required for fuel supply	Medium volumes of water storage required	Medium water used for power generation	No impact on downstream water quality

Figure 14 Water use in different energy technologies. Source: Pegasys, 2013

In the pre-generation (construction) phase for PV installations, water is required for the manufacture of materials for the PV-cells, which could or could not occur in the same catchment as the installation. The manufacturing process demands water of a high quality standard which is further purified to remove chemical residues from equipment and to clean and rinse the panels. Furthermore, water is used to run the manufacturing plant and its infrastructure. The pre-generation phase water use has been estimated (ERC, 2013) to be around 276-1942 litres/MWh (international data). On-site, water is needed to build roads and other infrastructure around the plant, and this can be highly variable, but is probably negligible. About 15 litres/MWh is needed for panel cleaning on occasion, but the frequency of this has not been quantified for South Africa and will depend on the climate of the site and other local factors. The impact of PV on water is negligible (ERC, 2013).

For wind energy, water is required in the pre-generation phase for the usage of steel, iron and glass fibre to manufacture wind turbines, and for the mining of rare earth minerals required for the production of the turbines. The former could or could not take place in the same catchment. However, the magnets used in wind turbines have an important rare earth component known as neomycin which is imported almost entirely from China. A large wind turbine (approximately 3.5 MW) generally contains 600 kg or rare earth metals. Every ton of rare earth mineral produced uses 75 m^3 acidic wastewater and one ton of radioactive waste residue (which contains water). Wastewater from rare earth mining in China is often discharged without appropriate treatment, impacting on potable water. The water use in the production of rare earth elements such as neomycin does not impact on water use in South Africa, but it does impact on the water footprint globally. The pre-generation water use is around 170-320 litres/MWh (international data, ERC, 2013). Water use for turbine and infrastructure construction onsite is negligible. The generation of wind energy does not require water and only small volumes of water are possibly needed to wash the turbine blades on occasion.

With respect to the BRC, the Environmental Impact Assessment for the West Coast 1 wind farm near Vredenburg states that “as no water use will be associated with the proposed project, no water use permits or licenses are required to be applied for or obtained” (Savannah Environmental, 2010). Therefore the geographical water footprint will depend entirely on where the turbines are manufactured.

The water requirements of biogas plants vary depending on the type of organic waste being used and the size of the plant.

> As a rough guide, where cattle manure is used, 40 kg of manure (average daily for one cow) requires 40 litres of water for the mixing of the slurry that is fed into the digester (RCSD, 2008), and this generates about 1.2 m^3 or 26 MJ of biogas per day. Thus the water demand for power generation is 5538 litres/MWh.

Water is also required for sanitary (cleaning) purposes. Treated sludge can be used to spread on farmland as a fertilizer. There is a risk of water pollution when systems fail to operate properly. Thus, when planning a biogas plant the opportunity cost of water needs to be considered. In areas where water is a scarce resource or too far from the plant, biogas generation might not be an efficient investment. Options for water recycling such as redirecting water after it is was used to clean a kraal may pose a solution.

An important feedback to consider in this inter-linkage is the mitigative power of transitioning to local renewable energy technologies with a vastly reduced carbon footprint. This will, in the longer term, keep global warming in check and contribute towards reducing the negative impacts on water availability expected in the BRC. A co-benefit is to reduce the high dependence on increasingly expensive fossil fuels, which stimulates competitiveness across all economic sectors.

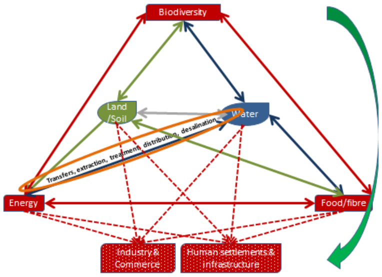
Future risks

- Planned manufacturing plants for renewable energy components (PV panels, turbine blades) in the Saldanha IDZ and Atlantis areas will require water in sufficient quantity and quality, under already constrained supply and allocations, possible future reductions in supply due to climate change, and persistent quality issues;
- Large-scale biogas plants require careful consideration of local water supply and sludge discharge;
- Future changes in the national and provincial policies on biofuels could open the door for biofuel production in the BRC which would draw on both green and blue water resources with possible implications for food production and food security.

Key opportunities

Solar PV and wind energy have a relatively low water footprint and offer viable on-grid and off-grid options for energy security.

4.5 Energy for water security



KEY FACTS

- In South Africa, the water sector uses only 3% of all electricity consumption but is highly dependent on electricity; the WCWSS has a lower water use since raw water is mostly gravity fed to the water treatment works;
- Water pumping requires energy. Typically, around 1.8kWh are required to supply 1m^3 of water to households in the Western Cape;
- For the WCWSS, including the BRC, preferred new water supply options include three options which will have high operational energy requirements: water re-use, TMG aquifer abstraction, and sea water desalination;
- Reverse osmosis membrane technology desalination plants use around 3 to 5.5 kWh electricity per m^3 of water produced;
- Groundwater pumps powered by renewable energy (wind, solar PV) offer feasible options for farmers. The average energy use rate of groundwater pumping for irrigation ranges between 0.2 and 0.6 kWh/m^3 water.

Energy is required at almost all stages of the water-use cycle, from abstraction and pumping to water treatment plants, distribution to users, transfer to waste water treatment plants, re-cycling in some cases, and final discharge. In the bigger picture, the water sector in South Africa is not a significant energy user, contributing only 3% to all electricity consumption (Deloitte, 2012) but is high on the list of dependency on water (electricity costs as % of total costs is 5%).

In the context of the BRC, the smooth functioning of the WCWSS is reliant on small amounts of electricity for the pumping of water through a network of water treatment works, pipelines to consumers, and wastewater treatment works for eventual discharge. Most of the dams within the WCWSS are situated in the mountainous catchment areas, and raw water flows by gravity to the water treatment works which are generally situated at lower elevation. Except for the water treatment works at the Voëlvlei Dam, which has a small pumping requirement, pumping is limited to post-treatment distribution. Typically, around 1.8kWh are required to supply 1m^3 of water to households in the Western Cape (DEA&DP, 2007). Additionally, at four of the City's major treatment works, the potential energy is also used to generate electricity from turbines, which is used to operate the respective treatment works, and reduce or eliminate the need for electricity supply from the national grid.

Since the supply of water is currently only marginally greater than demand, further development of surface and groundwater will become necessary in the near future (DWA, 2013). The Western Cape Water Reconciliation Strategy Study (DWAF, 2007c) focused on reviewing the future water requirement scenarios and assessing the best possible options for meeting these requirements within a planning horizon to 2030 – be it surface water options (very limited), the transfer of water from neighbouring WMAs, urban and rural water conservation and demand management, further clearing of alien invasive plants, reuse of treated effluent, or the development of alternative water resources such as groundwater and desalination.

Based on the current status of the feasibility studies, the following interventions were considered available for possible implementation, when a new supply-side intervention is required (DWAF, 2007c; DWA, 2013):

- Berg River-Voëlvlei (Phase 1) Augmentation Scheme
- Water re-use
- TMG Aquifer
- Desalination

It can be assumed that at least three of these options (water re-use, groundwater abstraction and sea water desalination) have high operational energy demands. This will likely increase the cost of water. Since desalination is already in pilot phase in an adjacent Municipality, the next section will address this technology.

The Western Cape Sustainable Water Management Plan (DEA&DP and DWA, 2012) states that "desalination is well suited for consideration in the Western Cape, particularly where the water demand centres are located along the coast and where storage capacity in existing infrastructure is available to absorb the 'product water'."

The feasibility of desalination plants in the BRC needs to consider current and planned surface and groundwater supply schemes. An important factor is cost. The cost of desalination has been estimated at about R6-7/m^3 (DWAF, 2007c). Such costs, however, need to be weighed up against (i) proposed increases in energy costs; and (ii) infrastructure required to integrate product water into existing distribution networks.

It has been suggested that alternative energy sources (e.g. wind and solar power) for desalination plants should be investigated to reduce reliance on the national electricity grid.

A pilot seawater desalination plant has been developed at Lambert's Bay on the West Coast (Cederberg Municipality), just north of the BRC (van Vuuren, 2014). The town obtains it water from groundwater sources, with six production boreholes, but abstraction rates are high and unsustainable, risking deterioration of water quality and seawater intrusion into the aquifer. The pilot plant uses reverse osmosis technology to treat the seawater to potable standard. The plant is located next to the existing Lambert's Bay water treatment works, allowing it to feed into the existing distribution network. While the plant will have an initial capacity of 1700 m^3/day, the infrastructure has been so designed to allow capacity increase up to 5000 m^3/day in future.

Desalination is energy-intensive: when reverse osmosis membrane technology is used, electrical energy consumption is around 3-5.5 kWh/m^3. Energy savings are achieved in the Lambert's Bay plant by using energy recovery pressure exchangers to recover the residual energy of the brine stream. This energy will be used in conjunction with a booster pump to boost a portion of the feed pressure to the membranes. Processes are designed to improve the quality of the wastewater (brine) produced by the plant, which is discharged into the ocean at 150 m distance from the coast.

At a vastly different scale but nonetheless highly efficient and beneficial is the use of renewable energy to pump groundwater for local agricultural use. Groundwater pumps driven by wind turbines, windmills or solar PV panels are an established technology which are particularly useful for livestock watering (connected to tanks) and other applications in remote areas across farms. As PV panels become more affordable and the energy efficiency of the panels and the pumps increases, this technology is finding increasing favour.

The average energy use rate of groundwater pumping for irrigation ranges between 0.2 and 0.6 kWh/m^3 water (Wang et al., 2012). This depends on the vertical distance over which the water is lifted and the efficiency of the pumping system.

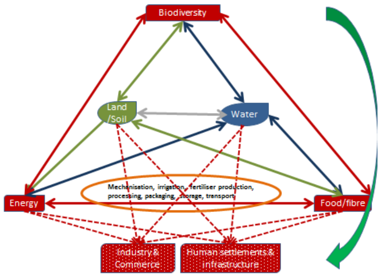
Future risks

- Increased energy costs
- Electricity supply interruptions due to insufficient national grid capacity

Key opportunities

Potentially massive boost to water supply if affordable clean energy can be harnessed.

