Agriculture and biodiversity conservation in the South African water-stressed Kouga catchment

An inventory and integrated assessment relating land management and ecosystem services

Clara Veerkamp

May 2013

Facilitated by lovinglands

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MSc Thesis in Environmental Science

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This thesis finds its origin in my personal interest in understanding our relation with the environment and how we influence the (eco)system. Through Wageningen University, the contact was made to Living Lands, an NGO in South Africa. Living Lands is working towards sustainable land management and was planning to start working in the Kouga catchment. Because Living Lands was new to the area, limited information about the area was available and limited contact with the people living there existed. I liked the idea to contribute to this project and to be doing something which was really needed. In this way, I found myself in the role of making initial contacts with locals, collecting necessary information for my thesis research and creating a first picture of the situation in the Kouga catchment. I stayed for seven month in South Africa, combined my thesis research with my internship, which was followed by some more months at Lumen (WUR) writing my thesis report. The whole thesis process I would describe as a great learning journey with ups and downs. It was always more than 'just' writing a thesis. This process enriched and inspired me personally and professionally.

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Abbreviations

ARC	Agricultural Research Council
ArcGIS	Geographic Information System software product
BMR	Baviaanskloof Mega Reserve
BNR	Baviaanskloof Nature Reserve
CAPE	Cape Action for People and the Environment
CBA	Critical Biodiversity Area
CDC	Coega Development Cooperation
CFR	Cape Floristic Region
DWAF	South African Department of Water Affairs and Forestry
DEAT	South African Department of Environmental Affairs and Tourism
E2A	Eden to Addo Initiative
ECP	Eastern Cape Parks
FNR	Formosa Nature Reserve
Global GAP	Global Good Agricultural Practices
GNR	Groendal Nature Reserve
GRI	Garden Route Initiative
IUCN	International Union for Conservation of Nature
LL	Living Lands
NBSAP	National Biodiversity Strategy and Action Plan
NEMBA	National Environmental Management: Biodiversity Act
NMMM	Nelson Mandela Bay Metropolitan Municipality
NSBA	National Spatial Biodiversity Assessment
IB	Irrigation Board
IAPs	Invasive Alien Plants
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
STEP	Subtropical Thicket Ecosystem Planning
TMG	Table Mountain Group
WfW	Working for Water
WMA	Water Management Area
WoF	Working on Fire

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Summary

The South African Kouga catchment is renowned for its high agricultural productivity and unique and largely endemic biodiversity. The catchment also provides vital water for irrigation, consumption and domestic purposes to users within and outside the catchment. Water shortage, biodiversity loss and land degradation have long been recognized as important issues in the Kouga region. To deal with these issues, sustainable catchment-scale management is needed, but different ideas exist on how to achieve this, especially between farmers and nature conservationists.

The concept of ecosystem services potentially bridges economic and conservation interests. However, awareness and knowledge of the catchment's ecosystem services among different stakeholders, including scientists, is missing. This constrains catchment restoration and the development of innovative sustainable management options in the Kouga catchment.

This study aims to develop a comprehensive information base for the Kouga catchment and to analyse the relations between land management and ecosystem services. A review of scientific and grey literature and semi-structured interviews with experts, land owners and nature conservationists provided this study's qualitative data.

The Kouga catchment, which covers an area of 282,000 hectares, is extremely rugged due to high mountain ranges with acidic, nutrient poor and well-drained soils. Lower lying valleys have better developed soils. The catchment's climate is Mediterranean characterized by low rainfall but the large topographic variation result in strong rainfall differences. The catchment intersects three internationally recognised biodiversity hotspots, six biomes and many different vegetation types. The invasion of alien plants decreases biodiversity, especially along the main Kouga River. This river flows towards the Kouga dam, which is important for providing domestic and irrigation water to downstream users. Although farmers own most of the catchment's land, only a tenth is used for agriculture (i.e. extensive livestock farming and intensive fruit farming); the rest is non-agricultural land. Half of the catchment's vegetation is pristine and 55 % of this falls within state-owned protected areas. 42% of all land is degraded and 8% is transformed.

The literature review and expert opinion showed that the agricultural areas and riparian zones are severely pressed due to unsustainable farming practices and invasion of alien plants. However, farmers perceive their land as healthy (because high production) and regard alien plants as the main environmental threat because they cause water insecurity. The ecosystem services' analysis showed that the Kouga catchment has a great capacity to provide all ecosystem services. Stakeholders identified water supply, regulation and purification, and the prevention of floods, droughts and soil erosion as key ecosystem services. Local farmers also highlight the importance of fruit production, raw material (e.g. fuel wood and wool) supply and the catchment's recreation potential. Habitat services are mostly appreciated by nature conservationist. Nature conservation keeps the mountainous areas in good condition.

By comparing, cross-checking and integrating the findings of different studies an integrated overview of the Kouga catchment emerges. The resulting information base answers this study's central research question how land management and ecosystem services are related. Local water security and the two opposing views on the desired catchment management (biodiversity conservation vs. agricultural production) were important issues.

Local water security, which was identified by all interviewed stakeholders, depends on the catchment's capacity to regulate, purify and provide water, to prevent soil erosion and to mitigate droughts and floods. This capacity strongly decreased by high water abstraction, construction of dams, weirs and channels, conversion of natural land into cultivated land, livestock grazing and high

chemical input. Nature conservation, on the other hand, protects and restores natural vegetation and this has a large positive effect on local water security. Especially removing invasive alien plants positively influences these ecosystem services.

In general, land management in the Kouga catchment is guided by the two visions of agricultural production and biodiversity conservation. To optimize agricultural production, farmers have converted natural land into cultivated land (still on-going), use fertilizers, pesticides and herbicides in fruit farming, and frequently graze and burn grasslands. These farming practices threaten habitat and other services. This affects both long-term agricultural production and biodiversity protection. Measures to stimulate habitat services can reduce agricultural production negatively, because these measures entail reclaiming of land, removing structures, promoting limited fertilizer and pesticide use and reducing livestock. However, biodiversity conservation and especially removing alien plants, supports the catchment's capacity to provide the identified key services. Moreover, habitat protection also enhances pollination and pest and disease control. This benefits agriculture.

Integrating different methods and data resulted in a comprehensive information base for the whole Kouga catchment but also identified data and knowledge gaps. Especially the interviews with local land owners proved to be essential to collect specific data. Although quantitative data are lacking, observed trends are robust and provide a good basis for further research. The ecosystem services concept helped to identify key issues and disentangle complex relations. Understanding trade-offs between ecosystem functionality and land management could enhance communication among local stakeholders.

It can be concluded that agriculture is the main economic driver of the Kouga catchment and broadly recognized as very important for the catchment. However, while agriculture enhances food supply, it alters a range of other crucial ecosystem services on which it strongly depends itself. These changes in turn cause environmental decline, such as biodiversity loss, and also hamper long-term agricultural production. Nature conservation as an important management options, unfortunately often lacks acceptance among local people due to limited communication and collaboration, and lack of clear objectives. Conservation practices might on the short term decrease agricultural production, but they also support the catchment's capacity to provide crucial ecosystem services. Thereby, biodiversity is crucial for ecosystem functionality, which also benefits agriculture on the long-term.

To achieve sustainable management, all stakeholders in the Kouga catchment need to recognize the importance of both biodiversity conservation and agriculture, and the interdependence in terms of management measures and affected ecosystem services. The trade-offs between and consequences of all management practices and ecosystem functionality need to be communicated to raise awareness and stimulate cooperation between different stakeholders. Only this approach will help to identify the best practices for sustainable catchment management. As biodiversity instrumentally provide many ecosystem services, its protection and restoration is necessary. This needs to be integrated in current land management to ensure sustainability. Removing invasive alien plants could be a bridging element to start cooperation among the different groups because it directly benefits both biodiversity conservation and agricultural production in the Kouga catchment.

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1. Introduction

1.1. Background

South Africa is richly endowed with biodiversity and natural beauty. This is recognized by scientists and tourists. The country is currently ranked as “the third most biologically diverse country in the world” (Crane 2006). Nine biomes can be found in South Africa with a wide range of unique vegetation types, such as Succulent Karoo, Fynbos, Nama - Karoo, Thicket, etc. (Mucina and Rutherford 2006). This great diversity provides habitats for indigenous plant and wild animals, whereby especially many plant species are endemic to South Africa. Tourists from all over the world come to enjoy the spectacular natural beauty of the country. In fact, tourism, much of which is nature-based, accounts for about 10 per cent of South Africa’s GDP (NBSAP 2005). Especially the biological richness of the Cape Floristic Region characterized by its endemic Fynbos vegetation, the Succulent Karoo Biome and the Maputaland-Pondoland Region form a popular tourist attraction, due to the area´s internationally recognized “biodiversity hotspot” status (NBSAP 2005).

However, South Africa’s nature is under great pressure and the country faces the highest extinction rate in the world (Crane 2006). Forty percent of South African terrestrial ecosystems are currently threatened (Driver et al. 2012). Therefore, to safeguard the nation’s biodiversity, South Africa signed the Convention on Biological Diversity (CBD) in 1995. In total, 193 parties signed this international legally binding treaty, which aims primarily at the conservation of biodiversity (CBD 1992). In line with this, several research and projects have been set up in South Africa to restore and conserve the environment through policy, legislation and specific restoration actions.
The National Biodiversity Strategy and Action plan (NBSAP 2005) is such a policy plan and an example of a restoration action is the Working for Water program (WfW). This program has been implemented throughout the country to clear so-called Invasive Alien Plant species (IAPs). IAPs are seen as a major threat to native biodiversity (Driver et al. 2012). Additionally, water availability is also threatened by these exotic plant species because they generally consume a lot more water than native flora. As South Africa is a water-stressed country, any further pressure on water resources would have serious consequences for the health of ecosystems, but also for agricultural practices and human well-being. In this way, water security plays a crucial role for South Africa’s socio-economic development and nature conservation.
Water has been regarded as the most limiting factor to South Africa’s economic growth, especially for its agriculture (Blignaut et al. 2009). With the introduction of irrigation by the first European settlers, agricultural production expanded both in scale and in range of products. Today, the agriculture sector is dominated by large-scale farming providing a wide range of products, from fruits to crop, meat and wine. The majority of the country (86%) is used for agriculture purposes (NBSAP 2005). Because many products are exported, the agricultural sector is very important to South’s Africa economy and development. However, 1.3 million ha of the land is under irrigation which utilizes more than half of South Africa’s available freshwater (Oosthuizen 2002; Perret 2002). This makes the agricultural sector both heavily dependent and, at the same time, the most important pressure on the country’s water availability.

It has been widely recognized in South Africa’s policy that fair and effective water allocation is essential to deal with water limitation. Since the end of the apartheid era (1994), the government has adopted various water policies to establish an effective and fair water management scheme (Oosthuizen 2002). Additionally, much of the water legislation is oriented towards more sustainable use of water resources for irrigation and drinking water (Perret 2002). Water is likely to become an increasingly limited resource, due to an increasing demand for water by humans and decreasing water availability due to climate change and loss of biodiversity (Collier et al. 2008; Jansen 2008).

Especially the management of river catchments plays a crucial role in maintaining water security. This management does not just include water or riparian zone management. Land management practices that also influence the availability of water and a catchment's biodiversity include agriculture (e.g. through use of fertilizers and land clearing), forestry (e.g. through cutting frequency, infrastructure needed) as well as restoration and conservation of nature (e.g. alien clearing, protecting areas, fire prevention)(NBSAP 2005; Driver et al. 2012). This illustrates that the sustainability of a river catchment ultimately depends on the choices of different stakeholders, and not just policy-makers or conservationist.

1.2. Problem Statement

Various ideas exist on how to reach economic and ecological sustainability on a catchment scale, thereby ensuring sufficiently available water, agricultural production and ecological integrity. Policy makers, nature conservationists and local land owners often have their own recipe for ensuring this sustainability. Nature conservationists generally promote the establishment of nature reserves to protect local biodiversity and ensure a healthy environment, whereas farmers alter the natural land to make optimal use of natural resources to ensure agricultural production. Agricultural practices are often seen as an impeding factor to biodiversity conservation; conversely, farmers often perceive nature conservation as a limiting factor to (their) economic growth.

These conflicts of interest can constrain the development of sustainable management options which can on the long term, cause a decline in environmental health and agricultural productivity. The concept of ecosystem services has been recognized by its potential to bridge economic interest and nature conservation to reach sustainability because it highlights the relation of nature and human well-being. Ecosystem services are defined as "benefits people obtain from nature" which support human livelihood (Millennium Ecosystems Assessment 2005). To determine best practices for sustainable catchment management, it is thus crucial to understand the relation between land management types and ecosystem services.

Biodiversity, water security and agriculture are important issues in Kouga catchment as well. The Kouga catchment is located between the Eastern Cape and Western Cape Province in South Africa. The area is famous for its high biodiversity and the catchment provides irrigation and drinking water to users within and outside the catchment. Moreover, agricultural production contributes greatly to the economic development of the area, while it is one of the biggest consumers of this water at the same time.

The issues of water shortage, loss of biodiversity, and land degradation are recognized by several reports which (partly) capture the Kouga catchment (e.g. Powell et al. 2009; Mander et al. 2010). However, important knowledge on the state of the catchment as a whole is currently missing and current assessments are either incomplete or large-scale (Living Lands 2011). Moreover, awareness and a common understanding among stakeholders is missing, which forms an important constraint to the development of innovations for sustainable catchment management (Living Lands 2012).

1.3. Objectives and Research Questions

The objectives of the study are twofold: 1) to develop a comprehensive information base on the environmental state of, and 2) to provide insights into the relations between land management and ecosystem services in the Kouga catchment. This knowledge will provide valuable information to local people, researchers and policy makers to recommend sustainable catchment management options in the Kouga catchment.

To achieve the objectives of this study, the following research question were formulated:

1. *What are the main biophysical and environmental characteristics of the Kouga catchment?*
2. *What are the main land management types in the catchment?*
3. *What is the environmental state of, and threats to, the ecosystems in the Kouga catchment?*

4. *What are the main issues that constrain sustainable management in the Kouga catchment?*
5. *Which ecosystem services are provided in the Kouga catchment, and by which factors are they influenced?*
6. *What is the relation between land management types and the provision of ecosystem services in the Kouga catchment?*

1.4. Study area

The Kouga catchment is located in the south of South Africa. It largely falls within the western region of the Eastern Cape Province, and within the eastern region of the Western Cape Province. The area consists of several mountain ranges and valleys in-between these mountain ranges.

The boundaries in the west are close to Haarlem, and in the east at Joubertina and along Suuranys Mountains; the southern boundaries are the Tsitsikamma Mountains, whereas to the north the Kouga and Baviaanskloof Mountains border the catchment (see Figure 1).

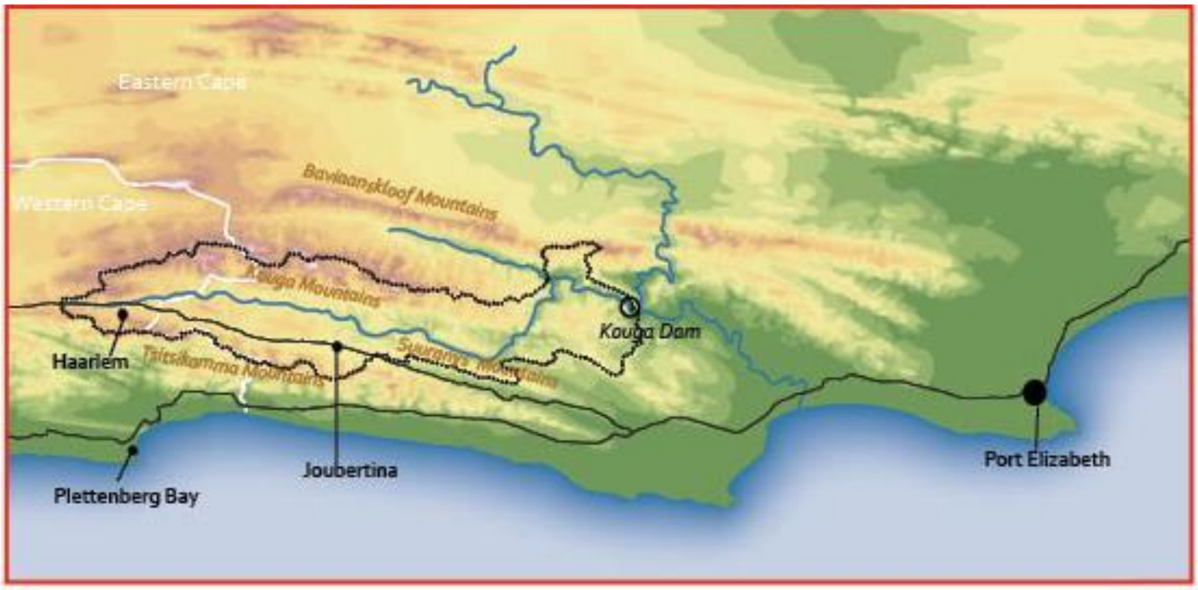

Figure 1: The study area - the Kouga catchment in South Africa
(Map: this thesis based on ArcGIS data by (Euston-Brown 2006) and (Vlok et al. 2008))

In total the catchment covers an area of approximately 282,000 hectares (Powell and Mander 2009) and is inhabited by around 15,000 people (DWAF 2004). Its main city is Joubertina. The Kouga River is the catchment's main river and therefore also gives the catchment its name.

The Kouga catchment partly belongs to the Baviaanskloof Nature Reserve (BNR), which is a World Heritage Site and is also part of the Baviaanskloof Mega Reserve (BMR) planning domain. The BMR could potentially become the "most diverse area within southern Africa (Skowno 2007).

1.5. Outline of the report

The report will proceed as follow. Building on the introduction and objectives of the study in chapter 1, the following chapter (Chapter 2) describes the method used for data collection and analysis. The results of the study are presented in chapters 3 to 7. Chapter 3 outlines the topography, geology, geomorphology, climate, hydrology and diversity of flora and fauna summarized as biodiversity. This is followed by a chapter about the land management types in the catchment (see Chapter 4). Next, the environmental state of, and threat to the Kouga's ecosystems are presented (see Chapter 5). In chapter 6 the findings of the ecosystem services analysis are outlined. Together, these first chapters describe the main biophysical and environmental characteristics, land management, environmental state and the ecosystem services of the catchment. This knowledge forms the information base for further analyses. Based on this information, the relation between land management and the provision of ecosystem services is analysed (see chapter 7). Chapter 8 discusses the used methods and findings critically. The final chapter (chapter 9) highlights the main findings acquired during the research followed by recommendations for future research and the development of sustainable catchment management options in the Kouga catchment.

2. Methods and literature review

In this chapter, the methodology that was used is described. The chapter is divided into the used framework (2.1), the way of data collection (2.2) and the method of analysis (2.3).

2.1. Methodological framework

The framework shown in Table 1 gives an overview of the methods used in this study in relation to the research steps and questions. A systematic approach was followed, which means that data collection and analysis was done in a stepwise manner. Each step is based on different sources of data, classified as primary and secondary data. The different steps are not exclusively based on *one* data source but rather guided by one type of data. In addition, other data sources were also used, depending on the quality and reliability of the initial data source.

Table 1: Study framework

Methods of data analysis	Data source	Method of data collection	Research questions	Chapter(s)
Step 1: Inventory of the biophysical and environmental characteristics and land management	Primary data	Interviews, questionnaires, observations	**RQ1:** What are the main biophysical and environmental characteristics of the Kouga catchment? **RQ2:** What are the main land management types in the catchment?	**Chapter 3** **Chapter 4**
Step 2: Ecosystem assessment	Primary data and Secondary data	Literature review and ArcGIS study Interviews, questionnaires, observations,	**RQ3:** What is the environmental state of, and threats to, the Kouga catchment? **RQ 4:** What are the main issues that constrain sustainable management in the Kouga catchment?	**Chapter 5**
Step 3: Ecosystem Services Analysis	Secondary data	Literature review	**RQ 5:** Which ecosystem services are provided in the Kouga catchment, and by which factors are they influenced?	**Chapter 6**
Step 4: Combination of step 1, 2 and 3	Primary and secondary data	Integration of local and scientific data	**RQ 6:** What is the relation between land management types and the provision of ecosystem services in the Kouga catchment?	**Chapter 7**

Through the 'method of inventory' core information about the biophysical and environmental characteristics and the land management types in the Kouga catchment are collected from

interviews, questionnaires and observation to answer the first two research questions **(step 1)**. In the following step, the environmental state of and threats to, the Kouga catchment are assessed by an ecosystem assessment **(step 2)**. Results are either based on secondary data (literature review and ArcGIS study) or primary data (interviews, questionnaires and observations). By combining this different data, the main issues constraining sustainable management in the Kouga catchment become evident. To identify the main ecosystem services provided in the study area, and by what factors they are influenced, an ecosystem service analysis was done **(step 3)**. A literature review delivered the necessary conceptual information, classified as secondary data.
By combining the results of previous steps, the relation between land management and the provision of ecosystem services in the Kouga catchment is studied answering research questions six **(step 4)**. The added value of this final step in this study is the integration of local knowledge and scientific expertise. Based on the findings of this analysis, recommendations for the development of sustainable management options in the Kouga catchment are formulated.

The process of data collection and analysis followed an iterative approach. This process allows the researcher to shift the focus of attention over time depending on what has been learned and which parts of the problem have been found. Thereby, researcher's judgements and findings are exchanged with those of various stakeholders. This will make sure that the research questions are critically reflected on.
Details on how data was collected and analysed are given in sections 2.2 and 2.3.

2.2. Data collection

Data collection was mainly done during fieldwork in South Africa between October 2011 and May 2012[1]. Information was collected from primary and secondary sources. In total, I conducted 44 Interviews and 23 questionnaires, in addition to extensive observations (primary sources providing first-hand information); secondary sources were obtained from literature review.

2.2.1. Primary data

To assess the biophysical and environmental characteristics of the Kouga catchment and how the land is managed (RQ 1-3), primary data was particular important. This data provided local and case study specific information as well as people's perceptions and understanding. Data was collected through interviews, questionnaires and observations.

Figure 2: Interview with local people, questionnaires and observations were important methods to collect data as it delivered first hand-information
(Photo: Author)

a) Interviews

Due to the fact that literature about the study area was limited, often difficult to access and outdated, interviews with stakeholders in the field were important to collect more updated and

[1] During my fieldwork in South Africa, I also did my internship with Living Lands in the Kouga catchment

accurate data, and to assess people´s perception, meanings and definitions of situation and construction of reality (Punch 2005). Interviewing is a common method to collect data from people in this situation (Kumar 2005) and was thus an important method to collect data in this study.
Due to the fact that stakeholders were scattered over a large area and contacts were limited available within the PRESENCE learning network, the choice of respondents (interviewed stakeholders) was guided by the 'snowball method'. The application of the 'snowball method' is a common network sampling method for studying in this kind of situation (Bernard 2011). The first contacts to stakeholders had been established by PRESENCE learning network and the extension officer of the Kouga catchment area. After an interview, respondents were asked to point out other stakeholders in the area *we should talk to,* to build up a network of stakeholders. Later on, purposive sampling methods were used to ensure that the whole catchment would be covered, i.e. representatives of different areas and other land management practices could be approached.

Interviews were conducted with different stakeholders in the catchment as well as outside the catchment's boundaries. In total, 44 stakeholders were interviewed during data collection in South Africa. Stakeholders were divided into primary and secondary categories due to their influence on ecosystem (
Table 2). Primary stakeholders were classified as people who have a direct influence on the land such as local farmers and nature conservationists.

Table 2: Identified primary and secondary stakeholders in the Kouga catchment

Type of stakeholder (number)	Characteristics	Vision/ Purpose	Influence on ecosystem
Primary stakeholders (31)			
Farmers (29)	Private land owner, men, Afrikaans, since generations in area, own majority of the land	Agricultural production	Direct, work directly on the land
Eastern Cape Parks (ECP) (2)	Environmental governmental institution, since 2004 in area, own some land	Conservation of biodiversity	Direct, work directly on the land
Secondary stakeholders (13)			
Eden to Addo (E2A) (1)	Environmental, governmental program, since 2009 in area	Establishment of natural living corridor	Indirect, need to work together with land owner to influence ecosystem
Working for Water (WfW) (1)	Environmental, governmental program, since 1995 in area	Water security, job creation, restoration of biodiversity	Limited direct, influence once by cutting down alien plants
Other institutions: Municipality, Department of Agriculture, Disaster manager, Church (5)	Environmental, governmental and social institutions, changing representatives	People's well-being, stable economy, secure agricultural production, safety,	Indirect, influence through policy an advice, don't own the land
Scientists (6)	Outside the area	Research	Indirect, influence through giving advice

In line with this classification, 31 primary and 13 secondary stakeholders were interviewed. Primary stakeholders´ perceptions were regarded as a very important reference point as they were the biggest land owners of the study area and are directly working on the land. Their understanding of the ecosystem is determined how the land is managed and will be managed in the future.

Secondary stakeholders have an indirect influence on the land in the study area but having valuable knowledge about the area or/and institutional power. They brought in different perceptions and expertise to the research. Secondary stakeholders are representatives from environmental institute (local conservation agency ECP, E2A), governmental institution (Department of Agriculture, Disaster manager, Working for Water (WfW), Coega Development Corporation (CDC)) and social institutions (church). Additional, scientific expertise was consulted as well by interviewing different experts from scientific institutions and disciplines (Stellenbosch University, Agricultural Research Council (ARC), South African National Biodiversity Institute (SANBI), ecologist and soil scientists) to give the scientific background of certain issues which came up during interviews with local stakeholders. Some stakeholders had different roles in the area at the same time, such as representatives of the ECP as being part of an environmental institute as well as a local land user in the area. In this case stakeholders were considered as both, primary and secondary stakeholders.

During field work, unstructured, semi-structured and structured face-to-face interviews were held with stakeholders. Most interviews were semi-structured interviews conducted with the local land owners including farmers and nature conservationists. The interviews were initiated by phrases such as: "*I would like to understand the area*"; "*I would like to listen and learn from you*" to understand the respondents' perspectives, experiences and challenges in the study area. It was up to the respondent how much he would like to tell.

Most interviews were done together with another student working on her thesis research about social learning in natural resource management in the Kouga catchment[2]. Together we developed a set of predetermined questions which were asked during an interview including following topics: Land management and use; state of the land, challenges, future plans, involvement in sustainable natural resources management and social network/relationships. I guided the first part of the interview due to the topics related to my research. My colleague guided the second part of the interview (see Appendix I for an example of interview questions). During an interview open-end questions such as "*How do you manage your land?*" and *"What are the main challenges regarding your farming practices?"* were asked. Additionally, more spontaneous questions were also often formulated during the interview depending upon the context of discussion. In particularly, towards the end of the interview, respondent were given more freedom in what they would like to tell or point out by them. Often the interview ended up with a walk through their fields or orchards. The last part of the interview can be classified as unstructured interviews as questions were raised "on the spur of moment" (Kumar 2005). Repeated interactions with certain stakeholders were done to enhance understanding and accurate information which are given by in-depth interviews (Kumar 2005). All interviews were recorded.

Figure 3: Unstructured interview: Often the interview ended up with a walk through the orchards
(Photo: Author)

Unstructured interviews were also conducted with stakeholders representing environmental, governmental and social institutions in the Kouga catchment.

After field work, respondents were often again contacted by email to clarify and discuss findings and to fill in remaining knowledge gaps.

[2] For more information see: Draugelyté, E. (2012). Dissonance in social learning: towards maintenance of natural resources in the Kouga catchment, South Africa. MSc Thesis, Wageningen University.

b) Questionnaire

A more structured interview was done in the form of a questionnaire (see Appendix II). In total, 23 questionnaires were filled in by the same local land owners as interviewed. The same topics as during the interviews were asked in the questionnaire but as closed-ended questions. This means that respondents only had to tick the category that described their answers best. The purpose of the questionnaire was to make sure that all topics of interest were covered, as it could happen that during the interview certain issues might be missed due to the respondent's choice or lack of time. Moreover, this method of data collection was meant to provide quantitative data.

As interviews also included sensitive questions, a questionnaire might be a better choice than doing an interview as it ensures anonymity (Kumar 2005). Thereby, the timing for the questionnaire was also important. The questionnaire was filled in by the respondents at the end of the interview. At the end of the interview a kind of relation between the interviewer and respondent could be build up which helped to obtain accurate information (Kumar 2005).

c) Observation

Observation is another method to collect primary data about a study site. "Observation is a purposeful, systematic and selective way of watching and listening to an interaction or phenomenon as it takes place" (Kumar 2005). Different meetings were attended in the area such as the farmers' association meeting, local municipality meeting and nature conservation meetings. At this kind of meetings, different key stakeholders of the area were present to discuss certain issues of the area. This was a good opportunity to see people's different opinions and visions on issues such as water or biodiversity, without getting involved in the activities of the group. Observations were also done with every trip to the study area to get a better understanding of the landscapes´ dynamic. Several photos were taken from the field to illustrate certain aspects. Finally, a helicopter flight above the catchment helped to observe and understand the area as a whole system.

2.2.2. Secondary data

Next to primary data, secondary data sources were consulted. Secondary data sources are more typically scientific reports and articles. This kind of data helped to understand the biophysical and environmental characteristics from a scientific point of view, quantified the environmental state and identified ecosystem services in the Kouga catchment. Secondary data was collected from literature including an ArcGIS study.

a) Literature review and ArcGIS study

Literature review was done throughout the whole study process. Most useful data from literature were found in different reports about regions where the study area party falls in, such as the Baviaanskloof –Tsitsikamma report (Mander et al. 2010), Eastern Cape Biodiversity Conservation plan (Berliner and Desmet 2007), Gamtoos River System report (Haigh et al. 2004) and Klein Karoo development report (van de Merwe and et al. 1991). More specific literature about the study area was limited. Data from literature about the case study were primarily obtained from two project reports namely the Baviaanskloof Mega Reserve (BMR) project report made by (Euston-Brown 2006); the Garden Route Initiative (GRI) project report made by (Vlok et al. 2008). These reports also include two ArcGIS databases which enabled a simple GIS analysis. Due to the fact that the two studies addressed only parts of the Kouga catchment, ArcGIS data needed to be combined into one database to fully capture the entire catchment. The northern part of the catchment is described by the BMR project; the GRI project describes the southern part of the catchment. However, different terminologies and classification categories between the two databases constrained the accurate synthesis of ArcGIS data. To the best of my knowledge, these two ArcGIS database and project reports are however the most suitable information sources at this moment. Both ArcGIS databases are also used by local nature conservationist agency (ECP), NGO (LL) and in South African scientific literature.

The reports "Baviaanskloof – Tsitsikamma Payment for ecosystem services: a feasibility assessment" by (Mander et al. 2010) also made use of the same ArcGIS databases. Therefore, when estimating the extent of land cover and land use types in the study area, own calculation were not always needed and most data (area/hectares) could be adopted from these reports. However, accurate description about typology was sometimes missing or/and data were different between reports and ArcGIS data. In this case, most representative data were chosen based on local people and expert judgment, or margins including the data from different sources were presented.
For the analysis of the ecosystem services of the study area, scientific literature was mainly used. It provided information to understand the concept of ecosystem services; quantitative data however was very limited. Most information and some data could be found in scientific articles, journals and books, as well as in regional and national reports (grey literature). Most sources dealt with studies conducted in, or relevant for South Africa.

2.3. Method of Data Analysis

Following the methodological framework a stepwise approach was used that ultimately lead to a study on the relation between different land management types and ecosystem services (step 4). Details on how collected data were analysed are given per step in the following sections.

2.3.1. Step 1: Inventory of the main biophysical and environmental characteristics and land management

The inventory aims to collect and/or collate core biophysical and environmental information and how the land is managed to answer RQ1 and RQ2. Inventories are often used method of data collection to describe the character of ecosystems while providing a comprehensive information base. The Ramsar Convention on Wetlands, for instance, has adopted the inventory methodology as a tool to guide appropriate ecosystem assessments and management planning (de Groot et al. 2006; Davidson and Finlayson 2007). In line with this approach, information about the topography, geomorphology, geology, climate and hydrology was collected and analysed. Based on this information the spatial distribution of the main vegetation types and some animals in the study area was studied. This inventory was followed by the identification of the main land management types and description of how the land is managed. Together with the biophysical and environmental characteristics this information formed a kind of 'basis layer', upon which all further analysis in this study were built.

Information was mainly gathered by interviewing local land owners, conducting questionnaires and by doing field observations (primary data). Furthermore, a literature review (secondary data) was conducted at a later stage to fill in knowledge gaps and/or to complement this local knowledge. Local farmers as well as nature conservationists were consulted as the direct managers of the land. Due to the fact that fruit farmers and livestock farmers are the biggest land owners in the area, it was important to assess the area from their point of view, to understand how the land is managed and by which goal or vision land management was lead.
Literature review and ArcGIS provided also provided quantified data. Although quantitative data was limited (see *literature review & ArcGIS study*), representative numbers could be given for the assessment of biodiversity. Data were primarily obtained from the two ArcGIS databases by (Euston-Brown 2006) and (Vlok et al. 2008). Additionally, the STEP database by (Lombard et al. 2003) was consulted for a more general overview of the area and to cross-check data. However, it was not possible to compare and combine both existing ArcGIS database without losing some accuracy in data. Some vegetation classes, for instance, were based on different classification system which meant that the same vegetation classes could be named differently. Therefore, it was chosen to present the biome level rather than the vegetation class level. In addition, ArcGIS data was sometimes less detailed to capture local spatial differences. If possible, local knowledge and scientific literature was consulted to ensure more in-depth analysis and to decide which data would be correct or most representative. In addition, expert judgement was also taken into account as data were

discussed with experts during interviews. This cross-checking provide a more accurate and detailed picture of the study area.
Quantitative data about the land management types were primarily adopted from the "Baviaanskloof – Tsitsikamma Payment for Ecosystem Services" (Powell et al. 2009; Powell and Mander 2009; Mander et al. 2010) and the two ArcGIS data bases, which were described earlier. The reports were also the only available reports providing this kind of information. However, the availability of quantitative data was limited, due to different classifications, terminologies and scopes between the two ArcGIS databases and available reports. To be able to combine and compare data several choices needed to be made. For instance 'Irrigated agriculture' (land use category in BMR study) and 'farm' (land use categories in GRI study) in the Langkloof were summarized as 'fruit farming' in this study. When it came to calculation of the land coverage data between the used information sources were sometimes contradicting. In this case, the most reliable data was chosen or a range of data was shown like in the case of the estimation of the total area of fruit farming in the Langkloof. Literature stated 7.000 hectares, but ArcGIS identify 16.171 hectares. Most probably the difference can be explained by different scales interpretation and ArcGIS errors. These errors couldn't be corrected for, since experts were also unaware of which data would be "more correct". But nevertheless, ArcGIS data were important information and the newly compiled ArcGIS data ultimately enabled the visualization of findings through the creation of maps as well as estimation of the extent of land use and cover.
The biophysical and environmental characteristics of the study area are described in *Chapter 3*. *Chapter 4* presents the main land management types Kouga catchment.

2.3.2. Step 2: Ecosystem Assessment

The ecosystem assessment aimed to identify the environmental state of, and threats to, the Kouga catchment (RQ3), and to assess the main issues constraining sustainable management development in the Kouga catchment (RQ4). This assessment did not include any valuation method but followed the South African method of a biodiversity assessment. According to this method, the environmental state can be estimated by assessing the ecosystem threat status and ecosystem protection level (Berliner and Desmet 2007; Driver et al. 2012). The degree of habitat transformation and degradation will help identify the ecosystem threat status; the ecosystem protection level describes to what extent natural habitat is protected. This information was primarily based on information from literature review and ArcGIS study. In addition, in this study, local people's perception on the health of the Kouga catchment was added to this assessment, presented by qualitative data, to more comprehensively represent and incorporate the different views hold by stakeholders. By combining this different kind of data and information, the main issues in the catchment were identified.

As said before, literature review provided conceptual knowledge needed for this assessment. ArcGIS data from the BMR and the GRI studies ((Euston-Brown 2006) resp. (Vlok et al. 2008)) delivered quantitative data for the ecosystem threat and protection level in the Kouga catchment. Other studies from the region, such as the Subtropical thicket ecosystem planning (STEP) project by (Lombard et al. 2003) were used as an additional input to this assessment and compared to available data. Due to the fact that different terminologies and classification systems were used in the studies it was difficult to combine these data without losing accuracy in data, similarly to step 1. For assessing the transformation and degradation level in the catchment GIS data was needed to be new categorized. Different degradation classes of Euston-Brown (partially degraded, heavily degraded and severely degraded) were summarized as 'degraded'; remaining classes as 'natural'. Data about transformed areas were not explicit given, but in the report transformation was directly linked to the land use. Therefore the different land uses categories in the BMR study (dry-land, old cultivation, irrigated agriculture, large dams, urban/peri-urban) were classified as ´transformed`. The GRI study made a clear distinction between degraded and transformed areas and no extra calculation was needed. 'Degraded' was made up by two classes: the degradation class and alien degradation (moderate to dense alien infestation) class. Heavy alien infestation and land use were summarized as

'transformation' class; the remaining areas as `natural`. With the help of ArcGIS, a map of the environmental state of the Kouga catchment could be made to give a spatial overview.
These findings were compared to what people in the catchment said about the environmental state of and threats to, to the Kouga catchment, predominantly given by qualitative data from interviews and questionnaires. Results were shown separately based on primary and secondary stakeholders, to present the different views hold by stakeholders.
As the final step in this assessment, a synthesis of previous results was made to specify the overall state of, and threats to, ecosystem integrity and to indicate general trends in the catchment. By doing so, the main issues in the Kouga catchment could be identified. These issues need to be taken into account when dealing with sustainability in the Kouga catchment. The findings of the ecosystem assessment are described in *Chapter 5*.

2.3.3. Step 3: Ecosystem Services Analysis

Through the Ecosystem Services Analysis RQ5 could be answered. The purpose of this analysis was to identify the main ecosystem services provided in the Kouga catchment, and to assess by which factors these services are influenced. The central aspect in this analysis is the concept of ecosystem functions and services which is illustrated by Figure 4. This concept is used to describe ecosystem the complex relation between people and the natural environment.

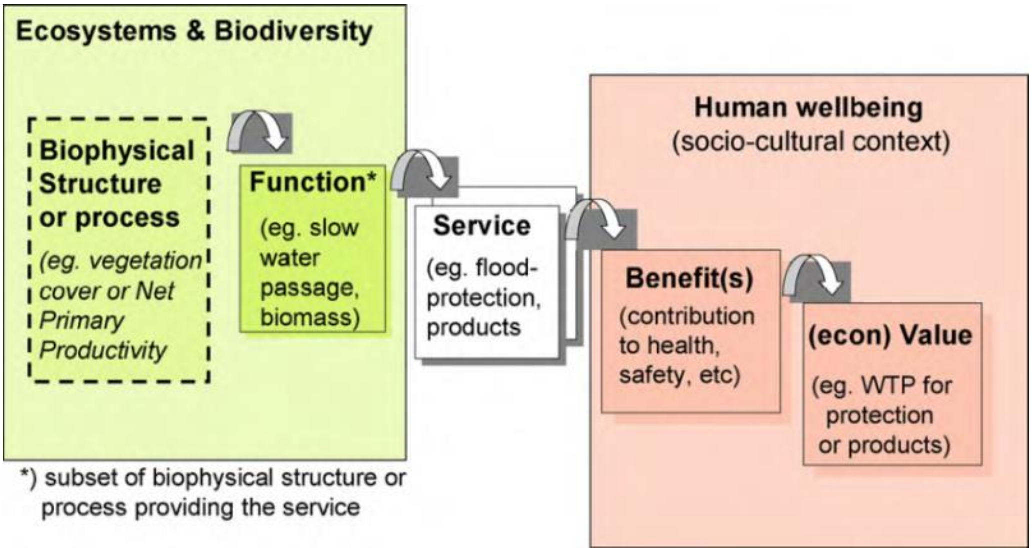

Figure 4: Framework of cascade model which links ecological complexity (biophysical structures and processes) to human well-being (ecosystem services) (de Groot et al. 2010)

The provision of ecosystem services is generally described to follow a kind of "cascade", which links ecological aspects to human well-being (Figure 4). A central aspect of this cascade are the ecosystem services. Ecosystem services are the "benefits people obtain from nature" (Millennium Ecosystems Assessment 2005) which "satisfy human needs, directly and indirectly" (de Groot et al. 2002). The production of these services depends on the functions of the ecosystem. Ecosystem functions refers to the *capacity* of an ecosystem to produce a service (de Groot 1992). In other words, the potential of an ecosystem to provide for example water or food is termed ecosystem function; the actual use of this potential, in this case the provision of water and food, correspond to ecosystem service. Biophysical structures and processes underpin ecosystem functions and the delivery of services. These aspects are the result of interaction between and among species, with the abiotic environment and the biotic environment itself.
For illustration, vegetation cover (structure) generates a great diversity of plants and thus biomass (function) which can be used by human for consumptive purpose (service). Ecosystem functions can also have multiple uses as, for example, vegetation has also a crucial role in the prevention of soil erosion (service).