4.6 Energy for agriculture and food security



KEY FACTS

- Farms receive electricity directly from ESKOM through the national grid, with a small additional contribution from renewable sources (mainly solar PV); diesel makes up most of the balance of on-farm energy use;
- 'Embedded energy' is found in agro-chemicals and packaging and these inputs are sensitive to energy pricing;
- Post-harvest processes (cold chain, processing, packaging) are energy-intensive;
- Agriculture uses 1% of energy (all sources) (Western Cape Province), 1% (West Coast District Municipality), 9% (Cape Winelands District Municipality);
- Agriculture uses 2.2% of electricity supplied directly by ESKOM (nationally), 6% (Western Cape Province), 10% (West Coast District Municipality), 23% (Cape Winelands District Municipality);
- Energy use is concentrated at earlier stages of the value chain (on-farm) but cold storage of fruit and dairy processing shows significantly higher energy use at later stages in the value chain;
- Household expenditure for energy (mainly electricity) for cooking is roughly equivalent to the cost of energy to produce the raw food.

Supply

The Berg River Catchment imports almost all its electricity requirements from the national grid through the national and wholly state-owned utility ESKOM. ESKOM also owns and operates the national high voltage transmission system. ESKOM energy is heavily coal-based (ca. 90%), with a smaller nuclear (5%) component and the remainder from gas turbine, hydroelectric and pumped storage schemes. Renewable energy production through solar and wind is still very low. The single nuclear power station is situated just north of Cape Town (but not in the Berg catchment) but feeds into the national grid. ESKOM currently produces 95% of South Africa's electricity requirements and also supplies electricity to neighbouring countries. The remaining 5%

of the requirements is provided by municipalities, Independent Power Producers (IPP's) and imports from the South African Power Pool (SAPP). Non-grid energy is produced by a variety of sources, e.g. small-scale windmills on farms, solar water heaters in urban settlements and on some farms, and photovoltaic cells for private and commercial use.

The Western Cape has a good supply of renewable energy sources such as wind, sun and waves. Provincial policy (DEA&DP, 2010) sets a target for electricity generation from renewable sources in the Province as 15% of the electricity consumed in the Western Cape by 2014, as measured against the 2004 consumption baseline. It is expected that at least 1000 MW of wind generation capacity will be installed in the Western Cape by end-2014, with wind farms mainly located along the West Coast, in the Great Karoo and in the Overberg region (Abrahams, 2011).

The BRC has two small wind farms, one full-scale wind farm and another under construction (see above).

ESKOM supplies electricity directly to commercial farmers. It sells in bulk to municipalities, which distribute to consumers within their boundaries, including many agro-processing facilities.

Other sources of fuel for agricultural purposes include diesel and petrol, and likely some coal for larger manufacturing plants. These are trucked in from Cape Town.

The heavy dependence on fossil fuels renders the region vulnerable to price increases and shocks, supply disruptions and possible costs associated with carbon pricing in the future. In the Cape Winelands District, electricity accounts for just over a third (37%) of energy consumed but this translates to 69% of GHG emissions. This is due to it having a high emissions factor resulting from its source in low grade, 'dirty' coal.

Demand by agriculture

Energy is a key input in agricultural production, but different goods involve very different production, storage and transportation processes and associated energy costs. Energy requirements include fuel for transport (usually diesel, on-farm and for distribution), electricity (for irrigation pumping, greenhouse climate control, cooling and storage, packaging), and the energy required to produce fertilisers and other agro-chemicals and packaging materials. The manufacture of metal, glass, paper and plastic packaging for food and beverages is highly reliant on electricity as an input with electricity costs for a packaging company, such as Nampak, amounting to 4% of total costs (Deutsche Securities, 2010), especially when cold-chain methods are necessary (HSRC, 2008). Energy is also needed in the food manufacturing industry for processing lines. Deloitte (Deloitte, 2012) has found that some forms of agro-processing are more energy costly than others, such as fish and meat processing and baking. The animal feed production and dairy industries are also relatively electricity intensive.

In 2010, sales of electricity to agriculture amounted to 2.2% of the national total (Statistics South Africa, 2012). This does not include the 38% of electricity sold to the "redistributors". In the Western Cape, energy (all forms) use by the agricultural sector was around 1% in 2013, but energy-related emissions (CO2e) were 3% (DEA&DP, 2013). When only electricity is taken into account, proportional use by agriculture in the province came to around 6%.

However, these figures are higher in the rural districts with intensive agriculture: agriculture uses 9% of energy (23% of electricity, 10 times the national average) and is responsible for 16% of GHG emissions in the Cape Winelands District. These trends can be ascribed to the electricity needs of agro-processing (e.g. dairies, wineries, fruit packaging and processing, abattoirs) particularly in the Drakenstein Municipality. In the West Coast district, agriculture accounted for 1% of energy use (3% of emissions) and 10% of electricity use. Thus, agriculture in the BRC is significantly more electricity-intensive than the national average, reflecting the high value-added.

Energy use in agricultural value chains

The recent analysis by Notten et al. (2014) reveals quite varied energy-use patterns between the farm, food processing and retail stages of the value chain for different foods, and a general tendency for energy use to be concentrated at earlier stages of the value chain, particularly before the farm gate. The authors considered the direct energy use of the food and agriculture industries (electricity and fuel), as well as the energy needed by other industries in order to produce important material inputs like fertilizer and packaging.

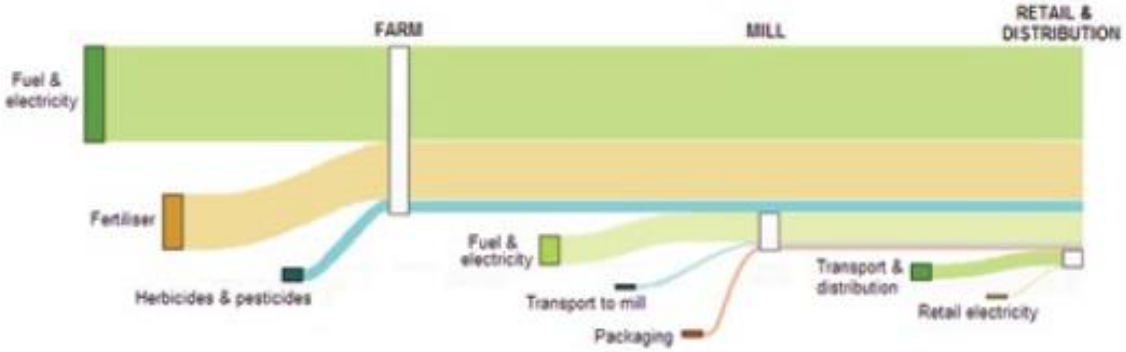


Figure 15 Life-cycle energy use in the maize meal value chain. Source: Notten et al., 2014

Maize is not widely grown in the BRC but is included here to broadly represent staple grains for milling (Fig. 15). Dryland maize farming requires fuel for soil tillage, crop management and harvesting operations. Maize also requires high fertiliser inputs. After the farm, maize requires energy-intensive milling to produce refined maize meals After milling and packaging, the maize meal is transported to retail outlets, where electricity consumption such as lighting and air-conditioning make a minor contribution to the total value chain energy. The analysis shows that the dominant energy consumption occurs before the mill, primarily from the production of fertilizer and on-farm energy use.

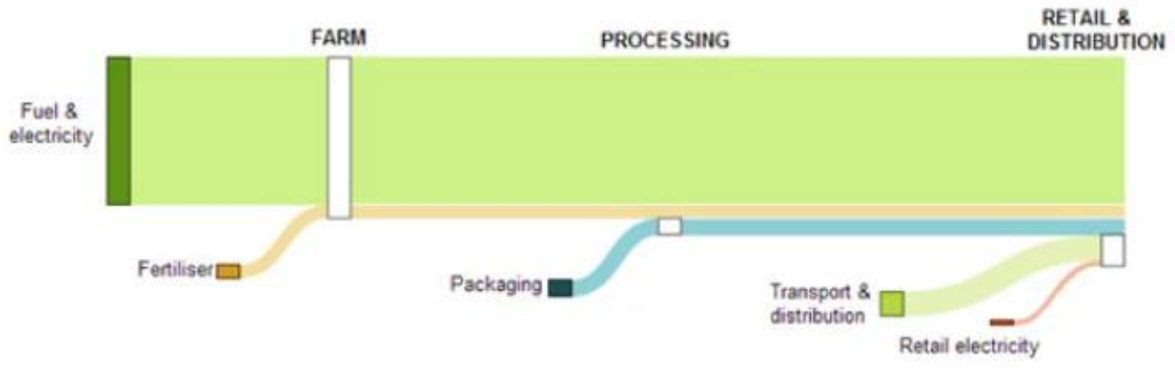


Figure 16 Life-cycle energy use in the potato value chain. Source: Notten et al., 2014

Potatoes are intensively produced under irrigation in the Sandveld (West Coast), parts of which fall within the BRC. Potato farms use fuel for ploughing and harvesting, and electricity for pumping water (Fig. 16). Farmers also apply nitrogen fertilisers that are produced in energy-intensive processes. The analysis shows that the bulk of the energy inputs occur before the farm gate. On-farm energy makes a much larger relative contribution to potato production than maize on a per-kilogram basis, which can be explained by the greater requirement for traction energy in ploughing and harvesting, extensive use of irrigation, and the high water content of potatoes that reduces their fertiliser requirement.

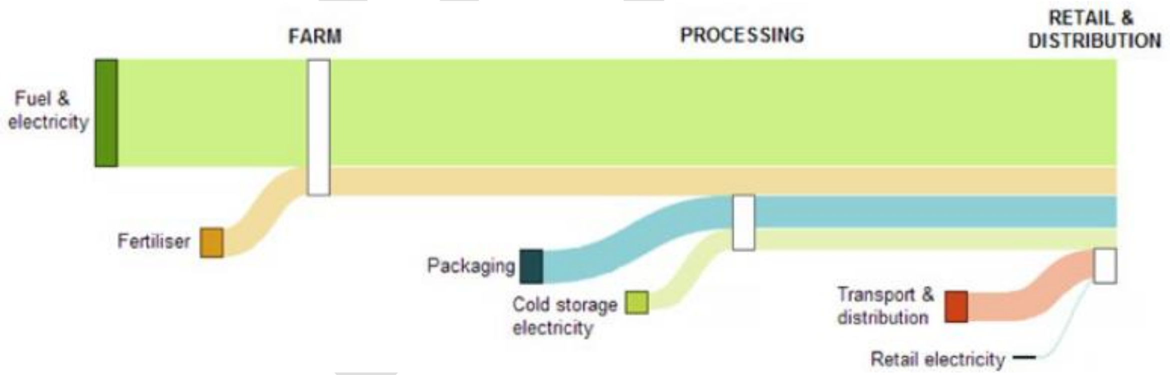


Figure 17 Life-cycle energy use in the apple value chain for the domestic market. A cold storage period of two months is assumed; in practice this can be up to one year, and most fruit is exported, thus escalating the energy use for cold storage. Source: Notten et al. 2014

For irrigated apples, less fuel is required in tillage, sowing and harvesting, although fuel is still required for orchard management (e.g. planting, pruning) and harvesting (Fig. 17). New apple orchards also take several years to produce fruit, during which time they still require management and add to a farm's energy requirements. Apples are harvested seasonally and stored under refrigeration for extended periods to provide a year-round supply to the market. The analysis reveals that the energy profile of the apple value chain is broadly similar to that of the other crops, but with a distinctively higher energy contribution from later stages. This is primarily due to the energy implications of extended cold storage and the cold chain requirements of transport and distribution. Packaging also makes a relatively larger contribution to apples than to potatoes or maize.

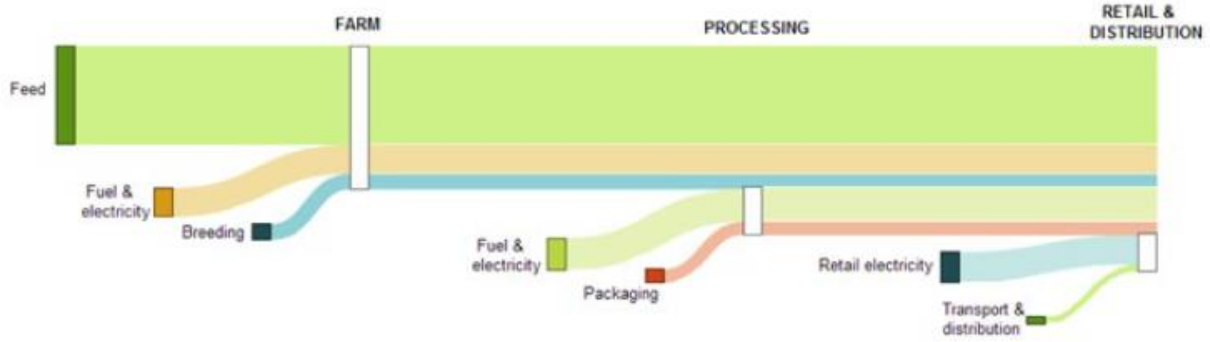


Figure 18 Life-cycle energy use in the chicken value chain. Source: Notten et al. 2014

The "farm" stage of the chicken value chain is an intensive grow-out facility, which receives day-old chicks from a hatchery and houses and feeds them for a period of about 42 days, at which time they are ready for slaughter. Grow-out facilities use energy for ventilation, temperature control and lighting, among other purposes (Fig. 18). This case study considers the supply of an oven-ready whole bird, cling-wrapped in a polystyrene tray. The relevant processing stages include slaughtering, cleaning and packaging the carcass. A continuous cold chain operates between the processing facility and the retail outlet, including refrigerated display.

Feed is a major energy component in the chicken value chain, and this typically has a maize content of over 50%, so an indication of the energy breakdown of the feed supply can be inferred from the maize farm inputs. The requirement for in-store refrigeration is clearly evident in the retail electricity component (as a relative comparison).

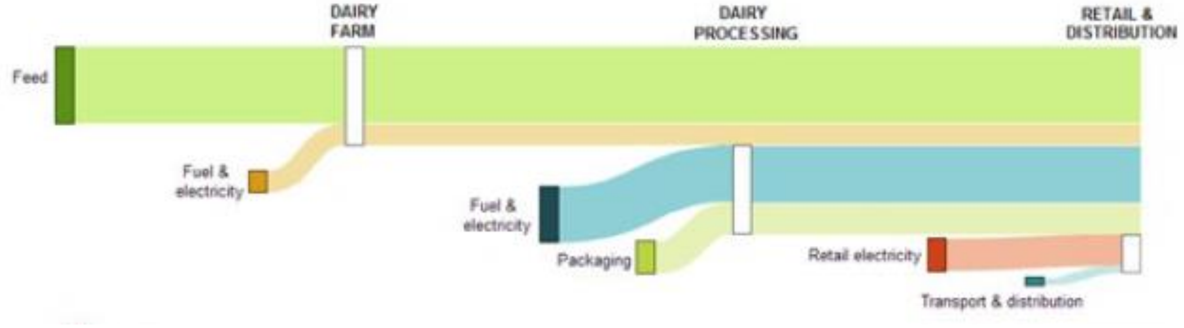


Figure 19 Life-cycle energy use in the dairy value chain. Source: Notten et al. 2014

Dairy production is complex and a number of stages in the value chain are energy intensive (Fig. 19). Feed for the herd of cows is a major input, which includes purchases of straw, single feed ingredients and formulated feed concentrates. Concentrates are formulated dairy feed rations that, in common with chicken feed, will usually have a large maize component. In addition to purchased feed, many dairy farmers maintain pastures and grow supplementary feed crops on the farm. Direct energy consumption therefore includes some of the irrigation and fuel use in common with crop growing, added to the energy requirements for milking sheds, refrigeration and other needs.

At the dairy, raw milk is processed to yield a wide variety of dairy products. This case study follows the production of one litre of full-cream milk, which involves transport from the farm to a processing facility in a refrigerated tanker, pasteurisation and packaging in plastic bottles, with temperature control maintained throughout. Direct energy use includes steam raising, refrigeration and pumping. From the dairy the packaged milk is transported in refrigerated trucks and placed in refrigerated display units at the retail store.

As for chicken production, animal feed purchases are the largest life-cycle energy contributor, but because of on-farm pasture and feed cropping and the high energy requirements for processing, it represents a considerably smaller proportion of the total.

Carbon footprint of fruit and wine

The Confronting Climate Change (CCC) Project is an on-going strategic industry initiative aimed at supporting the South African fruit and wine sectors' efforts to effectively respond to the challenges posed by climate change (www.climatefruitandwine.co.za). A key theme of the project is the provision of a freely available on-line carbon emissions calculator together with the technical training supporting its adoption and use. The aim is to enable farms, packhouses, wineries and other "actors" across the supply-chain to undertake accurate measurement of the energy-use and carbon-emissions intensity of their respective business activities. Such measurement is generally accepted as a prerequisite for the effective management towards greater resource-use efficiency, reduced emissions and the long-term sustainability of business activities and operations.

A major milestone of the project is the development of robust and representative industry benchmarks of the carbon-emissions of each major commodity. Against these benchmarks individual businesses can evaluate their own results, and the collective profile of the industries can be developed and their performance tracked over time. The process of benchmarking supports credible industry-level reporting as well as supporting the identification of opportunities for improvement and best-practice at the business-level. Updates on this data analysis will be done bi-annually using the approved datasets that are added through the workshop data collection process.

After three years, the database analysis shows significant contributions from grid-supplied electricity (for the pumping of water and for cold storage), followed by fuel (mainly diesel consumption on-farm and for transport) and nitrogen-based synthetic fertilizers (CCC, 2013). Detailed results will be made publicly available in 2014.

Options for the reduction in carbon-intensive energy use are under investigation by a number of researchers and industry practitioners. Energy audits and subsequent interventions have delivered significant savings. The most common approach is the switching to renewable energy for pumping, storage and packaging, as well as the installation of variable speed drives for irrigation.

Energy for food preparation

Across the BRC, around 90% of households use grid electricity for cooking. With 5-8% using gas or paraffin (Statistics South Africa: http://beta2.statssa.gov.za/). Research suggests that household expenditure for the energy costs of cooking is roughly equivalent to the cost of energy used to produce the raw food (Notten et al., 2014). This is an important consideration for the energy-food security nexus component.

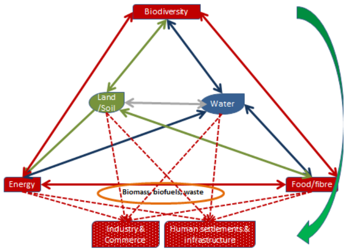
Future risks

- Energy supply cannot keep up with demand, leading to continued uncertainty of supply, and interruptions and rolling blackouts;
- Continued steep increases in energy prices reduce competitiveness and deter investment in the agricultural sector;
- Renewable energy generation does not deliver to expectation owing to a sub-optimal regulatory framework and lack of investment;
- Export markets drive the need to reduce embedded carbon in agricultural produce from the region, and measures taken e.g. taxation, have negative impacts on competitiveness;
- Climate change (warming) drives up the energy needs for cold chains of perishable products;
- A weakened agricultural sector leads to reductions in food production, thus risking shortfalls and rising food insecurity as well as job losses.

Key opportunities

Renewable energy can contribute to sustained profitability of farming, retention of export markets (through reductions in the carbon footprint) and even provide an income stream in a diversified farming portfolio. Energy efficiency can be improved by optimizing pumps and other equipment. Reductions in diesel and fertilizer use through conservation agriculture methods reduce the carbon footprint and save costs.

4.7 Agriculture and food waste for energy security



KEY FACTS

- There are two commercial biogas projects on farms in the Berg WMA, one based on cow dung (dairy) (3 MW capacity) and the other on mainly chicken manure since the volume of grape pommace is too low (winery);
- Chicken manure has twice the biogas production potential of cow manure;
- One tonne of grape pommace can produce approximately 828 kWh of renewable electricity.

The national and provincial biofuel policies do not currently permit the use of food feedstocks such as grains for the production of bioenergy, and there are currently no applications for biofuel projects in the BRC area.

Agriculture can, however, contribute to energy production through the conversion of biological waste to biogas (methane) using wet organic waste such as manure, abattoir waste, solid wastes (skins, pulp) from wineries, solid wastes (skins, pulp) from fruit juice and vegetable processing factories, and unsold fruit and vegetables and other food waste (DOA, 2010). Large enterprises such as dairies, piggeries, chicken farms, feedlots, other year-round factories and large food retailers are best suited since an assured and sustainable minimum supply of waste is required. However, small-scale biogas digesters are also available and are suited to a cluster of small households with livestock or other sources of waste.