To identify the ecosystem services in the Kouga catchment, a literature review was done to understand the concept of ecosystem services. Within literature, a wide range of classification of ecosystem services is being used, and there might be never a final classification (Elmqvist et al. 2010). However, it is important to be clear about the terminology and classification used to support a better understanding and to be able to communicate the results. In this study, the classification system is adapted from the TEEB - project *(2010)* and de Groot (2002) which are one of the most widely used classification. These sources summarize ecosystem functions and services into four major groups:

- Production functions which providing natural resources (provision services)
- Regulating functions which maintain essential processes and life support systems (regulating services)
- Habitat functions which provide habitat for wild plant and animals (habitat services)
- Information functions which provide information opportunities for cognitive development (cultural and amenity services)

Information on different services was gathered and organised following this classification. Interviews and field observations yielded results on many different ecosystem services. Findings of previous steps were taken into account and translated and analysed from an ecosystem services point of view. Moreover, South African literature was considered as well, to fill in knowledge gaps, especially in the case of exploring the capacity of the study area in provision of certain services such as medicine resources and recreation. Both examples are not used in the study area, but ecosystem structure and processes determine the capacity of these services.
All identified ecosystem services are described in more detail including the underlying ecological processes and functions, how people benefit from the services, where these services are provided in the catchment and which factors influence the provisioning of these services. There is no quantitative analysis, rather a qualitative analysis. The main ecosystem services identified in the Kouga catchment are described in *Chapter 6.*

2.3.4. Step 4: Combination and integration

The final step in this study involves the combination and integration of previous findings. This provided an integrated overview of the area which could be used as a kind of information base upon which further research can build. This knowledge was also needed to analyse the relation between land management and ecosystem services in the Kouga catchment (RQ6).
The analysis was based on the identified main issues that were found to constrain current management in the catchment. Thereby, the concept of ecosystem services was used as a bridging element to analyse the impact of certain land management practices on the identified issues. An important step in this final step was the integration of local knowledge with scientific expertise. This helped to provide integrated insights in the relation between different land management types, ecosystem services as well as on consequences and trade-offs among diverse management objectives. The complex (inter)relations where graphically represented in flowchart like figures, which helped to visualize the findings and capture the complexity of relationships in the catchment in a simplified, easy to communicate manner. Based on these findings, recommendations could be identified on how to improve current land management towards sustainability.

3. Inventory of the main biophysical and environmental characteristics of the Kouga catchment

This chapter describes the main biophysical and environmental characteristics of the Kouga catchment.
To understand the current situation of the Kouga catchment, information about the topography, geomorphology, geology, climate, hydrology and biodiversity were collected and analysed. The form and structure of the surface of the landscape will explain the movement of sediments, local climate, pattern of rivers and streams and soil structures. Knowing this biophysical information, environmental characteristics such as the distribution of plants and animals will become evident.

3.1. Topography & Geomorphology & Geology

Topography refers to the shape of the earth's surface. The surface of Kouga catchment is extremely rugged. Due to several high mountain ranges, steep ´kloofs´ (gorges) and deep mountain slopes are dominant features of the area.

Figure 5: The surface of the Kouga catchment is extremely rugged, mountains are rising up to 1850 metres above sea level (Photo: Author).

There are four major mountain range complexes trending east-west, parallel to the ocean. In the South the Tsitsikamma Mountains boarder the catchment and separate it from the ocean. To the north the Kouga Mountains and Surranys Mountains are located. Behind these mountain ranges the catchment also adjoins the Baviaanskloof Mountains (see Figure 6).

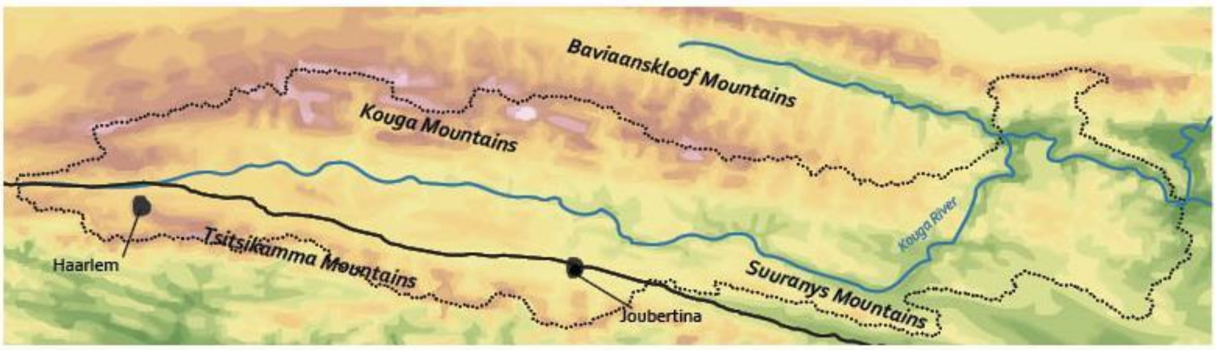

Figure 6: Several mountain ranges, trending east-west, and parallel to the ocean dominate the topography of the Kouga catchment. (Map: this thesis based on ArcGIS data by Euston-Brown (2006) and Vlok et al. (2008))

The highest point in the Kouga catchment is at Hoekop in the Baviaanskloof Mountains with 1850 metres above sea level (CSS2 2009). Kouga Mountains rise up to 1705 metres above sea level (at Hoosberg); Tsitsikamma Mountains climbing up to 1500 metres above sea level. The lowest point is

around 160 metres above sea level at Rooikrans, the place where the Baviaanskloof River joins the Kouga River (Haigh et al. 2004).
The mountain ranges are part of the Cape Folded Mountains. These mountains cover most of the southern tip of South Africa, characterized by being heavily buckled and folded (Du Toit and Haughton 1954). Contrasting to the rugged mountain ranges, there are some flat plateaus at higher altitude known as the 'Old African Surfaces'. In-between the mountain ranges some valleys occur at 200 to 850 metres above sea level (Chief Directorate National Geo-spatial Information of South Africa 1984; van de Merwe and et al. 1991); the biggest one called the Langkloof Valley (at around 300 m.a.s.l.). Narrow valleys also exist along the rivers at lower altitude (van de Merwe and et al. 1991). Towards the east, along the Suuranys Mountains, the surface becomes more open, and hills rather than mountains characterize the topography.

The landscape of the Kouga catchment is a product of cycles of sedimentation and erosion which took place over millions of years as a result of tectonic uplift and subsidence (see Appendix III). These geological processes formed a mosaic of different soil type origin from the underlying rocks (Du Toit and Haughton 1954) .
In line with this, the Kouga catchment is geologically formed by rocks of the Cape Supergroup which consist of the Table Mountain, Bokkeveld and Witteberg Group (Du Toit and Haughton 1954). The Table Mountain Group (TMG), which basically consists of different layers of sandstones, is the dominate rock formation in the Kouga catchment. From South to North these are simplified the Peninsula Formation (quartzite, hard sandstone), the Cederberg Formation (narrow shale band), the Thando Formation (more soft sandstone), the Kouga Formation (hard sandstone) and the uppermost and most northerly sandstone layer the Baviaanskloof Formation (Schafer pers. comm. 2012). These rock formations are very old and have been washed out and hardened over millions of years. This makes them nowadays extremely weather resistant (Buckle pers. comm. 2012). Moreover, these sandstones have a high quartzite character but lack minerals and clay contents. These were washed out during the 'African cycles of erosion´. Soils origin from these sandstones are nutrient poor and well-drained (Du Toit and Haughton 1954; Schafer pers. comm. 2012). The Cederberg shales are slightly different from the other formations as shale containing larger quantities of minerals and clay. However, this formation is only found in the mountainous areas as a thin shale band, surrounded by poor sandstone. Another shale formation is the Bokkeveld Group which occurs as another thin shale band through the catchment lying above the TMG, mostly in low-lying areas (Du Toit and Haughton 1954; Rebelo et al. 2006). These shale formations have a softer character and weather more quickly than the hard sandstones of the Cape Supergroup. In the Cape region, these shales are the "main contributor of weatherable minerals, clay minerals and water soluble minerals constitutes" (Macvicar and Loxton 1967). Indeed, also in the Kouga catchment this group gives rise to sweeter, fertile soils including a higher water holding capacity when comparing to other soils in the catchment. These soils are typically found on the floor of the catchment's valleys for example in the Langkloof (Schafer pers. comm. 2012). Deep fertile soils also occur along the river bank due to alluvial deposition as well as in some lower lying areas due to sediments of the Enon Formation (Uitenhagen Group). This formation consists of Conglomerate (alluvial stones in a sandy matrix) which are remnants of the rapid erosion of higher lying areas after elevation changes during early days (Rebelo et al. 2006; Erlank et al. 2009). Occasionally, the TMG is overlain with the old mature land recognized as the old African Surfaces. These rocks weather faster than the pure sandstone which gives rise to deep red soils which are more fertile and clayey (Rebelo et al. 2006).

Figure 7: The Kouga catchment is geologically dominated by different layers of hard sandstones giving rise to nutrient poor soils (Photo: Author).

3.2. Climate and extreme events

The climate of the Kouga catchment falls into the Mediterranean type of climate. In generally this means warm and dry summers with cold and wet winters (Van Wilgen et al. 1996). Summer in South Africa is from mid-October till mid-February with maximum temperatures in January. May to August are winter months, minimum temperatures are usually measured in July.

However, due to the large topographic changes different micro-climates exist within the Kouga catchment which can differ from the general Mediterranean profile. Rainfall and temperature within the catchment vary that much that average numbers for the whole catchment would present the catchment imprecise. Generally speaking, it can be stated that temperature rises with every mountain range going from the south to the north, as well as from the west to the east. In this way, the Tsitsikamma Mountains are much cooler than the Baviaanskloof Mountains, and the Suurveld area is generally warmer than at Haarlem at the top of the catchment (CSS1 2009; CSS2 2009).

Figure 8: During winter, snow can fall on higher altitude in the Tsitsikamma and Kouga Mountains and in the Langkloof. In summer temperatures can raise up to 45 ˚C in the Baviaanskloof Mountains (Photo: A. de Witt).

During winter time, snow is seen on higher altitude in the Tsitsikamma and Kouga Mountains. Frost also occurs regularly in the Langkloof Valley (van de Merwe and et al. 1991; Haigh et al. 2004) but is seldom measured in the Suurveld (Plessis pers. comm. 2011) and rarely seen in the Baviaanskloof Mountains. Northern parts of Kouga and Baviaanskloof Mountains have a much milder climate during winter months (CSS1 2009; CSS2 2009). During summer these areas are also warmer than the Tsitsikamma Mountains and the lower lying Langkloof valley. Temperatures in the Kouga and Baviaanskloof mountains can rise up to 45˚C (Markham 200?) as also measured during summer 2012. However, they are seldom higher than 37˚C (Haigh et al. 2004). Temperatures in the Langkloof can rise above 30˚C but mostly only for some days (van de Merwe and et al. 1991); the sea breeze come through the Tsitsikamma mountains keeps the valley cool during summer (Huyssteen 2008).

Looking at precipitation, the Kouga catchment is classified as a semi-arid region. This means, on average there is a rainfall deficit (Jansen 2008) and mean annual rainfall is below the world average of 860mm per year (Blignaut et al. 2007). According to (Mander et al. 2010) and the CSS reports (CSS1 2009; CSS2 2009) mean annual rainfall in the Kouga catchment is approximately 500mm. Hosking and Preez (2004) identify a mean annual rainfall of 547mm. Data from the (DWAF 2004) state that the mean annual rainfall varies from 450 mm to 685 mm.

This different numbers show that it is hard to describe the Kouga catchment with one number because of spatial variability due to topographic differences. However, in general rainfall in the Kouga catchment follows orographic patterns which means coming from the coastal mountains further inlands, the annual rainfall decrease. This means, the wettest area are the Tsitsikamma Mountains where around 1000mm per year rain falls on the surface. The Kouga and Baviaanskloof Mountains are the driest areas in the catchment, with less than 400mm rainfall on average per year (van de Merwe and et al. 1991; Jansen 2008). Coming from the Tsitsikamma Mountains towards the Langkloof valley rainfall decrease to average annual rainfall of 500mm and 472mm in Heights respectively Joubertina. Moving from Heights westwards along the valley towards Haarlem average rainfall increase from 500mm to 700mm per year (Markham 200?). The Suurveld region in the east has a rainfall between 400 and 550mm annually per year (CSS1 2009; Plessis pers. comm. 2011).

Different rainfall patterns within the catchment are also recognized in the monthly precipitation. It seems that the catchment lies on a transitional location between the winter- and summer rainfall regions of South Africa. However, winter rains as falling in the south-western Cape and characterizing the Mediterranean climate type, often do not reach the Kouga area. And thus in the western part of the catchment most reliable rain falls during spring and autumn following the so-called bimodal rainfall system (Cowling and Pierce 2009; Mander et al. 2010; Buckle pers. comm. 2012). Going towards the east, rainfall during summer increase gradually (Reeves pers. comm. 2012). Other literature stated that rainfall can be very variable (van de Merwe and et al. 1991).

Other typical climate characters of the Kouga catchment are hail events, thunderstorms and strong winds. Hail and thunderstorms occur regularly during summer month (van de Merwe et al. 1991). Whereas thunderstroms are more seen in the northern mountainous areas, hail is mainly expierence in the Langkloof valley (de Witt pers. comm. 2011). During autumn and winter, dry hot berg wind can be expierenced in the mountainous area (Erlank et al. 2009). Also extreme climate events such as floods and droughts are regularly (naturally) seen in the Kouga catchment. However, the past years were exceptionally tough and the area has been struggling heavily with floods, droughts and hailstorms (see Figure 9). "*During last years, the area was several times declared a disaster area*" (de Witt pers. comm. 2011).

3.2.1. Floods and droughts

On average once every 10 years the area experience a flood (Haigh et al. 2004; Jansen 2008). However, local people explained that during the last years flood events seems to happened more regularly.

In 2006 and 2007 the area was facing severe floods which were often referred to "*the largest floods in living memory*" by interviewed farmers. Even though the largest flood since measurements (started in 1937) was occurring in 1981 when on average 1067mm of rain fell on the surface of the catchment (van der Merwe et al. 2011). Nevertheless, rainfall data (measured in Joubertina) from the Eastern Cape Department of Rural Development & Agriculture measured in the year 2006 and 2007 a total average annual rainfall of 785,2mm and 715,8mm respectively, which is above the average annual rainfall in two following years (Table 3).

Table 3: Average rainfall in Joubertina, *measured since 1937 (van der Merwe et al. 2011)

Year	Rainfall (mm)	Period of
Average*	472	*Natural*
2006	785	*Flood*
2007	71	*Flood*
2008	330	*Drought*
2009	352	*Drought*
2010	365	*Drought*
2011	615	*Natural*

It is difficult to suggest if extreme climate events happened more regularly in recent decades compared to earlier decades. Based on available data no clear trend is seen (Sandbrink 2013). But South Africa, on average, has been hotter and drier during the last 10 years (Blignaut et al. 2009). Available rainfall measurements in the Kouga catchment support this statement (Table 4). It seems that during the last recent decades the month of dry periods increased. Moreover, interviewed stakeholders explained that it seems that climate events became more extreme. Flood events are characterized by so-called "flash floods" which are caused by large amount of rainfall within a very short time. *"In the past we had regular light rains ensuring a constant water supply. Now we have short bursts of flood rainfall and very little in between"* (adapted from (Sandbrink 2013). For instance, on a ´rainy´ day the water level in the Kouga Dam increased by approximately 24.5 metres within a day (Jansen 2008). Heavy rainfall causes erosion of kilometre or river banks but also crops and infrastructure (dams, channels, houses and roads) were extremely damaged, especially during the flood of 2007. The damage to the storage dams played a crucial role in the following years as the region experience a server drought period; "*It was the worst drought in 134 years*" (Hodgson pers.

Table 4: Occurrence of wet and dry periods in the Kouga catchment since 1940 (adapted from (Sandbrink 2013))

Decade	Wet months (> 70mm rainfall)	Dry months (< 30mm rainfall)
1940-1949	12	12
1950-1959	21	12
1960-1969	17	12
1970-1979	16	36
1980-1989	17	36
1990-1999	18	12
2000-2010	18	48

comm. 2011). Also rainfall measurements in Joubertina indicate a longer dry period during last decades when compared to earlier decades (Table 4) and average annual rainfall decreased to 330mm, 352mm, and 364mm of rainfall in 2008, 2009 and 2010 respectively (Table 3). Due to low rainfall, increased water needs and the limited water storage capacity, local people experienced serious water shortages in the area. Moreover, during this time, the risk of fires increased dramatically. There were some "devastating" veldt fires especially in the mountainous areas which also spread down to the valleys causing huge damage to infrastructure and orchards (Hodgson pers. comm. 2011). The latest fire spread from Avontuur to Joubertina and burnt 142.000 hectares including orchards and infrastructures (Strydom pers. comm. 2011).
In spring 2011 the first adequate rainfall after three years of drought was measured and people and nature breathe a sigh of relief and started to recover from the past extreme climate events. However, in 2012 heavy rainfalls in the mountains were experienced again. In July 2012, 400mm of rain was measured within two days. Also the Kouga Dam rose from 84 per cent to 107 per cent on these "rainy" days. Luckily, the catchment was untroubled by another flood.

3.2.2. Hail

Hailstorm is a natural climate phenomenon in the Kouga catchment. Storms with hail so big as golf balls happened often in the Kouga catchment (Huyssteen 2008). Nevertheless, local stakeholders mentioned "*abnormal hailstorms*" locally during last years. In 2006, 2007 and 2008 there were big hail storm in the area of Louterwater which damaged orchard seriously especially because fruits were almost ready to be harvested (Kou-Kamma emerging farmer forum pers. comm. 2011). In 2011 again "serious hailstorms" damaged fruit orchards between Misgund and Krakeel (van der Merwe, Gqodwana et al. 2011).

Figure 9: During last years, the Kouga catchment was several times declared a 'disaster area' due to severe floods, droughts, fires and hailstorms (Photo: A. de Witt and D. Hodgson)

3.3. Hydrology

Hydrology describes water movements in an area. It is a continues cycle of water falling down on the surface and returning to the atmosphere. A catchment is a geographic region "where water from rain (or snow) becomes concentrated and drains downhill into a river or lake" before evatransporated back to the air (Vromans et al. 2010). In this way, catchments are the areas where water is naturally retained by acting as a huge water reservoir.

As rainfall is low in South Africa, the country entirely depends on their catchments for their water supply. Indeed, most of the country's surface water is generated by catchments (Egoh et al. 2008). Due to this reason, South Africa´s water governance divides national catchments into different water management units to ensure an effective use of its water supply.

The Kouga catchment (Catchment L82) is located in the Gamtoos River System (Catchment L) which is part of the regional Fish to Tsitsikamma Water Management Area (WMA), the largest WMA in South Africa (DWAF 2004). For administrative purpose the catchment is further divided into nine quaternary catchments (L82A-I), the "finest national scale catchment boundary" (CSS1 2009) (Figure 10). This division is also used in this report.

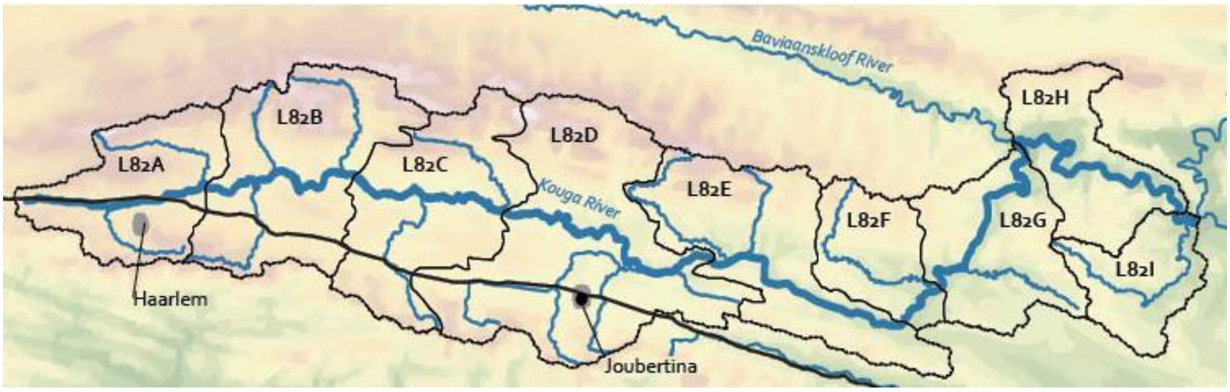

Figure 10: The Kouga catchment is drained by the Kouga River including its tributaries. Based on the hydrology, the catchment is divided into 9 quaternary catchments (L82A-I) falling under the regional Fish to Tsitsikamma Water Management Area (Map: this thesis based on ArcGIS data by Euston-Brown (2006) and Vlok et al. (2008))

Catchments are "areas that are drained by a single river system, including its tributaries" (Egoh et al. 2008). In the Kouga catchment, it is the Kouga River which drains the catchment (Figure 11). The river originates in the Tsitsikamma Mountains in the south and the Kouga Mountains in the north (L82A) and forms its main channel close to Haarlem (Haigh et al. 2004). From there, the river flow eastward, parallel to the mountains, through the catchment. Close to the Suuranys mountains the river change its direction and flows northwards between the Kouga and Suuranys mountains. This untypical flow pattern is explained by the evolution of the mountain ranges. From there the Kouga River 'ends up' in the Kouga Dam (L82I). Below the Kouga Dam, the Groot River joins the Kouga River to form the Gamtoos River, which flows to the sea. On its way to the Kouga Dam, the Kouga River is feed by a several tributaries as for example Krakeelriver, Waboom River, and the Baviaanskloof River, its main tributary. The Kouga River System is entirely dependent on rainfall and snow, "there is no evidence of substantial groundwater inflow" (Jansen 2008). Along the river and its tributaries, some wetlands are found (Haigh et al. 2004).

Figure 11: The Kouga catchment is drained by its main river – the Kouga River, which is fed by several tributaries (Photo:

In its natural state, the Kouga River is a perennial river, which means there is a continuous flow through the whole year.

However, interviewed land owners mentioned that during last years the Kouga River showed periods of very low water flow. Most tributaries of the Kouga river typically show low or no flow during summer (van de Merwe and et al. 1991).

3.4. Biodiversity

South Africa is often praised by its high biodiversity. Biodiversity was also brought up as an important feature of the Kouga catchment during interviews with land owners in the Kouga catchment. Following the most widely used definition origin from the Parties to the Convention on Biological Diversity (CBD), *biodiversity* is described by "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this include diversity within species, between species and of ecosystems" (United Nations 1992). In this manner, the term biodiversity reflects a "hierarchy of increasing levels of organization and complexity" (Elmqvist et al. 2010) which encompasses a broad spectrum, from genetic variation to different biomes occurring in a certain area. Variation is often expressed by composition e.g. different ecosystems or plant species within a certain area. Stakeholders in the Kouga catchment often used plant variety as an indicator of biodiversity. However, it is not only the composition, which define biodiversity. According to Scholes and Biggs (2004) different levels of structure and function are also aspects of biodiversity and should be included when determine biodiversity level. However, last aspects are more difficult to measure and biodiversity mostly refer to composition variety, in particularly plant species diversity.

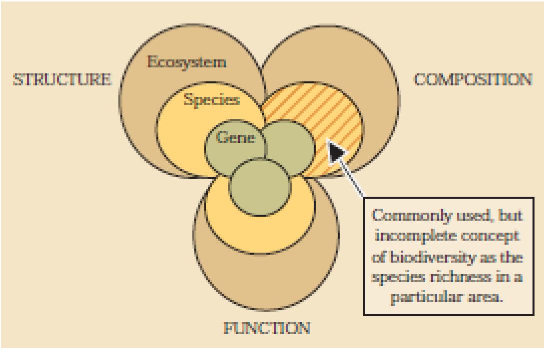

Figure 12: The multi-faceted nature of biodiversity (Scholes and Biggs 2004)

3.4.1. Biodiversity Hotspots

An analysis of biodiversity based on species composition is the recognition of so-called "biodiversity hotspot". In this case, biodiversity refers to the high concentration of endemic species. South Africa has three internationally recognized biodiversity hotspot (NBSAP 2005). All three biodiversity hotspots intersect with the Kouga catchment. The Cape Floristic Region to the west, the Maputaland-Pondoland Region (Albany Centre of Endemism) in the east, and in close neighbourhood the Succulent Karoo in the north-west of the catchment.

a) The Cape Floristic Region (CFR)

The CFR stretches from Cape Peninsula in the Western Cape to Port Elizabeth in the Eastern Cape. In this way, the Kouga catchment is entirely within the CFR. The CFR is globally recognized as one of the world's biodiversity hotspot, it might be even the "hottest" hotspot of the world (Van Wilgen et al. 1996). It has the highest density of plant species in the world, approx. 70% of them are endemic (CSS1 2009), and compose of the smallest of the world's six Floral Kingdoms. In 2004, the Cape Floral Region was declared as a World Heritage Site. Its unique fynbos vegetation covers the CFR. This region is among the most popular tourist attraction of South Africa.

b) The Maputaland-Pondoland Region

The Maputaland Pondoland Region covers parts in the east of the catchment, represent by the Thicket Biome. Within the Thicket Biome, 20 – 25% of its plant species are endemic to South Africa. Especially the Valley thicket, which also grows in the Kouga catchment, is of great importance because it has the "highest incidence of rare and endemic plants" of all thicket habitats (Cowling and Pierce 2009).

c) The Succulent Karoo hotspot

The Succulent Karoo hotspot lies official outside the catchment´s boundaries. However, succulent Karoo vegetation is found in the northwestern arid part of the catchment. The catchment´s closeness to the Succulent biodiversity hotspot and the occurrence of some succulent vegetation types in the catchment support the neighboring Succulent Karoo hotspot and put the catchment on high importance. This hotspot has the richest succulent flora on earth and 68 percent endemism in plants (Berliner and Desmet 2007).

3.4.2. Biomes and vegetation types

The variety of biomes and its associated plant species richness is also often used to express biodiversity in a certain area. The concept of biome is generally based on vegetation characteristics which belong to the same 'community' (Rutherford et al. 2006). When comparing different scientific classification systems of biome typology, different classification systems appear. On global scale there are different biome types than on national scale. Nevertheless, in this report, the South African biome concept is applied to highlight certain unique vegetation structures such as the fynbos and thicket vegetation, which would fall out of the global biome classification approach. Both biomes are endemic to South Africa.

The biomes in the Kouga catchment are defined by (Mucina and Rutherford 2006). With their definition the Kouga catchment is home to five biomes from South African's nine biomes (Mucina and Rutherford 2006). But local land owners also mentioned the occurrence of Succulent Karoo vegetation as an additional biome in the north-western part of Kouga catchment. (Ferreira pers. comm. 2011; Hodgson pers. comm. 2011; Versveld pers. comm. 2012). This vegetation might be an extension of the neighbouring Succulent Karoo Biome as biomes don't follow sharp boundaries and intermediate boundaries between different biomes can occur (Rutherford et al. 2006). Euston-Brown also indicate Succulent Karoo vegetation in a mosaic with thicket and forest in the north-western part of the catchment (Euston-Brown 2006). Another important vegetation community are described by wetland and riparian vegetation which are mostly referred to ecosystems rather than biomes.

In this way, the Kouga catchment is home to six biomes plus wetlands and other riparian ecosystems:

- ❖ Fynbos (including Renosterveld)
- ❖ Albany Thicket
- ❖ Grassland
- ❖ Savanna
- ❖ Forest
- ❖ Succulent Karoo
- ❖ Wetland and riparian vegetation types

By combining the databases from the Baviaanskloof Mega Reserve Project (BMR) by Euston-Brown and the Garden Route Initiative (GRI) by Vlok, an accurate and detailed representation of the

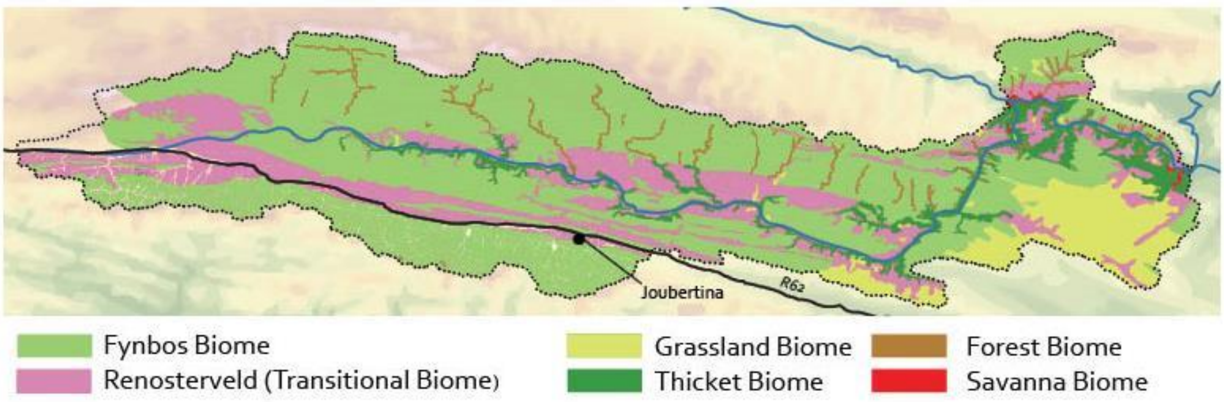

Figure 13: Overview of the biomes found in the Kouga catchment. Succulent Karoo Biome and riparian ecosystems are excluded; renosterveld is presented as a transitional Biome. (Map: this thesis based on ArcGIS data by Euston-Brown (2006) and Vlok et al. (2008))

different vegetation types per biome can be given. Figure 13 gives a spatial overview of the biomes (excluding the Succulent Karoo Biome and riparian ecosystems) in the Kouga catchment.

Table 5 provide qualitative information about the vegetation coverage in the study area.

Table 5: Overview vegetation coverage in the Kouga catchment (adapted from Mander et al., (2010))

Vegetation	Hectares	%
Fynbos total	207067	80.83
Mountain fynbos	90763	35.43
Grassy fynbos	64779	25.29
Renosterveld	33880	14.41
Fynbos mosaic	17645	6.89
Thicket total	22539	8.80
Solid	15549	6.07
Mosaic	6991	2.73
Grassland total	23189	9.05
Solid	21475	8.38
Mosaic	1714	0.67
Savanna total	499	0.19
Forest	1256	0.49
Succulent Karoo	?	?
Wetlands and water bodies	1620	0.63
Total	256169	100

From Figure 13 and Table 5 it is seen that vegetation of the Fynbos Biome is the dominant vegetation class (80.83 %) in the Kouga catchment. This biome is also represented by the most different vegetation types. In the north-east, the Fynbos Biome interlinks with the (Albany) Thicket which covers 8.80 per cent of the total surface. Mosaics with the Grassland Biome are seen in the eastern part of the catchment. 9.05 per cent of the total land is covered by grassland vegetation. Savanna and Forest vegetation are represented in smaller portion (0.19 resp. 0.49 per cent). Inter-linkages between the Forest and Fynbos Biome occur seldom due to different growth requirements (such as fire and nutrient level in soil), but forest patches are often imbedded by thicket vegetation in the Baviaanskloof and Kouga mountains. A mosaic of savanna and thicket vegetation is seen in the most north eastern part of the catchment. In the north-western part is vegetation of the Succulent Karoo Biome occurs within the Fynbos Biome. There are no quantitative data about the coverage of Succulent Karoo vegetation. Quantitative data about the coverage of wetlands and riparian ecosystems are less accurate. The National Land Cover Database (2000) classified 1 620 hectares as wetland and water bodies (Powell and Mander 2009) whereas most likely, artificial water bodies take in the biggest part in this estimation. Water bodies potentially can be surrounded by riparian vegetation.

The biomes are represented by 32[3] different vegetation types (excluding Succulent Karoo vegetation types). In the appendix (Appendix IV) more detailed information about the vegetation classes of each biome are given, including a spatial map. A description of the biomes is given bellow.

a) Fynbos Biome

The biggest part of the Kouga catchment is covered by the Fynbos Biome. This biome is found throughout the whole catchment due to nutrient poor sandstone soils. The transition from summer to winter rainfall and the north to south aridity gradient change vegetation composition and give rise to the great plant species diversity within the Fynbos Biome (Rebelo et al. 2006; Skowno 2007). The Fynbos Biome in the Kouga catchment is represented by 18 different fynbos vegetation classes from which seven vegetation classes are classified as transitional biomes. These biome classes refer to mosaics of fynbos vegetation and others non-fynbos vegetation (see Appendix IV). The name of the

[3] Mander, M., J. Blignaut, et al. (2010). Synthesis Report. Baviaanskloof - Tsitsikamma Payment for Ecosystem Services: A Feasibility Assessment. Everton, Future Works. Estimated 38 different vegetation types in the Kouga catchment. This estimation is based on the same data as used in this study. However, double counting of certain vegetation types which occur in both ArcGIS database and adding stream and rivers as vegetation types explain the difference findings between the PES study and this study.

Figure 14: Fynbos (evergreen, hard-leafed shrubs) is the dominate vegetation type in the Kouga catchment characterized by Protea flowers and renosterveld (Photo: Author).

vegetation class gives already a good impression of the habitat type and place of appearance. For example the name “Kouga Mesic Fynbos” refers to a moister habitat (mesic) in the Kouga Mountains. The same counts for the other vegetation classes outside the Fynbos Biome.
Due to the parallel mountain ranges, vegetation generally occurs in an altitudinal zonation. The mountains are primarily occupied by solid fynbos vegetation classes; lower lying areas by mosaics of fynbos, grass and rensosterveld vegetation.
In line with this, the top of the mountains are covered by different mountain fynbos groups, namely the ´Kouga Mountain Fynbos Complex´ (in the North) and the ´Tsitsikamma Mountain Fynbos Complex´(in the South) (Lombard et al. 2003). The soil here is very limited in nutrient concentrations a precondition for fynbos growth. Moreover, fires, another precondition for the growth of fynbos, caused by lightning happen regularly in the mountains. Fire is an important ecological process for fynbos because fynbos vegetation depends on fire for regeneration and is therefore adapted to regularly fires.

The biggest contributor to the Fynbos Biome is the *Kouga Mesic Fynbos* which covers 21.86 per cent of the total catchment. This fynbos vegetation class is found in the upper parts of the Kouga Mountains towards the Baviaanskloof Mountains. On higher altitude (above 1400 metres above sea level), *Kouga Subalpine Fynbos* occurs which is home to several endemic species (Euston-Brown 2006; Vlok et al. 2008). On lower altitude, the Kouga Mountains are covered by the *Kouga Arid Fynbos* which stretch till the Suurveld region. In the upper warmer, north facing slopes of the Baviaanskloof Mountains, *Kouga Restioid Fynbos* occur.
Fynbos types covering the higher Tsitsikamma Mountain slopes are classified as *Tsitsikamma Subalpine Fynbos*. Below this fynbos class, the *Tsitsikamma Mountain Proteoid* as well as the *Tsitsikamma Ericacaouse Fynbos* is found. Both prefer a permanently wet and cool habitat which is warranted by the cool sea breeze from the ocean. Going towards the west rainfall increase and mid-slops of the Tsitsikamma mountains are covered by *Mesic Proteoid Fynbos* variations (Vlok et al. 2008).
In the valleys deeper soils exist which change vegetation structures clearly. Fynbos vegetation decrease and forms mosaics with other vegetation types or get replaced by renosterveld or grassland vegetation. Grassy Fynbos variations “occur on the lower, warmer and drier mountain slopes below Mesic Fynbos” (Euston-Brown 2006). The grass elements can vary due to climate and soil condition. Generally, going eastwards (more summer rain and deeper soil) grass types “tend to completely dominate” and grassy fynbos becomes more a grassland variant (Euston-Brown 2006). This type of grassy Fynbos is also known as “Eastern Fynbos” (Cowling 1984 in (Rebelo et al. 2006)). Along the Langkloof valley another grassy fynbos class namely the *Langkloof Waboomveld* (Waboom= Protea

spp.) is identified, growing in close neighbourhood to renosterveld and grassy fynbos where soils are more fertile (Vlok et al. 2008).

Clay rich soils with nutrient-rich soils derived from shale (Bokkeveld Group) and alluvium deposits as seen in the valleys, forming a mosaic of renosterveld and fynbos vegetation. Renosterveld is typically dominated by the Renosterbos (*Elytropappus rhinocerotis*) and other ericoid-leaved shrubs. Often plants are endemic (Euston-Brown 2006). In the past renosterveld was commonly occupied by large herds of migrating animals. Nowadays, only patches of former renosterveld variations are left due to frequent fires, heavy grazing pressure and establishment of orchards (Vlok et al. 2008). On lowlands, another fynbos mosaic is found, namely the *Baviaanskloof Sandolienveld* which shows elements of fynbos, renosterveld and thicket vegetation. This mosaic grows on the hotter and arid north facing slopes of the Baviaanskloof Mountains. A fynbos mosaic with thicket vegetation, seen in the eastern part of the study area, close to the Gamtoos Valley is classified as the *Gamtoos Fynbos Woodland.*

b) Thicket Biome

Vegetation of the Thicket Biome is characterized by its dense formation of evergreen, woody, semi-succulent and thorny shrubs and low trees (2-3 m) (Mucina and Rutherford 2006). Almost nine per cent of the Kouga catchment is covered by thicket vegetation (see Table 5). It grows below fynbos vegetation, at lower altitude on the slopes of the mountains and along the Kouga River and its tributaries. This thicket types are also often called *valley thicket* due to its location in the landscape.

Thicket prefers to grow in areas where it is safe for regular fires because thicket is not prone to fires as fynbos vegetation. Moreover, thicket plant species also do not grow on leached out soils like fynbos but prefers higher nutrient concentrations in the soil. However, fertile soils are limited in the Kouga catchment. In this way, thicket vegetation is only found on the narrow bands of shale and on alluvium depositions. Towards the north-eastern part of the catchment thicket vegetation get more abundant, because of summer rainfall and slightly increases in soil fertility.

Figure 15: A typical plant of the Thicket Biome is the Spekboom (*Portulaccaria afra*) (Photo: Author)

The Thicket Biome in the Kouga catchment is represented by one 'true' (solid) thicket vegetation class namely the *Baviaanskloof Spekboom Thicket,* and several thicket mosaics (*Elands Woodland, Gamtoos Bontveld, Gamtoos Valley Thicket and Groot Woodland)*. The *Baviaanskloof Spekboom Thicket* grows along the Kouga River and at the Kouga Dam. This class is also the biggest contributor to the Thicket Biome (6.11%). It is home to the Spekboom (*Portulacaria afra*), a plant species which is only found in South Africa. Transitional Biomes including thicket vegetation appear primarily as patches in the north-eastern part of the study area, often closely related to grassy fynbos and savanna. The *Groot Woodland* thicket mosaic is partly found along the Kouga river with a high tree species diversity and many endemic plant species (Euston-Brown 2006).

c) Grassland Biome

Often literatures argue between the difference between grassy fynbos and grassland. Exact determination is difficult because historic frequent fires and heavy grazing by livestock in certain areas increased the grass component in the field. In this way, grassy fynbos could have changed to a grassland variant artificially. But on the other side, grassland vegetation also occurs naturally in the catchment. In this report the grassland biome is defined by (Vlok et al. 2008) which refers to vegetation classes where grasses (mainly *Poaceae*) dominate todays land cover. In this way, the Kouga catchment has two grassland types covering approximately nine per cent of the catchment's surface (Table 5).

The dominant grassland type is the *Sour Grassland* vegetation. This vegetation typically grows on the open hill landscapes in the eastern part of the catchment, due to the acidic character and higher loam content of these sandstone mountains. *Sweet Grassland* forms a mosaic with Valley Thicket on red soils of remnants of the old African Surface in the Kouga and Baviaanskloof Mountains (Euston-Brown 2006; Erlank et al. 2009). It occurs as small patches on top of these flat hills as for example around Bergplaats in the Baviaanskloof Nature Reserve. This grassland type is also found in the Suuranys Mountains but limited. In the past sweet grass type was probably more seen, but are now less common in the area "due to being exposed to frequent fires and heavy grazing pressure" (Vlok et al. 2008).

d) Forest Biome

The Forest Biome is limited represented in the Kouga catchment comparing to the other biomes (Table 5). Most forest areas in South Africa are small (<10 ha) (Rutherford et al. 2006) which is also the case in the Kouga catchment. The Forest Biome in the Kouga Catchment occurs in small, narrow patches restricted to riparian zones along rivers and deep fire-safe kloofs. The alluvial valley floors provide nutrient richer soils which afford a very different flora compare to surrounding fynbos and thicket plant species. Tall tree species such as Yellowwood trees, dominate these areas. The most represented forest vegetation class in the Kouga catchment is the Subtropical forest which is seen along tributaries in the more eastern part of catchment as well as in L82B. The central part of the Kouga and Baviaanskloof mountains is occupied by the Afromontane Forest. The Temperate Forest is restricted to a very small patch (4 hectares) on the boarder to the Baviaanskloof Nature Reserve in the north-western part of the catchment.