A secondary benefit is that the treated effluent can be used for irrigation. Also, the sludge that is generated once the energy has been extracted still contains a significant amount of organic material, and all the fertilizer nutrients that were fed to the digester, and may be applied as a slurry or dewatered and converted to a granular natural fertilizer.

This study identified only one current commercial biogas projects on farms in the BRC, and one just outside the borders of the BRC but within the Berg WMA:

1. Malmesbury: The project is located on one of SA's biggest dairy farms, Vyvlei Dairy farm owned by Morester, which supplies milk to Clover from an estimated 7,000 dairy cows permanently residing on the farm. The targeted electricity generation capacity of the biogas plant is 3 MW, expected to come on stream by 2014. The location provides (i) proximity to key fuel supplies, (ii) grid access and (iii) sufficient water supplied by water collection dams, boreholes and small streams.
2. Simondium (although this is just outside the BRC): Backsberg Estate Cellars has an installed biogas digester on site and is the only carbon neutral winery in South Africa. Chicken manure is the main feedstock currently used in the biogas digester as the current total tonnage of grape pomace is considered too low (Dillon, 2011). Chicken manure has a high production potential of 80L of biogas per kilogram compared to 40L of biogas per kilogram produced from cow manures and faeces.

The production of biogas can generate renewable energy as follows (Dillon, 2011):

- One cubic metre of biomethane contains approximately 10kWh of chemical energy.
- Biogas contains approximately 60% biomethane and therefore one cubic meter of biogas contains approximately 6kWh of chemical energy. To convert this to electrical energy, a co-generation engine can be used to produce both heat and electricity.
- Since one metric tonne of grape pomace will produce approximately 230 cubic metres of biogas, one tonne of grape pomace should produce approximately 828kWh of renewable electricity.

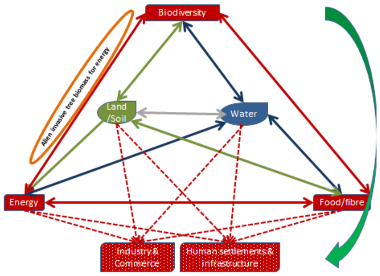
Future risks

- The regulatory environment continues to place barriers to investment in biogas plants;
- The water requirements cannot be met at local scale to make projects feasible.

Key opportunities

Biogas energy can contribute to sustained profitability of farming, retention of export markets (through reductions in the carbon footprint) and sustainable waste management solutions.

4.8 Alien biomass for energy security



KEY FACTS:

- Wood from alien invasive trees is a source of energy with a ready market (wood chips)

The upper catchment and riparian zones of the BRC remain heavily invaded by alien plant species, many of them trees. The cost of clearing these trees is enormous but this can be offset by using the cleared biomass as a commercially viable energy product. The Western Cape Department of Agriculture, through its Land Care programme, has launched a project to convert removed alien tree biomass into wood chips which are sold on the export and local market. Wood chips are an effective source of bioenergy (through direct combustion or gasification) and can be used in various industrial processes. The project is operational along the riparian zone of the Berg River near Hermon and Kersefontein.

Tree felling does, however, contribute to carbon emissions, although the figures in this case are likely to be negligibly small. The Western Cape is arguably in any case not suited to the strategy of maintaining or planting large numbers of trees as a carbon mitigation strategy, and the negative impacts of alien trees almost certainly far outweigh the potential mitigative benefits.

This example speaks to various components of the FEWLB Nexus in the BRC:

- Ecosystem and biodiversity rehabilitation, especially in catchments and along river banks
- Rehabilitation of hydrological processes and water flows
- Freeing up productive land for other uses
- Contribution to renewable energy
- Economic contribution for land owners
- Job creation

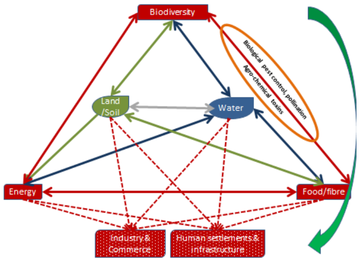
Future risks

- Variable export market conditions
- “Once-off” clearing of one area followed by relocation to a new site – thus requiring inputs and cooperation from multiple land owners and role players, and mobility of labour
- Input costs exceed returns thus making projects dependent on continued external funding
- Success with existing alien stands may encourage land owners to plant these species – this would require careful environmental studies and regulation

Key opportunities:

Diversification of income for landowners with large tracts of alien infestation.

4.9 Biodiversity for agriculture and food security; impacts on biodiversity



KEY FACTS:

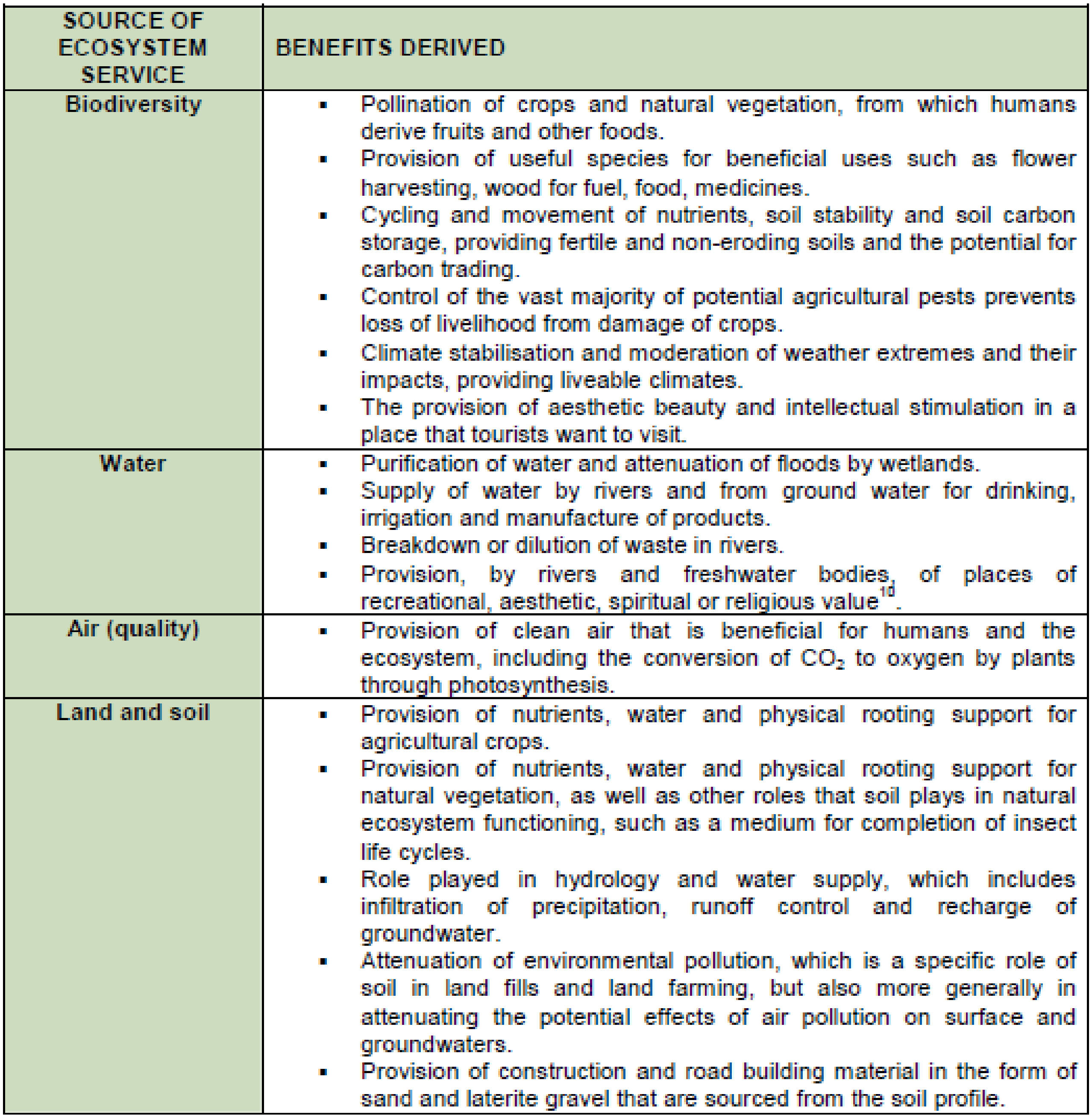
- The fynbos flower industry is vitally dependent on the genetic richness of the fynbos flora;
- Integrated Pest Management (IPM) used by many BRC farmers seeks to work with natural predators to control agricultural pests;
- The Cape Honeybee is a critical pollinator of deciduous fruit and vegetable crops and is dependent on fynbos as forage in the off-season;
- The Biodiversity and Wine Initiative (BWI) has facilitated the conservation of 130,000 ha of natural vegetation; for every hectare placed under vineyard, an additional hectare of natural vegetation is committed to conservation.

As in the case of water security, the inter-linkages between biodiversity & ecosystems and agriculture/food security relate to ecosystem services. Most importantly, healthy ecosystems and biodiversity benefit agriculture through the provisioning and regulation of water, both surface and groundwater. The economic value of ecosystem services is not well understood and estimates for South Africa have been made at national level and sometimes local level (e.g. City of Cape Town), but figures are not specifically available for the BRC.

Ecosystems provide genetic resources which are exploited by farmers. In the BRC (and wider fynbos biome), the fynbos cutflower industry is growing at a healthy pace, and is providing a viable option for farmers in areas with nutrient poor soils and limited water resources, not suited to intensive fruit, grain or livestock production.

The main commercially grown fynbos flowers are members of the Proteaceae (*Protea*, *Leucadendron*, *Leucospermum*, *Serruria*), but *Brunia*, *Chamelaucium* and others (*Phylica*, *Erica*) are also grown. Flowers are both cultivated and harvested in the wild on farms and in the mountains (under a permit system), but in the western production cluster (which includes the Berg River catchment) production is entirely cultivated. The vast majority of product (around 90%) is exported, with the balance split between the florist industry, local supermarkets, the street trade and sales directly to the public. There are strong signs of continued growth in the near future, since one in four hectares of fynbos orchards are not yet in production.