Figure 16: In fire-safe *kloofs* small forest patches evolved dominated by tall Yellowwood trees (Photo: Author)

e) Savanna Biome

The Savanna Biome is the smallest biome in the Kouga catchment (approx. 500 hectares). This Biome is representing by a Savanna mosaic - the *Baviaanskloof Thicket Savanna*, which is formed with plant species of the thicket biome. In the past, this biome supported games including buffalo, elephant and black rhino. Today, savanna vegetation is only left to some alluvial valley floors in the Baviaanskloof Mountains, close to the *Baviaanskloof Spekboom Thicket* (L82G-J).

f) Succulent Karoo

The Succulent Karoo Biome comprises shrubs with succulent leaves and steams which are used as water storage organs. Succulent Karoo vegetation prefer an even and mild climate with winter rainfall (Mucina and Rutherford 2006). These characteristics are present to a certain extent in the upper catchment area. In this way, it is not surprisingly to find this vegetation in the most north-western part of the catchment towards the Baviaanskloof on semi-arid hills (Boshoff 2005; Ferreira pers. comm. 2011; Versveld pers. comm. 2012). There are no qualitative numbers about the amount of area covered in the Kouga catchment by the Succulent Karoo vegetation.

g) Wetland and riparian vegetation

Wetland and other riparian vegetation do not fall into the used biome concept but rather present unique ecosystems. These ecosystems support the representation of high

Figure 17: Riparian and wetland vegetation grows along rivers and artificial water bodies (Photo:

plant diversity (Richardson et al. 2007) and should be not excluded from the biodiversity analysis.
Most of the catchments cultivation is happening in former wetlands because of better soil qualities. Wetland soils area characterised by higher nutrient concentrations and by a better water holding capacity due to higher clay contents (Schafer pers. comm. 2012). In the past, the Langkloof area was primarily covered by wetlands. Today, only some smaller natural wetlands are left (Buckle pers. comm. 2012) but often invaded by alien plants. The biggest left (palmiet) wetland is between Joubertina and Heights; a smaller one was seen in the Suurveld but heavily invaded by alien plants. Some dense, untouched smaller wetland vegetation still occurs along the Kouga river and its tributaries where the area is poorly served with roads (Haigh et al. 2004). Most wetland vegetation is around artificial water bodies such as water storage dams, irrigation furrows and drainages in the Langkloof valley.

3.4.3. Fauna

Due to its wide variety of different habitat types, a great diversity of animals is present in the Kouga catchment. This diversity will be not listed but some species will be highlighted to give a brief expression of the great variety of animals in the Kouga catchment.
The catchment is home to several "African game" such as Black Rhino, Cape Mountain Zebra, Cape buffalo, eland and kudu. Different species of antelopes are spotted in the catchment such as Red Hartebeest, Mountain Reedbuck, Duiker, Grysock, Klipspringer, bushbuck etc. to only mention some of them. Also present are leopard, caracal, aardvark, jackal, vervet monkeys and baboons.
Most wild animal are living in the Kouga and Baviaanskloof Mountains. The majority of the large mammals have been re-introduced to the catchment. The Old African Surface serve as a sufficient habitats for game due to higher productivity (Reeves pers. comm. 2012).
The Kouga catchment is also a "*paradise for bird watcher*" (Ferreira pers. comm. 2011) as different species of swallow, sunbirds, and kingfishers as well as the African Black Eagle and Stanley's bustard are regularly seen in the catchment. *"A pair of fish eagle is regularly seen at my dam; this is quite unique for this area"* (Baldie pers. comm. 2011). Since recently, the Blue Crane Bird is visiting the grassland areas in the catchment again, thanks to conservation measures in the area (Plessis pers. comm. 2011). This bird is classified as a vulnerable species. Kouga´s fauna is also home to several enedmic species. For instance, a high degree of endemism is recorded for the reptile species i.e. the leopard tortoise an often seen species in the mega-reserve area. The rivers are relatively poor in species diversity, but show a high degree of endemism within the amphibian and fresh-water fish community (Boshoff 2005). However, indigenous fish species are often classified as threatened or endangered due to the invasion of exotic fish species.

Figure 18: Typical residents of the Kouga catchment: Kudu, Baboons and a young leopard tortoise (Photo: Author (a,c), Living Lands (b))

3.4.4. Invasive Alien Species

The Kouga catchment is also home to some invasive alien plant and animal species which influence local biodiversity negatively, as these species displace native flora and fauna.

With the settlement of the first European farmers in South Africa, exotic species were introduced to the country, especially invasive alien plant species (IAPs). Most of the alien plants originated from Australia and Europe. These exotic, fast growing species were planted for commercial forestry and providing shade for livestock and people. These plants established and spread in the new environment so well that they threat natural ecosystems, habitats, or species with environmental and/or economic harm, they became invasive (Scholes and Biggs 2004). Nowadays, about 10 per cent of the country´s area is dominated by IAPs (DWAF 2012). Nationally wide the invasive by alien species is recognized as a "large and growing challenge in South Africa"(Scholes and Biggs 2004), especially due to the threat to water security and native biodiversity. Exotic species consume significantly much more water than the native flora which change the stream flow and decrease the water availability in the area. Moreover, IAPs are fast growing species which replace the natural flora and causes loss of biodiversity. An additional ecological effect by IAPs is their increased nitrogen cycling rates with the consequence of changing nutrient concentration in the soil which effect native flora negatively. In South Africa, about 750 native plant species are threatened with extinction due to invading plant species (UNEP 2012). IAPs invade all biomes, but the fynbos is the most invaded biome in South Africa (Richardson and Van Wilgen 2004), invaded by more than 150 exotic plants (Van Wilgen 2009. Around 30 species of them have a "major ecological significance" on the natural ecosystem (Van Wilgen 2009).

Figure 19: Invasive alien species are found in the entire catchment. Black wattle is primarily seen along the Kouga catchment, Hakea species often in the fields (Photo: Author).

In the Kouga area, 54 different exotic plant species are found (CSS1 2009). The main IAPs are Black Wattle (*Acacia mearsnii*), Longleaf wattle (*Acacia longifolia*), Hakea, gums (*Eucalyptus spp.*), *Sesbania punicea*, pines and Prickly Pear (Koyo pers. comm. 2012). Exact numbers about the area invaded by alien plants in the Kouga catchment are not available. The CSS reports calculated approximately 5,347 hectares of "substantial invasion by alien plants" in the WfW project area (L82A – G) (CSS1 2009). Boshoff (2005) estimated that from the 180.000 hectares cleared by the WfW teams, 95% are invaded again, and another 80,000 hecatares remain invaded. (Mander et al. 2010) calculated an area of 212,667 hectares of IAPs has been mapped in the Kouga catchment, whereas at least 989 hectares are highly infested. Others sources suggests that 10 -12.5 per cent of the Kouga catchment is covered by IAPs at 100 per cent density (Living Lands 2011).

IAPs are found in the entire catchment, whereas "main alien infestation" is between the Langkloof and the Kouga Mountains (Skowno 2007) and around Louterwater (Koyo pers. comm. 2012). The

densest invasion occurs along the Kouga River by Wattle species and Sesbania. Hakea are well established on the mountain hills. Pine trees occupy the Tsitsikamma Mountains and coming down till the Langkloof. There are pine plantations on the other side of the Tsitsikamma Mountain. Eucalyptus spp. are typically found close to farm houses, providing shade to livestock and people. Prickly Pear is found within thicket vegetation along the rivers.
Since the last 30 years these alien plants, especially acacia spp. became a significant problem in the Kouga catchment (Versveld pers. comm. 2012).

On the fauna side, small mouth bass and other exotic fish species are recognized as invasive species threatening indigenous fauna in the Kouga River (Haigh et al. 2004; Reeves pers. comm. 2012). These fish species were introduced to the rivers for fishing but populated the river so much that endemic fish species are nowadays often classified as threatened or endangered such as the Eastern Cape Redfin (*Pseudobarbus afer*) which is on the IUCN Red Data Species list (Reeves pers. comm. 2012).

4. Inventory of land management types in the Kouga catchment

This chapter aims to describe the land tenure, management and use.
As shown in previous chapter, natural diversity characterizes the catchment. These characteristic determined how the land is used by people. Since generations, people modify and manage the land and shape today's land cover artificially (see Appendix V).

4.1. Land tenure

The Kouga catchment covers an area of 282,000 hectares in extent (Mander et al. 2010). As shown in Table 6, the majority of the land in the Kouga catchment is in private hands (approximately 66.52 %), mainly owned by (white) farmers. The State owns 29 per cent which are basically the mountainous areas and belong to the Baviaanskloof Nature Reserve (BNR) and Formosa Nature Reserve (FNR). The communities and municipalities in the Kouga catchment have 6,482 and 1,645 hectares respectively of land including the six settlements (Twee Riviere, Joubertina, Krakeel, Louterwater, Misgund and Haarlem) within the catchment. Additional, more than 4,100 hectares of land are relocated to the communities as part of the Land Reform Programme (BEE projects see Box 1).

Table 6: Land tenure in the Kouga catchment (adapted from (Mander et al. 2010))

Land Tenure	Hectares	% of total area
Private	190 000	66.52
State	83 400	29.20
Community	6 482	2.27
Land Reform Programme	4 100	1.44
Municipality	1 645	0.58
Total	285 627	100.00

Box 1: Black Economic Empowerment (BEE)

It is important to mention that land in South Africa is mainly owned by white people because black and coloured people were not allowed to farm as part of the Apartheid regime. These people were labour and families were working for generations for the white farmers. This separation is still predominant but since the end of the apartheid era in 1994, inequalities have been trying to wipe off. Previously disadvantaged South Africans got the same rights as white South Africans and with the help of the government several so-called Black Economic Empowerment (BEE) projects were established. In the agricultural sectors this means black and coloured people are allowed to farm and building up their own business as an emerging farmer, financially supported by the government. Nowadays, there are around 80 BEE projects in the Kou-Kamma municipality from fruit farming to essential oil production. Approximately 20 emerging farmers are in the Langkloof (Strydom pers. comm. 2011; van der Merwe pers. comm. 2012). However, reasonable active projects are fewer (van der Merwe pers. comm. 2012) and emerging farmer still struggling a lot with finance problems and knowledge gaps (Kou-Kamma emerging farmer forum pers. comm. 2011).

4.2. Land management and land use

Farmers are the biggest land owner in the catchment, but agriculture is limited to certain places. The biggest part of the Kouga catchment (88.77 %) is "*used by nature*" as the catchment is largely covered by mountains. Around 28 per cent of this land is under protection by nature conservation. Cultivation including extensive and intensive agriculture is on around 10 per cent of the total land area. Infrastructure including dams and urban and per-urban development, counts for 0.5 per cent (Table 7).

Table 7: Land cover and land use in the Kouga catchment (adapted from Mander et al., 2010 and ArcGIS data from (Euston-Brown 2006) and (Vlok et al. 2008))

Land cover	land use	hectares	% of total area
Mountainous area	Nature	248 043	88.77
	From which protected areas	80 000	28.63
Infrastructure	(larger) dams	774	0.28
	Urban/per-urban development	693	0.25
Cultivation[4]		29 897 *39 068*	10.70 *10.60*
extensive agriculture			
	Livestock farming	14 022	5.02 *3.80*
	Dry-land and old cultivation	8 804	3.15 *2.39*
	Vegetable gardening	61	0.02 *0.00*
	Honeybush farming	10	0.00 *0.00*
intensive agriculture			
	Deciduous fruit farming	7 000	2.51
	ArcGIS data on irrigated agriculture (BMR) and farm (GRI)	*16 171*	*4.39*
Total		279 407	100.00
Total		*368 578*	*100.00*

Although there are no exact numbers, Table 7 show that extensive livestock farming and intensive fruit farming are the main farming practices in the Kouga catchment. Deciduous fruit farming mainly produce apple and pears. Livestock farming farm includes the grazing by cattle and sheep and the production of Lucerne, grass, oats and wheat (dry-land). Vegetable crops (e. g. potatoes, onions, tomatoes, butternut) are also planted but in limited amount (approx. 61 hectares). Cultivation of honeybush plants (*Cylopia* spp.) for the production of honeybush tea is a new commercial farming practice in the study area. Currently there are around 10 hectares under cultivation, expansion of this farming practices are planned for the coming years (van der Merwe pers. comm. 2012). There are a few farmers working on the production of essential oils from fynbos plant species, but on a very small scale.

[4] There are different data about how much land in the Kouga catchment is under intensive agriculture by fruit farming. Mander et al., 2010 calculated 3,524 hectares of 'irrigated agriculture' in the Kouga catchment (based on the same ArcGIS data). However when comparing this to the used ArcGIS data source, this calculation only includes the 'irrigated agriculture' in the BMR study side. GRI ArcGIS data estimate additional 12,613 hectares fruit farming (category 'farm' in the Langkloof is assumed to be equal to fruit farming). This would mean that in total 16,171 hectares are under irrigated agriculture/farm summarized as intensive fruit farming (4.39%). Official statistics from the fruit sector in South Africa (Horgo Tree Census (2011)) and local fruit farmers estimate 7,000 hectares under fruit farming in the Langkloof area (2.51%).

Figure 20 illustrate how the land in the Kouga catchment is spatially arranged.

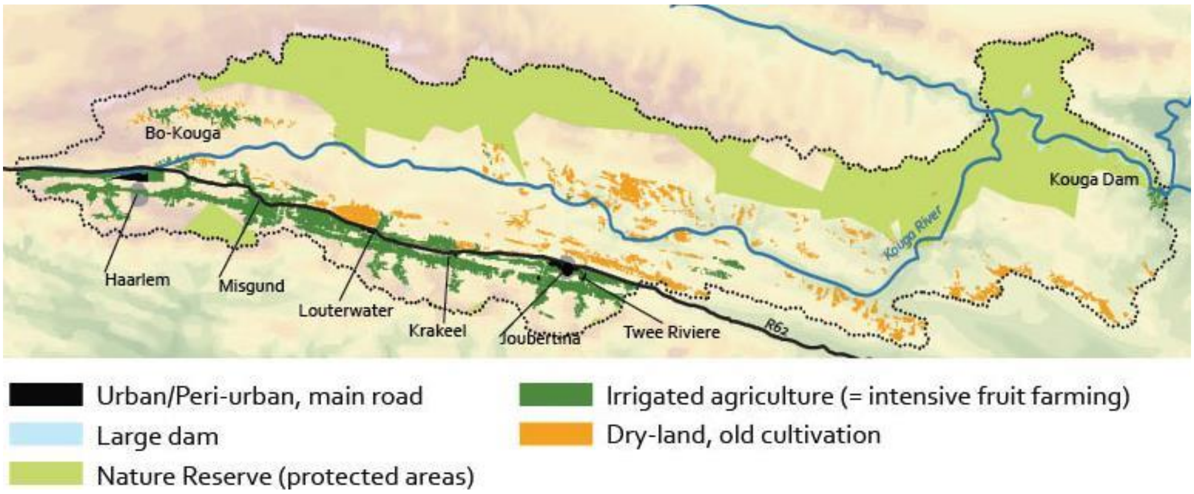

Figure 20: Land use in the Kouga catchment including Urban/Per-urban development, large dam, nature reserves, irrigated agriculture, dry-land and old cultivation. This map does not show grazing by livestock due to data restriction. But often livestock grazing is close to dry-land farming (Map: this thesis based on ArcGIS data by Euston-Brown (2006) and Vlok et al. (2008))

Urban and peri-urban development occurs along the main road (R62). In the north-east stretches the Kouga dam. Nature Reserves are established in the mountainous areas. Cultivation mainly occurs on lower lying areas. Intensive fruit farming is located along the R62 between the Kouga and Tsitsikamma Mountains, in the Langkloof valley. Dry-land and old cultivation are predominately towards the Kouga Mountains. Grazing by livestock is not taken into account in Figure 20 due to lack of ArcGIS data. However from a helicopter flight above the catchment it was seen that dry-land and old cultivation are often associated to livestock farming and/or grass fields lying close to these areas. Especially the eastern part of the catchment is predominantly used by livestock farming.

Based on the main land management types the Kouga catchment is divided into four different areas (Figure 21): The Langkloof is characterized by intensive fruit farming; extensive livestock farming mainly happens in the Suurveld, the Kouga Dam takes in the north-east of the catchment, and the mountainous areas (including Tsitsikamma, Kouga and Baviaanskloof Mountains) are primarily non-farming areas, but managed by nature conservation. The following paragraphs will give more insights into the land management and use of these four different areas in the Kouga catchment.

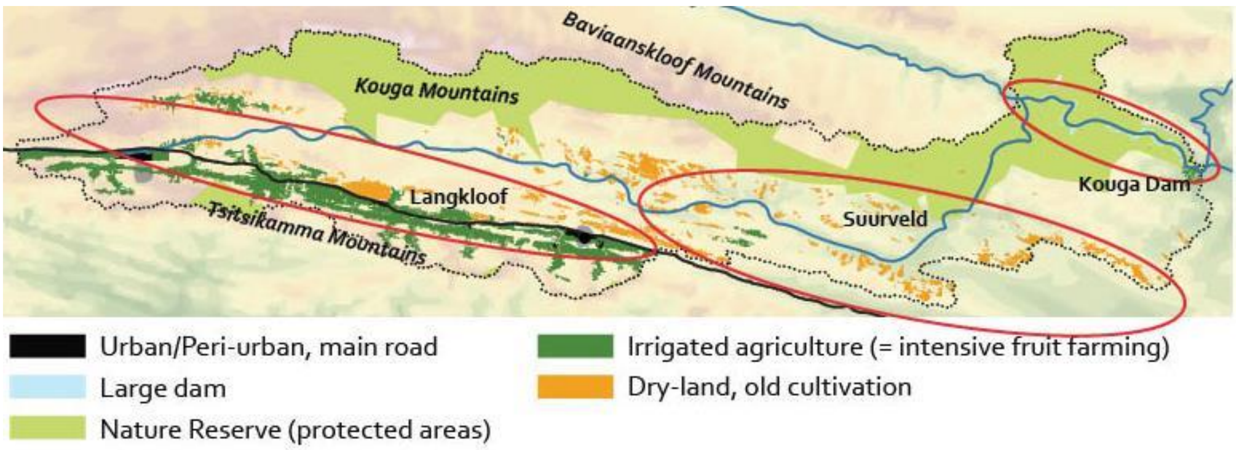

Figure 21: The Kouga catchment is characterized by four different main land management types: Fruit farming in the Langkloof, nature conservation in the mountains, and livestock farming in the Suurveld area. The north-eastern part of the catchment is occupied by the Kouga Dam (Map: this thesis based on ArcGIS data by Euston-Brown (2006) and Vlok et al. (2008))

4.2.1. Conservation of biodiversity in Kouga's Mountains

The Tsitsikamma, Kouga and Baviaanskloof mountains cover almost 90 per cent of the whole catchment. The mountains generally consist of poorly developed sandstone and are thus overgrown by fynbos vegetation. Because fynbos has a low agricultural value, the mountainous areas are hardly used by agricultural purpose. There are some grazing fields and orchards in the mountainous areas where soil is more fertile due to underlying shale formations. Some mountain hills and in-between valleys are used as grazing fields by livestock farming due to higher nutritious vegetation. Especially the old African Land Surfaces are favourable grazing fields of livestock and wild animals. The narrow valleys in-between the mountains also give rise to some isolated orchards (e.g. in the Bo-Kouga seen in **Error! Reference source not found.** 20). These orchards mainly consist of hard stone fruits (peaches, apricots) and citrus (Markham 200?), but the total area is decreasing due to higher transport costs (Ferreira pers. comm. 2011; Versveld pers. comm. 2012).

Another farming practice in the mountainous areas is dry-land agriculture, producing grain and animal fodder. However, also this farming practice decreased on scale due to changing climate and economic reasons (see Box 2).

> **Box 2: Dry-land agriculture** is a farming practice that totally depends on rainfall. This farming method is often practiced in arid and semi-arid countries where water availability is limited or water is difficult to transport. In the past, dry-land farming was common in the Kouga catchment, especially for the growing of wheat. Nowadays, this practice is economically not efficient enough anymore. "*Wheat prizes went down and too less rainfall in the area decreased wheat production*" (Plessis pers. comm. 2011). "*A lot of wheat fields were transformed into orchards, especially in the Langkloof Valley*" (de Witt pers. comm. 2011). Others are still visible as old farmland.

The mountainous areas are primarily managed by nature conservation. South African's environmental protection focuses on biodiversity conservation. It is argued that biodiversity underpin the function of the ecosystem and thus support the resilience of an ecosystem (Berliner and Desmet 2007). Biodiversity considerations are also mainstreamed in South African's policy including development planning, capacity building and community empowerment (NBSAP

Figure 22: The mountains of the Kouga catchment are primarily managed by nature conservation. Outside the protected areas lower lying valleys in-between the mountains are sometimes used for livestock grazing and orchard farming due to nutrient richer soils (Photo: Author).

2005; DEAT 2011). National policy frameworks highlight the importance of biodiversity as "the national capital of the country" upon which people depend (DEAT 2011). In this way, conservation of biodiversity is necessary to protect natural environment and to safeguard human well-being. Conservation management in the Kouga catchment is also leaded by this vision. Since early 1920 the Kouga catchment is partly under protection, but since 1987 conservation focus on biodiversity protection through the maintenance of natural habitat. The objectives of current conservation management in the Kouga catchment are "to protect the unique biodiversity, landscapes and natural resources of the Baviaanskloof Region" and to promote "sustainable use of biodiversity and heritage features" (Erlank et al. 2009).

a) Establishment of Nature Reserves

To protect the natural habitat, Nature Reserves are established. A nature reserve is a protected area which means that land is primary used by conservation activities. The mountainous areas of the Kouga catchment basically fall under the Baviaanskloof Cluster Reserves. This cluster is made up by three nature reserves: the Baviaanskloof Nature Reserve (BNR), the Formosa Nature Reserve (FNR) and the Groendal Nature Reserve (GNR) (Figure 23).

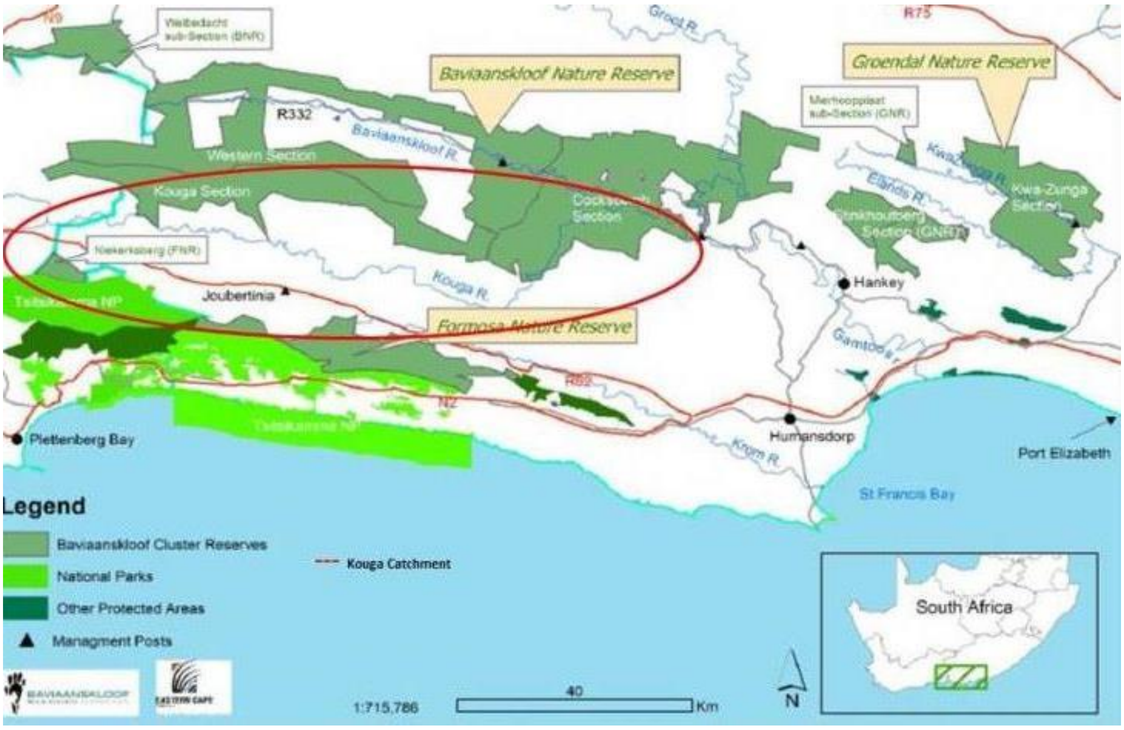

Figure 23: Location of Eastern Cape Parks Board Baviaanskloof Reserve Cluster. The red circle shows the location of the Kouga catchment (adapted from (Erlank et al. 2009))

Approximately 80,000 hectares (approx. 29 %) of the total area of the Kouga catchment are legally protected. Northern parts of the catchment fall into the BNR (between 36,341 and 45,113 hectares by the Kouga Section and 36,092 hectares by the Cockscomb Section). In the south, the catchment is protected by the FNR (2 640 hectares) ((Erlank et al. 2009) and ArcGIS data from (Euston-Brown 2006)). The GNR has no direct contact to the catchment. The Nature Reserves are managed by Eastern Cape Parks (ECP) mandated to conserve biodiversity.

In 2004, the BNR was declared as a World Heritage Site as part of the Cape Floristic Region (CFR). Moreover, the Baviaanskloof area is also identified as one of the three priority areas in the CFR suitable for the creation of a so-called mega-reserve, a "conservation landscape". The planning of the Baviaanskloof Mega-Reserve (BMR) planning domain started in 2002 with 1.030,414 hectares in extent. The idea is to conserve "regions biodiversity and natural resources" aligned with "rural and agricultural development needs" (Skowno 2007). It is argued that this mega-reserve could be one of the most bio-diverse areas within southern Africa (Skowno 2007). The Kouga catchment partly falls into the BMR. However, so far this initiative is only a plan and the planning domain has no clear boundaries yet. Most probably the R62 in the Langkloof will be the southern boundary of the mega-reserve. The southern side of the R62 is managed by another planning domain, namely the Garden Route Initiative (GRI) including the Tsitsikamma National Park. These protected areas are managed by South African National Parks (SANParks). To connect different protected areas, the establishment of a 'living corridor' through the Kouga catchment is under discussion by the Eden to Addo Corridor Initiatives (Markham pers. comm. 2011) (see Appendix VI).

b) Identification of Critical Biodiversity Areas (CBA)

Due to the fact that the Kouga catchment is so huge, the identification of so-called ´Critical Biodiversity Areas´ (CBA) helps to guide conservation management systematically (Erlank et al. 2009). CBA are natural landscape features which are recognized as important areas to reach national biodiversity targets (Holness et al. 2010). Throughout the catchment, inside the protected areas as well as outside, CBA are identified (ArcGIS data from (Euston-Brown 2006; Vlok et al. 2008))

Riparian zones along the river, including indigenous forest, thicket and wetland vegetation in the northern part of the catchment are highlighted as important conservation areas by ECP. These areas are also under protection by the BNR. Outside the nature reserve, the fynbos-renosterveld vegetation in the Langkloof area and the grassy fynbos vegetation the Suuranys are identified as priority areas which support national biodiversity conservation targets In the south, mountain fynbos vegetation, growing in the Tsitsikamma Mountains, are classified as 'Ecological Support Areas', but which fall outside any formal protection.

Although the Kouga catchment has several CBA and is recognized as an important transitional region (due to its different micro-climates) for biodiversity persistence, conservation measures primarily focus on protection of habitat within the nature reserve; outside the reserve conservation activities are rather limited due to financial circumstances and land ownership.

c) The principle of wilderness

The management of biodiversity conservation in the BNR is primarily based on the wilderness principle. This means more or less to leave nature as much as possible to itself in order to maintain local biodiversity. However, there are also people living in the Baviaanskloof region and the area offer great tourist attractions which support the local economy. Therefore, the BNR is divided into different zones which include different levels of human interventions (Erlank et al. 2009). The Kouga Section is classified as a 'Pristine Zone' which is guided by a ´true´ wilderness belief. This means management interventions are very limited in this area. The northern part of the Cockscomb Sections is classified as the 'Remote Zone' where more interventions are allowed. There are also some tourist activities. The remaining areas (FNR and southern part of the Cockscomb Section) represent the 'Primitive Zone', which have infrastructure to give access for recreation and management but on a limited basis. The management in this zone focus on the "maintenance of a "natural" experience for visitors" (Erlank et al. 2009).

d) Management of wildlife

"The overall management goal is to protect species" (KG pers. comm. 2011). Thereby, wildlife management becomes a special devotion in biodiversity conservation in the BNR (Reeves pers. comm. 2012). Certain key species such as Black Rhino, Buffalo and Cape Mountain Zebra are priority species because they take in important roles in the area. For instance, these animals support herbivory, a key ecological process of thicket and grass vegetation. Moreover, "*large mammals are also touristic attractions*" (Reeves pers. comm. 2012). Most of the large mammals are re-introduced to these areas. Management basically consist of the monitoring of wildlife and control (and reparation) of fences. Because these animals lack their natural predator, computer predator- prey simulation models are used to predict the ecological balance. If necessary, animals are taken out the

reserve. In 2012, 15 buffalos were taken out the Baviaanskloof Nature Reserve for the first time because the population of buffalos exceed the predicted natural balance.

e) Control of Fire events

Another important conservation measure is the control of wild fires. Fynbos is the dominant vegetation type in the protected areas and contributes greatly to the biodiversity level in the catchment due to its high plant diversity. Fynbos vegetation depends on fire for regeneration. Therefore, an efficient fire management is essential for the maintenance of fynbos and its biodiversity.

Fire management in protected areas changed during history due to an increased understanding of the ecology of fynbos. Before 1968, the official fire management was to protect fynbos areas from fire (Van Wilgen 2009). After 1968 it was a policy of prescribed burning of fynbos vegetation based on the assumption that regularly fires are needed to safeguard water flow from catchment areas as well as limiting the spread of fires (Van Wilgen 2009). But recent studies have shown that "fynbos fires are not fuel-dependent" and prescribed burning do not reduce wildfire incidence (Van Wilgen 2009). It is rather the weather condition (and human unawareness) which drive occurrence of wildfires (Van Wilgen 2009; Strydom pers. comm. 2011). Today, there is no prescribed burning in the BNR anymore. In line with the wilderness principle, fires should only occur naturally by lightning or falling rocks. In this way, fire management within the nature reserve only includes monitoring and establishment of fire breaks due to national laws. Interventions are only allowed when fire comes to close to human settlements (Strydom pers. comm. 2011).

To maintain biodiversity best, a fire interval of 10 -15 years is recommended by ECP. Other scientists indicate a fire return for fynbos between 15-25 years, renosterveld can burn more frequent (2-10 years) (Rebelo et al. 2006). If an area is not burnt for longer than 50 years plan diversity decrease. Naturally, fire occurs mostly in late summer and early autumn, towards the end of the dry season. As a result of this natural fire regime, a mosaic of different vegetation ages arises (see Appendix VII). This will prevent spreading of huge wildfires and enhance biodiversity (Reeves pers. comm. 2012). The occurrence of IAPs and human unawareness however altered the natural fire regime, especially outside the nature reserves. "*People's negligence is one of the main causes of fires in the catchment*"

Box 3: "Disastrous fires" in the Kouga catchment

Fires happen regularly in the Kouga catchment and can be seen as a natural phenomenon. The catchment's vegetation needs fire to fulfil their life cycle. However, during dry season the risk of fire increased as seen during the drought period from 2008 till 2011 when devastating veldt fires threatened local communities, especially in the Langkloof area.

In January 2008, a huge fire raged in the Kouga Mountains but also came down into the valleys. A damage of approx. 10 million was recorded. The area was a "disaster area". In 2009 an area of 74.000 hectares burnt from Joubertina towards the Kromme catchment. 2010, a fire was in the Langkloof and damaged 142.000 hectares of mainly agricultural land. The damage was around 25 million ZA Rand. In 2011 and 2012 there were big fires in the mountainous areas of the Tsitsikamma and Bo-Kouga which spread down to populated areas (Strydom pers. comm. 2011).

During interviews, residents of the catchment mentioned their fear of "disastrous fire". They argue that parts of the mountainous areas did not burn for a long time. Older fynbos vegetation accumulates more litter and fuel loads which cause more intense fires. However, ECP argues that there will be no big spreading of fires in the area due to the fact that a natural mosaic of different post-fire veld ages exists (see Figure 3 in Appendix VII).

To prevent and manage wildfires in the valleys, land owners formed different Fire Protection Associations (FPA) (e.g. Langkloof's FPA). In addition, Working on Fire (WoF) teams funded by the South African Government, employee local people to raise awareness around fire and how to protect the area in case of a fire event (Strydom pers. comm. 2011). A disaster manager works closely together with local WoF teams, nature conservationist and farmers to coordinate the management of fire events in the Kouga catchment.

(Strydom pers. comm. 2011). Very little fires are caused by lightning. Combined with the occurrence of IAPs in the catchment and drought periods, more intense fires are recognized which constrain conservation of biodiversity and threaten local people (see Box 3).

f) Eradication of Invasive Alien Plants

Invasive Alien Plants (IAPs) threat biodiversity (Driver et al. 2012). Therefore, the eradication of alien invasion is a core restoration activity in Kouga catchment to protect biodiversity, not only within protected areas but also on private land.

Since 1995, control of IAPs is mainly accomplished by the Working for Water (WfW) program (see Box 4). In this programme, economic development and ecological health is connected to ensure biodiversity conservation and human welfare by clearing alien plant and creating jobs (DWAF 2012). Since its establishment, local WfW teams clear alien plants in the whole Kouga catchment through mechanical clearing. The Kouga Section is one of the priority areas of alien clearing due to high density of IAPs and conservation status (KG pers. comm. 2011). A guiding principle in the IAPs management is to start clearing from the top of the catchment towards downstream areas. This will help to stop further seed dispersal (Koyo pers. comm. 2012). But also in the Langkloof valley, WfW teams are seen regularly, especially around Louterwater where black wattle trees stands very close to each other. Initial alien clearing is mainly based on cutting down alien species or trying to pull them out and a spray treatment. It is argued, that natural vegetation will re-established after clearing. "*Most of the rivers up in the Kouga Mountains are cleared once*" (Koyo pers. comm. 2012) but within some month dense population of exotic species grow there again. (McConnachie et al. 2012) support this statement as they showed that the coverage of IAPs in in the catchment seems to have increased despite all the clearing efforts. Most IAPs build up persistence seed banks in the soil which means new seedlings can germinate quickly and re-colonize the area. Therefore, follow-up operations are crucial to reach long-term restoration of the site. In general, there are two follow-up treatments by the WfW team, after that responsibility is taken over to the land owners for subsequent follow-ups.

Nevertheless, high density of IAPs is still found in the catchment due to the relative small area WfW is working on (1.4 per cent of the total catchment area since 2002 (McConnachie et al. 2012)). Local land owner often complained about the ineffective work by WfW due to "*wrong management*". WfW however argue that it is often the low follow-up commitment among the land owners. Another factor is also the use of different chemical treatments, which seems to be ineffective and often is too expensive. The potential of biological control gets more and more attention. Currently, Port Jackson willows (*Acacia saligna*) are treated with the gall-forming rust fungus *Uromycladium tepperianum*, to lower the population density. The application of biological control is desirable by local people but there are many restrictions to its usage due to forestry plantation.

Box 4: Eradication of IAPs: First concern about the impact of IAPs raised in the late 19th century. Since 1982 the invasion of exotic plants in South Africa is recognized as a "problem of global concern" due to their aggressive water consumption and displacement of native biodiversity. However, it took a long time till real actions followed to control the spread of IAPs. In 1995, South African government established the **Working for Water** (WfW) programme (http://www.dwaf.gov.za/wfw/). The idea is to empower the most marginalized in society through the creation of jobs in the clearance of IAPs. The program is globally recognized as one of the most outstanding environmental conservation initiatives. Since its inception the WfW is working with ten teams in Kouga catchment which have 180.000 hectares cleared in the catchment (Boshoff 2005). Implementing agent is the Gamtoos Irrigation Board based in Patensie.

g) Protection of honeybush plants

Several plants of fynbos biome are used for commercially, as for example the Rooibos and Buchu. The mountains of the Kouga catchment host another indigenous plant, namely the honeybush plants (*Cyclopia* spp.) or heuningsbos (in Afrikaans) (Figure 24). Honeybush has been used for centuries by South Africans for its "health giving properties" and sweet honey-like aroma (Du Toit et al. 1998) but since the 19th century *Cyclopia* spp. is used for the production of honeybush tea (Schutte 1997). The commercial use of honeybush plants is seen as a new upcoming farming practice in the Kouga catchment. There are 23 species of honeybush, endemic to the coastal districts of the Western and Eastern Cape Provinces (du Toit et al., 2008). But only three species are currently used for commercial use: *Cyclopia intermedia* ("Bergtee"), *Cyclopia genistoides* ("Kustee") and *Cylopia subternata* ("Vleitee") (Joubert pers. comm. 2012). *Cyclopia intermedia* grow wild in the Baviaanskloof, Kouga and Tsitsikamma Mountains. Climate and soil condition are suitable for the growing of these plants. *C. intermedia* grow on higher altitudes (ranging between 500m and 1700m) and are adapt to rocky, sandy soil with low pH, low nutrient levels and nematode free soils (Joubert 2012).

Wild harvesting of honeybush plants in the Kouga Catchment area has a long tradition and was never a problematic issue. However, during all conversation, local stakeholders mention their concern about the unsustainable harvesting of honeybush plants during the last years. Overharvesting of the herbal beverage has been recognized due to its increasing popularity overseas, especially in Germany, The Netherlands, UK and USA (Joubert 200?). The biggest demand is for *C. intermedia*.

In 2011, ECP declared two honeybush species as protected species. Moreover, a new legislation around how to manage honeybush harvesting was set up recently. One of the core activities of ECP (mainly in the FNR) is the protection of honeybush plants which mainly includes the monitoring of the nature reserves and arresting people who illegal harvest honeybush plants in the reserves. Moreover, ECP started to communicate their concern towards the local people. Regular meetings with different representatives of the area (Formosa Liaison Forum) support the exchange of information around the honeybush plants among other topics. However, illegal harvesting still takes places, the local police in the Langkloof is even talking about a "*criminal black market*" organizing illegal harvesting in the mountains (Palmer pers. comm. 2012). Worrying is also that no one knows how much wild honeybush is left in the mountainous areas.

To decrease the pressure on the wild harvesting, cultivation of honeybush plant species might be a solution. In 1999, an organized honeybush industry was official started with the establishment of the South African Honeybush Tea Association (SAHTA). 100 - 200 hectares are currently under cultivation in the Eastern and Western Cape Province, with the majority in the Langkloof (SAHTA 2012). The local Department of Agriculture estimate the cultivation of honeybush in the Kouga Catchment on approximately 10 hectares (van der Merwe pers. comm. 2012).

The cultivation of honeybush is regarded as having a great potential for an alternative farming practice in the area, especially as a source of income for resource-limited communities. Although scientific research on this plant already began in 1881 (Joubert 200?) honeybush farming is still a new practice and more or less on an experimental level. A lot of aspects about the plant are unknown, especially about the plants` ecology and cultivation, which limits current honeybush farming and around 80 per cent of the honeybush is still wild harvested (Joubert pers. comm. 2012; Malgas pers. comm. 2012).

Figure 24: The honeybush plant is an indigenous shrub with fine trifoliate leaves and bright yellow flowers. Since centuries honeybush plants are used by Kouga's people for medicinal purpose. Due to illegal harvesting, certain honeybush species are protected species. (Photo: L. Huijgen)

4.2.2. Extensive livestock farming in the Suurveld

Suurveld (or Suuranys) refers to the area of the Suuranys Mountains which are lying in the eastern part of the Kouga Catchment. The northern slopes of these mountain range are part of the Kouga catchment, the southern part are falling within the Kromme catchment.

Figure 25: The Suurveld is dominated by livestock grazing (mainly sheep) including dry-land farming for the production of grain animal fodder (Photo: author).

The Suurveld area *"is different from the other parts of the catchment" (Plessis pers. comm. 2011).* Climate and soil structures leaded to a very different landscape when comparing to the rest of the catchment. The Suuranys has a more open and hilly (rather than mountainous) character. Summer rainfall and generally better developed soils (higher loam content and higher nutrient concentrations) give rise to grassy vegetation types. *Sour Grassland* vegetation is the dominant vegetation type in the Suuranys area. This vegetation type is perfectly adapted to the "sour" (acidic) character of the soils (due to absent of lime in the soil), which also gave the area its name. Steeper, north facing mountain slopes are covered by fynbos vegetation. In between these areas, mosaics of renosterveld vegetation occur, especially in lower lying valleys where nutrient concentration is slightly higher. *Sweet Grassland* vegetation is limited to the old African mature landscapes where lime is present.

Due to the higher grass component, the Suuranys is predominantly used by livestock farmers, especially sheep farming. Interviewed livestock farmers explained to have between 2000 and 2500 sheep per farm. (Mander et al. 2010) calculated an area of 14,022 hectares of *Sour Grassland* used by livestock farming in the Suurveld. It is not clear if this calculation also includes dry-land farming, which is often practiced by livestock farmers to produce grain and animal fodder (mainly wheat, oat and Lucerne). The total hectares used by livestock farming therefore might be larger. (Powell and Mander 2009) also concluded that livestock grazing might be more extend because grazing on sweet grassland could additionally be on around 16 000 hectares. But these areas difficult to access and might be therefore not continuously used by livestock. The exact area used by extensive livestock farming is therefore difficult to estimate. Livestock farming might range between 14,022 hectares and 38,826 hectares.

Since the 18th century, farming in the Suurveld area is noted. Most farmers live since generations in the area learning from their fathers how to farm the land (Plessis pers. comm. 2011). They farm with sheep, mainly Merino breed for wool production, but also for meat production. Besides, farmers also have some cattle for an extra income, but the Suurveld area is "*more suitable for sheep farming*" (Plessis pers. comm. 2011).