Table 2 The ecosystem services provided to the people of the Cape Winelands District. ***Source: de Wet and Audouin, 2007.***



SOURCE OF ECOSYSTEM SERVICE	BENEFITS DERIVED
Biodiversity	▪ Pollination of crops and natural vegetation, from which humans derive fruits and other foods. ▪ Provision of useful species for beneficial uses such as flower harvesting, wood for fuel, food, medicines. ▪ Cycling and movement of nutrients, soil stability and soil carbon storage, providing fertile and non-eroding soils and the potential for carbon trading. ▪ Control of the vast majority of potential agricultural pests prevents loss of livelihood from damage of crops. ▪ Climate stabilisation and moderation of weather extremes and their impacts, providing liveable climates. ▪ The provision of aesthetic beauty and intellectual stimulation in a place that tourists want to visit.
Water	▪ Purification of water and attenuation of floods by wetlands. ▪ Supply of water by rivers and from ground water for drinking, irrigation and manufacture of products. ▪ Breakdown or dilution of waste in rivers. ▪ Provision, by rivers and freshwater bodies, of places of recreational, aesthetic, spiritual or religious value[1d].
Air (quality)	▪ Provision of clean air that is beneficial for humans and the ecosystem, including the conversion of CO_2 to oxygen by plants through photosynthesis.
Land and soil	▪ Provision of nutrients, water and physical rooting support for agricultural crops. ▪ Provision of nutrients, water and physical rooting support for natural vegetation, as well as other roles that soil plays in natural ecosystem functioning, such as a medium for completion of insect life cycles. ▪ Role played in hydrology and water supply, which includes infiltration of precipitation, runoff control and recharge of groundwater. ▪ Attenuation of environmental pollution, which is a specific role of soil in land fills and land farming, but also more generally in attenuating the potential effects of air pollution on surface and groundwaters. ▪ Provision of construction and road building material in the form of sand and laterite gravel that are sourced from the soil profile.

Cultivation practices are becoming increasingly intensive, and this includes selection and breeding for suitable traits. The gene bank provided by the fynbos flora is a critical resource for horticultural breeders. For example, it can provide clues for pest and disease resistance and climatic tolerance, particularly pertinent in the face of climate change. From this point of view, conservation of the genetic pool has significant benefits for agriculture.

Ecosystems and their complex food webs also provide a diversity of natural predators which can be beneficial for pest and disease management on farmland. Integrated Pest Management (IPM) is an established and widely used approach on fruit farms in the BRC, whereby natural predators are allowed to keep crop pests in balance, with targeted chemical interventions based on careful monitoring being permitted only when the balance is seriously disturbed.

Of particular importance for the agricultural economy of the Western Cape is the pollination of most deciduous fruit and many vegetable crops by the Cape honeybee. This bee species is only found in the Western Cape and parts of the Eastern Cape (effectively in the Fynbos biome). Farmers requiring pollination services generally pay commercial beekeepers to place sufficient numbers of hives in orchards and fields during the pollination period. Beekeepers in the Western Cape use fynbos and *Eucalyptus* stands (aliens) as an important forage resource for their managed bees at other times of the year (SANBI, undated). They also use canola or lucerne fields as forage, and often trap wild swarms in these regions. Managed honeybees often abscond from hives to become wild again, and therefore the wild and managed populations are really one population.

While the Cape honeybee is officially classified as not threatened, it is experiencing threats, including diminishing forage resources, pests and diseases, as well as problems arising from misuse of pesticides and insecticides in the environment.

Some of the most threatened ecosystems of the BRC, such as Renosterveld and lowland fynbos, occur in the midst of agricultural land and remain under threat from farming expansion and practices. Since 2004, the wine industry has developed a partnership with key local and international conservation bodies (under the leadership of WWF) called the Biodiversity and Wine Initiative (BWI). While the primary goal is to protect natural habitats on privately owned wine farms, it also encourages wine producers to farm sustainably. Some 130,000 ha of natural area have so far been conserved by BWI producers, greater than the current vineyard footprint of 102,000 ha (www.wwf.org.za). For every hectare under vineyard, an additional hectare of natural vegetation is committed to conservation. The Initiative recognizes that protection of ecosystems and biodiversity benefits not only the natural system but also protects vital ecosystem services which underpin sustainable agriculture.

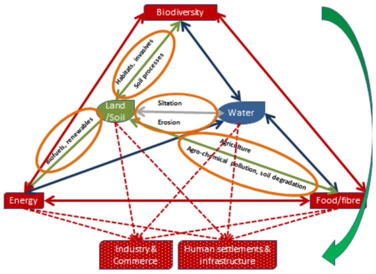
Future risks

- Degradation of natural ecosystems on farms and surrounding farmland, through farmland extension, habitat fragmentation, continued invasive alien infestation, agro-chemical pollution and incorrect waste disposal, with negative feedbacks on agricultural production potential;
- Loss of species and thus genetic resources for climate-adapted cultivated crops;
- Decline or loss of Cape honeybee colonies due to disease, agro-chemicals or other threats, resulting in reduced crop yields;
- Decline or loss of natural predators of agricultural pests resulting in outbreaks.

Key opportunities

Sustainable farming in collaboration with the environment and conservation sector can support agricultural production potential and is an effective marketing strategy in the export market.

4.10 Land: linkages to biodiversity, agriculture/food and energy



KEY FACTS:

- The BRC comprises 24% urbanized areas, 60% agricultural areas, 1% forestry areas, and only 2% of the catchment area remains natural;
- Between 1986/7 and 2007 there was an expansion of artificial bare areas (25%) and urban vegetated areas around urban centres (202%) – this represents accelerated urban expansion and golf course developments; this pressure is expected to continue in future;
- Land use changes have resulted in the loss of and increasingly threatened state of lowland biodiversity, especially Renosterveld which is now restricted to 5% of its original area;
- Large tracts of land (13% of catchment area) are heavily infested with alien invasive plants;
- Land use changes from natural vegetation to agriculture, on some shales in the mid-catchment, has resulted in salinisation of the soil;
- Land requirements for wind farms of 60-90 MW capacity are around 2200 – 2800 ha;
- Conservation Agriculture is being increasingly adopted by Swartland grain farmers.

This Landsat scene taken during winter 1998 illustrates the degree of development in the Berg River catchment (Fig. 20). The prominent orange-red colour indicates crop and stock farming areas, much of which comprises dryland grain farming. Some bright pale blue areas also represent agricultural areas, but suggest a different crop type or soil moisture status. The rusty brown-green colour east of Langebaan is also prominent and represents sandy recent deposits with little or no crop farming. Much of this area has been invaded by alien vegetation. The light brown colour in the upper parts of the catchment in the vicinity of Wellington and southwards signify intensive vine and fruit farming while light blue areas in the high lying parts of the catchment demarcate outcrops of hard, resistant rock of the Table Mountain Group (TMG). These areas are characterised by fynbos vegetation and a thin or absent soil cover. These high lying areas are the few remaining remnants of natural vegetation in the catchment.

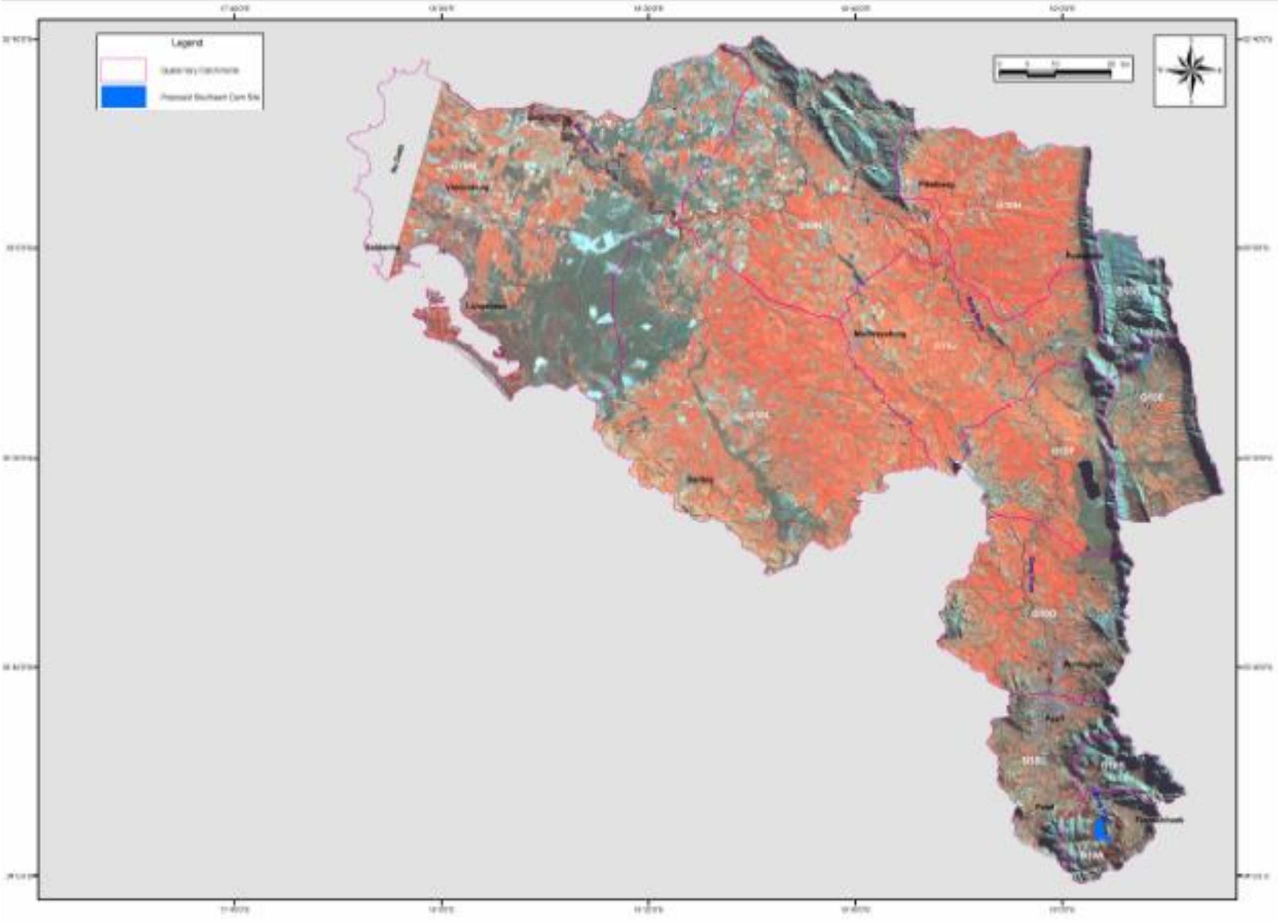


Figure 20 Landsat-TM Scene 175/83 of the Berg River catchment. Source: DWAF, 2007a.

The Berg River catchment comprises about 62% area developed for agricultural purposes. The main land use within the catchment consists of intensive and extensive agriculture, plantation forestry in the high altitude high rainfall areas, commercial industries, residential areas and protected areas.

Land in the upper Berg River area is primarily used for wine farming, with some deciduous and citrus fruit and table grape farming. Commercial indigenous cutflower fynbos production (Protea and others) is practiced, particularly in the areas of Paarl, Porterville and Hopefield. Flowers are grown on farms (sometimes under irrigation) or harvested wild on the farms or in mountain regions (under permit).

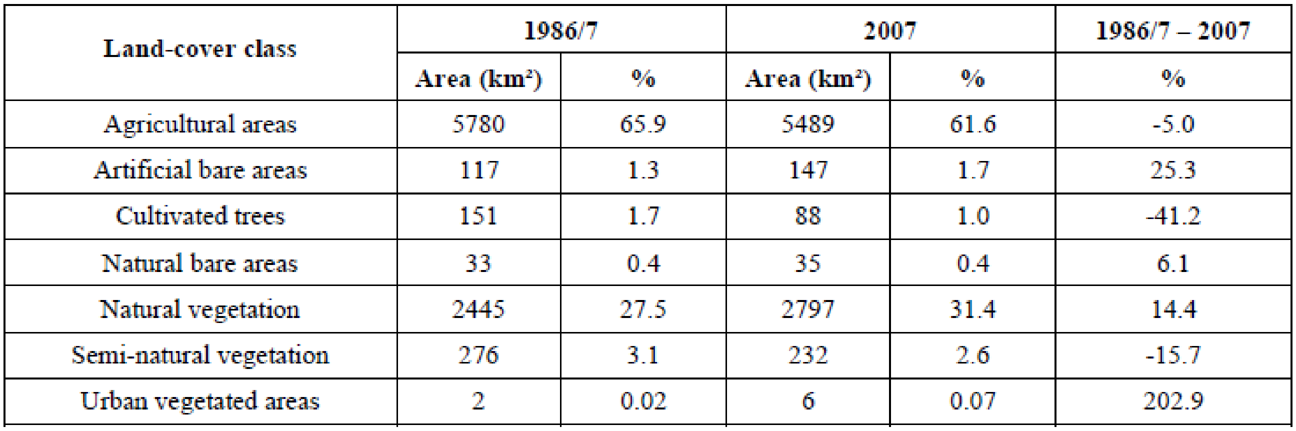
Much of the area south and west of the Berg River Dam in the uppermost catchment near the source, remains largely in a natural state and comprises mountain fynbos. However, sizable areas are infested with alien vegetation of high density. A concerted effort is being made by a number of government agencies and land owners to remove all alien vegetation within the catchments.

In the middle catchment, some forestry (1%) is found east of Voëlvlei Dam in the Witzenberg area. In the middle and lower Berg River area, land use transitions from wine and fruit farming to winter grains grown under dryland conditions, and stock farming (sheep and cattle). Only the Groot Winterhoek wilderness area remains in an essentially natural state, whilst overall only 2% of the total catchment area is natural. A high density of alien vegetation exists (13% of the total catchment area), much of it in the lower catchment area around Langebaan, Langebaan Road and Hopefield.

Recent land use change

A study by Stuckenberg et al. (2013), using multi-temporal remote sensing land cover change detection techniques, found that the Berg River catchment experienced a significant increase (14%) in area under natural vegetation from 1986/7 to 2007 (Table 3, Fig. 21). Other significant changes included the expansion of artificial bare areas (25%) and urban vegetated areas (202%) around urban centres. This can be ascribed to accelerated urban expansion and golf course developments. The extent of commercial forestry (cultivated trees) in the upper reaches of the catchment was reduced by 41%.

Table 3 Land-cover changes in the Berg River Catchment between 1986/7 and 2007. Source: Stuckenberg et al., 2013.



Land-cover class	1986/7		2007		1986/7 – 2007
	Area (km²)	%	Area (km²)	%	%
Agricultural areas	5780	65.9	5489	61.6	-5.0
Artificial bare areas	117	1.3	147	1.7	25.3
Cultivated trees	151	1.7	88	1.0	-41.2
Natural bare areas	33	0.4	35	0.4	6.1
Natural vegetation	2445	27.5	2797	31.4	14.4
Semi-natural vegetation	276	3.1	232	2.6	-15.7
Urban vegetated areas	2	0.02	6	0.07	202.9

A 5% decrease in agricultural areas translates to a reduction of about 290 km², much of which occurred in areas of marginal agricultural potential. However, caution should be used when interpreting these results as lengthy fallow periods are practiced in the lower catchment. Natural vegetation reclaimed from previously cultivated areas (agricultural areas, cultivated trees) is unlikely to exhibit as rich a compositional diversity as do areas of pristine vegetation cover.

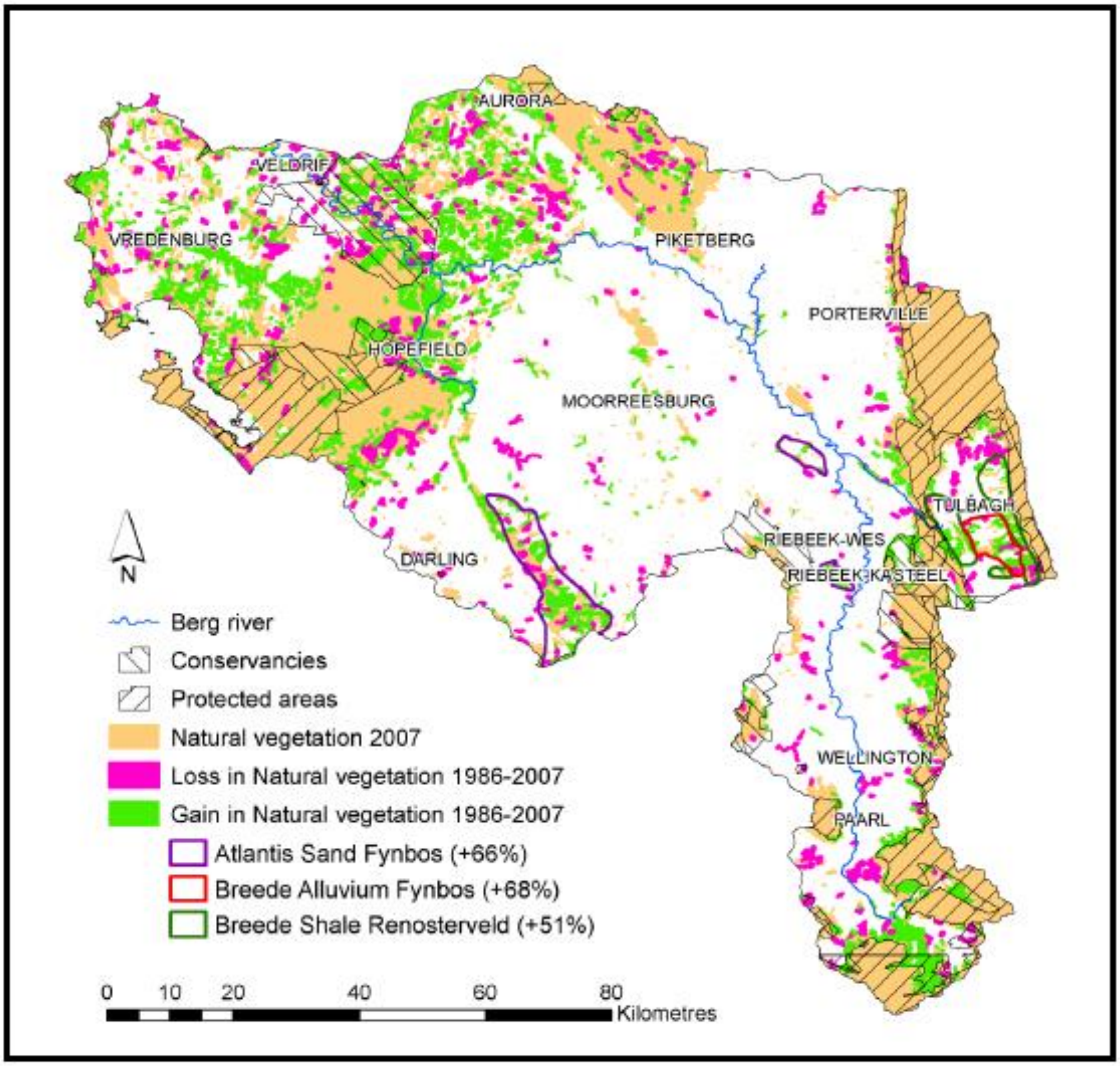


Figure 21 Gains and losses in natural vegetation from land cover change analysis indicating protected areas and conservancies in the Berg River catchment. Source: Stuckenberg et al., 2013

The following changes in land use are likely to occur in future (DWAF, 2007b):

- Limited increases in irrigated areas along the Berg River, perhaps growing at between 1% and 2% per annum, but depending global market conditions and possible trading in water rights between the urban and irrigation sectors;
- Paarl/Wellington and Malmesbury are expanding at high rates, as is the Saldanha/Vredenburg area due to the establishment of industries and the growth in the property market;

- The afforested areas will probably be retained, other than possibly within the catchment areas of Wemmershoek Dam and the Berg River Dam (where significant clearing has already occurred).