Nevertheless, the Suurveld is a marginal farming area. Due to low nutrient concentration and the acidic character of the soil, the grass quality is not very high. This means, farmers have to provide their livestock with extra minerals and nutrients in form of lick blocks. Moreover, the stocking rate on the field must kept very low, "*approximately 20 sheep can grass on 100 hectares*" (Pretorius pers. comm. 2011) to prevent overgrazing. A grazing rotation strategy is applied to support regeneration of the grass fields and to ensure provision of grazing resources throughout the year. Therefore, grass fields are divided into different camps which can range between 80 and 150 hectares (Plessis pers. comm. 2011). Livestock is moved between the different camps.

On cultivated land, fodder and grain are produced (by dry-land farming). The terrain has many slopes and hills. Therefore, cultivated land is typically applied in a terrace form to prevent soil erosion (Figure 26). To improve productivity of the field, chemical fertilizers are applied. Some farmers also work with compost.

Figure 26: Dry-land cultivation is typically applied in a terrace form to prevent soil erosion and to keep the rainwater longer.

Another important aspect of livestock management is the prevention of diseases. Due to medicinal input disease play in general a minor role in the area. There are always certain diseases present (such as tick borne disease or wireworm) which are treated preventable by medicine; some vaccination have to be done every year as well. But on the other hand there aren't a lot of diseases in the area because of the low animal population. However, disease like the rift valley fever which is spread by a mosquito is a new issue in the area and farmers need to be careful with development of resistance due to high doses of medicine (Plessis pers. comm. 2011; Plessis pers. comm. 2011).

a) Prescribed burning

Fire is a common farming practice in the Suurveld area. To increase the quality and quantity of the grass elements, the fields are regularly burnt. Livestock farmer call it "*scheduled block burning*". Therefore, grass field camps are burnt on different time intervals based on the vegetation composition. Camps with smaller slopes covered with a grassy fynbos are generally burnt once in 3- 4 years. Once in 7 years camps with fynbos vegetation are burnt, mainly growing on steeper slopes. Another farmer states that he burns the field once in every 8-11 years. More frequent burning happens as well. After burning, grass plants appear within 6 weeks and provide fresh fodder (Plessis pers. comm. 2011). Sheep go from fresh burnt field to fresh burnt field following the rotating system. In generally, the camp can be used for 3 years or longer. Before the area is burnt again livestock farmers often give the field "*a cycle of rest*" to regenerate (Plessis pers. comm. 2011). After this time the fields are 'ready' to burn again. Fire season is from January to March, when temperature cools down and soil is not too dry after summer rainfall. To be allowed to burn their fields, farmers have asked for a permit from the local farmers association.

Field fires are applied since generations as a farming practice; Khoisan people already burnt the fields for hunting and managing the environment. However, prescribed burning is a big discussion point between (livestock) farmers and nature conservationists. Whereas farmers would like to burn more frequently to increase re-sprouting species such as grasses en thus productivity of their field, nature conservationists want to apply a natural fire cycle which means longer fire return interval. Farmers often argue that they "must burn" their fields, because this vegetation is adapt to fire and thus fire "don't damage the fynbos". Moreover, vegetation "will not burn when they are too young" (> 4 years). In the scientific wold different opinions exist on the optimal fire regime. However, nature conservationists criticize too frequent burning by farmers due to the loss of plant diversity. It is argued that shorter fire return intervals, favour grass species due to their (naturally) rapid growth after a fire event. However, re-seeders (such as protea spp.) will not get the chance to fully mature within a shorter cycle, seeds can't developed before the next fire cycle. In this way, repeated frequent burning can cause local extinction of re-seeders and thus loss of biodiversity (Van Wilgen 1982; Vlok and Yeaton 2000; Van Wilgen 2009).

b) Conservation of leopard?

Since some years, leopards are seen on farmland but killing livestock. In the past, farmers were allowed to hunt and shoot leopards, but nowadays this is forbidden due to conservation legislation. The leopard is a protected species. It is one of the remaining top predators and plays a crucial role in the ecosystem. But livestock farmers in the Suurveld work together with nature conservationist to find alternative solutions to deal with the leopard such as non-lethal hunting practices and financial compensations for the lost livestock. *"At the moment we have a good relationship with nature conservationist. We are working together. When we have a problem with leopards, we phone them and decide what to do with the `problem animal´. For instance, in 2004, a leopard killed sheep on my farm. We caught the leopard brought it to the Addo Elephant National Park"* (Suuranys livestock farmer).

Figure 27: Since some years, leopards are seen on farmland killing livestock. But the leopard is a protected species (Photo: Living Lands).

4.2.3. Intensive fruit farming in the Langkloof

The Langkloof is a broad valley lying between the Tsitsikamma Mountains and Kouga Mountains. It stretches along the R62 from Kareedouw to Avontuur, but in this report the Langkloof refers to the part located within the Kouga Catchment namely from Heights to Avontuur (L82A-D).
The Langkloof is dominated by intensive deciduous fruit cultivation. It's the second largest deciduous fruit producer of South Africa and renowned for its fruits world-wide (Horgro Tree Census 2011).

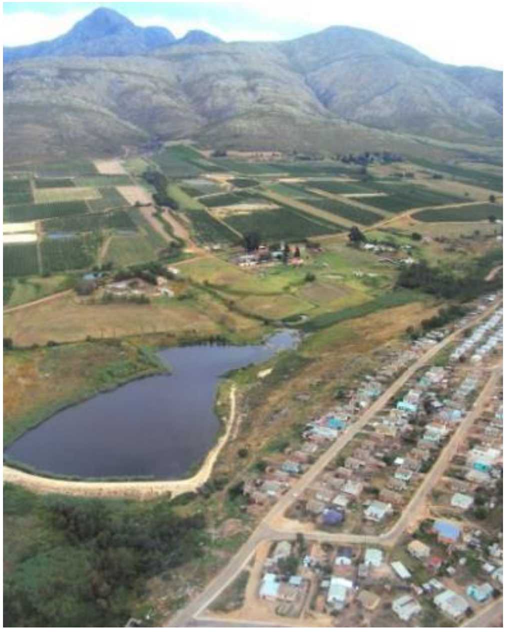

Figure 28: The Langkloof is dominated by deciduous fruit farming. Most residents of the Kouga catchment live in the Langkloof, and working in the orchards along the R62.

Climate and soil structures make the area suitable for the cultivation of fruit trees. The contiguousness to the sea brings a cool breeze from the sea over the mountains. This keeps temperature milder during summer and during winter the necessary cold units (frost) are present. Moreover, nutrient richer soils on the valley floors derived from shale and alluvial depositions as well as a marked clay accumulation, are better requirements for the cultivation of fruit trees than surrounding sandy soils. In the past this area was characterized by wetlands, nowadays most wetlands in the Langkloof are drained and converted into orchards.

Available ArcGIS data estimate that in the Langkloof an area of 16,171 hectares is under fruit farming. But most probably this number is too large and primarily linked to land tenure. According to official statistics, approx. 7,000 hectares in the Langkloof are intensively used for growing apples (66.5%), pears (25.5%), plumes (3.6%), apricots (3.1%), and peaches (2.6%) (see Appendix VIII) (Horgro Tree Census 2011). Other parts of the Langkloof are not intensively used by fruit farmers. Often fruit farmers have some cattle to graze in the areas towards the mountains for "*some little extra income*" (fruit farmer). The total fruit production generate a gross income of approx. R87,000 per hectares per year (Powell and Mander 2009). Production even increased over the last years, and most farmers plan to expand in the next years. Most of the fruit is destined for the export to Europe; production for the local market is limited. Due to the European economic crisis more and more farmers try to find new trading opportunities in the Far and Middle East, Asia and Russia. The economy of the catchment greatly depends on Langkloof's fruit production. Langkloof's fruit industry is managed by approx. 150 farmers whereas around 20 of them are "*really big*" owning more than one farm in the

area (van der Merwe pers. comm. 2012). There are 22 emerging farmer in the Langkloof working in the fruit sector (van der Merwe pers. comm. 2012).
Throughout the whole year, fruit farmers are working in their orchards. Fruit farming is very labour intensive, especially during harvesting time. Up to 80% of the local people found their work in the fruit farming (Kou-Kamma emerging farmer forum pers. comm. 2011)

a) Irrigation management

The most crucial management practice for the fruit production is irrigation because rainfall water would be not sufficient for the cultivation of fruit trees. *"From September onwards we have to irrigate our orchards. Water is running the whole day long and through the night, till the first good rain fall in winter. Then we stop with irrigation"* (Fruit farmer). (Baselmans 2011) interviewed 15 farmers in the Langkloof and calculated an annual average of 5,461 m^3 irrigation water use per hectares of orchards. The DWAF estimated an average annual irrigation water use in the Langkloof of 32 million m^3 per year in 2000 (DWAF 2004). The primarily water source are the tributaries of the Kouga River, taking water directly from the Kouga River is not allowed. The water is pumped to communal or farm dams. Every farmer has several smaller farm dams on his property (Figure 29). It was estimated that in 1992 the total capacity of all dam's in the Langkloof is around 26 million m3 (DWAF 2004). (Notice, since1992 onwards it is prohibited by law to build any new dams in the Kouga catchment). Surface runoff water is stored in the farm dams as well, but makes a smaller contribution to the total water supply. Via a canal system the water is transported to the irrigation system of the orchards.

Figure 29: Farms dams are close to the orchards, to store irrigation water (Photo: Author)

During dry periods, especially during the last years, farmers also made use of groundwater for irrigation via boreholes. Therefore, farmers have to bore up to 200 meters deep to get water.
There are a few bigger joint and communal dams (Haarlem dam, Joubertina dam, Apiesrivier dam) which are managed by a water schedule to manage a fair water allocation to the different users. This means, at different times of the day different farmers are allowed to pump water to their farm dams. Every dam has an irrigation boards (IBs) to the water allocation between farmers and local communities. The IBs schedule at which time which farmers are allowed to pump water from the joint dam or weir to his smaller farm dam.

b) Other orchard management practices

Next to irrigation, pruning, soil preparations, spraying, thinning and harvesting are other important farming practices within the fruit farming.
During winter time, trees are pruned which means old branches are removed and other branches are cut back for the optimal growth of the trees. To support a healthy tree development soil preparations are vital. Due to the naturally relative low nutrient concentration in the soil, farmers have to fertilize a lot. To apply the right combination of plant nutrients (mainly Nitrate, Phosphorus and C), soil and leaf analysis are done regularly. Most fertilizer as based on chemicals, some farmers also use compost or/ and mulch as natural fertilizer to improve soil quality. During growth season, nutrients are added to the irrigation water.
During the blossom period (spring time), spraying is applied to reduce pest and weed growth in the orchards. In general, spraying is applied preventative. The main agricultural pest is codling moth (*Cydia pomonella*), but also snout beetle, bollworm, Mediterranean fruit fly (*Ceratitus capitata*) and fungi can cause big damages to the fruits. On the other side farmers are heavily depend on some insects (especially bees) for pollination of the fruit trees. Without pollination there is no fruit development. Therefore, farmers have to be carefully that the chemicals will not negatively affect

pollinators. There are clear guidelines for the use of chemicals for spraying due to GLOBAL GAP certification (Global Good Agricultural Practice) (formerly EUREPGAP). To be allowed to export to Europe, farmers have to follow the requirements of GLOBAL GAP. With the establishment of this certification in 1997, the use of chemicals in the fruit industry was dramatically cut down. Heavy so-called red-label chemicals are not allowed anymore due to environmental, labour health risk and food security. Moreover, farmers have to monitor their land in terms of flora and fauna and have to make a conservation plan for each farm. Farmers are forced to search for more environmental friendly alternatives to control pest and prepare the soil. Even though most farmers still perceive the reduction of their chemical input in the orchards as very difficult, the use of alternative farming practices and the awareness around environmental health have increased. For example since five years, pheromones are applied by all interviewed farmers to disturb mating activities of the codling moth. Fruit farmers completely abdicate to chemical spraying in the case of codling moth predation. Another approach seen on one farm is the integrated pest management (IPM). This pest management control agricultural pest in a more ecological approach which emphasis the controlling and monitoring of pest development rather than spraying in advance (Baldie pers. comm. 2011). To give an example, roses are often planted around orchards which are attack by pest insects first before attacking orchards. In this way, the roses sever as indicator when spraying is needed.

Figure 30: Apples are harvested during summer month and sorted and packed directly on the farm either on small scale (left photo) or big scale (right photo). (Photo: Author)

During summer month, picking season starts (Figure 30). Harvesting time varies between the different fruits and varieties. Generally speaking, apples are picked from February till end of May, whereas pears harvesting starts in January and ends in February. Apricot (November till December), peaches (October till February) and plums (November till January) are picked earlier in the season (South African Fruit Farms 2012). Bigger farms have their own packing and cold storage sheds where fruits can be stored up to 10 month. Smaller fruit, damaged fruits and fruits with less quality are often brought to the local fruit juice factory in Louterwater (Granor Passi Lankloof) to make concentrate juice.

4.2.4. The Kouga Dam – the water supplier

Apart from the smaller farm and community dams, the Kouga is the biggest storage infrastructure in the area located in the northeast of the catchment (Figure 31). The dam was built in 1969 and has a storage capacity of 128.7 million m^3 (CSS1 2009). Between 73 per cent and 77 per cent of the water in the Kouga Dam originates from the Kouga River, the Baviaanskloof River supplies around 20 per cent to the dam (Jansen 2008).

The Kouga Dam has a significant importance for downstream areas. It is a key water source for the Nelson Mandela Bay Metropolitan Municipality (Port Elizabeth) for drinking water and for domestic and industrial use. Moreover, downstream agricultural land in the Gamtoos Valley depends on the water from the Kouga dam for agricultural purpose. Here, 9982 hectares are cultivated by mainly orange trees which need to be irrigated (Jansen 2008). From the Kouga Dam, the water is canalized through the Gamtoos valley, and ends up in the Lorie dam reservoir from where water is transported to Port Elizabeth (Jansen 2008).

Figure 31: The Kouga dam is the biggest storage infrastructure in the catchment (around 400 hectares) (Photo: author)

Box 5: Water security: A reliable water supply is very crucial for agriculture, nature and human well-being in and outside the catchment. However, South Africa is a semi-arid country, and water availability is limited. The fruit farmers of the Langkloof became very good water manager and created a complex but fine-tuned water management (including IB, pipelines, canals and dams) to make optimal use of the available water. But water is still experienced as the main limiting factor for economic growth in the area. Periods of water abundance and water shortage happened during the last years. Especially last drought period provoke farmers to discuss about the possibility to increase the water holding capacity in the catchment. More water needs to be stored during heavy short time rainfall intervals, to buffer following dry periods, as argued by local fruit farmers. One possibility could be to increase the storage capacity of the dams or/and to build a second big dam such as the Kouga Dam.

Scientists identify a decrease of the total rainfall in southern Africa which certainly increase the pressure on local water security (de Wit and Stankiewicz 2006; Blignaut et al. 2009). At the same time, water demand will increase significantly, especially when the industrial site in Port Elizabeth (Coega IDZ) is fully operationally. This supports the need for increasing the water holding capacity in the catchment, whether artificial or natural.

Current water situation already force people to reduce water. In 2010 the government put out water use restriction. Farmers in the Kouga catchment at the same time search for new technologies to farm “water wise”. Most fruit farmers use drop irrigation to be more water efficient, only some areas are left irrigated by sprinklers. To increase the moisture in the soil, leaves and weeds are often left under the fruit trees and are not killed with herbicides anymore. Additionally, mulch is more and more applied by fruit farmers, which works as a natural fertilizer and prevent moisture loss.

5. Assessment of the environmental state of Kouga's ecosystems

This chapter describes the environmental state of and threats to, the Kouga catchment.

Information collected from national and regional biodiversity assessments give first quantitative insights into the environmental state of the catchment identify the drivers of environmental decline (5.1.). This assessment is followed by presenting local people's perceptions (including land users and experts) on the state of Kouga's environment (5.2). By combining the different kind of data and information, the main issues constraining sustainability in the catchment are identified (5.3).

5.1. Assessment of environmental state of Kouga's ecosystems based literature review

In South African literature, the environmental state of an ecosystem is described by two headline indicators: the ecosystem threat status and the ecosystem protection level (Berliner and Desmet 2007; Driver et al. 2012).

5.1.1. Ecosystem threat status

The ecosystem threat status describes to what degree an "ecosystem is still intact or alternatively losing vital aspects of their structure, function and composition" (Driver et al. 2012). National biodiversity assessments classify loss of habitat as the biggest threat to (terrestrial) ecosystems intactness. Therefore, in this study habitat loss is used as an indicator to assess the ecosystem threat status.

Loss of habitat is caused by habitat fragmentation, transformation or/and land degradation. Habitat fragmentation is a result of lost ecosystem connectivity when for instance infrastructure cut through a natural area. Habitat transformation and degradation is described differently in the two available regional biodiversity assessments (BMR and GRI study) due to different classification systems and the identification to what extent an ecosystem is changed. In the BMR study, Skowno (2007) defined transformation as land uses (including cultivation, plantations, built-up areas and large dams) that replace natural vegetation or degraded it to such an extent that ecological processes stop functioning. The GRI study adds very heavy alien infestation to this category. In this way, transformation used to describe an area which "has completely transformed and nearly completely replaced natural vegetation" which is caused by land uses and/or alien infestation (Holness et al. 2010). Moderate to dense alien infestation is categorized under degradation. This means, the GRI study categories alien infestation as a driver of degradation and transformation of natural habitat depending on the density of infestation. In the BMR study however, alien infestation seems to fall inclusively under degradation. Degraded natural habitat describe areas which have been over utilized or have been highly infested by alien plants over a longer period and consequently reduced or altered the natural vegetation cover (Skowno 2007) or where natural habitat of the environment had not yet recovered from previous activities (Holness et al. 2010).

As a result of these different classifications systems, the combination of data from both studies is not possible without losing some accuracy (see Chapter 2: Method) but trends can be identified.

Table 8 gives an overview of the estimated areas in the Kouga catchment classified as natural, degraded and transformed based on ArcGIS data from the BMR and GRI study (Euston-Brown 2006; Vlok et al. 2008).

Table 8: Estimated quantitative data of the environmental state of the Kouga Catchment based on (Euston-Brown 2006) and (Vlok et al. 2008)

State	Hectares	% of the total catchment
BMR		
Natural	186 220	
Degraded	169 745	
Transformed	17 795	
GRI		
Natural	24 484	
Degraded	3 378	
Transformed	14 071	
Total	415 693	100.0
Natural	210 704	50.7
Degraded	173 123	41.6
Transformed	31 866	7.7

From Table 8 it is seen that the scarce majority of the study site is classified as natural (50.69 per cent); remaining areas are altered and/or changed due to land degradation (41.65 per cent) and habitat transformation (7.67 per cent).
Land degradation is the biggest threat to the Kouga's natural environmental. Degradation is caused by overgrazing, too-frequent burning or/and alien infestation leading to loss of ecological integrity. Transformation of natural habitat occur on smaller scale and refers to the replacement of natural vegetation by heavy alien infestation and land uses including dry-land and old cultivation, irrigated agriculture (= fruit farming), large dams and urban/peri-urban development.

Figure 32 illustrates where degradation and transformation of natural habitat occur in the Kouga catchment. Remaining parts are classified as natural; small gaps in the Langkloof are a result of lack of data.

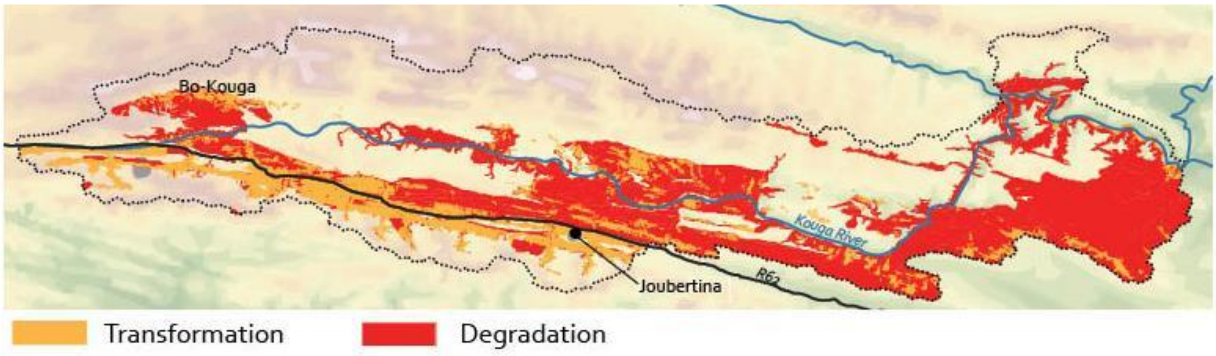

Figure 32: Ecosystem threat status: Transformation and degradation of natural habitat in the Kouga catchment (Map: this thesis based on ArcGIS data by Euston-Brown (2006) and Vlok et al. (2008))

In Figure 32 it is seen that undisturbed natural areas are mainly found in Kouga's mountains (including the Tsistikamma, Baviaanskloof and Kouga Mountains). Both BMR and GRI studies classify the mountainous areas as pristine to good condition resp. as natural. This means mountain fynbos vegetation is intact and ecological processes can function. There are some areas in the Kouga and Baviaanskloof mountains which are classified as degraded and/or transformed which changed the natural flora (in particularly *Baviaans Sandolienveld* vegetation). Drivers of this alteration are some isolated orchards, dry-lands and old cultivations. Some more accessible areas have also been exposed to frequent fires and heavy grazing after fires which has severely degraded these areas (Euston-Brown 2006). A more concentrate threat to ecosystems in the mountains is seen in the Bo-Kouga. Human activities in particularly fruit farming, dry-land and old cultivation replaced parts of the *Kouga Renosterveld Sandolienveld* vegetation. Most activities in this area took place in the past, but environment is not yet recovered from previous activities (Versveld pers. comm. 2012).
Up in the Tsitsikamma Mountains the GRI study identify some isolated patches of degradation (approx. 135 hectares) which was caused by the installation of radio telecommunication masts (Vlok et al. 2008). Moreover, fynbos vegetation in the Tsitsikamma Mountains is under increasing pressure by exotic plants, coming from the pine plantation at the other side of the mountains.

The biggest concentration of habitat transformation is seen in the Langkloof, along the R62. Fruit farming, urban, development, dry-land, old cultivation and alien infestation altered natural habitat significantly. The Langkloof valley is primarily covered by fynbos-renosterveld (in particular *Langkloof Renosterveld, Haarlem Fynbos Renosterveld, Langkloof Waboomveld, Kouga Grassy Fynbos*, *Baviaans Sandolienveld, Kouga Mesic Proteoid Fynbos* and *Tsitsikamma Mountain Proteoid Fynbos*) which is under great threat by orchards, livestock farming, housing and alien infestation. (Euston-Brown 2006) classifies this area as transformed and heavily degraded due to dry-land and fruit farming. The GRI study categorize the Langkloof mainly as 'Farm', a transformation level rather than degradation category; degradation in the Langkloof area is mainly caused by alien infestation. Especially along rivers and wetlands in the Langkloof, invasion of alien plants pose a great threat to the natural ecosystem according to GRI data (Vlok et al. 2008).

North of Joubertina towards the Kouga Mountains another concentration of environmental decline is seen. Between Braamriver and Opkomst natural vegetation (*Baviaans Renoster sandolienveld and Baviaans Sandolienveld*) is classified as heavily degraded and severely degraded habitat. This alteration is associated with dry-land and old cultivation which caused overutilization of natural resources (Euston-Brown 2006).

In the Suurveld alien infestation, dry-land and old cultivation are the main driver of loss of natural habitat. Here, mainly sweet and sour grassland vegetation (S*uuranysberg Sweeg Grassland* and *Suuranysberg Sour Grassland*) as well as grassy fynbos and renosterveld vegetation (*Langkloof Bonteveld, Kouga Grassy Fynbos, Kouga Arid Fynbos* and *Baviaanskloof Sadolienveld*) are under great threat due to extensive livestock farming. Grassy fynbos is most vulnerable to fire leading to changes in vegetation composition (Euston-Brown 2006). The spread of invasive species puts an additional pressure on natural habitats. Euston-Brown classified the majority of these habitats as heavily degraded. Sandolienenveld vegetation is even classified as severely degraded linked to livestock farming (Euston-Brown 2006).

Degradation and transformation of natural vegetation is also recognized around the Kouga Dam. The building of the Kouga Dam and establishment of orchards in former riverbed mainly replaced thicket vegetation (*Baviaanskloof Thicket Savanna*, *Gamtoos Bontveld,* and *Baviaanskloof Spekboom Thicket*). (Euston-Brown 2006) classified this areas as heavily to severely degraded. Along the Kouga River and its tributaries, thicket vegetation (mainly *Baviaanskloof Spekboom Thicket*) is also heavily degraded due heavy alien infestation. Indeed, (Powell et al. 2009) estimate that the main area of infestation in the Kouga catchment are the riparian zones along the Kouga River and its tributaries in the Kouga mountains.

5.1.2. Ecosystem protection level

The ecosystem protection level describes the extent to which ecosystems are protected by national legislations (Driver et al. 2012). Ecosystem protection in South Africa focuses on biodiversity conservation. Therefore, South Africa has a Biodiversity Act (NEMBA Act 10 of 2004) which guidelines the management and conservation of South Africa's biological diversity and its components. This Act also promotes the establishment of so-called 'bioregional plans'. The Kouga catchment falls within the Cape Action for People and the Environment (C.A.P.E.) and the Subtropical Ecosystem Planning Project (STEP) which focus on the management and conservation of the CFR and Thicket Biome respectively (CSS1 2009). Moreover, the northern part of the Kouga catchment is part of the proposed BMR Planning domain, managed by Eastern Cape Parks (ECP), the regional conservation agency. The southern part belongs to the GRI planning domain, another plan to conserve and protect biodiversity by CapeNature, the provincial conservation agency in Western Cape.

Although different long-term strategies and visions for biodiversity conservation in the area exist, this does not mean that the catchment is actually under adequate protection. Based on available ArcGIS data it is calculated that approximately, 80 000 hectares (approx. 30%) of the Kouga catchment are under formal protection through the Baviaanskloof Nature Reserve (BNR) and Formosa Nature Reserve (FNR), whereas the BNR is the biggest contributor to the protected area level in the Kouga catchment (Figure 33).

The catchment also have some informally protected areas which are municipality, private or voluntary conservation areas including private game reserve and conservancies such as Mountain Pastures Game Lodge and the Suuranys Conservancy area. The exact hectares of informal protected are missing.

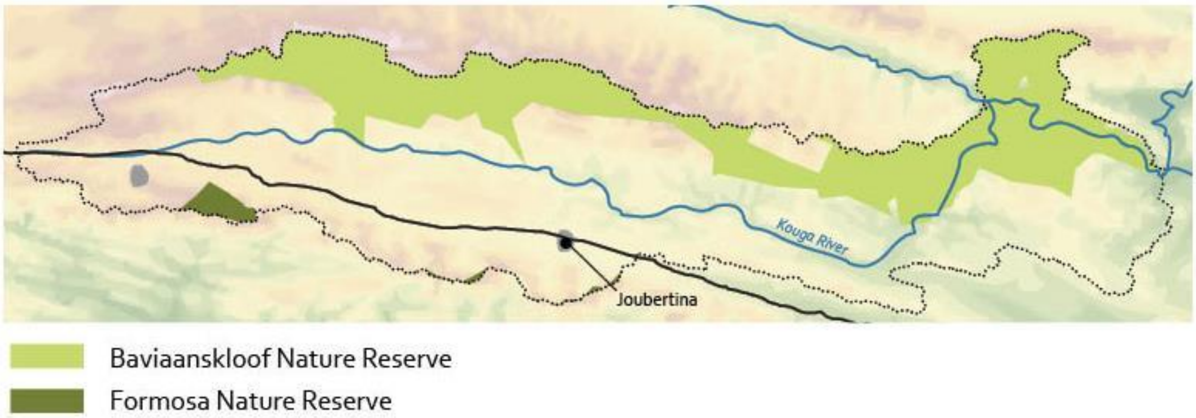

Figure 33: Ecosystem protection state: The protected areas of the Baviaanskloof Nature Reserve and Formosa Nature Reserve falling in the Kouga catchment (Map: this thesis based on ArcGIS data by Euston-Brown (2006) and Vlok et al. (2008))

By combining and Figure 32 and Figure 33 and it can be concluded that the Kouga and Baviaanskloof Mountains, covered by the '*Kouga Mountain Fynbos Complex*', are intact as a result of formal protection. According to (Lombard et al. 2003) mountain fynbos vegetation in the catchment is "currently not vulnerable". Indeed, these areas are even recognized as wilderness areas by local conservationists. Good and health population of large mammals such as Buffalo seen in this area are often used indicator of healthy ecosystems in the BNR (Erlank et al. 2009). Moreover, critical biodiversity areas (CBA) along the tributaries of the Kouga River are conserved as part of a protected area (BNR). Especially forest habitats which are endemic to South Africa are well conserved and recognized as intact (Skowno 2007). Vegetation in the Tsitsikamma Mountains only partly falls under protection (as part of the FNR) even though riparian zones and mountain fynbos vegetation in the Tsitsikamma Mountains are identified as critical biodiversity areas. These areas are primarily under great threat due to alien infestation.

Thicket vegetation along the Kouga River and its tributaries is also highly infested by invasive alien plants; although some parts are part of the BNR. The riparian zones falling outside formal protection are categorized as "vulnerable" habitats, vegetation at the Kouga Dam is categorized as "critically endangered" (Lombard et al. 2003).

Eastern grassy fynbos areas are not well represented in protected areas, as well as the fynbos-renosterveld mosaic in Langkloof valley and Bo-Kouga. Both vegetation types are critical biodiversity areas (Euston-Brown 2006), but as a result of intensive and extensive land use, these habitats are degraded and transformed and consequently recognized as "vulnerable" habitats (Lombard et al. 2003). National survey classify the Langkloof renosterveld vegetation and (Humansdorp) grassy fynbos even as "endangered" ecosystems (Mucina and Rutherford 2006).

Renoster sandolienveld vegetation (classified as fynbos-renosterveld mosaic) in the Langkloof and in valleys in the Kouga Mountains are under great pressure due to transformation and degradation. The majority of this vegetation class is classified as partially degraded, partly also severely degraded or/and transformed mainly due to farming practices. Surprisingly, this vegetation type is not explicit recognized as a threatened vegetation by the regional biodiversity assessment (Skowno 2007) and is also not part of any protection.

5.2. Assessment of the environmental state of the Kouga catchment based on stakeholders' perceptions

From the literature review it is concluded that the Kouga catchment is partly in a good state, partly under threat due to transformation and/or degradation of natural habitat. Whereas most healthy ecosystems are protected areas, outside the reserves ecosystems are under great pressure due to agriculture, infrastructure and alien infestation. These findings are based on national and regional assessment, not on information from the study area itself. Therefore, to get a better picture of the environmental state of Kouga catchment, local knowledge gathered from interviews in the field is consulted and compared to available literature. The following paragraph will present local people's (primary stakeholders) and expert's (secondary stakeholders) perception on the environmental state of the catchment.

5.2.1. Experts' perception on the environmental state of the Kouga catchment

Representatives from local social, environmental and governmental institution as well as individuals, which are not farming on commercial scale in the area, are classified as 'experts'. Experts are secondary stakeholders, as they do not directly manage the land. Representatives of ECP recognized as primary stakeholders but in this assessment classified as experts due to their knowledge capital and their position in this issue.

Most interviewed experts suppose that the Kouga catchment is generally in a good state. Especially the mountainous areas are recognized by their natural, "*untouched*" status associated with the high level of biodiversity in these areas. "*Ecosystem health and high biodiversity go hand in hand*", which legitimizes the need for conservation of biodiversity to maintain ecosystem health, according to experts.

Surprisingly, when talking with experts about the environmental state, they often exclude cultivated land from any environmental considerations rather focus on the protected areas in the mountains. When asking experts explicit about the environmental state of the whole catchment, the perceived environmental state of the catchment decreases due to farming. Agricultural land is often recognized as an area with less or no biodiversity comparing to natural areas. Some experts described agriculture as the "*destroyer of the natural vegetation*" and "*agriculture in the Kouga catchment has overwhelmingly the greatest extent, and has caused the greatest loss of species*"; other opinions such as *"agriculture in the Kouga is a relative sustainable land use"* were also heard. However for most experts, land use, in particularly fruit and livestock farming, is the chief threat to Kouga's nature.

Figure 34: *"Biodiversity is important for ecosystem resilience*" and thus needs to be protected, according to experts. Agriculture however cause loss of biodiversity and is seen as the chief threat to Kouga's nature. Main argumentation is the transformation of natural land into agricultural land (Photo: M. Kruger (left), author (right))

Main argument is the transformation of natural areas into farming areas (grass field and orchards) which cause loss of biodiversity and thus reduce ecosystem resilience, according to experts (Figure 34). Farming related management practices such as the intensive use of fertilizer and pesticides and prescribed burning are additional threats to the environment. *"Fruit farming is still using tons of poisons in the orchards while polluting the water and destroying the soil". Moreover, "Overgrazing is still happening"* and "*grass fields are too frequently burnt*" which increase the risk of soil erosion and loss of biodiversity. One expert gave the example of an area in the Bo-Kouga. Here, agricultural activities depleted the area so much, that the area is "*farmed out*" and farming in the area is not valuable anymore. In addition, gullies developed along the river as a result of overgrazing, which "*destroyed the natural river bank*" and cause higher sedimentation rates downstream. In the Kouga

Mountains, areas of low vegetation cover were seen surrounded by intact fynbos vegetation. Experts explained that these areas were in the past used by livestock farming.

Farming does not only reduce biodiversity but also threat local water security, according to experts. The catchment is classified as a semi-arid region, which means any further decline in the water supply has serious consequences to humans and the natural environment. However, "*in the Langkloof we see overuse of water*" due to the high water abstraction by fruit farming according to experts. This changes the natural water flow and decrease water quantity. *"During the last years, there were rivers which stopped flowing during summer month, which didn't happen before"*.
The invasion of alien plants is also recognized as a driver of water shortages in the catchment. All interviewed experts perceive IAPs as a big environmental problem in the Kouga catchment. But it is not only the concern about the decrease of the water supply by these species, but also its great threat to the local natural biodiversity. Clearing of IAPs is therefore an important restoration activity to maintain ecosystem intactness.
However, it seems that IAPs have been becoming a bigger problem and more areas are densely populated by exotic species despite of clearing activities, according to experts. "*We are going to lose the battle against them (IAPs) if we go on like this".* This expert refers to the ineffective work of alien clearing due to lack of awareness and willingness of local land owners to commit to restoration activities.
Another threat to Kouga's environment are the possible impacts of climate change which will also influence water availability in the catchment. Climate change could be the possible driver behind the occurrence of the extreme climate events during last years, according to experts. However, knowledge about this issues and its impact on the area is limited. "*A lot of things are unknown and we do not have enough good knowledge about the impacts of climate change*". But it could be also human activities in the catchment itself which enhance the occurrence of extreme events. *"I had the impression that the water flow measured in 2007 during flood was more concentrated due to the canalization of streams, changes of floodplains and destruction of wetlands by orchards".* "*A lot of flood damage could be prevent as for instance orchards are not build in the floodplain*", explained by another interviewed expert. The restoration of riparian zones is seen as a crucial element to cope with extreme climate events. Riparian vegetation absorb water "*like a sponge*" during heavy rainfall which decreased the stream flow and also cause less damage to downstream land use. However, no active restoration activities, beside IAPs clearing are happening. In some areas, nature recovers naturally from pervious environmental decline without any active restoration activity. Old cultivations in the Bo-Kouga, for instance, show *"a strong natural recover process".* But this process is quite slow. *"Sine 15 years of restoration on my land which used to be cultivated land, I only managed to restore 50%" of my land*. This is because South African environment is more sensitive and therefore restoration is more difficult and needs more time, as explained by a local ecologist. More active restoration activities are recommended by most experts to support the natural recover process.

Since some years, the illegal harvesting of wild honeybush plants in the Kouga catchment becoming an increasing environmental (and social) problem. In some areas, honeybush plants are nearly depleted but exact information are missing. Nature conservationist, governmental representatives and farming communities are concerned about this development and work together to find a ways how to protect this plant from further depletion. First meetings and workshops with different stakeholders were hold to identify the problem in the Kouga catchment in more detail in order to establish a management plan.

5.2.2. Local land users' perception on the environmental state of the Kouga catchment

In contrast to what experts said, almost all interviewed farmers (28) argued that their land is in a healthy state; three farmers mentioned that their land is in general healthy but that there are "*some areas in the Kouga catchment which run the risk of soil erosion*".

Farmers also argued that the environmental state of the land is a quite important issue not only for nature conservationist and scientists, but also for local land users because they "*depend on the environmen*t" (Figure 35).

Figure 35: All interviewed farmers argued that their land is in a healthy state because of the agricultural productivity. (Photo: Author)

"Farmers in the Kouga are quite aware of their environment because they depend on the environment".

"It is not a formal agreement but most farmers will feel like the same: If you look after the environment the environment will look after you".

"I try to have a low impact on the land and try to be a good farmer to give my farm to future generations in a better state than it is now." (Quotes from the field)

"good looking trees" and *"good looking livestock"* which produce "*good products*" were used as typical indicators to support farmers' argumentation for the healthy state of their land. Agricultural productivity is thus directly related to the health of the land. Thereby, a good water and soil quality is essential to keep productivity according to the interviewed land users. Most fruit farmers were satisfied with their soil quality indicated by "*there is life (micro-organism, earthworm) in the soil*" and it *"smells like a forest*". To improve the health of the soil some fruit farmers try to spray less chemicals "*because otherwise the soil becomes too hard and loss fertility on long-term*". Moreover, fertilizers are applied to improve soil fertility. Soil and leave analysis are done on regular basis within the fruit farming to specify fertilizer and to work "*responsible*". Also within livestock farming, famers *"try to prevent overgrazing and prevent soil erosion"* to keep productivity and to maintain the healthy state of their land. "*To improve the land*" and to enable a higher livestock production grass fields are burnt regularly and fertilizers are applied. There are no big problems with soil erosion, as concluded by a livestock farmer.

The water quality in the Kouga catchment is said to be also good. Farmers argued that water is "*very clean*", it might be even "*the best water quality in the region because it directly comes from the mountains*". However, water in the tributaries along the settlements was sometimes identified as being "*dirty*". A typical explanation was that the sewage from housing areas goes directly into the rivers.

Fruit farmers also used the certification by GlobalGap as an indicator of their healthy farming environment. One fruit farmer in the Langkloof even stated that "*the Langkloof is probably one of the healthiest farming environments of the world*".

When having a broader look on the whole catchment, local land users specified that the state of the environment in the Kouga catchment improved, especially during the last years. Farmers believe that nature is getting better because wild plant and animal species are seen back on agricultural land. "*Natural vegetation recovered in certain areas. We also discovered new plant species such as a watsonia species (endemic plant species). I didn't see them in the Kouga area before.*" It might be the work of conservationists and the better environmental behaviour and awareness of the farmers which improved the environmental state of the Kouga area according to some farmers. Especially the change in the spraying regime was recognized as an important factor for the better environmental

health. "*I use fewer chemicals then in the past because of the environment*". "*Since five years I use mating disruption for codling month as an alternative to spraying. It´s quite successful and more easy to use. Nevertheless, I still think spraying is better practice to improve productivity. But this is bad for the environment"*.
In the Langkloof a smaller wetlands was restored by a farmer's initiative to make it "*beautiful*" and "*healthy*" again, which resulted in a constant water flow again. In the Suurveld livestock farmers and nature conservationist work closely together with nature conservationist to protect the Blue Crane Bird, a vulnerable bird species which is seen since some years back in the grass fields of the Suurveld.

Figure 36: 92 % of the interviewed farmers indicate that they are concerned about the water security in the Kouga catchment. Especially water shortage during summer time is a huge challenge to local farmers (Photo: Author).

However, farmers also mentioned some (environmental) challenges in the area which hamper the productivity of their land.
All interviewed farmers talked about water. In the questionnaires 92 per cent of the interviewed farmers indicate that they are concerned about the water security in the Kouga catchment; eight per cent are not worried. During the last years there were periods of water shortage and periods of water abundance which caused huge damages to the economy of the area. Water shortage is a bigger challenge than flood events, farmers classified in the questionnaire. Most farmers accepted the unpredictability of nature and take it as a reality into account. Other farmers, however, think that global climate change is the driver behind these extreme climate events. But all interviewed farmers believe that something have to happen to deal with the fluctuating water availability. Some request for a second dam to increase the water holding capacity in the catchment to store more water, other searching for new technologies to work more water efficient especially in the fruit farming, such as drip irrigation and the use of mulch.
The main threat to the water provision is the invasion of alien plant species. All interviewed farmers are aware of alien plant species in the catchment, and most of them see invasive alien as a challenge for the area (87 per cent). To deal with this challenge, farmers often try to clear their land because IAPs "*consume our water*" and use arable land. Individuals also clear up in the mountains "to keep the land health". "*I try to keep the numbers down by my own initiative, but we do not have enough resources to be successfully*". All farmers welcome the work of the Working for Water (WfW) teams, but they would like to see local WfW more regularly on their land to clear IAPs. Most interviewed farmers were not satisfied with the work of WfW as they are working *"inefficient"* and *"too slow".* Consequently, the invasion of alien plants will also in future be a big environmental problem whereas people and nature have to deal with.
Another challenge to farming in the Kouga catchment is the spread of disease and agricultural pest on cultivated land. In fruit farming the control of agricultural pest is an important farming practice. Due to restriction by GlobalGap fruit farmers had to decrease their amount of pesticides dramatically during the last 10 years. However, famers often would like to spray more because pests are still visible in the fields and damage the fruit production. Moreover, "*it seems that pests like the fruit fly and bollworm, build up a resistance to certain chemicals with the consequence that some pesticides are not working anymore"*. This means farmers have to search for new pesticides. Some fruit farmers use alternative pest control methods such as pheromones and natural pest control by wildlife in the orchards (i.e. guinea fowl) to compensate chemical spraying. In livestock farm areas it is mainly the spread of disease which damage productivity. The development of new diseases such as the rift

valley fever, demand high medicinal input to keep productivity. But also a "*pest problem*" is recognized in the livestock areas. During the last years, leopards were seen in the agricultural area causing loss of livestock, especially sheep. On the one hand farmers see the appearance of the leopard as an environmental improvement thanks to nature conservation. But on the other hand, they criticize conservation management. They often argue that there are too many leopards for the area and not enough food available "otherwise leopards would not go for livestock".
The overharvesting of honeybush in the catchment is recognized by both, fruit and livestock farmers as an environmental problem in the catchment. "*Honeybush harvesting is illegal and damages the environment. Therefore we need to do something against it*". Most farmers welcome the work of local nature conservationist to protect this species and keep their eyes open for illegal harvesting. There are some areas in the Kouga catchment which face a significant reduction of natural honeybush plant species which is a "*concern in the area*", according to local land users.
Another topic brought up by the interviewed farmers is fire events which damage agriculture and nature. Fire events occur naturally in the area and are also used as a practice in livestock farming to improve the growth of grass. In addition it is argued that *"fynbos vegetation needs to burn to prevent soil erosion"*. However, during the last years the area experienced huge uncontrolled fires which caused damage rather than supporting the health of the environment. In the questionnaire farmers specify their concern about fire events occurred in the Kouga catchment with 78 per cent. But only 35 per cent name fire as a challenge. It is more the current fire management in the nature reserve which they criticize. "*Fire is not a problem but it is the lack fire which causes a higher risk of disaster fires*". "*I don't understand why nature conservationist doesn't apply the block burn system anymore".*
The work of nature conservation seems to be less comprehensible to local land owners, not only when talking about the fire management. Often farmers do not support conservation management because they *"don't understand what nature conservationists want to achieve with their nature reserves"* due to lack of clear objectives and communication towards land owners about the benefits of nature conservation to agriculture as the statement *"Why should I care about the fynbos? It does not benefit my farming?"* show.

5.3. Key issues constraining sustainability in the catchment

Previous assessments show that different views are hold by stakeholders which greatly influence how sustainability in the catchment is perceived. Nature conservationists want to reach sustainability through the management of biodiversity conservation. Agriculture is thereby seen as the main threat to biodiversity. In this way, mountainous areas are in good condition due to nature conservationist, but cultivated land in the Langkloof and Suurveld are degraded and transformed, with the consequence of loss of biodiversity. Farmers however, perceive their land as healthy due to the high agricultural productivity of their land. To keep this productivity on the long term, farming practices, such as fertilizer and clearing of land, are needed. The work of nature conservationist is thereby often perceived as hampering their farming. This opposing views on the desired management of the catchment need to be taken into account when developing sustainable management options.

Local water security is seen by all interviewed stakeholders as one of the main challenges in the Kouga catchment. Farmers identity IAPs as the main threat to Kouga's environment because these plants threats local water security. Experts and literature agree on that, but adding the loss of biodiversity as a consequence of the invasion of exotic plants.

6. Analysis of ecosystem services provided in the Kouga catchment

As shown in previous chapters, different perspectives and objectives exist on the ecosystem and its management. This can make communication among different stakeholders difficult and management efficient. The analysis of ecosystem services can help to "bridge the divergent (world) views and approaches" (Le Maitre et al. 2007) to develop a shared understanding. Moreover, the dynamic of the Kouga catchment as a whole can be captured and explained systematically by the use of the ecosystem services concept, which support the understanding of the relation between nature and human well-being.

This chapter describes the main ecosystem services identified in the Kouga catchment. It will show where these services are provided in the catchment and by which factors are the influenced.

Table 9 gives an overview of the identified ecosystem services following the classification by TEEB (2010) and de Groot et al. (2002). The last column in this table describes the place where identified services are primarily provided in the Kouga catchment. A more detailed description of the ecosystem services in the Kouga catchment is followed bellow.

Table 9: Ecosystem function and services with examples identified in the Kouga catchment (based on TEEB (2010) and (de Groot et al. 2002))

Function and service categories	Goods and services identified in the Kouga Catchment	Place of primarily provision in the Kouga Catchment
Production	***Provision of natural resources***	
Food	Agricultural crops (fruit, wheat, vegetable); meat (sheep, cattle, game); honey; honeybush;	Cultivated land (orchards, grass fields)
Water supply	Provision of water for drinking, industrial, domestic and agricultural use (irrigation)	Natural land
Raw material	Construction material, fuel wood, wool, fodder, pasture, fertilizer, potential of biofuel	Cultivated land, IAPs
Genetic resources	Support for cultivated plants, wild animals breeding	Natural land
Medicinal resources	Medicinal plants (e.g. aloe, honeybush), essential oils and herbs	Natural land (fynbos, thicket)
Ornamental resources	Decorative plants, souvenirs, esp. fynbos plants	Natural land
Regulating	***maintenance of essential ecological processes and life support systems***	
Air quality regulation	Removal of air pollutants to provide "*fresh and clean air*"	Natural land, cultivated land
Climate regulation	Removal of greenhouse gases (e.g. by spekboom plants); support stabilization of climate	Natural land (fynbos, thicket, forest)
Water regulation	Uptake and release of water; Water availability	Natural land (mountainous area)
Natural Hazard mitigation	Mitigation of flood, drought, fires, storm protection;	Natural land (mountainous areas)
Waste treatment	Removal of nutrients from water (water purification)	Natural land (riparian zones, wetlands)
Erosion prevention	prevention of damage from soil erosion	Natural land
Soil fertility	Maintenance of "healthy" and productive soil	Naturally low , on cultivated land high
Pollination	Pollination of wild plants species; pollination of	Natural land

	fruit trees	
Biological control	Natural pest control, seed dispersal	Natural land
Habitat or supporting	***providing habitat (suitable living space) for wild plant and animal species***	
Lifecycle maintenance	Maintenance of biodiversity/healthy habitat (Eden to Addo corridor, biodiversity conservation (wildlife management)	Natural land
Gene pool protection		Natural land
Information	***Providing opportunities for cognitive development***	
Aesthetic information	Biodiversity, agricultural diversity, valued scenic and remote area	Natural & cultivated land
Recreation	Some tourism, farm cottages, hiking trails, outdoor sport	Natural & cultivated land
Cultural and artistic inspiration	National symbol's; World Heritage Site; inspiration for art	Natural& cultivated land
Spiritual and historic information	Historical farm houses; spiritual sites (e.g. Kouga-Mummy);	Natural & cultivated land
Scientific and educational information	Use of nature for scientific research, unknown flora and fauna	Natural & cultivated land

6.1. Provision services

Production functions refer to the capacity of ecosystems to deliver natural products to people, such as food and water. Through photosynthesis and plant nutrient uptake, energy, carbon dioxide, water and nutrients are converted into biomass. This biomass provides different opportunities for consumptive use by humans ranging from food to genetic resources. These resources can be divided into biotic resources (products from living plants and animals) and abiotic resources (products from non-living environment such as minerals). Abiotic resources are often not renewable, thus not unlimited available even in a sustainable management. Therefore, only renewable resources, mainly associated to biotic resources, are taken into account in this analysis.


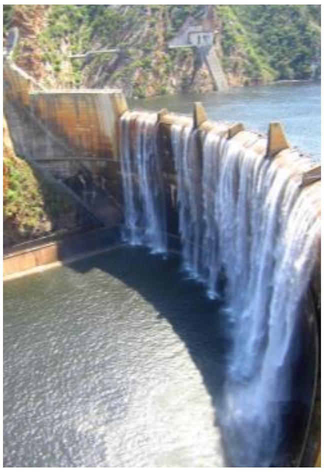


Figure 37: The Kouga catchment provide various provision services including fruits, drinking water and pasture to feed livestock

6.1.1. Food

Throughout history, the Kouga catchment has changed dramatically, from a natural area just used for the harvesting of wild foods, to an area in which intensive agriculture and extensive livestock farming is main provider of food and the major factor for the local economy and international food market.

Through the conversion of solar energy and nutrients into edible plants and animals, wildlife products are provided to and consumed by people. Wild species used to be an important food source to the first inhabitants of the Kouga catchment. However, with the arrival of European settlers, people started to cultivate plants and domesticate animals to increase food production in the area. Nowadays, most food provided in the Kouga catchment is derived from non-wild species by growing crops (mainly fruits) and rearing livestock (sheep and cattle). Only a small part of the local diet is still based on wild plants and animals (e.g. game meat, honey, fish, honeybush).

a) Wild and agricultural products

Wild harvesting occurs mainly in the mountainous areas of the catchment, outside the protected areas. Wild products are largely for local consumption. For example, fruits of an exotic cactus plant (prickly pears) are used for jam and are often sold by local people along the road. An exception is honeybush, which is commercially used for tea and mainly harvested in nature. Honeybush is becoming increasingly popular abroad and therefore its export has increased over the years.

Cultivation and domestication occurs mainly in the Suurveld and Langkloof area. Products from cultivated lands are primarily for the international market.

The eastern part of the catchment is used by extensive livestock farming, of which the main products are meat from cattle and sheep, and wool. For the production of meat and wool, grasslands are needed for livestock to graze on. These grasslands are the result of conversion of natural fynbos and renosterveld through frequent burning. To maximise productivity extra mineral feeding and medicines are given to the animals, and the grasslands are burnt regularly to increase grass quantity and quality.

Most intensive fruit production takes place in the Langkloof, where mainly apples and pears are being grown. The Langkloof is renowned world-wide for its fruit production and exports mainly to Europe and Asia. *"The Kouga catchment lives on the production of deciduous fruits in the Langkloof"* (local resident). To cultivate fruit trees, orchards are needed which naturally do not occur in the catchment. Therefore, large-scale conversion of wetlands and renosterveld area into orchards has been taken place, a process which still goes on, in order to optimise the production of fruits.

b) Factors influencing food provisioning

Currently, agriculture focuses on the maximal provision of a certain ecosystem service namely food provisioning. Thereby, intensive management interventions such as the use of pesticides and fertilizers as well as additional irrigation water are needed to keep this productivity artificially high. Nevertheless, agricultural production still largely depends on natural processes such as water regulation, pollination and soil fertility. Therefore, any changes in the surrounding environment can alter productivity as well. As already seen during last years, the productivity of orchards and grasslands are influenced by extreme climate events such as drought, floods and hailstorms. Moreover, productivity can be reduced by decreasing soil fertility as well as natural pests, plant diseases and wildlife (e.g. leopards). But also European food export legislations influence the food production in the Kouga catchment. "*I had to reduce the amount of chemical pesticides and herbicides that can be used in my orchards due to GLOBAL GAP restrictions, but I still struggle with pests which harm my fruits*" (local fruit farmer). The final factor that can impact agricultural activities in the Langkloof and Suurveld are measures introduced by nature conservationists. Management to improve biodiversity in this area can, for instance, lead to reduced farmlands and number of allowed animals. Additionally, invasion of alien plants in the grasslands in the Suurveld area decrease land availability for livestock grazing and orchards.

6.1.2. Water supply

Catchments generate water which can be stored and/or extracted by people. However, it is not the catchment on its own which determine the amount of water retained and stored but rather the ability of the catchment (in particularly by vegetation and soil) to filter rain water as fresh water which is used by people (de Groot et al. 2002). South Africa's mountain fynbos catchments are regarded as being very important for the provision of fresh water (Van Wilgen et al. 1996). These areas receive most of the rainfall of the country and drain it through the watershed. In the Kouga catchment, fynbos vegetation and sandy soil types in the Kouga catchment contribute to a better absorption of water within the catchment which enhances the provision of water supply downstream (see water regulation). According to (DWAF 2004) the Kouga catchment generate 148.2 million m^3 of water per year.

a) Drinking, industrial, domestic and irrigation water

The Kouga catchment has a considerable capacity to provide water to people, which is also greatly used by several stakeholders outside (downstream) and inside the catchment boundaries. 1.5 million Inhabitants of the Nelson Mandela Metropolitan Municipality (NMMM) receive water from the Kouga River for industrial, domestic and drinking use as well as the Gamtoos valley, an important agricultural area for South Africa, which depends on water from the Kouga catchment for irrigation. But also within the catchment, people rely on water for drinking, domestic and agricultural purpose. The fruit industry in the Langkloof entirely depends on the catchment for irrigation water. In addition, the natural ecosystem and its biodiversity depend on water for its functioning.

b) Water management to optimize water supply

For the provision of water, water reservoirs are needed. Wetlands are natural water basins to store fresh water (Collins 2005). However, to maximise the water storage capacity in the area, land users in the Kouga catchment have built several artificial water reservoirs (dams). "*These dams are the heartbeat of the area"* (local resident). The biggest water reservoir is the Kouga Dam, which has a storage capacity of 128.7 million m^3 (DWAF 2004) This dam is an important water source for downstream users such as the Gamtoos Valley and the NMMM.

To optimise water supply, water provisioning is carefully managed. The Kouga catchment is part of the regional Fish to Tsitsikamma Water Management Area (WMA), the largest WMA in South Africa (DWAF 2004). This WMA regulates the water delivered to the NMMM. But also within the catchment, different water management units (Irrigation Boards) are establish to distribute available water among the different users such as farmers and communities. Most of the used water within the catchment comes from the tributaries of the Kouga River because taking water from the Kouga River directly is not allowed. Groundwater is also used as a water source by local stakeholders, especially during dry periods. The TMG aquifer in the catchment may have important storage potential (CSS1 2009).

c) Factors influencing water security

Sufficient water supply is seen as one of the biggest challenges in the catchment area by local stakeholders. "*People even fight around water rights*" (local farmer). Especially during drier periods water users restrictions are experienced by the catchment´s people.

There are different factors that influence the water security in the Kouga catchment. Invasion by alien plants is one of these factors. Statements like "*they take our water*" refer to the increased water use by alien vegetation compared to native vegetation which has resulted in decreased water yield. The highest reduction of the water run-off is shown in the fynbos shrubland and grassland (Van Wilgen et al. 2008), which are dominant vegetation types in the Kouga catchment. Groundwater recharge is also reduced due to exotic plants, highest numbers are measured in the fynbos biome (Van Wilgen et al. 2008). This has serious consequences for water availability in the catchment. Currently, within the Fish to Tsitsikamma WMA 4.4 per cent of the registered water is lost by exotic infestation; future scenarios prognoses 8.7 per cent of reduction of the water yield in the Fish to Tsitsikamma WMA (Blignaut et al. 2007). Local WfW teams in the catchment try to minimise the impact of alien plants on the water supply by cutting down IAPs. It is important to note that land users tend to clear alien plants on their own land, but do not directly link larger stretches of alien trees further upstream as part of the problem.

An additional pressure on the water security in the Kouga catchment is said to come from the high demand of water by the fruit industry. "*There is a huge overuse of water in Langkloof. Sometimes the river stops flowing during summer time*" (local land owner). This pressure might be even more significant due to climate change as "*water will become scarcer in the future"* (local land owner). But also outside the catchment boundaries, water demand is expect to increase especially due to the growing industrial sites and population numbers in Port Elizabeth (Coega IDZ) (CSS1 2009).

6.1.3. Raw materials

Natural ecosystems in the Kouga catchment provide renewable biotic resources which can be used for construction, fuel (wood) and other uses such as animal food (grass), fertilizer (mulch) and wool.

a) Construction material & fuel wood

Construction material and fuel wood is provided by strong, fast growing tree species with a high biomass and a high combustion value. Fuel wood is often the primary energy source for people in South Africa, as electricity is often limited available (Scholes and Biggs 2004). Indeed, people in the catchment were regularly seen carrying dry wood.

Woody species can also be used as mulch. Therefore, organic material is break down in small pieces and spread on plants as a natural fertilizer. Decomposition of this material leads to the release of nutrients and organic matter to the soil.

However, woody biomass is not abundantly available in the Kouga catchment, because natural ecosystems in the catchment are limited in (fast-growing) tree species due to soil structures. There are only a few small patches of forests in the Kouga Mountains which have the potential to provide wood. But these areas are difficult to access and mainly under nature protection. Moreover, forest species such as Yellowwood trees, are very slow growing species. Consequently, local people use fuel wood and timber mainly from exotic tree species such as black wattle and pine trees. These species were once introduced to South Africa for the provision of raw materials. Nowadays, exotic trees are found throughout the whole catchment, fast growing and easy to burn. IAPs can be also used as 'natural fertilizer'. In fruit farming, IAPs such as the black wattle are break down into wooden chips are used as mulch by some fruit farmers. The use of mulch also helps to conserve moisture and promote the growth of soil organism. One farmer also pointed on the possibility of IAPs to use as biofuel. The usage of IAPs is regarded as having a great potential, however currently its application is limited in the area due to its size and limited organization.

b) Wool & pasture

Another important raw material provided in the Kouga catchment is wool. The Suurveld is predominantly used by sheep farming. However, wool (as well as meat) production largely depend on the provision of animal food such as grass, to feed livestock. Grassy fynbos and grassland ecosystems in the Kouga catchment are used as grazing fields for livestock. Most grazing fields are located within the *Sour Grassland type* in the eastern part of the catchment and *Renosterveld* vegetation in the Langkloof valley, which both have a low grazing potential although it is higher than the fynbos vegetation types. To enhance the grazing potential, grass fields are frequently burned. "*Sour grass fields need to burn to produce green grass which feeds my livestock*" (local livestock farmer). Some parts of these areas are also cultivated with e.g. oats, wheat and Luzern. Luzern is also used to enhance nutrient concentration in the soil and thus enhancing the quality of grass, as Luzern is recognize by its high N-fixation potential.

The mountainous areas are also used by extensive livestock farming to some extent, even though these areas have a very low potential to support livestock farming due to its limited grass component and accessibility of the area. Narrow in-between valleys and the old African surface have a higher capacity to provide animal food than surrounding fynbos vegetation and are thus typical grazing fields for livestock. However, these areas, especially the old African surface areas also recognized for its importance to support large mammal's presence, a focus in biodiversity conservation.

c) Factors influencing provision of raw material

There are several factors which influence the provision of raw materials in the Kouga catchment. As described, fuel wood is currently obtained from exotic species. However, this service might decrease. IAPs management is driven by the goal to eradicate exotic species because of their aggressive water consumption and displacement of the native flora. But with this eradication, the actual and potential use of IAPs as a raw material could be lost and local people have to find alternative fuel wood which is only limited available. This might put an additional pressure on the remaining indigenous forest areas in the Kouga Mountains. But on the other side, the invasion of alien trees can also lead to decreased land availability. Invaded land is difficult to cultivate and grazing potential decrease which in turn decrease the provision of animal food, too. The management of biodiversity conservation also lead to decreased land availability for farming. Another factor which influences Kouga's capacity to provide animal food is climate change. Most livestock farming in the Kouga catchment is entirely depending on rainfall. A changing climate, in particularly less rainfall, influences the cultivation of grains and pasture negatively. This is already recognized as several farmers had to decrease their wheat production and sheep population due to decreased rainfall. The generation of wool is an important economic driver of the Suurveld which depend on a stable animal food production.

6.1.4. Genetic resources

Genetic material is available in wild plant and animals. Cultivated plants and domesticated animals once originated from wild species. Diversity of genetic material still support cultivation of plants and wild animal breeding and plays an important role in food security. "Wild crop relatives remain an essential source of genetic diversity for plant breeders of new varieties" as well as "genetic diversity increase production and decrease susceptibility to pests and climate variation" (Elmqvist et al. 2010).

a) Commercial use of genetic resources for crop and livestock breeding

Commercial use of genetic resources is also seen in the Kouga catchment. Fruit farmers have a great variety of different fruit tree species which once originated from the wild. Changing environmental factors such as climate and changing market force them to change and improve certain qualities of their fruits. New species are cultivated which in turn depend on the genetic material of wild plants. Wild genetic diversity is also equally important to livestock farming as farmers are always alert to new breeds which are better adapted to the area to enhance productivity.

Natural ecosystems in the Kouga catchment support the provision of genetic resources. Especially fynbos ecosystems in the protected areas are regarded as providing a great diversity of genetic resources with a considerable potential. Cultivated land however is characterize by monocultures which have a low genetic diversity.

The benefits of the genetic diversity of the Kouga catchment seem to be less recognized by the catchment´s residents. "*Fynbos does not benefit my farming*" (local farmer). Indeed, local food security depends on genetic resources origin from European and Asian countries. However, wild animal breeding, such as the buffalo breeding in the BNR is an important income to local nature conservationist and is supported by Kouga's genetic diversity. Moreover, the cultivation of new crops, such as honeybush has still a strong reliance on wild exemplars as the cultivation of honeybush is in the experimental stage. Wild honeybush species occur in the mountainous area of the catchment which can provide genetic material to the on-going research.

b) Factors influencing provision of genetic resources

Even though genetic diversity in the catchment is less commercially used by local land users, this service is more valued by nature conservationists and scientists. The provision of genetic resources is often summarized as biodiversity. Thereby, it is argued that genetic diversity is a pre-condition for the provision of other ecosystem services (see habitat services). For instance the provision of the pollinator services is strongly linked to the variety of plant species. To maintain local biodiversity, nature reserves are established in the catchment. A plant nursery at the Kouga dam grows indigenous plants to support the protection of genetic resources. These plants are used for restoration purposes within and outside the nature reserves.

However, genetic resources are under threat by environmental degradation. In some mountainous areas, overharvesting of honeybush is recognized which decrease the genetic variety of these wild plants. One of the biggest threats to biodiversity is the conversion of natural land into farmland.

Other genetic resources used for agricultural production in the Kouga catchment are also under threat due to global loss of biodiversity.

6.1.5. Medicinal resources

Medicinal resources encompass the variety of biochemical substances in natural biota which benefit human health. Many substances from nature are seen back in drugs, pharmaceuticals and cosmetics.

In the Kouga catchment this services is mainly attribute to plants with medicinal properties. The use of medicine from plants has been known to South Africans for centuries; however a lot of this indigenous knowledge is forgotten and not well researched yet. Scientific literature estimates that around 3 000 different plant species are used in traditional medicine in South Africa (Thring and Weitz 2006); approx. 38 indigenous plant species are commercialized for medicinal purpose (Van Wyk 2008).

The Kouga catchment is home to a great variety of plants having a potential to be used for medicinal purpose. Especially the natural areas of the Kouga, Tsitsikamma and Baviaanskloof Mountains provide various medicinal plants. The Khoisan people already used these plants for medicinal purpose (Wessel pers. comm. 2011). Today this potential is mainly used by the ´coloured´ and ´black´ communities in the catchment. Western health care often don´t recognize the value of this medicinal resources.

An exceptional case is the honeybush plant which is used for its "*healthy giving properties*" by local people as well as exported to foreign countries, especially to Europe as herbal tea. Another well-known medicinal resource is the aloe plant. This plant from the thicket biome is a renowned plant used for its wound healing potential. Some farmers also make use of fynbos plants for the production of herbs and essential oils which they sell to tourists and drugstores. Though, this potential is limited used by people in the catchment. There are different projects planned to increase the use of this capacity, especially by the local community as a source of income. Nature conservation in the mountains indirectly supports the provisioning of medicinal resources as this benefit is closely linked to a healthy diverse vegetation community. Environmental degradation such as transformation of natural land and unsustainable use of natural resources influence this capacity negatively.

6.1.6. Ornamental resources

The variety of biota in natural ecosystems can provide opportunities for ornamental use. Especially the fynbos biome provide some important flowers and greens which are harvested in the wild for ornamental purpose in South Africa (Turpie et al. 2003). Moreover, the wildflower industry and European horticulture industry use a lot of different flowers and bulbs from the CFR, which also falls within the catchment.

The capacity of the Kouga catchment to provide ornamental resources is mainly associated to the "*wild*" natural areas in the mountains, which are covered by fynbos vegetation. However, this function category is not used in the Kouga catchment. Tourist might take natural resources with them as decorative plants and souvenirs but this service is poorly used as the area is also limited by tourists. However local land owners are aware of the high value of fynbos plants for ornamental purpose. *"If I cut down the fynbos and sell it, I would be a millionaire"* (local farmer). But national restrictions of biodiversity conservation and bad infrastructure limit this potential according to local land owners.

Although this service is not used by local land owners, degradation and transformation of natural habitats can decrease the availability of ornamental resources. The "protection and a sustainable use of the natural resources" (the two objectives of the BNR management (Erlank et al. 2009)), support the provision of ornamental resources, indirectly, by maintaining natural vegetation.

6.2. Regulating services

This group of functions and services depend on the maintenance of essential ecological processes and life supporting systems such as the transformation of energy into biomass or biogeochemical cycles. These processes are "regulated by the interplay of abiotic factors with living organisms" (de Groot et al. 2002). Regulating functions provide many services regulating environmental quality, such as clean air, good water quality and fertile soils. However, often these services are not recognized as they have indirect benefits to people. That is why optimization of a regulating function usually not happened until the function decrease. Agricultural production in the Kouga catchment is highly depending on these functions and services, for example water quality, soil fertility and pollination are major factors contributing to fruit production.

Figure 38: Regulating services are often not recognized as they have indirect benefits to people such as the capacity of spekboom to regulate climate by carbon sequestration and the capacity of wetlands to regulate water and buffer extreme climate events such as floods and droughts. Also pollinators such as bees, contribute indirect to maintenance of local plant diversity and fruit production.

6.2.1. Air quality regulation

By regulating air quality life on earth is possible. Even though this service is often not recognized directly by people, farmers in the Kouga catchment mentioned the importance of "*fresh*" and "*clean*" air when working outside on the fields which has a direct health effect to them. Good air quality is also important for the production and growth of agricultural crops.

The maintenance of clean and breathable air is determined by biogeochemical processes which are influenced by many biotic and abiotic factors. Natural ecosystems, especially vegetation have a great influence on processes that for example regulate the CO_2/O_2 balance through the production of oxygen and storage of carbon during photosynthesis. Moreover, pollutants such as ammonia and sulphate can be removed from the atmosphere by plants. Natural vegetation as well as exotic species such as fruit trees and invasive tree species are able to clean the area. Vegetation also enhance the capacity of an ecosystem to capture dust particles (aerosols) which occur e.g. after a fire. Fires in the catchment is a natural phenomenon, but also used as a farming practices. A good air quality is also support by the low population density as well as by limited traffic and industry in this area which could negatively influence air quality regulation by emission of pollutants.

6.2.2. Climate regulation

Climate regulation is a life supporting service people obtain from nature. It is also closely linked to air regulation because atmospheric gases have a great influence on the weather. Especially the greenhouse gas-balance which causes the natural 'greenhouse effect' regulate global climate. Ecosystems are able to absorb greenhouse gases, e.g. CO_2, to maintain a favourable climate. This occur indirectly through photosynthesis by plants which leads to storage of carbon in biomass and in soil as organic matter (Elmqvist et al. 2010).

a) Micro-climate
The local climate in the Kouga catchment is determined by complex interactions between global circulation patterns and local land cover characteristics such as topography and vegetation cover. The Kouga catchment is extremely rugged which gives rise to a great diversity of land cover characteristics regulating temperature and rainfall patterns. This leads to different micro-climates within the catchment which also influence how the land is managed. For instance, the Langkloof is characterized by cold winters, a fundamental need to grow apples.

b) Factors influencing climate regulation – carbon fixation
Vegetation in the Kouga catchment has the ability to support the stabilization of climate locally and globally, especially due to its ability to store carbon. This service is mainly provided in the natural areas of the catchment as this areas are mainly covered by fynbos vegetation, which is characterized as a carbon-rich ecosystems (Cowling et al. 2004). Carbon fixation is used by plants for the production of fire resistant structure, carbon rich nectar and as a defence against herbivory (Cowling et al. 2004). Thicket vegetation (especially "spekboom" *Portulacaria afra*) is also recognized by its high potential of carbon sequestration. Another vegetation in the Kouga catchment providing a great sink for CO_2 are the small evergreen forest patches located in the Baviaanskloof and Kouga mountains. Forests also play an important role in reflection of incident radiation which prevents warming. Dark surfaces absorb more light than bright surfaces such as bare soil. This so-called 'albedo-effect' is an additional important climate regulation factor. Evergreen vegetation such as fynbos and grass vegetation have a similar effect on the albedo.
During interviews, climate patterns was one of the most mentioned topics. The catchment faces several extreme climate events during the last years which caused a lot of damage to the area, especially the economy of the area suffered due to loss of productivity. There are several opinions trying to explain the extreme climate events. There is one explanation which gains more and more attention, namely global climate change. Through the emission of greenhouse gases the climate regulation is disturbed which causing increasing temperatures and occurrence of extreme events such as droughts and floods. These gases originate from intensive land use among others. Through land practices the capacity to store soil carbon is reduced which increase the emission of this gas. Indeed, fruit farmers in the Langkloof identify a low carbon concentration in their soils although these soils are remnants of wetlands, which typically have a high carbon concentration (Collins 2005). There are also examples seen in the catchment which influence climate regulation positively. Certain farming activities (e.g. organic farming) can increase soil carbon concentration, so one fruit farmer. Another example to enhance the potential of carbon storage is recognized in the natural areas of the catchment by nature conservation. Restoration and rehabilitation of certain vegetation types such as fynbos and spekboom are argued to help to maintain a favourable climate and to mitigate the impact of climate change. Especially spekboom is regarded by its high potential of carbon sequestration which is also recognized by local restoration projects such as the Subtropical Thicket Ecosystem Planning (STEP) project. This project is working in BNR and planting together with local farmer spekboom. The uniqueness of this project is that farmers who are "farming spekboom" get incentives by the government as they contribute to the mitigation of global climate change.

6.2.3. Water regulation
Catchments play a crucial role in the regulation of water thereby contributing to the provision of fresh and clean water to people. Most rainwater falling in or flows towards these catchments. The regulation of the water is directly related to the capacity to store and retain water (see water supply service) and is greatly influenced by the vegetation cover and soil structures (de Groot et al. 2002; Egoh et al. 2008).

a) The role of fynbos vegetation in water regulation
Due to the soil's low nutrient concentration, plant growth in the catchment is limited to specialized plant species such as fynbos. Therefore, *"fynbos vegetation is very important for the water regulation*

in the Kouga catchment" (local land owner). Fynbos take up the energy of raindrops falling on the surface which prevent compaction and water can infiltrate better into the soil. The infiltration capacity of the soil in the catchment is high due to its sandy characteristics. But not all rainwater is directly 'lost' to infiltration. Fynbos vegetation also act as a kind of "*rainfall catcher*" (Strydom pers. comm. 2011), especially during periods of low rainfall. Water is intercept by fynbos vegetation and stored temporarily before released to soil and atmosphere gradually; this also keeps soil moisture which indirectly supports a reliable water supply within the catchment. Indeed, mountain fynbos vegetation of the Tsitsikamma Mountains, for instance, are the source of most streams and rivers downstream (Vlok et al. 2008). Most fynbos catchments have thus a relative low water run-off which is estimated to be between 35% and 55% of precipitation (Le Maitre et al. 2007).
As the Kouga catchment is characterized by a rainfall deficit, the capacity to absorb water by vegetation is an crucial function to retain water. Fynbos species are optimized in water conservation in semi-arid areas. Fynbos plants do not only have a great efficiency to absorb water from the air, but are also specialised in water uptake from the soil. Plants have cluster roots which increase the surface area for absorption of water from the soil (Cowling 1992). Proteoid shrubs also can take water from deeper soil layers by having a deep tap root system for water (Cowling 1992). In this way, soil moisture is kept and plants suffer less from water stress during drought periods. Indeed, periods of long water stress during summer month is not common in the fynbos biome (Cowling 1992). Next to fynbos vegetation, wetland ecosystems also have a great potential of absorbing water and release it slowly.

b) Factors influencing water regulation

Even though the biggest part of the catchment, namely the mountainous areas, is intact and contributes to a balanced water regulation, the natural water flow is altered. Transformation of natural land and high water abstraction by agriculture and alien vegetation influence the area´s natural capacity to regulate water. Especially the transformation of wetlands to agricultural land in the Langkloof Valley decreased the catchment's capacity to filter and store water. Moreover, dams, channels and pipeline alter the hydrological cycles and water abstraction from the river for agricultural purpose change the natural water flow. Another factor influencing the natural water regulation negatively is the invasion of alien plants. IAPs consume much more water than comparing with the native flora. Due to an increased plant biomass loads, plants need more water with the consequence of more water 'lost' by transpiration by these plants. This causes a significant decrease of stream flow. The highest reduction of the water run-off is shown in the fynbos shrubland and grassland (Van Wilgen et al. 2008), which are also the most invaded vegetation types in the Kouga catchment. An additional ecological impact by invasion of alien vegetation is the alteration of the composition of natural plants. This will modify the capacity to regulate the water as well.
Restoration of the remaining wetlands supports the reconstruction of the natural water regulation and provision as seen in the catchment. To give an example, after the restoration of a small wetland in the Tsitsikamma Mountains which showed almost no water flow, water was streaming again. Another example of restoration seen in the catchment is the cutting of IAPs by the local WfW programme and land owner initiatives. Special devotion gets exotic plants in riparian areas up in the mountains. This will also stop further seed dispersal downstream. IAPs eradication is seen as a critical aspect to enhance water regulation and to support water security in the region.

6.2.4. Natural hazard mitigation

Hazards like floods and droughts occur naturally. Ecosystem structures, especially vegetation structures can mitigate the potential effects of these hazards through its storage capacity and surface resistance (de Groot et al. 2002).

a) Ecosystem structures

The Kouga catchment is regularly faced by extreme climate events such as floods, droughts, fires and hailstorms. These hazards are influenced by vegetation and soil structure. Wetlands for example, can buffer and retain water during heavy rainfall and act as a natural barrier to floods (Collins 2005; Driver et al. 2012). The biggest wetland in the Kouga catchment is seen in the Langkloof; most dense and smaller wetlands occur along the Kouga River and its tributaries in the mountainous areas (Haigh et al. 2004).The surface resistance of the catchment is another aspect which can mitigate natural hazards. Hard rock formations in the Kouga Mountains, for instance, are extremely resistance to weathering which damper the impact of sedimentation and erosion during and after flood events. Moreover, the infiltration capacity of sandy soils is quite high, which act as a buffer against high rainfall intensity events, thus water can infiltrate faster and overflow is decreased.

In case of a fire event, natural fynbos vegetation is adapted to this disturbance. Fires are crucial for fynbos to fulfil their life cycle, but "*young fynbos vegetation does not burn*" (local land owner). This forms naturally mosaics of different vegetation ages which decrease the risk of huge fires in the mountains. The rugged character of the catchment limits the spread of fires in the mountainous areas, too.

b) Droughts and floods

During the last years, damage from drought and flood events increased in the Kouga catchment. Local people argue that the occurrence of droughts and floods increased as well as its dimension. This might be a consequence of transformation and degradation of natural ecosystems in the catchment which altered the catchment's natural capacity to mitigate natural hazards. "*Wetlands can take up water like a sponge. In the past we had more vleilands (wetlands) but they are now invaded by alien trees or put into orchards*" (local land owner). This development might have intensified natural hazards. IAPs, for instance, reduce the infiltration capacity of rainwater which leads to increased surface run-off during heavy rainfall events, which in turn cause increased soil erosion (Scott 1993). On the other hand, exotic species consume a huge amount of water which locally can lead to water shortages and enhance dry condition during periods of low rainfall. This also increases the risk of fires. Run away fire can spread more quickly when the surface is dry and a lot of potential fuel is around. IAPs have a higher biomass than native flora, more intense fires are measured. This in turn changes the natural fire regime and decreases the potential of vegetation to mitigate natural hazards. The eradication of IAPs will influence the catchment's capacity to mitigate natural hazard positively, especially when working in riparian zones. Other people argue that the increased occurrence of extreme climate events is caused by global climate change.

6.2.5. Waste treatment

Waste treatment is an essential function to obtain clean water from polluted water. This function depends on ecosystem´s capacity of water purification and nutrient cycling. Vegetation and soil organism are able to breakdown and store certain amounts of organic and inorganic waste. Wetlands for instance are recognized as natural 'water filters' purifying water by trapping pollutants. This cleans the water (Collins 2005) (see Box 6). But also other riparian vegetation are important buffer zones filter and control nutrients.

a) Importance of wetland and riparian vegetation

The Kouga catchment is drained by several rivers and streams, which are lined with riparian vegetation. There are also some wetlands in the mountainous areas. In this way, it is most likely that the full capacity of water purification is given in the mountainous areas. Indeed, local land users classified the water quality coming from the mountains as "*very good*". Clean water is also a precondition for the growth of good fruits. "*Last year*

Box 6: Importance of wetlands: Wetland ecosystems are amongst the most productive and economically valuable ecosystems in the world (Driver et al. 2012). It provides critical services including water purification, regulation and provision. This natural system regulates water supply by acting as a ´sponge´ and natural ´water filter´ that stores, purify and releases water slowly. In this way, it also can buffer impacts of floods and droughts. Moreover, wetlands are also recognized as natural ´water filter´, which filter and purify water and contribute to the provision of clean water to people.

there was one farm in the Langkloof, which did not get its GLOBAL GAP certificate because irrigation water was of bad quality" (local fruit farmer). Poor water quality in downstream areas might be linked to the high use of chemical pesticides and fertilizers in the farming areas as well as the sewage disposal in the community areas together with a decreased capacity to recycle water due to loss of wetlands downstream. The restoration of wetlands and riparian zones, especially around farming and community areas, can enhance the recycling capacity in the area. But this capacity cannot be fully successfully if the input of chemicals in fruit farming is not decreased and there is no sewage system in the community areas.

6.2.6. Erosion prevention

Erosion prevention is a very important function to prevent damage from soil erosion and to maintain agricultural productivity. Through soil erosion the topsoil layer, with its important organic matter, is washed away. Vegetation structures contribute to erosion prevention.

a) Factors influencing erosion prevention

In the Kouga catchment, fynbos vegetation is a key factor preventing soil erosion. It basically depends on the ability of the vegetation cover to take up the energy of raindrops falling on the surface to prevent compaction and erosion of bare soil (de Groot et al. 2002; Buckle pers. comm. 2012). Moreover, the root system helps to stabilize the soil. Indeed, fynbos species have a high root/shoot ratio (Cowling, 1992). Especially in steep terrain, such as in the Kouga catchment, a good basal cover is crucial to prevent soil erosion. The fynbos vegetation cover also indirect benefits the soil moisture regime which in turn prevent soil erosion, too. In addition, fine sandy soils contribute to a better resistance to runoff because water is absorbed easily.

The prevention of soil erosion is an important management factor in maintaining agricultural productivity. "*The protection of the soil surface supports my farming*" (local farmer). In livestock farming, dry-lands are typically cultivated in the form of terraces to prevent loss of soil. However, in fruit farming concrete management practices are often limited. Some fruit farmers *"(I) leave grass and weed plants under the fruit trees to prevent soil erosion. This also keeps soil moisture"* (local fruit farmer).

Farming practices, however, can also increase the risk of soil erosion. In particularly, overgrazing and too frequent burning can change the natural vegetation cover which in turn can lead to soil erosion (Euston-Brown 2006). Land users said that soil erosion is not "*a big issue*". However, other argues that "*soil erosion takes place*" (local land owner), especially in farming areas.

The invasion by alien vegetation also influences the capacity of erosion prevention. "Higher soil losses and suspended sediment exports" are measured in afforested catchments compared to fynbos catchments (Scott 1993). *"Along the rivers in the Kouga Catchment, IAPs grow and destabilized the river bank. Consequently, soil erosion takes place and heavy gullies erosion is seen"* (local land owner). Combined with the effect of lost wetlands, which would trap sedimentation, soil is washed away. Silting of weirs and dams is recognized in the Langkloof area and could be a consequence of these lost services. IAPs also have higher fuel loads which intensify fire which in turn result in greater risk of soil erosion due to soil heating. Nature conservation including IAPs eradication and fynbos protection, support the natural erosion prevention.

6.2.7. Soil fertility

Soil fertility is essential for the growth of plants. Soil becomes fertile through mineral weathering, accumulation of organic materials and the release of nutrients which is strongly controlled by a wide range of decomposer in the soil (de Groot et al. 2002). In case of the fynbos ecosystem, fire is the major mineralizing agent as decomposition is a very slow process within the fynbos ecosystem (Stock and Lewis 1986; Cowling et al. 2004). Nutrient concentrations in the soil, in particularly nitrogen and phosphorus increase shortly after the area was burnt (Stock and Lewis 1986).

a) *Natural and artificial soil fertility*

Both, local farmers and nature conservationists take care about the soil quality. However, different ideas are associated to the desired soil fertility. In generally, soil in the catchment is naturally very poor in nutrients. This is the optimal soil quality for the native flora, in particularly fynbos plants. The low nutrient availability in the soil is the selective force within this biome (Cowling 1992). In this way, nature conservationists prefer this soil quality to protect native vegetation. However, farmers associated with soil fertility, soil which can support productivity. In this case, a higher nutrient concentration is desired because cultivated plants (e.g. fruit trees, wheat plants etc.) need higher nutrient concentrations in the soil. To increase soil fertility, farmers add nutrients (especially nitrogen and phosphorus) to the soil by the use of fertilizer. Livestock farmers also use Luzern as a natural nitrogen fixer to enhance soil productivity. At the same time Luzern is also used as pasture for livestock. Additionally, grass fields are burnt regularly to increase soil´s nutrient concentration on short-term. However, too frequent burning also can lead to higher loses of nutrients by volatilization and experts argue that nutrient concentration might decrease on long-term (Buckle pers. comm. 2012).