Within the FEWLB Nexus framework, it will also become necessary to consider the availability of land for the siting of renewable energy plants, as well as other possible developments. Already:

- Land cover is highly transformed and only areas which are too remote, too steep or very unproductive have not been transformed for agriculture or urban development;
- Land use change has been responsible for the loss of, and current threatened status of high numbers of species, notably in the lowland vegetation types (especially Renosterveld);
- Large tracts of land are heavily infested with alien invasive plants especially in the unproductive sands of the West Coast around Hopefield and in river valleys;
- Soil salinization is a problem in some parts of the basin especially where natural vegetation on marine-origin shales has been converted to dryland cropping;
- Erosion, especially of riverbanks, is a serious problem which leads to loss of land and siltation of the river courses and floodplain.

The area of land required for wind farms solar farms is an important consideration and the current trend is to use farmland. The West Coast One wind farm near Vredenburg will have a cluster of up to 55 wind turbines over an agricultural area of approximately 2800 ha. The EIA advised that some turbines would have to be moved to avoid pockets of natural vegetation, sensitive wetlands and the Kasteelberg which is a heritage site and raptor breeding site.

The Hopefield wind farm comprises 37 wind turbines on some 2200 ha of farm land. The environmental impact assessment revealed that the area consists of high biodiversity but low conservation activities. The private developer has committed to set aside the southern part of the site (ca. 1000 ha) to be managed as a formal conservation area in order to maintain and improve the site's biodiversity value.

The Aurora-Rietvlei solar park, comprising 35000 PV panels on fixed frames, has been developed on 65 ha of a 200 ha section of farm land (previously used for potato production). In this case too, sensitive wetlands had to be taken into account (Haiden et al., 2014). The SlimSun (Swartland) solar park near Darling has 25000 PV panels on approximately 7 ha. In all cases, proximity to an ESKOM grid connection point (power transmission lines and sub-stations) is important in site selection.

Land which is already transformed for agriculture requires farming management which conserves its productive potential. Swartland grain farmers are increasingly adopting

Conservation Agriculture (CA) as a farming approach with proven benefits for soil fertility, water holding capacity and reduced erosion.

Future risks

- Land scarcity pushes up prices and prevents new entrants into the economy from launching financially viable enterprises;
- Remaining patches of natural vegetation and biodiversity come under increasing pressure for development, and agricultural land comes under pressure from low-density lifestyle property developments;
- Future changes in the national and provincial policies on biofuels could open the door for biofuel production which would require conversion of current agricultural activities with possible implications for food production.

Key opportunities

Land use planning within the FEWLB Nexus can realize opportunities for optimalisation of land for economic, social and environmental needs; Land management (Land Care) and Conservation Agriculture.

5. Summary and opportunities

The following tables attempt to summarise the FEWLB Nexus inter-linkages in the BRC. First, Table 4 shows the current status of the inter-linkages, where column headings represent the "actor" or "supplier" (e.g. "energy for…" or "impact of agriculture on…") and row headings represent the "recipient". Shades of green represent positive inter-linkages and shades of red negative ones, with degree of inter-linkage indicated by shading as well as numbers of ticks or crosses. Light blue shading with "Negl." indicates currently negligible inter-linkages.

Table 4 Status of current FEWLB Nexus inter-linkages in the BRC

	Agr/F	**Energy**	**Water**	**Land**	**Biod.**
Agr/F		√√	√√√	√√√	√√
Energy	Negl.		Negl.	Negl.	Negl.
Water	XX	√		√√	√√
Land	XX	Negl.	√√		√√
Biodiversity	XX	Negl.	√√√	√√√	

Second, Table 5 shows the opportunities which exist for a positive strengthening of each FEWLB Nexus inter-linkage. Letters stand for key development or intervention opportunities and are listed in Table 6.

Table 5 Opportunities for strengthened positive FEWLB Nexus inter-linkages

	Agr/F	**Energy**	**Water**	**Land**	**Biod.**
Agr/F		E	H	L	P
Energy	A		I	M	
Water	B	F		N	Q
Land	C		J		R
Biodiversity	D	G	K	O	

Table 6 Key development opportunities or interventions. Rank key: 1 – very high priority; 2 –high priority; 3 – medium priority

Key development opportunity or intervention	Rank
A: Waste-to-energy (biogas)	2
B: Reduced impacts on water quality, increased water use efficiencies	1
C: Land Care, improved soil management e.g. conservation agriculture	2
D: Protection of natural areas, biodiversity-friendly practices	2
E: Renewable energy for agriculture	1
F: Renewable energy for water abstraction & other water-related processes	1
G: Reduction of bird strikes on power lines and wind turbines	3
H: Assured water allocations to agriculture and new entrants	2
I: Water for development of renewable energy components	3
J: Healthy hydrological processes on land	3
K: Implementation of the ecological reserve, improvement in water quality	1
L: Protection of productive agricultural land from other development	2
M: Identification of land suitable for renewable energy plants	3
N: Protection of water courses from siltation	2
O: Protection of currently unprotected threatened terrestrial ecosystems	2
P: Protection of species and ecosystem services critical for agriculture	2
Q: Protection and rehabilitation of catchments and riverine habitats	1
R: Protection of ecosystem services critical for soil processes and health	2

6. Conclusions and initial recommendations

Some of the Berg River FEWLB Nexus inter-linkages are well-known and reasonably well quantified, but in some important areas data are incomplete, fragmented, or not readily available. For example, the high water demand of agriculture and its significant dependence on this water are well-established, but detailed data such as actual water licenses and unlicensed extraction rates are not readily available. Water resources are central to the Nexus at catchment level but its strategic importance and national-level planning and governance make it more difficult to analyse and act on within the local Nexus context. In this aspect, a successful Nexus approach will require further efforts at improving inter-governmental cooperation between the three tiers of government and between sectors. Also, integrated monitoring of water use at catchment level and not only within the WCWSS is important.

Water quality issues cut across the FEWLB Nexus and the current efforts to address poor water quality in the BRC provide validation for the usefulness of the Nexus approach at catchment level. Current plans and programmes in other areas typically address only parts of the Nexus, often with some success, but generally stop short of a Nexus-wide approach. An exception is the Berg River Improvement Plan (BRIP) which is conceptualized and structured to improve water quality in such a way that it has the potential to deliver a Nexus-based outcome. This is an example where data is not comprehensive and is highly fragmented, but the BRIP has a focus on coordinating monitoring efforts and improving data systems. The BRIP should be strengthened and could serve as a pilot "Nexus implementation" project which could be replicated to other areas of the Nexus and scaled up to other catchments.

The issue of land availability and land use is also a cross-cutting one. Currently available data and maps of land characteristics and uses are excellent and much effort has gone into this. However, there is little evidence that this information resource is being applied in a Nexus-based integrated manner yet. This is an opportunity for a pilot project or case studies to test the Nexus approach for real-life spatial and land use planning processes.

The energy "arm" of the Nexus is not well aligned with the other "arms" and the inter-linkages are poorly researched and quantified. For example, the energy requirements of different types of resource extraction or economic development are generally assessed in individual project feasibility studies, with little consideration given to the other parts of the local or regional Nexus beyond the standard EIA. Data are scarce and dispersed for most inter-linkages involving energy although current research efforts are starting to fill these gaps. This can be ascribed to the relatively recent emergence of energy supply constraints and instability, as well as price shocks and the need for carbon mitigation. The opportunities provided by renewable energy within the Nexus are numerous and significant.

Although the value of biodiversity within the Nexus is acknowledged by most actors and the sector itself has a strong conservation research basis, some of the inter-linkages (often those loosely termed "ecosystem services" or "ecological infrastructure") require further quantification and analysis. The linkages between the removal of invasive alien plants, water flows and restoration of other ecosystem services and land uses are well established and form the basis for the country's highly successful Working for Water programme – this is also a good example of a "Nexus project" and it would be interesting to frame the WfW programme accordingly in order to showcase its wider impact. However, there is scarcity of data and analysis on the economic and social returns provided by conservation and maintenance of healthy ecosystems to other parts of the Nexus. This is particularly true in light of the projected impacts of climate change and the need to focus on building resilient systems.

7. References

Abrahams, F. 2011. The Western Cape to share in the development of renewable energy. AgriProbe, December 2011, pp. 27-28.

Anchor Environmental Consultants, 2008. Berg Estuary Management Plan Part 1: Situation Assessment. Report to CapeNature and the C.A.P.E. Estuaries Management Programme. 85pp.

Archer, E., Conrad, J., Münch, Z., Opperman, D., Tadross, M. and Venter, J. 2009. Climate change, groundwater and intensive commercial farming in the semi-arid northern Sandveld, South Africa. Journal of Integrative Environmental Sciences 6(2): 139-155. DOI: 10.1080/19438150902916589

Baleta, H. and Pegram, G. 2014. Water as an input in the food value chain. Understanding the Food Energy Water Nexus. WWF-SA, South Africa.

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., Steduto, P., Mueller, A., Komorg, P., Tol, R.S.J., Yumkella, K.K. 2011. Considering the energy, water and food nexus: Towards an integrated modelling approach. Energy Policy 39: 7896–7906.

CCC, 2013. Pome fruit industry report/Stone fruit industry report/Citrus industry report/ Table grape industry report/Wine industry report. Year 2: 2013 Carbon footprint benchmark report. Confronting Climate Change, A South African Fruit & Wine Initiative. Confidential.

Davis, M. 2014. Managing environmental systems: the water-energy-food nexus. SEI Research Synthesis Brief. Stockholm Environment Institute, Stockholm.

de Clercq, W.P., Jovanovic, N. and Fey, M.V. 2010. Land use impacts on salinity in Berg River water. Research on Berg River water management. Report to the Water Research Commission. WRC Report No. 1503/1/10.

De Villiers, S. 2007. The deteriorating nutrient status of the Berg River, South Africa. Available on website http://www.wrc.org.za. ISSN 0378-4738 = Water SA Vol. 33 No. 5 October 2007. ISSN 1816-7950 = Water SA (on-line).

De Wet, B. and Audouin, M. 2007. Strategic Environmental Assessment for the management of Ecosystem Services within the Cape Winelands District Municipal Area. Environmental Strategy & Strategic Environmental Management Plan. Draft. CSIR Report No. CSIR/NRE/RBSD/IR/2007/0052/C.

DEA&DP and DWA, 2011. Western Cape IWRM Action Plan: Status Quo Report Final Draft. Chapter 8: The Berg WMA. Department of Environment Affairs & Development Planning, Government of the Western Cape Province, and Department of Water Affairs, Government of South Africa, Cape Town.

DEA&DP and DWA, 2012. Western Cape Sustainable Water Management Plan. Department of Environment Affairs and Development Planning, Western Cape Government, and Department of Water Affairs, Government of South Africa, Cape Town.

DEA&DP, 2007. Sustainable Energy Strategy and Programme of Action for the Western Cape. Department of Environmental Affairs & Development Planning, Government of the Western Cape Province, Cape Town.

DEA&DP, 2010. White Paper on Sustainable Energy for the Western Cape Province. Department of Environmental Affairs & Development Planning, Government of the Western Cape Province, Cape Town. [Online] Available: http://www.capegateway.gov.za/Text/2010/7/white_paper_-_sustainable_energy_western_cape.pdf

DEA&DP, 2013. Energy Consumption and CO2e emissions Database for the Western Cape. Department of Environmental Affairs & Development Planning, Government of the Western Cape Province, Cape Town.

DEA&DP, 2014. Western Cape Climate Change Response Strategy (revised). Department of Environmental Affairs & Development Planning, Government of the Western Cape Province, Cape Town.

Deloitte, 2012. The Economic Impact of Electricity Price Increases on Various Sectors of the South African Economy. A consolidated view based on the findings of existing research.

Deutsche Securities, 2010. Eskom - The "shocking" truth. In: Deloitte, 2012. The Economic Impact of Electricity Price Increases on Various Sectors of the South African Economy. A consolidated view based on the findings of existing research.

Dillon, C. 2011. Waste management in the South African wine industry. Dissertation submitted in partial requirement for the diploma of Cape Wine Master.

DOA, 2010. Biogas technology as an alternative source of energy and a means of climate change mitigation in agriculture. Department of Agriculture, Provincial Government of the Western Cape, Programme: Agricultural Economics. Elsenburg.

DWA, 2013. WC WSS Reconciliation Strategy Status Report, October 2013. Department of Water Affairs, Government of South Africa, Pretoria.

DWAF, 2004. River Health Programme State-of-Rivers Report: Berg River System. Department of Water Affairs and Forestry Pretoria. ISBN No: 0-620-32075-3

DWAF, 2007a. Berg River Baseline Monitoring Programme Final Report - Vol. 1. Introduction to the Berg River Catchment; Groundwater and Hydrology. DWAF Report No. P WMA 19/G10/00/1707

DWAF, 2007b. Proposal for the establishment of the Berg Catchment Management Agency. Department of Water Affairs and Forestry, Government of South Africa, Pretoria.

DWAF, 2007c. Western Cape Water Supply System: Reconciliation Strategy Study. DWAF Report No. P WMA 19/000/00/0507.

ERC, 2013. Renewable energy choices and water requirements in South Africa. Draft report for submission to the Water Research Commission. Energy Research Centre, University of Cape Town, Cape Town.

Escobar, M. 2013. Sustainable Development in Fragile Ecosystems: Applying the 'Nexus' Approach to the Orinoco River Basin in Colombia. Discussion Brief. Stockholm Environment Institute, Davis, CA.

Field, C.B. et al. (Eds) 2014. Climate Change 2014: Impacts, Adaptation and Vulnerability. Summary for Policy Makers. Intergovernmental Panel on Climate Change 5th Assessment Report Working Group II (IPCC AR5 WGII). www.ipcc-wg2.gov

Görgens, A.H.M. and de Clercq, W.P., 2005. Research on Berg River water management. Summary of water quality information system and soil quality studies. WRC Report No : TT 252/05.

GWSP, 2014. Water Energy Food Nexus. Moving towards sustainability. Global Water News No. 14, May 2014, pp.1-40. Global Water System Project (GWSP). www.gwsp.org.

Haiden, S., Midgley, S.J.E. and New, M. 2014. The Food-Energy-Water-Land-Biodiversity (FEWLB) Nexus in the Berg River Catchment, Western Cape. A Synthesis of Stakeholder Perspectives. African Climate and Development Initiative, University of Cape Town.

Hoekstra, A.Y. and Chapagain, A.K., 2008. Globalization of water, Malden, MA: Blackwell.

Hoff, H. 2011. Understanding the Nexus. Background Paper for the Bonn2011 Conference: The Water, Energy and Food Security Nexus. Stockholm Environment Institute, Stockholm.

Hortgro, 2012. Key Deciduous Fruit Statistics 2012. Paarl. www.hortgro.co.za

HSRC and MRC, 2013. The South African National Health and Nutrition Examination Survey, SANHANES-1. Human Sciences Research Council and Medical Research Council. HSRC Press, Cape Town.

HSRC, 2008. The Impact of Electricity Price Increases and Rationing on the South African Economy. In: Deloitte, 2012. The Economic Impact of Electricity Price Increases on Various Sectors of the South African Economy. A consolidated view based on the findings of existing research.

Kotzé, J.D.F., Beukes, B.H., van den Berg, E.C. and Newby, T.S., 2010. National Invasive Alien Plant Survey. Report Number: GW/A/2010/21. Agricultural Research Council: Institute for Soil, Climate and Water, Pretoria.

Kotze, M. 2011. Protea Producers of South Africa Producer Survey Results. Hortgro Services.

Lawford, R., Bogardi, J., Marx, S., Jain, S., Pahl-Wostel, C., Knüppe, K., Ringler, C., Lansigan, F. and Meza, F. 2013. Current Opinion in Environmental Sustainability 5: 607–616.

Louw, D.B., Johnston, P., Tadross, M., Schulze, R., Lumsden, T., Callaway, M. and Helmuth, M. 2012. Managing climate risk for agriculture and water resources development in South Africa: Quantifying the costs, benefits and risks associated with planning and management alternatives. IDRC grant number: 104 150. University of the Free State, Department of Agricultural Economics; University of Cape Town, Climate Systems Analysis Group; University of Kwazulu Natal, School of Bioresources Engineering & Environmental Hydrology.

Nel, J.L., Driver, A., Strydom, W.F., Maherry, A., Petersen, C., Hill, L., Roux, D.J., Nienaber, S., van Deventer, H., Swartz, E. and Smith-Adao, L.B., 2011. Atlas of Freshwater Ecosystem Priority Areas in South Africa. Maps to support sustainable development of water resources. WRC Report No. TT 500/11.

Notten, P., Bole-Rentel, T. and N. Rambaran. 2014. Developing an understanding of the energy implications of wasted food and waste disposal. Understanding the Food Energy Water Nexus. WWF-SA, South Africa.

Pegasys, 2012. Western Cape Water in the Economy. Deliverable two: Appendices. Draft report to the Water Research Commission, WRC K5/2075.

Perrone, D. and Hornberger, G.M. 2014. Water, food, and energy security: scrambling for resources or solutions? WIREs Water 2014, 1: 49–68. doi: 10.1002/wat2.1004.

Provincial Government of the Western Cape, 2010. Delivering the open opportunity society for all. The Western Cape's Draft Strategic Plan. Department of the Premier, Cape Town.

Provincial Government of the Western Cape, 2013. Western Cape Green Economy Strategy Framework. Cape Town.

RCSD, 2008. Biogas manual. Green-farm technologies for small and marginal farms. Resources Centre for Sustainable Development.

Ringler, C., Bhaduri, A., Lawford, R. 2013. The nexus across water, energy, land and food (WELF): potential for improved resource use efficiency? Current Opinion in Environmental Sustainability 5: 617–624.

SANBI, undated. Global Pollination Project and Honeybee Forage Project South Africa: Profile: Mike Mac Intyre – Beekeeper. Project Implemented by the South African National Biodiversity Institute (SANBI) as part of the GEF/UNEP/FAO Global Pollination Project (GPP), also entitled "Conservation and Management of Pollinators for Sustainable Agriculture through an Ecosystem Approach". http://www.sanbi.org/sites/default/files/documents/documents/gpphfpprofilemacintyre.pdf

SATI, 2012. Statistical Booklet 2012. South African Table Grape Industry, Paarl. www.satgi.co.za

Savannah Environmental, 2010. Final Environmental Impact Assessment Report: Proposed West Coast One wind energy facility and associated infrastructure on a site near Vredenburg in the Western Cape Province, for Moyeng Energy (Pty) Ltd.

Statistics South Africa, 2011. Agricultural Survey 2011 (Preliminary). Statistical Release P1101. Pretoria.

Statistics South Africa, 2012. Electricity, gas and water supply industry 2010. Report No. 41-01-02 (2010). Pretoria.

Statistics South Africa, 2013. General Household Survey 2012. Statistical Release P0318. Revised: 4 October 2013. Pretoria.

Stuckenberg, T., Münch, Z. and van Niekerk, A. 2013. Multi-temporal remote sensing land-cover change detection for biodiversity assessment in the Berg River Catchment. South African Journal of Geomatics 2(3): 189-205.

Turner, A.A. (ed.) 2012. Western Cape Province State of Biodiversity 2012. CapeNature Scientific Services, Stellenbosch. ISBN: 978-0-621-41407-3

Van Vuuren, L. 2014. New desalination plant to keep ‘Diamond of the West Coast’ shining. The Water Wheel Jan/Feb 2014 Vol.13 Issue 1.

Volschenk, T., de Villiers, J.F., Beukes, O. 2003. The selection and calibration of a model for irrigation scheduling of deciduous fruit orchards. WRC report. 892.

Von Bormann, T. and Gulati, M. 2014. The Food Energy Water Nexus: Understanding South Africa’s most urgent sustainability challenge. WWF-SA, South Africa.

Wang, J., Rothausen, S.G.S.A., Conway, D., Zhang, L., Xiong, W., Holman, I.P. and Li, Y. 2012. China’s water–energy nexus: greenhouse-gas emissions from groundwater use for agriculture. Environ. Res. Lett. 7 014035. (http://iopscience.iop.org/1748-9326/7/1/014035).

Wesgro, 2011. Saldanha Bay IDZ Feasibility Study Revision 1. Cape Town.

Western Cape Government Provincial Treasury, 2012a. Regional Development Profile Cape Winelands District. Cape Town.

Western Cape Government Provincial Treasury, 2012b. Regional Development Profile West Coast District. Cape Town.

Western Cape Government Provincial Treasury, 2013. Municipal Economic Review and Outlook. Cape Town. PR300/2013. ISBN: 978-0-621-42298-6