For orchard farming, a lot of fertilizers have to be applied to keep the favourable high nutrient concentration in the soil. This has a positive impact on the productivity. But the artificial nutrient adding change the natural (low) soil fertility. Nutrient concentrations are determinants of vegetation structure and function, a change in concentration has a negative impact on the natural vegetation. Especially fynbos plants will disappear and taken over by faster growing plants.

6.2.8. Pollination

For reproduction, plants need to be pollinated. Therefore pollen are transferred to the reproduction part (ovule) of the plant. This transfer can either happen by wind or organisms (pollinators). Without these pollinator species, many plants would ultimately become extinct (de Groot et al. 2002).

a) *Plant diversity and fruit production*

The Kouga catchment is home to a great plant diversity which attracts a wide variety of pollinators such as bees, flies, beetles, bats and sunbirds. These pollinators are crucial for the maintenance of local plant diversity. Especially the fynbos biome and its many flowering plants provide a habitat to many pollinators. The majority of fynbos plants are pollinated by insect (Cowling 1992). Local fruit production also highly depends on pollinators such as the Cape Honeybee, the most commonly used pollinators and endemic to the CFR. It is estimated that bees attribute with R800 million of the R1.2 billion turnover of fruit farmers in the Western Cape by their pollination service (Turpie and Heydenrych 2000). Indeed, farmers identify the importance of pollinators for the fruit production. To enhance the pollinator service and thus productivity, fruit farmers often put bee hives close to their orchards. This also provides honey to local people. Moreover, fruit farmers also mind pesticides which would harm any pollinators.

The most obvious factor influencing the capacity of pollination by insects and birds is loss of plant diversity, in particularly loss of flowers. The honeybee for instance need the diversity of flowering fynbos plants to overwinter in natural vegetation, otherwise it will die (Turpie and Heydenrych 2000). Moreover, many pollinators spent most of their foraging time in the fynbos. “Bees spent about 80 per cent of their time foraging in this vegetation” (Turpie and Heydenrych 2000). In this way, the decrease of native flora due to transformation and degradation of natural areas, reduce the area´s capacity to support pollinator services. This in turn will influence the plant diversity and fruit production in the Kouga catchment negatively.

6.2.9. Biological control

Nature keeps plant and animal populations’ densities low by its biological control function. Through predator-prey interactions communities and populations of species are maintained at lower average than population density would occur in their absence. This contributes to healthy ecosystems. This service is also very important for food security. Natural ecosystems have the capacity to control most of the potential pests and disease through interaction and feedback mechanism, which prevents damage to crops and livestock (de Groot et al. 2002).

a) *Agricultural pest and disease*

The natural ecosystems of the Kouga catchment contribute to the biological control service by providing a suitable habitat for diverse predator-prey interactions. Cultivated land, however, reduced the area´s capacity to support biological control. These area are namely dominated by monocultures supporting the development of high numbers of specific organisms which started to dominate and damage agriculture production. Moreover, diseases can spread quicker which harm crops and livestock. Therefore, the control of pest and disease in farming areas is an important management practice to maintain productivity. This control is primarily based on chemical pesticides and medicines, often sprayed and injected preventive. However, there are also examples seen where farmers make use of the natural enemy of a certain pests to reduce the population density of the pest organism. For example fruit farmers are pleased to see guinea fowls in their orchards and do not kill it anymore, as it happened in the past, because this animal eats on the snout beetle, an agricultural pest to fruits. Another farmer explained the importance of conservation of bats because *"bats are natural predators feeding on agricultural pests"* (local fruit farmer). One fruit famer applies successfully the ´Integrated pest management´ (IPM) which decrease the use of pesticides and enhance the natural pest control mechanism (Baldie pers. comm. 2011). But also IAPs management make use of biological control. Port Jackson Acacia plants growing in the Kouga catchment are treated with a biocontrol agent. A fungi species spread through these plants and will slowly reduce the reproduction potential of alien plant.
Another example of how to optimize biological control services is seen in Kouga´s protected area. One of the core conservation management activities is the protection of leopards. This top predator fulfils an important role in the predator-prey interactions and thus contributes to the maintenance of healthy communities and populations of many other species at lower trophic level. But also the protected areas itself contribute to the optimization of the catchment´s capacity of biological control by providing habitat to predator and prey populations which can interact with each other.

b) *Unknown predator-prey interactions*

Often predator-prey interactions are poorly understood and people are not aware of this function. For instance interactions between organisms in the fynbos biome are still often unknown. Loss of a certain species might have significant consequences on the natural biological control which in turn might affect other ecosystem services such as food provision. Honeybush cultivation experiment for instance is still limited successful because in cultivation certain disease and pests occur and damage cultivation which seems not happening in nature. It is argued that there are certain species from the fynbos biome contributing to the reduction of disease and pests but further research is needed (Ferreira pers.comm. 2012).

6.3. Habitat Functions and Services

This group of functions describes the capacity of natural ecosystems to provide refuge and reproduction habitat to all wild plant and animal species. Nature conservation in the Kouga catchment focuses on the maintenance of a healthy habitat to provide a suitable living space for species and to protect local biodiversity by the establishment of nature reserves. *"We need to protect biodiversity to get ecosystem resilience"* (local nature conservationist). In South Africa, biodiversity is even seen as an "umbrella service from which all other ecosystem services originate" (DEAT 2011). This also means if biodiversity decrease and a reduction in the provisioning of ecosystem services will follow. Therefore, the protection of natural habitat (= conservation of biodiversity) is necessary to maintain ecosystem services and human well-being.

The habitat function and service can be subdivided into lifecycle and gene pool functions and services which are closely linked to each other and contribute to the area´s capacity to provide natural habitat.

Figure 39: Habitat functions and services provide a suitable living space for indigenous plants and wild animals. In the Kouga catchment these services are primarily associated with the protected areas (Photo: Author, M. Kruger).

6.3.1. Lifecycle (migration)

Plants and animals need to realize their life cycle in order to persist. Through providing a refuge and reproduction habitat, wild animals and plants have the potential to migrate and to fulfill their life cycle and thus persist on long-term.

a) Protected areas

In the Kouga catchment, this service is primarily associated with protected areas of the BNR and FNR. Here, different ecosystems are protected which create a healthy space for indigenous plants and wild animals which contribute to the lifecycle service.
To optimize the catchment´s capacity to provide a suitable living space to wild animals and plants expansion of protected areas is desirable. This will connect different habitats with each other and enhance the potential of migration. Creation of landscape corridors such as the Eden to Addo, which cross the Kouga catchment, focuses on the connectivity of different ecosystems to increase the catchment´s integrity. This landscape corridor will enable migration and interbreeding of plants and animals and facilitate movement between ecosystems, according to nature conservationists.
However, the catchment´s capacity to support the natural lifecycle of native plants and animals is disturbed due to loss of natural habitat (see gene pool below). Moreover, existing plans for the expansion of current protected areas is limited by agriculture in the Kouga catchment. In order to realize the Eden to Addo plan, commitment of local farmers is needed. However, current conservation management limits agricultural practices in conservation areas, which means if farmers would join the Eden to Addo corridor, farming activities need to be changed.

6.3.2. Gene pool

Natural ecosystems contribute to the conservation of biological and genetic diversity as these systems serve as a ´storehouse´ of genetic information which protects the gene pool (de Groot et al. 2002). To provide this genetic information a living space for wild plants and animals is vital whereby each species group has its own requirements to exist.

a) Biodiversity

South Africa obligates itself to maintain biological and genetic diversity when they signed the CBD. Consequently, nature conservation focuses on the protection of biodiversity. Areas with high biodiversity level, such as the Kouga catchment, are thus mandated for protection. *“Biodiversity* *supports the resilience of Kouga's ecosystems. That is why biodiversity is so important an needs to be protected"* (local nature conservationist). The Kouga catchment is partly under formal protection. The mountains of the Kouga catchment belong to the BNR and FNR. These areas are regarded as natural habitats which have a high capacity to provide ecological refugia to wild plants and animals and allowing natural selection processes to maintain the vitality of the gene pool (de Groot et al. 2010).

To optimize gene pool protection, protected areas are managed by the wilderness principle; human intervention should be limited in these areas. To enhance the vitality of gene pool, size and connectivity of different habitats is desirable if possible. There are plans of expansion of current protected areas through the establishment of Baviaanskloof mega-reserves. It could be one of the most bio-diverse areas within southern Africa (Skowno 2007). This mega-reserve would also include other different landscape features which support biodiversity, which are currently outside any formal protection. Examples include the east to west and north to south macro-climatic gradient which give rise to the great diversity within fynbos biome. However, to be successfully implemented the commitment of local land owner is needed.

b) Factors influencing the habitat functions and services

There are several factors influencing the habitat function and services in the Kouga catchment. Transformation and degradation of natural habitat is the biggest threat to the provision of a suitable living space for flora and fauna. In the Kouga catchment, loss of habitat is primarily caused by agriculture and invasion of alien plants.

Natural vegetation of fynbos and renosterveld as well as wetlands is largely lost in the Langkloof due to the cultivation of fruit trees. Grassy vegetation in the Suurveld is under threat due to livestock farming. Moreover, the use of chemical pesticides and herbicides influences the health of neighbouring natural habitats. *"Fruit farming in the Langkloof use tons of chemicals which pollute our environment*" (local resident). Additionally, cultivated land is also often a barrier for migration and dispersal of organism.

The spread of IAPs is another great threat to habitat services in the Kouga catchment. These fast growing, exotic plants replace natural vegetation which decreases the catchment´s capacity to provide a suitable habitat for native plants and animals. The Fynbos Biome which is recognized by its high and unique biodiversity is one of the most threatened vegetation types in the Kouga catchment due to the invasion of alien plants. The successful implementation of current plans to increase the habitat service in the Kouga catchment by the establishment of landscape corridors and mega-reserves therefore depend on limitation of agriculture and eradication of IAPs.

6.4. Cultural and Amenity Services

This group of services is often categorised differently but summarizing quite similar subservices. In the TEEB classification, cultural and amenity services correspond to "aesthetic, spiritual, psychological and other benefits that human obtain from contact with ecosystems" (Elmqvist et al. 2010). These services contribute to human evolution and health by providing opportunities for cognitive development. Thereby, nature is seen as a "vital source of inspiration for science, culture and art, and provides many opportunities for education and research" (de Groot et al. 2002). Although these services might be not critical for survival, they nevertheless enhance life and often highly valued by people as having a "non-financial intrinsic value, related to spiritual, aesthetic and ethical consideration" (Scholes and Biggs 2004).

Figure 40: The Kouga catchment provides great opportunities for recreation and scientific research. In the mountains, several elements of spiritual and historic values are present such as San paintings in the Kouga Mountains (Photo: Author).

6.4.1. Aesthetic information

Aesthetic information refers to the "appreciation of natural scenery" (de Groot et al. 2002). This is given by attractive landscape features. Many interviewed land owners valued the Kouga catchment by its scenic and remoteness. They mentioned their enjoyment of the mountain scenery and the catchment´s biodiversity "*which is beautiful to look at*". But aesthetic information is not only assigned to natural areas. Cultivated land, especially the orchards scenery in the Langkloof is appreciate by local people as well. *"I love this land, and I enjoy living here"* (local land owner).

6.4.2. Recreation

Nature provides great opportunities for relaxation, refreshment and recreation (de Groot et al. 2002). This value is closely related to the attractiveness of the landscape to tourists. The Cape Floristic Region (CFR) is recognized for its high nature-based tourism value visited by tourists from both abroad and from South Africa. (Turpie et al. 2003). Tourists in the area appreciate the scenery of the landscape, its tranquillity (low noise level due to limited traffic, few people etc.) and great biodiversity which is unique to the world.

The Kouga catchment is part of the CFR and shows a great variety of landscape features, wildlife and natural sites covered with fynbos, thicket and savanna vegetation. Especially the ´wild´ and remote natural areas in the nature reserves in the catchment make the Kouga area an important option to consider for tourists and invites for hiking, walking and camping. But also the agricultural areas in the catchment might be interesting to tourists from the city. On farmland for instance "*more than 100 bird species are spotted*" which is a great opportunity for bird lovers, according to one farmer.

Numerous guest houses are seen in the area where people are invited to come to rest, enjoy the nature and go on hikes. Local residents see a great potential of (eco) tourism in the catchment. However, this potential is currently only sporadically explored maybe because of bad infrastructure, limited promotion and nature conservation restrictions in the nature reserves.

6.4.3. Cultural and artistic information

Many aspects of nature have a cultural significance. South Africa has a great variety of cultures differently shaped by nature. Also national identity is inspired by nature. They are several national symbols given by nature such as the Blue crane bird, Protea flower and Yellowwood tree. Nature features area also gave their names to national sport clubs such as the Protea inspired the national cricket team and the springbook the national rugby team.

The Kouga catchment has also a national significance. The above mentioned national symbols are seen in the Kouga catchment. Moreover, the mountainous areas of the catchment are internationally recognized by its cultural good. The Baviaanskloof Nature Reserve is declared as a UNESCO World

Heritage site, for its outstanding natural, historical and cultural value. The protection of the BNR contributes to the maintenance of this cultural resource.
An additional function of nature is its inspiration and motive for artistic work. Galleries are often decorated by paintings of nature (Wessel pers. comm. 2011). Especially fynbos flowers and landscape features like mountains and forests are commonly seen motives in South Africa. Creativeness can also be inspired by being in the nature. In the Kouga Mountains for instance lives a known artist who creates arts.

6.4.4. Spiritual and historic information

Nature provides “a sense of continuity and understanding of our place in the universe” (de Groot et al. 2002).
In the Kouga catchment, several elements of spiritual or historical values are present. Rock paintings in the Kouga Mountains for instance are evidences of centuries´ old traditions and culture of the San people. These paintings are also highly valued by art connoisseurs as well as archaeologists who use these paintings as a historical information source about this ancient time.
Spiritual and historic information value is also provided through the discovery of a mummified body in a sacred groove in the Kouga Mountains. Moreover, Old Dutch farm houses which are “*more than 150 years old*” (local farmer) seen in the catchment provide historical information about the first European settlers in the Kouga catchment. Also nowadays different religions in the Kouga catchment are present, such as the catholic belief and the Xhosa and Zulus myths which find spiritual inspiration in nature. Xhosa boys for example have to go ´to the bush´ as a ritual to become men. Catholic farmers also mention the importance of being in the nature to “*get closer to the creator*”.

6.4.5. Scientific and educational information

Nature provide “almost unlimited opportunities for nature study, environmental education and scientific research” (de Groot et al. 2002).
In Kouga catchment there are several examples of these services present. Unknown flora and fauna still exist in the catchment providing great opportunities for research. Moreover, knowledge gaps exist, e.g. about the pollination potential within the fynbos biome or about honeybush cultivation. The Kouga catchment could function as a ‘field lab’.
The great potential of the area to provide scientific and educational information is also recognized by the PRESENCE network, including various scientists, which are doing scientific research in the Kouga catchment.

7. Relation between water security, conservation of biodiversity and agricultural production in the Kouga catchment

In the previous chapters it was shown that the Kouga catchment is characterized by a natural diversity which leads to different ways how the land is used and managed by people. Different land management types are often guided by different interests. Langkloof´s farmers, for instance, use the land and manage it to optimize fruit production; whereas, nature conservationists restrict land use and manage their land in order to protect biodiversity. This causes conflicting interests and misunderstanding among farmers, nature conservationists and scientists, which result, from a catchment's point of view, in ineffective or unsustainable management. In order to improve catchment management in a sustainable way, a shared understanding among the different stakeholders is needed; consequences and trade-offs need to be clear.

This chapter aims at bringing the findings of the biophysical and environmental assessment (chapter 3 - 5) and the ecosystem services analysis (chapter 6) together to study the relation between land management and ecosystem services in the Kouga catchment. The analysis is guided by the identified main issues in the Kouga catchment, namely water security, and the two opposing views on the desired management of the Kouga catchment (biodiversity conservation vs. agricultural production). In this analysis, these issues are describes systematically by how ecosystem services and land management practices influence these issues.

7.1. Water security

Interviewed land owners in the Kouga catchment perceive water availability as the main challenge in the Kouga catchment**.** *"Water is the most limiting factor to agricultural production*" and inlfuence local development and environmental health*.* Local residents are concerned about the water security in the catchment area. Especially during the last years, the area faced extreme climate events (such as floods and droughts) which caused high damages to the economy and nature and induced *"water use restrictions"* for local people*.* But even in a 'normal year' water availability is a competing factor between up- (Kouga catchment) and downstream users (Gamtoos Valley and NMMM). The pressure on local water security is intensified due to prediction of climate change and the future invasion of alien plants (Blignaut et al. 2007; Blignaut et al. 2009).

To achieve sustainable water use it is important to understand which factors influence the water availability in the Kouga catchment. For a reliable, clean water supply, rain water needs to be filtered, retained and stored as fresh water. The catchment itself primarily determine the storage capacity, but vegetation and soil structures influence this capacity positively by regulating the uptake and release of water (de Groot et al. 2002). Moreover, vegetation cover and soil also mitigate natural hazards (e.g. flood and fires) which decrease damage to the ecosystems and maintain a stable water supply.
Land management such as agriculture and nature conservation, depend on a reliable, clean water supply. But certain land management practices also have an influence on the water flow through the catchment and thus change the provision of fresh water. Figure 41 illustrate the relation between management practices and ecosystem services, and its influence on the provision of a reliable, clean water supply. A more detailed description is followed.

Figure 41 shows that there are various ecosystem services which determine the provisioning of water, namely the catchment's capacity to regulate and supply water, prevent of soil erosion, purify water and mitigate droughts and floods. Farming and conservation practices alter the provision of these ecosystem services which in turn change the provisioning of a reliable clean water supply upon which current land management depend. There are most likely more aspects which influence the provision of a reliable, clean water supply; the following analysis however is kept to the most influential identified factors. Please notice, ecosystem services are also important on itself but are here described in coherence to the provision of a reliable clean water supply.

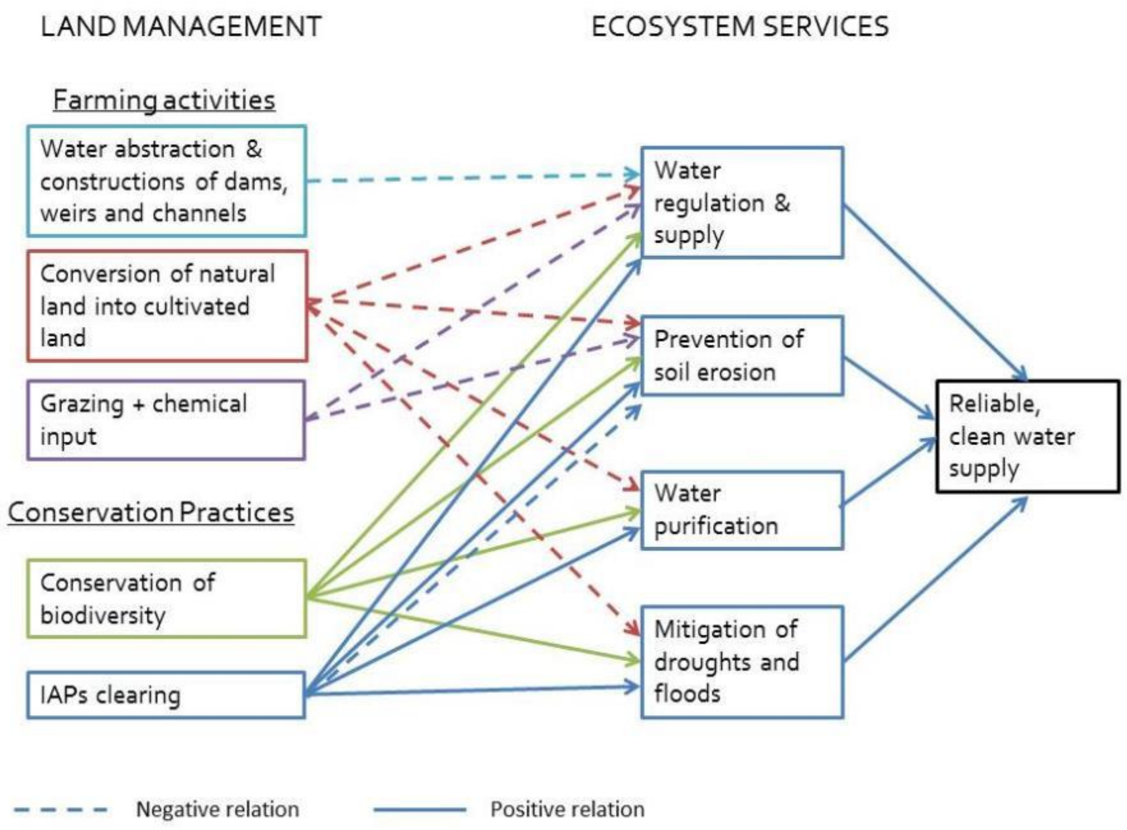

Figure 41: The relation between land management practices and ecosystem services with respect to the provision of a reliable, clean water supply in the Kouga catchment (Source: this thesis).

7.1.1. Water abstraction & construction of dams, weirs and channels

The Kouga catchment is a semi-arid region. Moreover, the catchment lies between the winter- and summer rainfall zones of South Africa and faces regularly naturally extreme climate events (see chapter 3). This means, rainfall is low and not absolutely reliable. To meet peoples' water demands, farmers in the Kouga catchment established a complex system of dams, weirs and channels. Abstraction of water from the catchment and its storage in dams ensure a continuous water supply for irrigation, domestic and drinking purposes. Especially the fruit farming depends on the provision of a reliable, clean water supply for the cultivation of fruit trees.

However, water abstraction and the construction of dams, weirs and channels has altered the regulation of the natural hydrological flow which has consequences for the total water supply in the catchment, especially for downstream users. According to (DWAF 2004), natural mean annual runoff in the Kouga catchment has decreased due to abstractions and other consumptive usages. A shortage of almost 1 million m^3 per year was measured in 2000. Thereby, irrigation is the largest user of water. It might be even stated that *"huge overuse of water in the Langkloof by fruit farming"* (local resident) caused the reduction of the total water yield in the catchment during last years. The growth of fruit trees itself puts an additional pressure on the local water availability because trees have higher evapotranspiration rates comparing to the natural vegetation. The same counts for the alien trees such as black wattle. Through the process of evapotranspiration, these plants consume much more water comparing with the low consuming native flora, which in turn reduces the stream flow and thus decrease the water supply in the catchment (Blignaut et al. 2007). The groundwater level and local climate is also influence by this process (Richardson and Van Wilgen 2004).

7.1.2. Conversion of natural land into cultivated land

Almost 50 per cent of the natural vegetation in the Kouga catchment show environmental decline (see chapter 5). Agriculture is one of the main drivers of loss of natural habitat. To cultivate fruit trees and support livestock farming natural areas (mainly wetlands and fynbos renosterveld vegetation) were converted into agricultural land. Most conversion took place in the Langkloof and Suurveld in the past, and natural vegetation was converted into orchards and grazing fields. This practice still takes place till today although to a smaller extent.

Naturally, plant growth in the catchment is limited to specialized plants species such as fynbos vegetation, which are mainly accountable for the water regulation in the catchment (see chapter 6). When losing these species the ability of the catchment to capture and store rainfall water is decreased. As a consequence, water runs off quickly instead of infiltrate into the soil. This in turn increases the risk of soil erosion and reduces the catchment's ability to store water. Continuous conversion of natural land into cultivated land puts an additional pressure on the already reduced capacity of the catchment to regulate and provide water.

The provision of a reliable, clean water supply is also influenced by the catchment's capacity to purify water and to mitigate natural hazards. This capacity is decreased due to conversion of natural land into cultivated land. Most orchards were established in former wetlands and floodplains, and streams and rivers were canalized to optimize water provisioning which compromised the catchment's natural ability to purify water due to lost riparian vegetation. Moreover, the catchment's capacity to mitigate natural hazards is reduced because wetlands and other riparian zones are important ecosystem for buffering flood and drought events (Collins 2005). The Kouga catchment regularly faces flood and droughts but during the last years occurrence and intensity of these events increased according to interviewed land users. This could be caused by the decreased capacity to mitigate these kinds of events. Others argue that more extreme climate events happen due to global climate change. Predictions of future climate change enhance the occurrence of extreme climate events (Blignaut et al. 2009). Both statements certainly stress the need to improve the catchment´s capacity to mitigate natural hazards to control future flood and drought periods.

7.1.3. Grazing and chemical input

The Suurveld is predominately occupied by extensive livestock farming. Grazing by livestock however, can affect water quality negatively. Experts and literature review prove the argumentation that grass fields in the Kouga catchment are locally overgrazed (see chapter 5). Overgrazing by livestock reduces the vegetation coverage which in turn increases the risk of soil erosion. This cause siltation of the river and thus reduce water quality downstream (Scholes and Biggs 2004). Moreover, grass fields are less capable of absorbing water with the consequence of higher run off and higher risk of desertification (degradation in dry regions) (Scholes and Biggs 2004).

The use of fertilizer, pesticides and herbicides in fruit farming puts an additional pressure on the water quality. Cultivation of crops close to the river "may increase eutrophication" due to fertilizer (Richardson and Van Wilgen 2004) and chemical pollutants from pesticides and herbicides which may leach out to the river and pollute water downstream. Often farmers do water analysis on their farm which *"do not measure any pollutants in the river water behind my farm*" according to some farmers. On another fruit farm, however, GLOBAL GAP inspector measured poor water quality which prohibits this farmer to export any fruit from his farm.

7.1.4. Conservation of biodiversity

Nature conservation is an important factor which influences the water balance in a positive way. The mountainous areas of the catchment are under formal protection by nature conservation. This means nature, in particularly natural vegetation and wildlife, is protected from human disturbance by the establishment of nature reserves. Through wildlife, fire, and honeybush management natural diverse vegetation is maintained and wildlife protection is ensured (Erlank et al. 2009). Restoration activities such as IAPs management are the only allowed active conservation activities, to rehabilitate ecological functions such as water regulation (see 7.1.5. bellow)

The protection of the natural vegetation, in particularly mountain fynbos, increases the capacity of the area to regulate and provide a reliable water supply (Vlok et al. 2008; Vromans et al. 2010). *"When we protect our fynbos, we have fewer run-offs but more water is stored"* (local nature conservationists) because these vegetation structures contribute to a better absorption of water within the catchment and thus enhance the provision of water downstream. Left intact riparian zones and wetlands in the mountains which are formally protected from human disturbance support the catchment's capacity to prevent flood and droughts which will cause less damage to surrounding areas (Collins 2005). Moreover, wetlands and other riparian zones are able to purify water which improve the water quality downstream (Collins 2005). This capacity is of great importance to maintain clean water supply for downstream users. Indeed, water quality in the mountains is of good quality but poorer in downstream areas (DWAF 2004). This might be related to the decreased water purification capacity due to transformed wetlands and to pollutants by agricultural and domestic sources (e.g. pesticides, fertilizers, sewage) in the Langkloof area.

7.1.5. IAPs clearing

Nature conservation in the Kouga catchment also includes the restoration of degraded habitats by mechanical clearing of IAPs. Invasion of alien plants is one of the main drivers of environmental decline in the Kouga catchment (see chapter 5). IAPs are found throughout the whole catchment, especially in riparian areas. Exotic plants replace natural vegetation and modify the catchment's capacity to regulate and provide water (Van Wilgen et al. 2008). To rehabilitate these functions, WfW teams and individuals trying to eradicate IAPs by mechanical clearing. (Powell and Mander 2009) estimates that "clearing of 3.100 hectares of riparian zones would deliver an additional 9.51 million m3 of water annually". But already the restoration of small wetlands can have positive results as seen after the clearing of IAPs in a small wetland in the Langkloof where the water flow was rehabilitated. Another benefit of IAPs clearing in wetlands and riparian zones is the rehabilitation of the catchment's natural ability to purify water and to mitigate flood and drought event. Intact riparian vegetation act as a buffer zone "that filters sediments and control nutrients" and control water flow (Richardson et al. 2007).

In the Langkloof, fruit farmers struggle sometimes with high sediments yield in their dams. This could be a consequence of the decreased capacity to prevent soil erosion in the Langkloof due to degraded riverbanks and wetlands. Intact riparian vegetation play an important role in stabilize stream bank (Richardson et al. 2007). IAPs clearing in these habitat increases the capacity to prevent erosion and thus reduce siltation rates in water (Van Wilgen et al. 1996). At the same time, clearing of alien vegetation can also have serious negative impacts due to open sandy banks along the river which increase the risk of soil erosion and thus reduce water quality (CSS2 2009). *"After WfW teams cut down all big Poplar (alien) trees along the river the problem was even worse. Now the river bank is not protected anymore and soil is washed away. Moreover, a lot of new small alien trees reinvaded the area quickly which cannot stabilize the riverbank. During the next flood everything will be washed away, and gullies will form"* (local fruit farmer). The success of IAPs clearing and the rehabilitation of water related services thus also depends on the invasive plants' ecological characteristics which demand careful management planning. Moreover, IAPs clearing needs to be done on bigger scale to be effective. (McConnachie et al. 2012) for instance estimate that local WfW teams work on only 1.4 per cent of the Kouga's catchment area since 2002 (data capture commenced only in 2002) which didn't reduce the coverage of IAPs in the Kouga catchment but even increased despite all the clearing efforts.

7.2. Biodiversity vs. Agriculture

A great natural diversity characterizes the Kouga catchment. Three biodiversity hotspots intersect the catchment, six of the country's nine biomes and 32 different vegetation types occur in the Kouga catchment (see chapter 3). On the other side, the Kouga catchment is also known for its high productive agricultural areas (see chapter 4). Fruit farming in the Langkloof is the economic driver of the catchment due to its world-renowned deciduous fruit production.

To maintain biodiversity, restoration and conservation of natural habitat is needed which provides a living space for indigenous plants and wild animals. Therefore, the Baviaanskloof and Formosa Nature Reserves are established and managed by the "principles of wilderness" (Erlank et al. 2009). This means, human activities such as agriculture and urban settlements are restricted in these areas in order to protect local biodiversity. To increase biodiversity in the Kouga catchment, nature conservationists would like to expand current protected areas as different plans for a mega reserve and wildlife corridors indicate. However, land availability is limited because farmers own most land. Nature conservationists perceive agriculture as a challenge to the protection of biodiversity.

To be able to cultivate in the Kouga catchment, natural habitat is converted into agricultural land. To increase productivity and to generate more economic income, agriculture needs to be intensified by means of efficiency and expansion of current agricultural land. However, suitable land is limited due to the biophysical characteristics of the area and nature conservation legislations. Farmers often see nature conservation as a limiting factor to economic development. *"I am skeptical towards these environmental protection agencies which become so environmental friendly that they destroy our economy*". "*Environmental legislation forces us to reduce the amount of pesticides, but we still have the pests which damage our fruits".*

Increasing agricultural production and protection level of biodiversity are the two main interests recognized in the Kouga catchment. Land management practices are driven by at least one of these goals. Figure 42 describes the relation of land management practices and ecosystem services with regard to increase agricultural productivity and protection of biodiversity in the Kouga catchment.

Figure 42 show that the catchment's capacity to regulate, purify and provide water, mitigate floods and droughts, prevent soil erosion, support pollination and control pests and diseases contributes positively to both agricultural production and protection of biodiversity. Farming and nature conservation practices alter the provision of these ecosystem services, which in turn influence the agricultural production, and protection of biodiversity in the Kouga catchment. This influence can be directly and indirectly. The relation is described in more details in following paragraph.

Please notice, Kouga's capacity to provide water strongly depends on other ecosystem services including water regulation, water purification and mitigation of natural hazard service as described in previous paragraph but are not explicit taken into account in Figure 42 for the clarity of the figure and its relation.

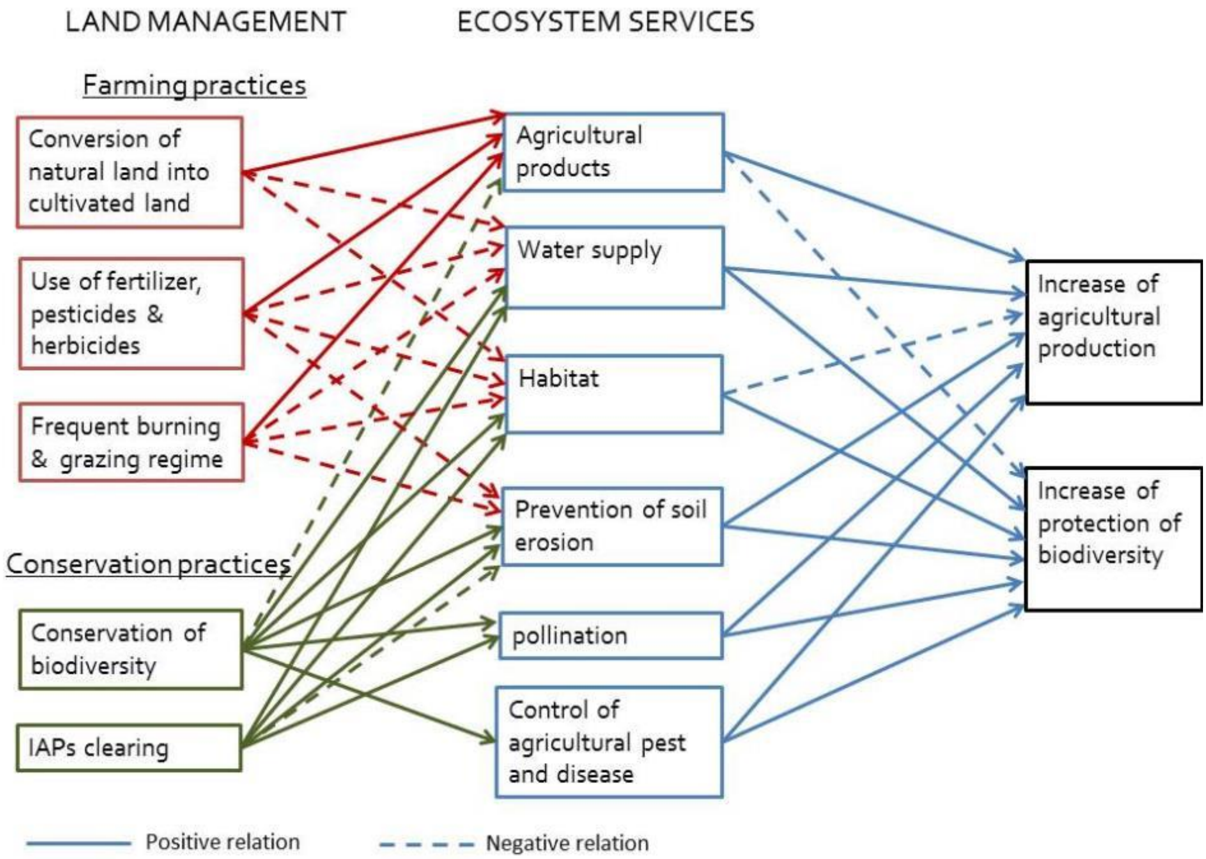

Figure 42: The relation between land management practices and ecosystem services in regard to increase agricultural production and increase protection of biodiversity in the Kouga catchment (Source: this thesis)

7.2.1. Conversion of natural land into cultivated land

Farming in the Kouga catchment is driven by the goal of agricultural production (mainly fruits, meat and wool). Therefore, natural land (mainly fynbos-renosterveld vegetation and wetlands) is converted into orchards and grasslands. Most conversion took place in the Langkloof and Suurveld, a process that still goes on. On the one hand, the conversion of natural land into cultivated land increases the productivity of the land. On the other hand, the catchment's capacity to provide refugia and reproduction habitat for wild species and animals has been decreasing. Agricultural land use is one of the main drivers of habitat transformation in the Kouga catchment and reduces the area's ability to maintain local biodiversity (see chapter 5). When losing indigenous fynbos species the ability of the catchment to capture and store rainfall water is decreased, too. This in turn influences both agricultural productivity and protection of biodiversity negatively.

7.2.2. Use of fertilizer, pesticides & herbicides

Another management factor, which further influences the natural plant diversity on cultivated land, is the fertilization of the soil. To increase productivity of the orchards, fruit farmers improve soil fertility by adding nutrients (especially nitrogen- and phosphorous- based) to their orchards. The use of fertilizer increase soil's nutrient concentration, which support and maintain plant growth. However, natural vegetation, which is adapted to nutrient-poor soil condition die, and other vegetation types adapted to nutrient-rich concentration, starts to dominate which in turn change species composition and decrease plant diversity.
Another farming practice to increase productivity of the orchards is the application of chemical based pesticides and herbicides to control agricultural pests and to reduce invasive weeds and other (unwanted) plant growth in the orchards. However, nutrients and pollutants may leach out to the ground- and river water which affects natural vegetation and water quality downstream (DWAF

2004; Richardson et al. 2007). In addition, reduction of plant cover on the orchard ground by the use of herbicides increase the risk of bare grounds, which in turn increase the risk of runoff and soil erosion. Some fruit farmers *"(I) leave grass and weed plants under the fruit trees to prevent soil erosion. This also keeps soil moisture"*. It reduces water use for irrigation, enhancing soil fertility and thus productivity. Moreover, one could argue that this also increase the catchment's capacity to support local biodiversity in the orchards.

7.2.3. Frequent burning & grazing regime

In order to ensure agricultural productivity, livestock farmers burn their fields regularly. This enhances the development of nutritious grass plants and provides pasture to feed livestock. However, other plant species which are not adapted to this frequent burning, such as fynbos, disappeared on long-term. Especially Grassy Fynbos is most vulnerable to fire which can cause local extinction of certain species (Vlok and Yeaton 2000; Euston-Brown 2006), reducing the area´s ability to maintain local biodiversity.

To increase productivity, grass fields are more frequently burnt and more animals are put on the fields. However, too-frequent burning and heavy grazing reduce the land's productivity on long-term. Livestock ranching reduce the plant coverage (Berliner and Desmet 2007). This decrease the land's capacity to prevent soil erosion as deep rooted plants such as fynbos are crucial to stabilize the soil. In areas like the Kouga catchment, this function is very important due to the areas topography and climate. Mountain fynbos area are recognized as being very prone to soil erosion (Haigh et al. 2004). In addition, soil erosion decrease infiltration of water into the soil. Consequently, less water is stored in the soil, which leads to higher water runoff and increase the risk of more intensive fires. This in turn causes loss of soil and nutrients as well as dehydration of the soil and soil fertility is decreased on long-term (Mander et al. 2010). Especially in areas like the Kouga catchment, where poor nutrient concentrations dominate, a further decline of nutrients may result in unproductive lands. Livestock areas are often classified as severely degraded habitats because of frequent fires and heavy grazing (see chapter 5). This lead locally towards "*farmed out land*" (e.g. in the Bo-Kouga area) which do not support any agricultural productivity anymore (Versveld pers. comm. 2012).

7.2.4. Conservation and restoration of biodiversity

Cultivation in the Kouga catchment is mainly restricted to the Langkloof and Suurveld. Local nature conservationist (ECP and individuals) primarily manages the mountainous areas. Nature conservation in the Kouga catchment focuses on the establishment of protected areas to provide a suitable habitat for flora and fauna, which increase the biodiversity level in the catchment. Certain conservation activities such as the control of fire events and wildlife support the catchment's capacity to provide suitable habitat for indigenous plants and animals. The natural fire regime in the BNR for instance gave rise to a mosaic of different vegetation ages, which enhance plant diversity. In addition, eradication of alien invasive plants by mechanical clearing support the restoration of intact ecosystems, which provide refugia and reproductive habitat to wild species and animals. Restoration of degraded areas by replanting indigenous vegetation also increases the catchment's capacity to support biodiversity. However, this restoration activity is done on very small scale, recommendations and plans exist for further application of this activity to maximize biodiversity in the Kouga catchment (González 2009).

The conservation and restoration of biodiversity does not only support local biodiversity itself, it also influences a lot of other functions and services in a positive way. According to nature conservationist the natural fire regime, "*prevent spreading of huge wildfires*". Moreover, protection of natural ecosystems provides important beneficial services to neighboring agricultural areas, for instance, through the protection of Kouga's natural vegetation natural water regulation and provision is maintained. IAPs clearing support the restoration of intact wetlands and riparian ecosystems, which support the area's capacity to purify water and to mitigate natural hazards. These ecosystem services are crucial in the Kouga catchment because the catchment naturally face regularly extreme climate events, which especially can hit downstream areas, such as the Langkloof. Intact ecosystems in the mountainous areas of the catchment also provide important habitats for pollinators and bio-control agents. Fruit production in the Langkloof highly depends on these services. Protection of natural vegetation also maintains the capacity to prevent soil erosion. Especially in rugged areas like the Kouga catchment, this capacity seems of high importance. In addition, conservation of biodiversity also supports recreation and the provisioning of cultural, historical, spiritual and scientific information. This value is recognized by the nomination of the BNR as a World Heritage Site. According to local farmers and nature conservationist natural areas in the Kouga catchment provide great opportunities for (eco) tourism and "have a strong recreational potential" (Erlank et al. 2009). Current wildlife management for instance enhances the area's touristic attractiveness. Recreational services are not exclusively restricted to natural areas. Cultivated land is an appreciated ´natural scenery´ by local land owners and contributes to an alternative income source in the Kouga catchment.

8. Discussion

As previous studied have shown the Kouga catchment is a complex socio-ecological system. The catchment is home to various ecosystems and biodiversity hotspots, which support the delivery of ecosystem services upon which land management such as agriculture and nature conservation depend. The catchment is constantly changing, due to natural and human causes, which in turn influence land management and the generation of ecosystem services. This dynamic situation demands a robust information base to enable proper ecosystem analyses. However, uncertainties will remain due to choices and assumptions that have to be made and the availability of data. This chapter focuses of the discussion of data collection and analysis, followed by the discussion of the results and the study´s contribution to nature conservation planning and management in the catchment.

8.1. Discussion of method used

In order to achieve the objective of this study, a step wise approach was applied. Each step contained different methods of data collection and analysis.

8.1.1. Discussion of data collection

When starting with this research it became clear that data about the study area was limited. Therefore, one of the objectives of this study was to collect information about the study area as much as possible in order to develop a comprehensive information base about the Kouga catchment as a whole. Data collection took the biggest part in this research and was mainly done during field-work in South Africa between October 2011 and April 2012. To deal with limited data availability, information was collected and combined from different sources such as literature, interviews, questionnaires and field observations.

a) Combining different data sources

Throughout the whole research, a literature review was done to provide basic information or to cross-check answers from stakeholders. In most cases, available literature consisted of more general information about certain topics (e.g. vegetation types, IAPs management and nature conservation in South Africa) rather than specific information about the Kouga. This information was thus considered as background information to understand the South African context. Based on this, more specific information from different assessment reports was collected. However, most of these reports were about regions where the study area only partly falls in, such as the Baviaanskloof-Tsitsikamma reports (Powell and Mander 2009), which made it difficult to describe the catchment as a whole. As a result, data might be too general in some cases and does not fully capture the catchment's diversity. The use of ArcGIS data enabled an overview of the study area as a whole. Two ArcGIS databases were available which cover different parts of the catchment (BMR and GRI domain). When combining and integrating these two databases almost the whole Kouga catchment was captured which allowed a spatial overview of the case study area. Due to the sheer size of the Kouga catchment (282 000ha), local people often did not recognize their physical position and natural and social dependencies in the catchment. With the help of ArcGIS data, maps and tables could be made, which helped to visualize findings and demonstrate the catchment as a whole towards different stakeholders. This aspect is important when it comes to opening dialogues on sustainable management options in the catchment. Both ArcGIS databases have also been used by the local nature conservationist (ECP), NGOs and in South African scientific literature, which could streamline communication of data outputs.

b) Different classification systems and scales

Nevertheless, the use of ArcGIS data was limited due to data inaccuracy and different classification systems between the two ArcGIS databases. In order to analyse available ArcGIS data some assumptions and choices needed to be made. For instance, the two ArcGIS do not edge-match seamlessly. In the Langkloof area some small gaps had to be ignored in order to develop data for the whole catchment. However, this might have led to inaccurate data when making calculation for the whole catchment and certainly asked for more detailed analysis to avoid misinterpretation of findings. Moreover, different categories of the land cover and state of the ecosystem between the two ArcGIS projects hampered the accurate combination of data. This means that more detailed information might be lost and the risk of double counting may exists. For example, `irrigated cultivation' and `farmland´ were land use categories in the Langkloof in the BMR and GRI ArcGIS data set respectively. I assumed that these categories were equated to 'fruit farming' as other irrigation or other farming practices in the Langkloof only exist on small scale, as far as I know from own field observations. However, when comparing this data to other information sources different results exist. Insufficient accurate land cover data may explain this difference. In another situation, the total area of degraded land was calculated. Because different categories of degradation and transformation classes exists between the two data bases, the calculated total area of the catchment was 418,693 hectares instead of 282,404 hectares. This was most probably the result of double counting. To avoid misunderstanding of the data, in most cases a range of data is shown. If possible, expert judgement was consulted to decide which data are correct or most representative.

To the best of my knowledge, the two ArcGIS databases are the most detailed available quantitative information sources about the study area. However, final results of the ArcGIS analysis contain some uncertainties due to inaccuracy in data and should be not simply taken for granted but rather seen as first quantitative, spatial 'snapshots' of the study area as a whole. The development of one detailed ArcGIS dataset is suggested to enable an in-depth quantitative study to improve the quality of data. This research has shown that new information will have to be generated if further research on the Kouga as a whole were to be conducted, since current data sources each have their limitations.

c) Disadvantages and advantages of interviews

Due to the fact that quantitative data was limited available I chose for a stakeholder-based approach to collect in-depth information about the study area and to fill in knowledge gaps. Most case study specific data was collected through interviewing local people. One the one hand, this kind of data collection gave me as a researcher great flexibility, especially in the case of semi- and unstructured interviews, which were the majority of my interviews. It was up to the respondent how much he/she would like to tell, I only guided the interview by a set of predetermined questions. But, on the other hand, this might also have lead to my own interpretations of the collected data. Moreover, the quality of data collected from an interview depends upon the quality of interactions between the interviewer and interviewee (Kumar 2005). To represent the information correctly, I spend a great amount of time in the study area and tried to listen and understand the respondent's perceptions, meanings and definitions. The interviews also included sensitive questions for instance about the environmental state or water related issues. Therefore, a kind of relation between the respondents and me was needed to retrieve honest answers. Repeated interaction with respondents enhanced the quality of information. Moreover, in-depth interviews strengthen the relationship between interviewer and interviewee which supports the collection of reliable data (Kumar 2005).
But interviewing is time-consuming. Consequently, this research needed more time than I planned in the first place. The research conditions also influenced my time management as respondents were scattered over a wide geographical area and the research area was difficult to access due to bad infrastructure, driving distance and car availability. In addition, as being one of the first students working in the area, a lot of work was needed before getting access to the respondents, in terms of logistic and network and trust building. Moreover, most interviews had multiple purposes, which meant interviews were not only done for my own research but also for a social learning project[5] and

[5] Living Lands project "Mobilizing civil society in the Kouga catchment"

other thesis research[6]. Consequently, an interview could sometimes take longer than three hours. On the one hand, a large amount of data could be collected from an interview. But on the other hand, the collection of more specific information for my research was sometimes limited. Repeated interviews were needed or/and other information sources were consulted to specify data or/and fill in knowledge gaps. However, the multi-facetted nature of the interviews also enabled me to create a holistic view on the study area and supported the understanding of the study area as a whole.

Although time was limited, I managed to interview 44 different stakeholders. One might say that this is a relative small size of respondents when compared to the more than 10.000 people living in the catchment. But those that were interviewed can be seen as key actors in the area. For instance, the majority of the catchment is owned by farmers, who also formed the majority of my interviewees. Moreover, I spoke to chairpersons and leaders of different associations and institutes (e.g. Langkloof's Farmers Association, ECPTA regional manager, Department of Agriculture, church) to ensure a complete and representative picture of the study area. However, most people I met were from a certain area (Langkloof) and I spoke to fewer people representing other areas in the catchment (e.g. Bo-Kouga and Suuranys). Moreover, I only had a few interviews with local people outside the farmers' community. These people might have very different views and knowledge about the study area. Interviews with for instance coloured and black people could have provided me with more information about medicinal and spiritual services used in the catchment. This information is now mainly based on literature review from other comparable studies. Therefore, it is important to stress that this research only intended to show trends and give first insights into the study area, but might not represent all knowledge and the situation of the whole catchment. I propose that follow-up work should also include other areas and communities within the catchment.

d) The usefulness and constraints of a questionnaire

Another information source in this study was the use of a questionnaire. A questionnaire was filled in by the respondent at the end of an interview. The purpose of the questionnaire was to make sure that all topics of interest were covered, as it could happen that during an interview certain issues might be missed due to the respondent´s choice or lack of time. In addition, this method of data collection was meant to cross-check data from literature and to provide quantitative data.

But it turned out that the questionnaire didn´t provide the expected results. Firstly, as this questionnaire was designed for two different researches, only parts of the questionnaire could be used for this study, other parts were used by the other researcher. Secondly, the questions which were asked were not precise enough for a further analysis. To be able to ask precise question the study area and the current situation should be known which was not the case when designing the questionnaire. Thirdly, the research also changed during the field study due to what have been learned. For instance, the question about fire in the questionnaire was not easy to answer by respondents. I found out that fire can have a different meaning to stakeholders and that the challenge is often not the occurrence of (wild) fires but also the lack of fire. This changed the focus of attention based on which parts of the problem have been found and made certain questions in the questionnaire less applicable for this study.

But it proved that the used questionnaire was a good method to open new conversations between me and the respondents. Respondents spontaneously provided me with extra information about certain topics while they were filing in the questionnaire. These conversations often had an informal character and new questions were raised on the spur of moment. In addition, the questionnaire was also a good way of being taken more seriously as a researcher and respondents became aware of their importance in this research.

[6] Draugelyté, E. (2012). Dissonance in social learning: towards maintenance of natural resources in the Kouga catchment, South Africa. MSc Thesis, Wageningen University.

e) Bias problem

Data collection was influenced by my presence in the context I researched (e.g. being a foreigner, a women and environmental scientist), and by my personal value judgement. Often respondents, especially the farmers from the Kouga catchment, saw me as a “green scientist” or/and as a “nature conservationist”. This might have influenced the information that they gave to me, especially when we talked about more sensitive issues such as the environmental state of their land, pesticides use, etc. In addition, sometimes I even saw myself in the role of an environmentalist when I talked to farmers about nature and farming and I sometimes didn’t agree with some statements. This might have influenced my attitude or facial expression, and therefore might have influenced how I selected and analysed the data. A scientific research should be based on facts, not on values and judgments. However, there are also voices which reject the value-free position in scientific research which doesn´t mean that you work less scientifically (Punch 2005). But still, values should not guide your research and it is important to meet the stakeholders with an open mind and without any judgement. I constantly reflected on my actions to reach this openness. By doing so it allows you to see more deeply and sharply and to get a fresh look on the situation and its opportunities (Scharmer 2007). Moreover, through my openness I realized that respondents also got more open-minded which improved the reliability of data.

f) ‘Grounded’ findings

During the research I developed an iterative process of collecting and analysing data. The strength of this process is to be able to develop your research further while improve the quality of findings. In the beginning, data collection was primarily based on local knowledge collected from land owners. I tried to meet stakeholders as open-minded as possible rather than starting my research with a hypothesis for testing. This means after finishing my interviews, I started with a first round of data analysis by ‘breaking data open’ and bringing data together. Local knowledge was taken as an important reference point in this study to ensure bottom-up reasoning. This also enabled me to get a grip of the current reality in the Kouga catchment. After that, experts’ judgement (from interviews with experts and review of scientific literature) was consulted guided by the emerging directions to compile a general overview and compare with what was learned from the interviews with local land owners. Therefore, another round of data analysis was done by integrating local knowledge and scientific expertise. Based on these findings relationships could be formulated and relations between land management and ecosystem services could be explained. In the end, the relations I found are perhaps quite obvious, considering the general situation in South Africa and earlier explorative studies on biodiversity conservation and agriculture expansion (Driver et al. 2012). However, my findings were completely grounded in case study specific data, in which views and knowledge from all relevant sources were integrated. This kind of research strategy might also be explained by the so-called ‘grounded theory’. It is a widely used research method when dealing with qualitative data. The purpose of the ‘grounded theory’ is to generate the theory on the basis of data by a cyclical process of collecting data and analysing data until a point of ‘saturation’ is reached (Punch 2005), i.e. statements were repeated and confirmed.

8.1.2. Discussion of data analysis

a) Integration of quantitative and qualitative information

This study presents the first inventory of biophysical and environmental characteristics and land management types of the Kouga catchment, which is based on quantitative and qualitative data. The integration of these different types of data enabled me to develop a representative picture of the case study site. Quantitative data are information about the case in numerical form. This kind of data helped to visualize findings by the creation of maps e.g. of the land use types in the catchment whereby. ArcGIS data proved helpful to provide a spatial and partly quantitative overview of the case study area. Qualitative data in turn are information in form of words and helped to provide the narrative explanations e.g. how the land is used. The two kinds of data often replenished each other, which improved my understanding of the study area. At the same time, data could be checked against each other which improved data validity. However, in-depth analyses were limited due to the scope of this study (a broad analysis of various aspects) and size of and large natural diversity in the catchment. This might have resulted in more general assumptions and findings. Moreover, data analysis was primarily based on descriptive rather than representing quantitative data due to limited and inaccurate data, which gives more space for own interpretations of the findings. More research would be required to further develop the information base and to increase the understanding of the relation between land management types and ecosystem services in the Kouga catchment. Further in-depth and quantitative analyses are recommended to strengthen results and to fill in knowledge gaps. The development of one detailed ArcGIS database for the case study area will help to provide spatial data and quantify findings. The ArcGIS data from the GRI project could be used as a reference data source.

b) Triangulation - the combination of different assessments

The notion of triangulation is to improve the accuracy of findings while combining different methods and/or data (Punch 2005). In this study, the method of triangulation enabled me to fill in knowledge gaps and improved the understanding of the case. The combination of quantitative and qualitative data (as discussed above) as well as local knowledge with expert judgement enhances the validity of the final findings and reduces uncertainties in the study (Punch 2005). Especially the integration of local knowledge with scientific expertise improved the reliability of the results by replenish each other. To give an example, in literature it was stated that there are five biomes represented in the Kouga catchment. In interviews, however, local land owners explained that vegetation of the Succulent Karoo Biome could be found on their land as well, which means that there are six biomes within catchment boundaries. Own observation confirmed this. In another case, local farmers explained the diversity of the climate of the study area. Literature gave me the right scientific bedding for this phenomenon and could be used as an evidence for descriptions and interpretations from the field. Moreover, the combination of different assessment can offset the weakness of another assessment and can check out the validity of data (Punch 2005). ArcGIS data were always checked against other data such as expert judgment. Moreover, the combination of different assessment sometimes provides another perspective on a particular phenomenon such in the case of the assessment of the environmental state. The integration of local knowledge to the ArcGIS study brought in a totally different view on the environmental state of the Kouga catchment. Different actors have different opinions and argumentations on certain (environmental) problems, which consequently also require different formulations. This need to take into account when analysing the situation in the case study area and develop sustainable management practices.

All in all, the method of triangulation helped me to provide a better and complete picture of the situation in the Kouga catchment, which is certainly an important aspect when doing an integrated ecosystem analysis and dealing with complex issues.

c) Opportunities and limitations of using the concept of ecosystem services to disentangle ecosystem complexity

The concept of ecosystem services translates the complexity of the ecosystems into something more ‘simple’ (ecosystem services) which enhance understanding and communication of the results among different people, certainly an important aspect in this study.

However, the ecosystem services analysis also has its limitations. Ecosystems generate multiple ecosystem services in a very dynamic and complex way. To capture this dynamic and complexity, a proper understanding of the ecosystem is crucial, especially in terms of the ecology behind the provision of ecosystem services. Therefore, robust biophysical and ecological data is needed to give representative and quantitative results. In addition, each ecosystem has its own character which asks for case study specific data to come as close as possible to reality. This study provides a first general overview of the key ecosystem services provided in the system. To go more in-depth in the Kouga

catchment system, specific case study sites can be selected and thoroughly analysis. It was beyond the scope of this research to select sub-plots for studying e.g. water regulation, pest control.
In addition, when making use of the concept of ecosystem services, one should be aware that the analysis does not always explicitly show the interaction among certain ecosystem services. This might create a more static picture of the system rather than a dynamic system. For instance, the catchment´s capacity to regulate water strongly influences the water supply. The function of water regulation in turn is, among others, influenced by the vegetation cover. Vegetation can also support pollination services and biodiversity. This shows how closely linked some ecosystem services are, and which can be therefore difficult to analyse and represent separately. However, these inter-linkages and simultaneously generation of ecosystem services seems to be often missing when making use of the concept of ecosystem services, especially when it comes to (economic) valuation and the development of management options. The economic value of for instance the food production in the study area does currently not include agriculture's dependency on water and the influence of pollination on the fruit production. On the other hand, water management does not improve fruit production per se if neighbouring ecosystems do not provide a habitat to pollinators.
For a better understanding of interdependencies among ecosystem services, a stepwise analysis of the provision of ecosystem services seems to be beneficial. The use of the concept of ecosystem services helped me to disentangle ecosystem complexity. Moreover, this allowed me to describe interactions between ecosystem functionality and land management while presenting important bundles of ecosystem services, in the light of the most important issues in the area. These bundles of ecosystem services are needed to be taken into account when analysing trade-offs between and consequences of land management practices and nature and when developing sustainable management options. However, it is important to mention that this analysis is based on the most influential land management practices and ecosystem services. There are certainly more aspects influencing Kouga's ecosystems, as well as to what extent these aspects are influential is different. For instance, when it comes to water abstraction, irrigated agriculture has a far bigger impact on the total water supply then dry-land agriculture. This also requires different formulation when it comes to the management options.
Therefore, after identifying and analysing the ecosystem services, the next step would be the quantification of the services and valuation of these generated benefits. This would give the ecosystem services a different perspective and might provide new insights to various stakeholders into the relation between land management types and ecosystem services. Especially the economic valuation might be helpful to raise the awareness of trade-offs and consequences of land management. The information that was compiled in this study has already proven to generate more awareness and communication among stakeholders, but quantified information will definitely improve this dialogue. To support communication and awareness raising among the different stakeholders, mapping and modeling of ecosystem services might be also beneficial as it illustrates and quantifies ecosystem services in a more dynamic and visual way. Supply and demand of ecosystem services differ geographically, as already identified in this research, and should be taken into account in the development of sustainable management. Results of these methods contribute to the finding of sustainable management options and can be used to support decision-making process.

8.2. Discussion of results

8.2.1. Dealing with uncertainties

The results of this study show that the Kouga catchment is an extremely complex system, constantly changing naturally and artificially over time and space. This high complexity and dynamics demand a robust information base to present the catchment in its true colour and to develop sustainable management options. However, as a researcher you should be aware that some kinds of uncertainties are inherent; others can be reduced by more knowledge. In order to improve the quality of the study and its final results, uncertainties need to be defined, accessed and communicated.

In this study, uncertainties mainly originate from the scope of the research as well as characteristics from the study area itself. On the one hand, it was necessary to include as many aspects as possible into the research to capture the catchment as a whole system. But on the other hand, this complexity and diversity demands for in-depth analysis to understand the system well. However, this in-depth analysis was not yet possible in this research due to time and data limitations. Consequently, final results are to some extent generalized and contain epistemic uncertainties. For instance, in the ecosystem services analysis I spent less time on the analysis of cultural and amenity services because I had focused my data gathering on provision and regulation services. However, to enhance the wholeness of the analysis and to improve the knowledge, it is recommended to include these services as well. Uncertainties also have origin in the unawareness of what I, the researcher, do not know. My research was guided by what people told me and what I observed, other aspect were ignored which might have left out other equally important aspects of the study area. However, there was no other alternative at that moment as other data was limited and it might be better to be roughly right than precisely wrong. To reduce this uncertainty, I tried to speak to many different people to represent the catchment well. But even though I interviewed key actors in the area, more interviews are recommended, especially outside the farmers' community to enhance diversity of respondents and thus representativeness of the final results.

Another source of uncertainty originates from the input data. For instance, some available ArcGIS appeared to be not representative (e.g. extent of fruit farming). Data were sometimes also incomplete (e.g. hectares IAPs in the Kouga). These uncertainties can be reduced through further research. However, at this stage it is important to address these uncertainties in the communication with stakeholders in order to avoid misunderstanding and mismanagement.

Even though final results contain uncertainties, this study provided a first comprehensive information base about the Kouga catchment as a whole including an overview of the available data and gaps in knowledge. The results supported a better understanding of the case study site upon which further research can be build. My findings are valuable for the new Living Lands project in the Kouga catchment[7]. Recent newsletters and an informative Kouga booklet have already been written, which were all based on findings of this research. There were distributed among the different stakeholders in the project area to enhance understanding of the Kouga catchment and to search for sustainable solutions.

8.2.2. Contribution of my study to nature conservation planning and management

a) Comparability and generalizability

A widespread criticism of case study based research concerns the data comparability and generalizability of findings (Punch 2005). Although this research was carried out in a case study area, the results are linked to a larger theoretical concept. The classification system of ecosystem functions and the associated services in this study was derived from the TEEB- project *(2010)* and de Groot (2002), and their approaches are among the most widely used within the concept of ecosystem services. This choice enhances data comparability. When it comes to generalization, the question arises whether this study should be generalized or not. There are types of case studies where generalization is not the objective. "The intention of the case study is not to generalize, but rather to understand the case in its complexity and its entirety, as well as in its context" (Punch 2005). This was certainly an objective of this research and thus it is important to understand the findings as case study specific results. But this study also show elements which might be more broadly applicable to other case studies and might contribute to the development of sustainable management planning (see below).

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[7] For more information see: Living Lands (2012) *Mobilizing Civil Society to support Living Landscapes in the Kouga catchment*

b) Integration of ecosystem services in conservation planning

In this study it was shown that conservation of biodiversity supports the provision of many ecosystem services (see Figure 42 page 77). It seems that biodiversity takes in a crucial role in the functioning of an ecosystem and its provision of services. Indeed, scientists have stated that biodiversity has a supporting role, but the exact contribution is under discussion (Egoh et al. 2007). Especially when it comes to the relation between biodiversity and ecosystem services different opinions exist which seems to hamper global nature conservation management.

In South Africa, nature conservation is defended by biodiversity which is argued to be an umbrella service from which all other ecosystem services originate (DEAT 2011). However, this argumentation seems to be not well communicated to laypeople, especially land managers. Nature conservationist and scientists in the catchment for instance argued to conserve nature to support biodiversity but thereby deny other benefits supported by biodiversity conservation, many upon which agriculture depend. Farmers expressed their *"lack of knowledge about the benefits of biodiversity*" during interviews and stated that they do not understand why nature conservation should be important. Consequently, certain agricultural practices have negative impacts on biodiversity and agricultural productivity (see Figure 42), which were largely unknown to farmers.

For about two decades the ecosystem services approach has gaining increasing attention worldwide. This approach focuses on the maintaining of ecosystem services. Biodiversity concerns are incorporated into this approach but are more seen as a "side benefit" of safeguarding ecosystem services (Díaz et al. 2009). For South African biodiversity conservation, this means to include ecosystem services in their planning. This integration seems to be difficult due to different perspectives on how to conserve nature and consequently ecosystem services concerns are rarely integrated into conservation planning (Egoh et al. 2007). However, from my research I can support the argumentation of integrating of biodiversity and ecosystem services in conservation planning and management. Thereby, I argue that the ecosystem services approach gives room for new opportunities within nature conservation while supporting the argumentation for protection of biodiversity and agriculture. Especially from a communicational point of view, the ecosystem services approach should be integrated into current conservation planning to successfully protect biodiversity. With the use of the ecosystem services concept, nature conservationist can for instance argue to protect fynbos due to its importance for water related services. This might enhance the commitment of more people also outside the nature reserves who will benefit from restoration activities. The relation between biodiversity and ecosystem services such as pollination upon which agriculture depends might stimulate farmers, for instance, to replant natural vegetation or reduce pesticides. In addition, the ecosystem services approach might also increase financial support for nature conservation from other institutes such as Department of Water Affairs or water companies. Goldman et al. (2008) identified that ecosystem services projects indeed attract on average more than four times as much funding than biodiversity conservation projects, because of greater cooperation and variety of finance tools.

c) The mediating role of programs on invasive alien plants clearing

It is obvious that conservation and restoration activities in the Kouga catchment need greater commitment of and cooperation among various stakeholders. To reach this, clearing of IAPs could function as a mediating role between nature conservationist and local land users. Clearing of IAPs is a common goal between the people in the Kouga catchment (Draugelyté 2012). Therefore, "collaboration (in the Kouga catchment) is recommended to be started in the context of water saving practices" (Draugelyté 2012), which also including eradication of alien plants species. A variety of stakeholders will benefit from the clearing of alien species. It does not only contribute to the restoration of natural habitat but also rehabilitate natural water regulation and provision of water upon which agricultural production in the catchment depends. The concept of ecosystem services might support communication of these benefits and strengthen the link of IAPs clearing and human well-being. This in turn can stimulate collaboration between the different stakeholders and further

enhance communication. Linking conservation actions to human well-being might support the societal relevance which might contribute to effective conservation actions (Egoh et al. 2007).
When once collaboration among different stakeholders is established, further conservation and restoration actions can be established including the integration of different perspectives which might lead to great success of conservation of nature.

9. Conclusion & recommendations

This final chapter presents the conclusion of this study followed by recommendations for further research and sustainable catchment management in the Kouga catchment.

9.1. Conclusion

The main biophysical and environmental characteristics of the Kouga catchment (RQ 1)

The terrain of the Kouga catchment is extremely rugged, with mountain ranges rising up to 1850 m.a.s.l. and valleys ranging from 200 to 850 m.a.s.l. The mountains are formed by the Table Mountain Group (TMG) which consists of different layers of sandstones. These sandstone layers give rise to acidic, nutrient poor and well-drained soils. Lower lying valleys are slightly different as they result from shale formations (Bokkeveld Group) which generate sweeter, fertile soils which have a higher water holding capacity compare to other soils in the catchment.

The Kouga catchment is generally described by a Mediterranean climate and classified as a semi-arid region (mean annual rainfall approx. 500 mm). However, due to the large topographic variation the climate can differ from the general climate profile and average rainfall pattern. Temperatures rise with every mountain range going from south to north, and west to east; precipitation increases the other way round. In the western part of the catchment most constant rainfall occurs during spring and autumn; whereas in the east, summer rainfall increases gradually. Although the Kouga catchment regularly faces extreme climate events such as floods, droughts and hail storms, during recent years the area was often declared a ‘disaster area’ due to severe environmental and economic damages caused by natural hazards.

The Kouga River is the catchment’s main river. It originates from the west of the catchment and flows eastwards, parallel to the mountain ranges. Untypically but naturally, the river then flows northwards and ‘ends up’ in the Kouga Dam. On its way to the dam, the Kouga River is fed by many tributaries, and afterwards it joins other rivers and flows into the sea.

An important characteristic of the Kouga catchment is its exceptional biodiversity. The catchment intersects three biodiversity hotspots, six biomes and 32 different vegetation types. The mountainous areas are covered by the endemic fynbos biome (approx. 82%), which is also the biggest contributor to species diversity in the catchment. Because soil’s nutrient concentrations are slightly higher in the valleys, they are occupied by a fynbos-renosterveld variant. The eastern part is characterised by grassy Fynbos, Grassland and Savanna vegetation (approx. 9% and 0.2% resp.). Thicket and forest vegetation are found in the fire-proof kloofs (approx. 9% and 0.5% resp.). Scattered succulent Karoo vegetation occurs in the western part of the catchment. Some wetland and other riparian vegetation grow along the Kouga River and its tributaries. The catchment’s biodiversity is negatively influenced by the invasion of alien plants (IAPs); around 54 different exotic plant species have invaded the catchment, especially along the Kouga River.

The main land management and land use types (RQ 2)

In total the Kouga catchment covers an area of 282,000 hectares. Although farmers own the majority of this land (approx. 190.000 ha) only 10% of the catchment is used for agriculture and almost 90% is natural. Around 80,000 hectares of this land are state-owned protected areas. These are primarily mountainous areas managed by nature conservationists. Human interventions are limited in conservation areas, and the focus lies on wildlife management, control of fire events, eradication of IAPs and the protection of honeybush plants.

Lower lying areas are predominately used for agriculture. The main farming types in the Kouga catchment are extensive livestock farming (14,022 –38,826 hectares) and intensive fruit farming (7,000 – 16,171 hectares). The open grassy areas in the east (Suurveld) are used for livestock grazing (mainly sheep) and dry-land farming (grain and animal fodder production). Prescribed burning of grass fields is a common farming practice in the Suurveld, which aims to increase the quantity and quality of grass. Cultivation of deciduous fruits occurs in the Langkloof valley along the main road. The valley is the second largest deciduous fruit producer of South Africa. The most crucial management practice is the irrigation of orchards. Other orchard management practices are pruning, soil preparations, control of agricultural pests and weeds by chemical spraying of herbicides and pesticides, and harvesting of the fruits. Dams cover 774 hectares of the total land. They include smaller irrigation dams and the largest dam - the Kouga dam, situated in the north-east of the catchment and providing drinking and industrial water to Port Elizabeth and irrigation water to other important agricultural areas (Gamtoos Valley).

<u>The environmental state of, and threats to, the ecosystems of the Kouga catchment (RQ 3) and the main issues (RQ 4)</u>

Numbers about to what extent the Kouga's environment is under threat vary, but nevertheless, a clear trend can be seen. About 50% of the total natural habitat is lost; 42% by land degradation and 8% by habitat transformation. According to literature and expert judgement, degradation in the Kouga catchment is caused by overuse of natural resources (grassland, water and honeybush), too frequent burning and/or moderate to dense alien infestation. Habitat transformation is mainly caused by heavy alien infestation, dry-land, old cultivation, irrigated agriculture, large dams and urban development. Agricultural areas and riparian zones are under severe pressure due to farming-related management measures and the invasion of IAPs, whereas mountainous areas are in good condition due to nature conservation. However, farmers perceive their land as healthy (because of its high productivity) and regard the invasion of alien plants as the chief threat to the environment because it results in water insecurity.

Two important issues were brought forward during the analysis which constrains sustainability in the Kouga catchment: local water security and the two opposing views on the desired management of the Kouga catchment (biodiversity conservation vs. agricultural production).

<u>The identified ecosystem services in the Kouga catchment (RQ 5)</u>

The ecosystem services analysis shows that the Kouga catchment has a great capacity to provide all ecosystem services. Stakeholders identified water supply, water regulation, water purification, natural hazard mitigation and the prevention of soil erosion as key ecosystem services. Local farmers also highlight the importance of food production (agriculture) and raw materials (e.g. fuel wood, wool), and the potential of the catchment for recreation. Habitat services are mostly appreciated by nature conservationists.

The provision of ecosystem services differs spatially and is strongly influenced by land management. Natural land in the mountainous areas has the capacity to provide many ecosystem services, especially water regulation and habitat services. Nature protection influences this potential positively. Cultivated land in the lower lying areas optimize the provision of agricultural products and raw material while reducing other ecosystem services such as mitigation of natural hazards and prevention of soil erosion.

<u>The relation between land management and ecosystem services in the Kouga catchment (RQ6)</u>

With the help of the ecosystem services concept, complex relations could be disentangled and the key issues could be related to key ecosystem services. This knowledge was needed to answer the central research question in this study, about the relation between land management and ecosystem services and to provide insights into the trade-offs between ecosystem functionality and land management.

Water security

The Kouga catchment is crucial for the provision of water that is used by stakeholders outside (downstream) and within the catchment boundaries. The water is used for drinking, domestic and

irrigation purposes. The amount of water that can be supplied depends mostly on vegetation coverage up in the hills. Fynbos vegetation has a crucial role in regulating water and enhancing the provision of water downstream. But water provision in the Kouga catchment is limited and unreliable anyway, as a result of its geographical location. Local water security is therefore an important issue identified by all interviewed stakeholders in the Kouga catchment.
Water security depends on the catchment's capacity to regulate, purify and provide water, to prevent soil erosion, and to mitigate droughts and floods. This capacity has been strongly decreased by high water abstractions, construction of dams, weirs and channels, conversion of natural land into cultivated land, livestock grazing and high chemical input. In other words, the provision of a reliable clean water supply is largely hampered by the management of those who depend strongly on it.
Nature conservation on the other hand seems to have a large positive effect on the local water security. Conservation of biodiversity aims to protect and restore natural vegetation, and thereby contributes to improving the catchment's capacity to regulate, purify and supply water, prevent soil erosion, and mitigate droughts and floods. Especially the clearing of IAPs has a positive influence on provision of these ecosystem services and thus support to maintain local water security.

Conservation of biodiversity vs. agricultural production
The Kouga catchment is home to outstanding biodiversity, which is currently protected by nature conservationists. But the catchment is also known for its high agricultural production, for which local farmers are responsible. The catchment's capacity to regulate, purify and provide water, mitigate floods and droughts, prevent soil erosion, support pollination and control pests and diseases contributes positively to both agricultural production and protection of biodiversity. However, agricultural production in its current form constitutes a clear threat to biodiversity protection, and expansion could lead to more increased water shortages and other problems. To optimize the provision of agricultural products, natural land has been and is still being converted into cultivated land, fertilizer, pesticides and herbicides are used in fruit farming, and grass fields are burnt frequently and grazed by livestock. These farming practices decrease the catchment's capacity to support the provision of habitat to wild plants and animals, thereby reducing local biodiversity. Moreover, the catchment's capacity to regulate, purify and provide water, to mitigate natural hazards and to prevent soil erosion are decreased by these farming practices which affects both agricultural production and protection of biodiversity on long-term.
On the other hand, measures to stimulate habitat services are generally perceived to affect agricultural production negatively, because these measures entail reclaiming of land (loss of agricultural land), removing structures and promoting limited fertilizer and pesticide use and reducing livestock capacity. But conservation of biodiversity supports the catchment's capacity to regulate, purify and provide water, to mitigate natural hazards, to prevent soil erosion, enhances pollination and control of (agricultural) pest and disease, especially through the clearing of IAPs in riparian zones. This in turn also benefits agriculture on the long-term. Currently, however, farmers feel limited possibilities as a result of biodiversity conservation, whereas biodiversity conservation is not optimal either because of farming practices.

To conclude, both farming and nature conservation practices optimize certain ecosystem services while reducing others. Agriculture is the economic driver of the Kouga catchment and broadly recognized as very important for the catchment. However, while it enhances the provisioning of food services, agriculture alters a range of other crucial ecosystem services on which it is strongly dependent itself. These alterations in turn drives environmental decline such as loss of biodiversity, and also hamper long-term agricultural production. On the other hand, nature conservation often lacks acceptance among local people as being an important management options, due to limited communication and collaboration, and lack of clear objectives. Conservation practices might on the short term decrease agricultural production but it is also shown that they support the catchment's capacity to provide various crucial ecosystem services. Thereby, biodiversity seems to have a crucial role in ecosystem functionality which also benefits agriculture on the long-term.

The trade-offs between and consequences of all management practices and ecosystem functionality need to be well communicated in order to start collaboration and to find best practices for sustainable catchment management.

<u>The first information base for the Kouga catchment as a whole</u>
To the best of my knowledge, this study presents the first integrated overview of the Kouga catchment as a whole. This was achieved by comparing, validating and integrating findings from various studies on biophysical and environmental characteristics, land use and management. In addition, through the ecosystem assessment and the ecosystem services analysis the core issue in the Kouga could be identified. Knowledge from scientific experts, land owners and nature conservationists proved to be a useful information sources. Altogether, this assessment provides an overview upon further research can build. Currently, the numerous partners within the "Living Lands" project is already making of the generated knowledge.

9.2. Recommendations

The integration of different information sources and the inclusion of local knowledge proved to benefit the development of a holistic, yet precise overview of the study area. The analysis of the relation between ecosystem services and land management practices was helpful to disentangle complex relations between people and the natural environment, and to analyses trade-offs. This method could be applied to other areas to get a better overview, to understand ecosystem complexity and the divergent views of important stakeholders, and to support the development of sustainable management options.
Based on the findings of this study, recommendations for contributing to the development of sustainable management options in the Kouga catchment are formulated.

a) Recommendations to improve water security

Water is the crucial factor for the environmental and economic functions of the Kouga catchment and its downstream areas. To improve the current water situation, the identified key services (water regulation & supply, prevention of soil erosion, water purification and mitigation of droughts and floods) need to be maintained and management practices which negatively influence these services need to be reduced. This could be done as follows.
First of all, water abstraction needs to be reduced. To sustain water regulation and supply in the long-term, especially fruit farming therefore needs to be more water efficient. Drip irrigation and the use of mulch are examples of being more water efficient. However, its application is still limited and more alternatives are needed to decrease water abstraction.
In addition, further conversion of natural land into cultivated land needs to be reduced. It was shown that this farming activity has multiple negative impacts on ecosystem services determine water security. However, rehabilitation of cultivated land towards natural land on short-term can be not recommended due the (economic) importance of agriculture for the catchment. But also on cultivated land, certain land management practices such as the use of mulch and prevention of bare soils can be suggested to improve water retention. Sensitive areas such as floodplains and degraded wetlands should be rehabilitated where possible due to their crucial role. Orchards built in the natural floodplain should be replaced to further away from the river in order to support the recovery of riparian zones and to control floods. Degraded areas which are not used anymore can be restored and rehabilitate by replanting natural vegetation. Moreover, overgrazing should be prevented and current spraying regime should become more environmentally friendly. A good basal vegetation cover will prevent soil erosion, which maintains productive soil and clean water. The use of compost and mulch instead of chemical fertilizer will reduce the pressure on water security while maintain agricultural productivity. To reduce spraying of chemical herbicides and pesticides, natural biological control might be an opportunity.

Fourthly, the mountainous areas should be kept to current conservation management. Vegetation in these areas is in good condition and show a great capacity to support water security.
Next, IAPs clearing should be done in a more systematic way and on bigger scale. It was shown that IAPs clearing contributes greatly to maintain local water security. Many different people already work on the clearing of IAPs in the catchment, but currently work is uncoordinated and ineffective. To successfully improve the water situation in the Kouga catchment clearing of IAPs should start in upstream areas to prevent further seed disposal downstream. Moreover, the focus should be kept on wetlands and riparian zones and more regular follow-up measures are needed to stop re-growth of IAPs. In order to reach wider commitment among local people, the benefits of this restoration practices should be well communicated to local people and the work of WfW teams and individuals should be mapped and made public to all stakeholders. This will help to organize the work and might mobilize more people to clear exotic plants in the Kouga catchment. A '*clearing team*' including WfW teams, nature conservationists, farmers and other local people is suggested to enhance collaboration. To restore and rehabilitate riparian areas clearing of IAPs might not be sufficient; it also requires some more input to maintain ecosystem resilience on long term. Wetlands are amongst the most productive and economically valuable ecosystems in the world. Replanting of natural vegetation and the building of gabion and concrete structure as seen in the Kromme catchment support the recovery wetlands and might be additional restoration and rehabilitation management practices in in the Kouga catchment.

b) Recommendations on how to integrate biodiversity and agricultural interest

It was found that ways of integrating biodiversity and agricultural interests are needed to develop initiative and opportunities for sustainable management options in the Kouga catchment.
To do so, first of all stakeholders need to recognize the importance of both biodiversity conservation and agriculture for the Kouga catchment and their interdependence in terms of management measures and ecosystem services that are affected. For instance, current biodiversity conservation often doesn´t accredit the ´natural´ value of cultivated land. One argument is that agricultural areas lack biodiversity due to its transformation of natural land. It is true that cultivated land has lower biodiversity then natural areas. However, also on cultivated land plant and animal diversity is seen, although it is still limited. For example some riparian vegetation is growing around artificial water bodies and a lot of different bird species are seen on farmland supporting the catchment's diversity. But farmers also should appreciate the benefit of natural areas in the Kouga catchment. "*The mountains are useless to us there are just nice to look at*", a typical statement of farmers which show their lack of awareness of especially regulating functions.
Secondly, as biodiversity is an instrumental the provision of many ecosystem services, protection and restoration of biodiversity is necessary. Mountainous areas are in good condition and should be thus kept to current conservation management. Cultivated lands show reduced capacity to provide ecosystem services. To rehabilitate these areas biodiversity should be increased on and around agricultural areas. For instance, natural vegetation can be replanted on old farmland or unproductive land. But also on cultivated land itself, patches of natural vegetation will influence the provision of ecosystem services positively. In orchards, neighbouring fynbos areas for example can benefit pollination services and thus increase agricultural productivity. Plant diversity will also contribute to biological control which will decrease the incidence of disease and pests in agricultural areas making pesticides less necessary. Obviously, the success of replanting natural vegetation in and around orchards depends upon certain other farming management practices such as a reduction of fertilizers and pesticides which influence the growth of natural vegetation, in particularly fynbos negatively. Some farmers already reduce their amount of chemical pesticides, herbicides and fertilizers which were shown to have positive impacts on agricultural productivity and biodiversity level in the orchards (see Appendix IX).
In livestock farming it is recommended to leave patches of natural vegetation and less frequent burnt patches in the grass fields to provide refugia and reproduction habitat for wild plants and animals. This diversity will also support prevention of soil erosion and water regulation and thus agricultural

production. In some areas livestock farmers already burn deeper slopes less frequent than open fields because deeper slopes are mainly covered by fynbos rather than grass plants. These areas could serve as priority areas for biodiversity in livestock areas because of their low importance to provide food to livestock. Longer fire cycles will enhance biodiversity and increase the capacity to stabilize soil and thus prevent soil erosion in these areas. Another management practices supporting biodiversity indirect is the grazing rotation system in livestock farming. This system ensures round-year access to pasture by supporting the regeneration of grass fields and reducing the risk of open bare soils. Longer "cycles of rest" will benefit local biodiversity and provision of pasture. Another possibility of how to improve biodiversity on farmland could be given by the several farm dams. These dams can provide another important habitat for vegetation, in particularly riparian vegetation and support a better water regulation.

To maintain biodiversity and agricultural production at the same time both nature conservationists and farmers need to work together. The clearing of IAPs could be a bridging element to start cooperation among the different groups. IAPs are recognized by all stakeholders as a challenge of the area because it threatens local biodiversity, water security and agricultural productivity. The clearing of invasive plants can also provide alternative incomes by the usage of black wattle for the production of mulch, biofuels and fuel wood. Alternative farming practices such as cultivation of honeybush and other fynbos plants for the production of honeybush tea and herbal oils respectively can be another example of cooperation between economic production and conservation of biodiversity. These farming practices are still very limited in the area but recognised by its great potential for the area to generate extra income to local people while protecting biodiversity (when natural resources are used sustainable). On long term the establishment of a Payment for Ecosystem Services (PES) scheme could be another opportunity to promote sustainable use of the catchment's capacity. Farmers who reduce impacts from farming practices should get financial incentives for the protection of biodiversity by this scheme for compensation. The establishment of a PES scheme can support the development of a nature-based economy as seen in the Baviaanskloof area. Furthermore, the promotion of tourism is highly recommended by local people and could serve as an alternative income to local people while protecting biodiversity. In order to offer more opportunities for a sustainable use of the catchment's capacity more scientific research is highly recommended. Thereby, farmers and nature conservationist can provide valuable information about the catchment and can learn from each other's experiences.

10.References

Literature

Baselmans, D. (2011). Preliminary study of the Kouga River catchment: Farmers' water and land use and their preceptions on nature restoration and alien invasive species Bachelor Thesis, University of Zeeland.

Berliner, D. and P. Desmet (2007). Eastern Cape Biodiversity Conservation Plan: Technical Report. Pretoria, Department of Water Affairs and Forestry. **Project No 2005-012**.

Bernard, H. R. (2011). Research methods in anthropology, Altamira Pr.

Binneman, J. (1999). "Mummified human remains from the Kouga Mountains, Eastern Cape." The Digging Stick **16**(2): 1-3.

Blignaut, J. N., C. Marais, et al. (2007). "Determining a charge for the clearing of invasive alien plant species (IAPs) to augment water supply in South Africa." Water SA **33**(1): 27-34.

Blignaut, J. N., L. Ueckermann, et al. (2009). "Agriculture production's sensitivity to changes in climate in South Africa." South African Journal of Science **105**(1-2): 61-68.

Boshoff, A. (2005). The Baviaanskloof Mega-Reserve: An environmentally, socially and economically sustainable conservation and development initiative. Terrestrial Ecology Research Unit (TERU) report No. 52, TERU.

Coetzee, K. (2002). Misgund Orchards, Baseline Audit, prepared for Mr. David Baldie & Sons, Conservation Management Services.

Collier, P., G. Conway, et al. (2008). "Climate change and Africa." Oxford Review of Economic Policy **24**(2): 337-353.

Collins, N. B. (2005). Wetlands: The basics and some more, Free State Department of Tourism, Environmental and Economic Affairs.

Cowling, R. and S. Pierce (2009). East of the Cape Conservering Eden. Simon's Town, SA, Fernwood Press.

Cowling, R. M. (1992). The ecology of fynbos: nutrients, fire and diversity, Oxford University Press Southern Africa.

Cowling, R. M., D. M. Richardson, et al. (2004). Vegetation of southern Africa, Cambridge Univ Pr.

Crane, W. (2006). "Biodiversity conservation and land rights in South Africa: Whither the farm dwellers?" Geoforum **37**(6): 1035-1045.

CSS1 (2009). The Kouga L82A1001 WFW Project. Working for Water Management Unit Clearing Plants, GIB West.

CSS2 (2009). The High Altitude WFW Project - L82G1001. Working for Water Mangement Unit Clearing Plans, GIB West.

Davidson, N. and C. Finlayson (2007). "Earth observation for wetland inventory, assessment and monitoring." Aquatic Conservation: Marine and Freshwater Ecosystems **17**(3): 219-228.

de Groot, R. S. (1992). Functions of nature: evaluation of nature in environmental planning, management and decision making, Wolters-Noordhoff BV.

de Groot, R. S., R. Alkemade, et al. (2010). "Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making." Ecological Complexity **7**(3): 260-272.

de Groot, R. S., B. Fisher, et al. (2010). "Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation." TEEB Ecological and Economic Foundations. Earthscan, London: 9-40.

de Groot, R. S., M. Stuip, et al. (2006). "Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services." Ramsar technical report ((3).

de Groot, R. S., M. A. Wilson, et al. (2002). "A typology for the classification, description and valuation of ecosystem functions, goods and services." Ecological economics **41**(3): 393-408.

de Wit, M. and J. Stankiewicz (2006). "Changes in surface water supply across Africa with predicted climate change." Science **311**(5769): 1917-1921.
DEAT (2011). Department of Environmental Affairs and Tourism: Framework for Biodiversity Mainstreming in Local Authorities. Pretoria.
Díaz, S., A. Hector, et al. (2009). "Biodiversity in forest carbon sequestration initiatives: not just a side benefit." Current Opinion in Environmental Sustainability **1**(1): 55-60.
Draugelyté, E. (2012). Dissonance in social learning: towards maintenance of natural resources in the Kouga catchment, South Africa. MSc Thesis, Wageningen University.
Driver, A., K. J. Sink, et al. (2012). National Biodiversity Assessment 2011: An assessment of South Africa's biodiversity and ecoystems, Synthesis report. Pretoria, South African National Biodiversity Institute and Department of Environmental Affairs
Du Toit, A. L. and S. H. Haughton (1954). The Geology of South Africa, Oliver and Boyd London.
Du Toit, J., E. Joubert, et al. (1998). "Honeybush tea–a rediscovered indigenous South African herbal tea." Journal of sustainable agriculture **12**(2-3): 67-84.
DWAF (2004). Fish to Tsitsikamma Water Mangement Area: Tsitsikamma to Coega Internal Strategic Perspective. South Africa, prepared by Ninham Shand in association with Umvoto Africa, on behlaf of the Directorate National Water Resources Planning.
Egoh, B., B. Reyers, et al. (2008). "Mapping ecosystem services for planning and management." Agriculture, Ecosystems & Environment **127**(1): 135-140.
Egoh, B., M. Rouget, et al. (2007). "Integrating ecosystem services into conservation assessments: a review." Ecological economics **63**(4): 714-721.
Elmqvist, T., E. Maltby, et al. (2010). "Biodiversity, ecosystems and ecosystem services." TEEB Ecological and Economic Foundations. Earthscan, London: 41-111.
Erlank, W., P. Zake, et al. (2009). Strategic Management Plan Baviaanskloof Cluster. Integrated Reserve Management Plan, Eastern Cape Parks. **11**.
Euston-Brown, D. (2006). Baviaanskloof Mega-reserve project: Vegetation Mapping Contract: Report on methodology, vegetation classification and short description of habitat units. Scarborough.
Goldman, R. L., H. Tallis, et al. (2008). "Field evidence that ecosystem service projects support biodiversity and diversify options." Proceedings of the National Academy of Sciences **105**(27): 9445-9448.
González, J. D. D. (2009). Technical Report of the Restoration of a section of the Witteklip Pilot Project for Rehabilitation of the Kouga River, Universidad Politécnica de Madrid.
Haigh, E., L. Bosman, et al. (2004). Catchment L The Gamtoos River System. Wetland maping and assessment in selected metropolitan water supply catchments in the Eastern Cape.
Hodgson, D. (pers. comm. 2011). Local farmer and chairperson Farmers Association. de Hoop, WC.
Holness, S., P. Bradshaw, et al. (2010). Critical Biodiversity Areas of the Garden Route - Conservation Planning Technical Report, Garden Route Initative, SANParks.
Huyssteen, A. v. (2008). Die Storie van Langkloof, Paardeneiland, Mega Digital.
Jansen, H. C. (2008). Water for food and ecosystems in the Baviaanskloof Mega Reserve : land and water resources assessment in the Baviaanskloof, Eastern Cape Province, South Africa. Alterra-report 1218. Wageningen, Alterra, Wageningen UR**:** 80.
Joubert, M. (200?). Honeybush Cultivation & Industry. Stellenbosh, WC, Honeybush Research Programme of the Agricultural Reserach Council
Kumar, P. (2010). The Economics of Ecosystems and Biodiversity: ecological and economic foundations, Earthscan/James & James.
Kumar, R. (2005). Research methodology: A step-by-step guide for beginners, Sage Publications Ltd.
Le Maitre, D. C., P. J. O'Farrell, et al. (2007). "Ecosystems services in South Africa: a research theme that can engage environmental, economic and social scientists in the development of sustainability science?" South African Journal of Science **103**(9-10): 367-376.
Living Lands (2012). Mobilizing civil society for Living Landscapes.

Lombard, A. T., T. Wolf, et al. (2003). GIS coverages and spatial anaysis for the subtropical thicket ecosystem planning (STEP) project. Port Elizabeth, Terrestrial Ecology Reserach Unit, University of Port Elizabeth.

Macvicar, C. N. and R. F. Loxton (1967). Soils of the Langkloof (Ongelegen to Heights). Pretoria, Department of Agricultural Technical Services.

Mander, M., J. Blignaut, et al. (2010). Synthesis Report. Baviaanskloof - Tsitsikamma Payment for Ecosystem Services: A Feasibility Assessment. Everton, Future Works.

Markham, R. (200?). Agricultural context. Langkloof Corridor Handbook.

McConnachie, M. M., R. M. Cowling, et al. (2012). "Evaluating the cost-effectiveness of invasive alien plant clearing: A case study from South Africa." Biological conservation **155**: 128-135.

Millennium Ecosystems Assessment (2005). Ecosystem and Human Well-being: Synthesis. Washington, DC, World Resource Institute.

Mucina, L. and M. C. Rutherford (2006). The vegetation of South Africa, Lesotho and Swaziland, South African National Biodiversity Institute.

NBSAP (2005). South Africa's National Biodiversity Strategy and Action Plan. Pretoria, Department Environmental Affairse and Tourism.

Oosthuizen, L. (2002). Land and water resources management in South Africa.

Perret, S. R. (2002). "Water policies and smallholding irrigation schemes in South Africa: a history and new institutional challenges." Water Policy **4**(3): 283-300.

Powell, M., R. Cowling, et al. (2009). Vegetation management for the optimal supply of water and carbon sequestration services report. Baviaans - Tsitsikamma Payment for Ecosystem Services. Everton, Future works.

Powell, M. and M. Mander (2009). Water Services Suppliers Report. Baviaans-Tsitsikamma Payment for Ecosystem Services. Everton, Future works.

Punch, K. F. (2005). Introduction to social research: Quantitative and qualitative approaches, Sage Publications Ltd.

Rebelo, A. G., C. Boucher, et al. (2006). Fynbos Biome The Vegetation of South Africa, Lesotho and Swaziland, South African National Biodiveristy Institute.

Richardson, D. M., P. M. Holmes, et al. (2007). "Riparian vegetation: degradation, alien plant invasions, and restoration prospects." Diversity and Distributions **13**(1): 126-139.

Richardson, D. M. and B. W. Van Wilgen (2004). "Invasive alien plants in South Africa: how well do we understand the ecological impacts?" South African Journal of Science **100**(1): 45-52.

Rutherford, C. M., L. Mucina, et al. (2006). Biomes and Bioregions of Southern Africa. The Vegetation of South Africa, Lesotho and Swaziland, South African National Biodiversity Institute.

Rutherford, M. C., L. W. Powrie, et al. (2006). Afrotemperate, Subtropical and Azonal Forests. The Vegetation of South Africa, Lesotho and Swaziland, South African National Biodiversity Institute.

Sandbrink, M. (2013). Kouga catchment in bad waters? A resilience study of fruit farmers' water management practices in the Kouga catchment, South Africa Thesis report.

Scharmer, C. O. (2007). Theory U - Leading from the future as it emerges. San Francisco, Berett-Koehler Publishers

Scholes, R. J. and R. Biggs (2004). Ecosystem Services in Southern Africa: a regional assessment. Southern African Millennium Ecosystem Assessment. R. J. Scholes and R. Biggs. Pretoria, South Africa, Council for Scientific and Industrial Research (CSIR).

Schutte, A. (1997). "Systematics of the genus Cyclopia Vent.(Fabaceae, Podalyrieae)." Edinburgh Journal of Botany **54**(02): 125-170.

Scott, D. F. (1993). "The hydrological effects of fire in South African mountain catchments." Journal of Hydrology **150**(2–4): 409-432.

Skowno, A. (2007). Baviaanskloof Mega-Reserve Biodiversity Assessment. Version 3.

Steyn, M., J. Binneman, et al. (2007). "The Kouga mummified human remains." South African Archaeological Bulletin **62**(185): 3-8.

Stock, W. and O. Lewis (1986). "Soil nitrogen and the role of fire as a mineralizing agent in a South African coastal fynbos ecosystem." The Journal of Ecology: 317-328.
Thring, T. and F. Weitz (2006). "Medicinal plant use in the Bredasdorp/Elim region of the Southern Overberg in the Western Cape Province of South Africa." Journal of Ethnopharmacology **103**(2): 261-275.
Turpie, J. and B. Heydenrych (2000). "Economic consequences of alien infestation of the Cape Floral Kingdom's Fynbos vegetation." The Economics of Biological Invasions. Edward Elgar, Cheltenham: 152-182.
Turpie, J. K., B. J. Heydenrych, et al. (2003). "Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies." Biological conservation **112**(1-2): 233-251.
United Nations (1992). "Convention On Biological Diversity."
van de Merwe, S. and et al. (1991). Klein Karoo-Substreekontwikkelingsprogram. Klein Karoo-Substreekontwikkelingsprogram. Elsenburg, Elsenburg Landbou-ontwikkelingsinstituut
van der Merwe, S., V. S. Gqodwana, et al. (2011). Agricultural Conditions Report. Kou-Kamma Area, Eastern Cape Department of Rural Development & Agrarian Refrom.
Van Wilgen, B. (1982). "Some effects of post-fire age on the above-ground plant biomass of fynbos (macchia) vegetation in South Africa." The Journal of Ecology: 217-225.
Van Wilgen, B. (2009). "The evolution of fire and invasive alien plant management practices in fynbos." South African Journal of Science **105**(9-10): 335-342.
Van Wilgen, B., B. Reyers, et al. (2008). "A biome-scale assessment of the impact of invasive alien plants on ecosystem services in South Africa." Journal of Environmental Management **89**(4): 336-349.
Van Wilgen, B. W., R. M. Cowling, et al. (1996). "Valuation of ecosystem services." BioScience **46**(3): 184-189.
Van Wyk, B. E. (2008). "A broad review of commercially important southern African medicinal plants." Journal of Ethnopharmacology **119**(3): 342-355.
Vlok, J. H., D. I. Euston-Brown, et al. (2008). A vegetation map for the Garden Route Initative. Unpublished 1:50 000 maps and report supported by CAPE FSP task team.
Vlok, J. H. J. and R. I. Yeaton (2000). "The effect of short fire cycles on the cover and density of understorey sprouting species in South African mountain fynbos." Diversity and Distributions **6**(5): 233-242.
Vromans, D. C., K. S. Maree, et al. (2010). The Garden Route Biodiversity Sector Plan 2010 for the southern regions of the Kouga and Koukamma Municipalities, SANParks, C.A.P.E.

Personal Communication

Baldie, W. (pers. comm. 2011). Local fruit farmer. Misgund, EC.
Buckle, J. (pers. comm. 2012). Scientist. Port Elizabeth, EC.
de Witt, A. (pers. comm. 2011). Local fruit farmer. Misgund, EC.
Ferreira, G. (pers.comm. 2012). Local honeybush farmer. Heights, EC.
Ferreira, N. (pers. comm. 2011). Local farmer. Kleinrivier, EC.
Joubert, M. (pers. comm. 2012). S. a. ARC. Stellenbosh, WC.
KG (pers. comm. 2011). Joubertina.
Kou-Kamma emerging farmer forum (pers. comm. 2011). Louterwater, EC.
Koyo, V. (pers. comm. 2012). Local manager Working for Water. Jouertina, EC.
Living Lands (2011). pers. comm.
Malgas, R. (pers. comm. 2012). Scientist at Stellenbosh University. Stellenbosh, WC.
Markham, R. (pers. comm. 2011). L. c. E. t. Addo. Karredouw, EC.
Palmer, A. (pers. comm. 2012). Formosa Liasion Forum Meeting. Joubertina, EC.
Plessis, D. d. (pers. comm. 2011). Local livestock farmer. Suuranys, EC.

Plessis, J. d. (pers. comm. 2011). Local livestock farmer. Suuranys, EC.
Pretorius, K. (pers. comm. 2011). Local livestock farmer. Suuranys, EC.
Reeves, B. (pers. comm. 2012). Ecologist at ECPTA. Patensie, EC.
Schafer, G. (pers. comm. 2012). Soil scientist. Krakeel, EC.
Strydom, A. (pers. comm. 2011). Disaster manager and chairman Langkloof Fire Protection Association (LFPA). Langkloof, .
van der Merwe, S. (pers. comm. 2012). Department of Agriculture. Joubertina, EC.
Versveld, D. (pers. comm. 2012). Local resident and scientist. Bo-Kouga, EC.
Wessel, M. (pers. comm. 2011). Local resident and artist. Kouga Mountains, EC.

Website

Chief Directorate National Geo-spatial Information of South Africa (1984). www.madmappers.com.
Deem, J. M. (2012). "http://www.mummytombs.com/mummylocator/group/khoi.htm." Retrieved 01, 07, 2012.
DWAF. (2012). "Working for Water." Retrieved 26, 06, 2012, from http://www.dwaf.gov.za/wfw/.
Horgro Tree Census. (2011). Retrieved 15, 02, 2012, from www.horgro.co.za.
SAHTA. (2012). "Honeybush." Retrieved 19, 09, 2012, from http://www.sahoneybush.co.za/.
South African Fruit Farms. (2012). "Growing Seasons." Retrieved 02, 06, 2012, from http://www.safruitfarms.com/growing-seasons.aspx.
UNEP. (2012). "Working for Water - a South African Sustainablity Case." Retrieved 09, 07, 2012, from http://www.unep.org/training/programmes/Instructor%20Version/Part_3/readings/WfW_case.pdf.

Appendix

Appendix I –Interview guide

- ✓ Always ask for explanation, avoid ~~“why”,~~ use “can you explain”, “what about”, “what is the reason”, “what is you experience/perspective”
- ✓ Note: race, gender
- ✓ Some questions will be asked just in case farmer’s attitudes fit the question...

I. Background information

1. Could you identify your property on the map?
   - ➔ Name of the farm
   - ➔ Identify land cover (farming area, main vegetation type, ecosystem)
2. What is the size of your farm?
3. Since how many years you are living and/or farming on this land?
4. How many generations of your family lived/farmed on this land?
   - ➔ How many years?
5. Is there someone in your family who probably assume the ownership of your land after you go to pension?
6. How many workers do you employ?
   - ➔ Understand his role of importance in the area

II. Land management and use

7. What do you farm (land uses)? (ask to describe a ´normal´ day at farm)
   - 6.1. How many ha each type of land use covers?
   - 6.2. How many years this type of land uses is on practice?
   - 6.3. What are the most important practices?
8. Do you use any pesticides, herbicides and/or chemical fertilisers?
   - ➔ Please explain why are you using them? What is the impact on the land?
9. Do you use any alternative practices? (*More environmentally friendly*)
   - ➔ Please explain your motivation to use alternative practices and their impact on the farming
10. Did you always farm like this or were there any changes in your farming practices?

III. State of the land

11. Do you consider that your farmland is healthy at the moment?
    - ➔ Degradation on the land?
12. What are the indicators to describe your land as healthy/degraded?
    - ➔ Note down what indicators he used
    - ➔ Ask to describe the area (biodiversity in the area, or hotspot, or other special attributes)
    - ➔ Identify on the map
13. Are there tourists in the area? And why tourist visit /should visit the area?
    - ➔ Agro-tourism, eco-tourism, diversity

IV. Challenges

14. What are the main challenges/issues regarding your farming practices?
    - ➔ Rank at least 3 the main important ones
    - ➔ Focus on the environmental issues, but socio-economic aspects are taken into account for later analyses

    14.1. What is, according to you, the biggest issue in the Kouga Catchment area?
15. Do you know the causes of these issues?
    → Explain the system, he might talk about ecological processes, linkages etc
16. Can you explain the impact of these issues on your land? (farming management, land cover, ecosystem)
    - ➔ Is this a new issue, or was it always a problem? Changes over time?
17. How do you deal with it?

17.1. What kind of help/support do you need to solve these issues?
  - ➔ F.e. alien clearing, more pesticides, different species for production, collaboration with other stakeholders, organizations, subsidies etc. (Restoration and conservation?)

V. Future plans

18. What´s your motivation to farm?
19. How would you describe the relationships you have with your land?
    - ➔ What is your motivation to manage in the way that you do? What responsibilities do you feel you have with your land?
20. What are your personal objectives regarding land management?
    - ➔ What do you want to achieve on or with your land? Do you have some personal plans regarding your farm?
21. Do you see any other potential in your land /the Kouga Catchment?
    - ➔ Tourism, honeybush tea production...
22. What should be done to improve this potential?
    - ➔ Communication, collaboration, subsidies, information, restoration, conservation...

VI. Involvement to sustainable natural resources management

23. What is your experience with environmentally friendly[8] farming practices?
    - ➔ Reduced pesticides, Reduced chemical fertilizers, Water saving practices, Fire control practices, Conservation practices, Alien clearing practices (black wattle)

    - ➔ In case (s)he is interested, ask from where information/knowledge came from

24. What is your experience in balancing environmentally friendly approach with economically valuable approach?

25. Do you need to meet particular standards regarding your farming (production) inside and/or outside South Africa?

[8] Clear explanation what is environmentally friendly farming methods – reduced human impact on the nature/environment. Possible attention points - Reduced pesticides, Reduced chemical fertilizers, Water saving practices (Alien clearing practices), Fire control practices, Conservation practices.
Could it be related/changed with Living landscapes concept?

- ➔ Legislation, environmental standards
- ➔ In case you are exporting to foreign markets, what king of standards do you have to meet (attention to environmental standards)? What kind of standards?

VII. Social networks/relationships

26. Who are the **key individuals or organizations** with whom you have collaborated/collaborating on (environmentally friendly) farming practices/projects during the last three years?

    25.1. Who are the key individuals or organizations with whom you wish to collaborate in order to farm more environmentally friendly?
27. Who are the **key individuals or organizations** with whom you have collaborated on environmental issues (aliens, fire, water security, land degradation, conservation/restoration) during the last three years?

    26.1. Who are the key individuals or organizations with whom you need to collaborate in order to solve these issues?
    - ➔ In order to identificate existing networks
28. What are your relationships with the neighbours?
    - ➔ Please indicate their properties on the map, and name them
29. How often and where do you meet your neighbours or the other farmers?
30. Are you a member of any local farming/business/local organizations?
    - ➔ If yes, how often are you involved in activities with these organizations?

Appendix II - Questionnaire

Interviewee(s): ____
Property name(s): ____
Interview date/time: ____
Interview location: ____

31. What is your awareness regarding these aspects?

Awareness:	**No**	**Yes**	**Something**
1.1. Are you aware about **environmentally friendly**[9] farming methods?	0	2	1
1.2. Are you aware if any alien plants occur in your land?	0	2	1
1.3. Are you concerned about the fires occurring in your land or the Kouga Catchment area?	0	2	1
1.4. Are you concerned about water security in the Kouga Catchment area?	0	2	1
1.5. Are you aware about land degradation in the Kouga Catchment area?	0	2	1
1.6. Are you aware on impact of climate change...?	0	2	1
1.7. Are you aware what kind of plant/animal species exist in your property?	0	2	1
1.8. Are you watching environmentally related programs, reading newspapers?	0	2	1

2. Do these challenges have an impact to you?

Challenges:	**Impact**						
2.1. Alien plants infestations	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
2.2. Fires	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7:** Very much
2.3. Water shortages	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7:** Very much
2.4. Water quality	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7:** Very much
2.5. Flood events	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7:** Very much
2.6. Land degradation/erosion	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7:** Very much
2.7. Climate change	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7:** Very much

[9] Clear explanation what is environmentally friendly farming methods – reduced human impact on the nature/environment. Possible attention points - Reduced pesticides, Reduced chemical fertilizers, Water saving practices (Alien clearing practices), Fire control practices, Conservation practices.
Could it be related/changed with Living landscapes concept?

2.8. Conservation & restoration practices	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7:** Very much

3. What is your behaviour regarding these aspects?

Behaviour:	**No**	**Yes**	**Something**
3.1. I attend meetings of an environmental organisation (specify which one)	0	2	1
3.2. I talk with others about the problems related with environment	0	2	1
3.3. I am recycling waste (for example, paper, plastic)	0	2	1
3.4. I buy organic, fair trade products	0	2	1
3.5. I use environmentally friendly methods on my farm	0	2	1
3.6. I was involved in alien plants clearing in the last 3 years	0	2	1
3.7. In case alien plants were removed from my property, I am maintaining this situation	0	2	1
3.8. I am a member of fire protection association	0	2	1
3.9. I am applying water saving practices	0	2	1
3.10. I undertaken nature conservation activities in the last 3 years	0	2	1
3.11. I am enjoying wildlife, indigenous birds, endemic plant species	0	2	1
3.12. I am using alternative non-lethal approaches to manage caracal, jackal and leopard	0	2	1

4. What is your willingness to participate in these actions?

Willingness to participate:	**Degree**						
4.1. I would be interested in finding out how to farm using environmentally friendly methods	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
4.2. I would like to remove alien plants from my property	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
4.3. I would like to join fire protection association	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
4.4. I would like to introduce water saving practices	Not at all:**1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
4.5. I would like to undertake nature conservation activities	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
4.6. I would be interested in finding alternative non-lethal	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much

approaches to managing caracal, jackal and leopard							
4.7. I would like to attend meetings of an environmental organisation	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much

5. What is your willingness to make these trades-offs?

Trades-offs:	**Degree**						
5.1. I would consider to change a certain farming practice, if there is an environmentally friendly alternative (greener technologies (organic pesticides, organic fertilizers) to it	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
5.2. I would consider to change a certain farming practice in order to protect environment	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
5.3. I would change a certain farming practice to more environmentally friendly, if my livelihood could be assured	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
5.4. I would consider adopting environmentally friendly approaches to my farming, even if they reduced my production, without receiving any compensation	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
5.5. I would like to take an environmentally friendly alternative to a certain farming practice, if offered appropriate incentives	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much

6. What incentives would be useful in encouraging you to join more environmentally friendly farming practices?

Incentive:	**Interest rate**						
6.1. Subsidies	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
6.2. Tax rebate	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
6.3. Access to a support network of like-minded farmers/ individuals/ organizations	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
6.4. Extension officer support	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
6.5. Access to scientific information and support	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much
6.6. Assuredness that your land stays	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much

healthy in the long term perspective							
6.7. Other	Not at all: **1**	**2**	**3**	**4**	**5**	**6**	**7**: Very much

7. Please indicate people who you feel are respected and influential in your community:

Name (Rank 1 for the highest influence)	**Why is (s)he influential?**	**Contact details**
7.1.		
7.2.		
7.3.		
7.4.		
7.5.		

Personal information

8. E-mail: ____
9. Tel:____
10. What language do you primarily use at home?

English	Afrikaans	Xhosa	Zulu	Other

11. What language is primarily used with farm staff?

English	Afrikaans	Xhosa	Zulu	Other

12. Marital status:

Single	Married	Separated or divorced	Widowed	Other (please specify)

13. Level of education completed:

High school	Diploma	Full degree	Post-graduate diploma	MSc degree	PhD degree	Other (please specify)

Appendix III – Geological History of Kouga catchment

Box 1: **Geological History of the Kouga catchment**

To understand why the surface of the Kouga Catchment looks the way it does today, geomorphological aspects needs to be studied. The Kouga Catchment has a long geological history (see Table1 below).

Table 1: Overview of some important events in the geological history of the Kouga catchment (adapted from (Cowling and Pierce 2009))

Geological stage	Age (millions of years ago)	Important events shaping the Kouga catchment
Archaean	46000	Birth of the Earth
Proterozoic	25000	First life on earth
Palaeozoic	300 – 450	Cape sedimentation
Mesozoic	290	Cape Folded Mountains
	140	"Birth of Africa", breakup of Gondwanaland
	80	African cycle of erosion
Palaeogene	35	Thicket and prototype of fynbos on Cape Folded Mountains
Miocene	20	1st tectonic uplift event
	12	Evolution of modern vegetation
Pilocene	Between 5 and 3	2nd tectonic uplift event

Table1 gives an overview of some important events in the geological history of the Kouga catchment. Geological processes took place over millions of years and caused tectonic uplift and subsidence. Ancient landscapes were formed between 300 and 450 million years ago when South Africa was still part of the supercontinent Gondwanaland. Due to earth movements Cape sediments were deposited (Coetzee 2002; Cowling and Pierce 2009). About 290 million years ago, massive uplifts folded and buckled the sediment and formed the mountains in the following years with the consequence of a L- shaped mountain range - the Cape Folded Mountains (Cowling and Pierce 2009). This mountain range stretch from Vanrhynsdorp in the north, via Cape Town in the south to Grahamstown in the east (Huyssteen 2008). The Kouga Catchment lies within this mountain formation.

However, most of the present landscape can be postdate to the breakup of Gondwanaland 140 million years ago. With the fragmentation of this super continent, huge amounts of materials have been eroded through the new continent; this was the time of the ´African cycles of erosion´. During this time, thicket and first prototypes of fynbos vegetation grown on the remnants of the Cape Fold Mountains (Cowling and Pierce 2009).But it were the two major uplift-events of geological formation in the post-Gondwanaland period which had a significant influence on the Kouga´s surface. The first African cycle of erosion was brought to an end by the first uplift-event around 20 million years ago (Cowling and Pierce 2009).The area of the Kouga catchment was uplifted by 200 to 250 meters which caused a renewed cycle of erosion. This erosion cycles washed out softer sediments; mud and conglomerate were deposited in basins and older rock formations got exposed. At this time, modern vegetation types such as fynbos, Karoo and grassland also evolved on the mainly leached out sediments (Cowling and Pierce 2009). Moreover, broad valley basins such as the Langkloof Valley were created as well as today´s flat-topped plateaus in the eastern part of the Kouga and Baviaanskloof Mountains (as for examples the Bergplaats). This land surfaces are remnants of the ´old African Surface´.

The second uplift event probably happened between 5-3 million years ago, precise timing of this uplift event is not clear yet. The magnitude of this event was even greater than the first uplift and areas in the Kouga raised up 200 to 850 metres (Cowling et al. 2004).

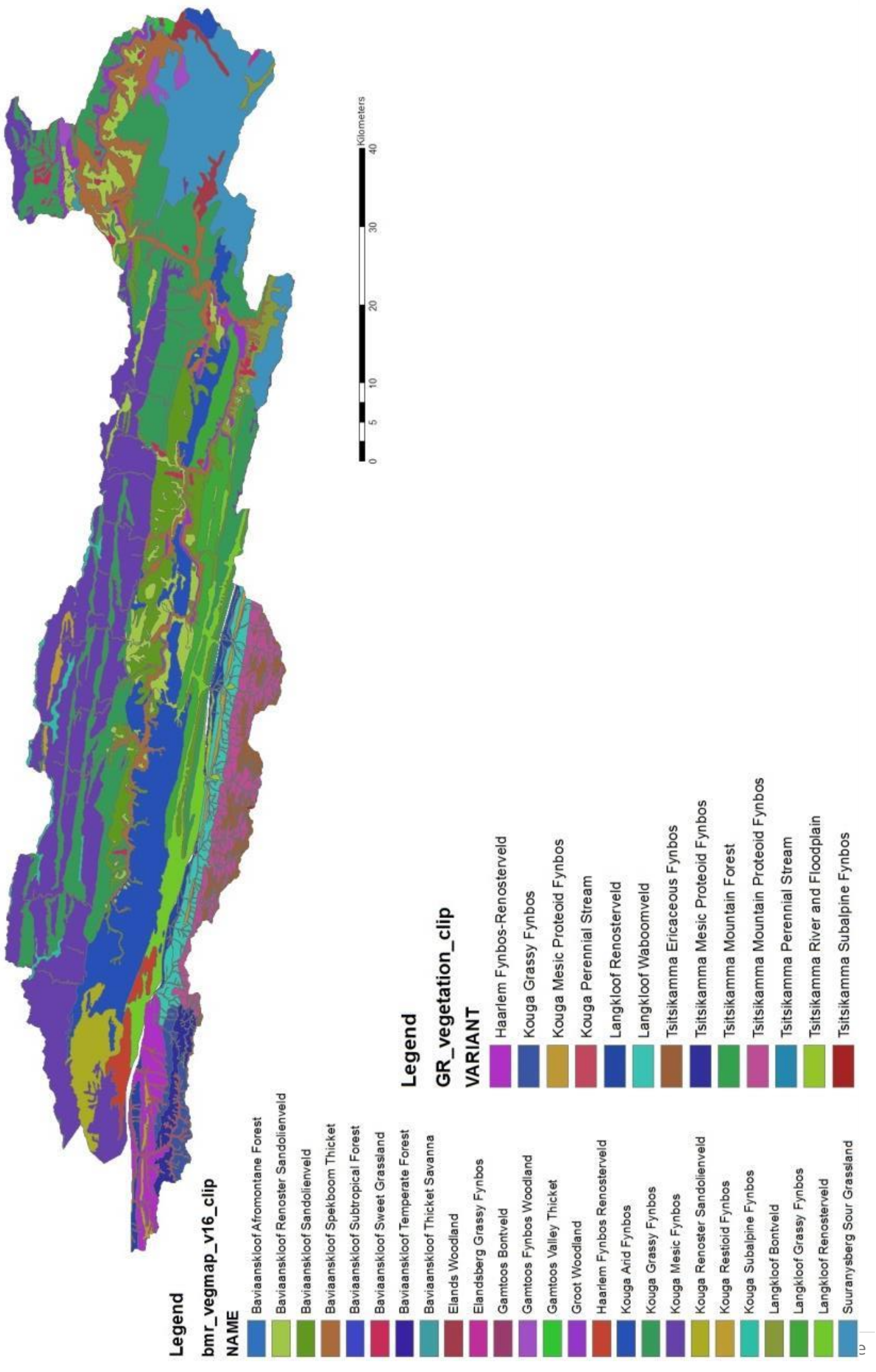
Appendix IV – Vegetation types in the Kouga catchment

Table 3: Vegetation types in the Kouga catchment based on Euston-Brown 2006 (BMR study) and Vlok et al., 2008 (GRI study)

Vegetation	Hectares	%
Fynbos total	**207067,4**	**81,83**
fynbos solid		
Kouga Mesic Fynbos	55636,4	21,72
Kouga Subalpine Fynbos	2542,7	0,99
Kouga Arid Fynbos	26147,2	10,21
Kouga Restioid Fynbos	937	0,37
Tsitsikamma Subalpine Fynbos	43,5	0,02
Tsitiskamma Ericaceous Fynbos	3934,8	1,54
Kouga Mesic Proteoid Fynbos	1521,6	0,59
Kouga Grassy fynbos	48284,1	18,85
Elandsberg Grassy fynbos	117,6	0,05
Langkloof Grassy fynbos	9221,3	3,60
Langkloof Waboombeld	7156,2	2,79
Fynbos mosaic		
Baviaanskloof Sandolienveld	16216,8	6,33
Gamtoos Fynbos woodland	1427,9	0,56
Renosterveld solid		
Langkloof Renosterveld	11939,3	4,66
Renosterveld mosaic		
Langkloof Bontveld	2452,3	0,96
Baviaanskloof Renoster Sandolienveld	11464,6	4,48
Kouga Renoster Sandolienvend	5360,2	2,09
Haarlem Fynbos renosterveld	2663,9	1,04
Thicket total	**22539,1**	**8,80**
Thicket solid		
Baviaanskloof Spekboom Thicket	15548,5	6,07
Thicket mosaic		
Elands Woodland	2078,8	0,81
Gamtoos Bontveld	143,9	0,06
Gamtoos Valley Thicket	341,2	0,13
Groot Woodland	4426,7	1,70
Grassland total	**23188,6**	**9,05**
Grassland solid		
Suuranysberg Sour Grassland	21474,8	8,38
Grassland mosaic		
Baviaanskloof Sweet Grassland	1713,8	0,67

Savanna total	**498,9**	**0,19**
Savanna mosaic		
Baviaanskloof Thicket Savanna (BMR)	498,9	0,19
Forest total	**1255,5**	**0,49**
Forest solid		
Baviaanskloof Afromontane Forest	443,4	0,17
Baviaanskloof Subtropical Forest	808	0,31
Baviaanskloof Temperate Forest	4,1	0,00
Wetlands and water bodies	**1620**	**0,63**
Total	**2561,169**	**100**

Figure 1: Spatial overview of vegetation types in the Kouga catchment (based on ArcGIS data)



Appendix V - Human History in the Kouga catchment

Box 2: **Human history in the Kouga catchment**

Since ancient times the Kouga catchment has been home to people. Archaeological evidences of early human presences are found throughout the catchment. In the Baviaanskloof area artefacts from rock shelters refer to humans occupation during the Middle Stone Age (100 000 to 30 000 years ago) (Boshoff 2005). 25,000 years ago the hunter-gatherer San lived in the southern part of South Africa. Prehistoric rock paintings in caves in the Kouga and Baviaanskloof mountains refer to their early presence in the Kouga catchment. An archaeological treasure was found in 1999 in a cave in the Kouga Mountains. The anthropologist, Dr. Johan Binneman found a mummified remains of a San man (Binneman 1999; Steyn et al. 2007). It is the first and only mummy ever discovered in Southern Africa and is dated back to 2 000 years ago (Deem 2012). In this way, the San people were probably the first residents of the catchment**.** Whereas the San people lived in the mountainous areas, the Khoi-Khoi (or Khoekhoen) mainly lived in the open grass fields of the valleys and plateaus. The Khoi-Khoi came around 2,000 years ago to the Cape region. They were nomadic people who were farming with large herds of Nguni cattle, sheep and goats. Often names for places are their heritage as for example "Kouga" is a Khoi word (which stands for manatee or sea cow) (Huyssteen 2008). From different records of early European who crossed the Langkloof, groups of Khoi-Khoi were often seen. In this way, **Khoi-Khoi people were the first farmers in the Kouga catchment.**

When in 1652 the first ship of the Dutch East Indian Company expedition reached Cape of Good Hope, the colonization of South Africa began. **From around 1760 onwards, first European settled in the catchment and started to farm the land** (Huyssteen 2008). The first settlement in the catchment is Haarlem (in L82A), founded in 1855. 1907 the village Joubertina (in L82D) was established, which is todays main settlement in the Kouga Catchment (Huyssteen 2008). During this time, livestock farming and wheat farming were the main farming practices. Livestock farming still continues up until today as an important farming practice, especially in the Suurveld. In the beginning of the 19th century farming become more commercialized and farming practices increased in scale (van der Merwe pers. comm. 2012).

At the end of the 19th century, citrus farming and vineyard farming were new upcoming and promising farming practices (Huyssteen 2008). However, this success didn't take for long. Soon farmers realized that climate conditions are not sufficient for wine growing. Moreover, sever flood events in 1916 and in 1932 take an end to the citrus farming; lemon and orange trees were water logged for month and died after that. This was the start for the deciduous fruit farming as farmers were looking for an alternative farming practices and more water resistance plants (van der Merwe pers. comm. 2012). **It was in the early 20th century when Alexander Baldie from Scotland, started planting apple trees (commercial) in the Langkloof** (Huyssteen 2008), other farmers followed soon his tactic. Today Alexander Baldie is known as the "apple pioneer" and his family is still farming with deciduous fruits in the Langkloof. The fruit industry in the Langkloof nowadays belongs to the top fruit producing areas of South Africa.

When looking at the more recent history, land use in the Kouga Catchment changed from a more extensive farming to a more locally intensive farming. Whereas around 40 years ago sheep, cattle, wheat and fruit farming exist in a combined way in the Langkloof (de Witt pers. comm. 2011), nowadays focus lies on (a growing) fruit production; other farming practices play a minor role from an economical point of view. Moreover, small scale farmers disappeared over the last years or get sold out by bigger fruit production companies, which is also a general trend in South Africa. However, the average farm size increased (Baldie pers. comm. 2011). In other parts, especially in the mountainous areas, active farming is getting less due to higher transport costs, less valuable farming areas (Versveld pers. comm. 2012) and nature conservation. For instance, whereas in 1991 dry-land agriculture in the Bo-Kouga were estimated on 6,000 hectares (van de Merwe and et al. 1991), today only small areas are remained (approximately 30 hectares) in this area.

BOX 3: **The BMR and other initiatives to conserve biodiversity in the Kouga catchment**

The Baviaanskloof Mega Reserve (BMR) is so far only a plan and different initiatives work on the implementation of a the proposed mega conservation area. However, to implement this plan, the commitment of private land owner to protect biodiversity is needed. Currently, the Biodiversity Stewardship Program tries to find voluntary agreements of private and communal land owners to protect local biodiversity by promoting sustainable use of natural resources and financial compensation. The Stewardship also works closely together with the Ede to Addo Initiative (E2A) to involve land owners and users to support the creation of the mega reserve. E2A aims to conserve biodiversity and ecosystems by creating a "living corridor" (Markham pers. comm. 2011). It is proposed to establish this corridor from the coastal Eden District, Western Cape to the inland Addo National Elephant Park, Eastern Cape (see Figure below). The vision is to link three mega reserves, namely the Garden Route National Park, the Baviaanskloof Mega Reserve and the Addo Elephant National Park. The Kouga Catchment falls within this initiative proposed by the Langkloof corridor which will connect the BNR and Tsitsikamma National Park. At the moment, three corridors are in discussion for the Kouga catchment, namely the Suuranys, Skilderkrantz/Heights and Misgund corridor. The corridor focuses on less transformed areas where nature is primarily intact. The idea it that land owners will not loss their land but rather protect the environment and its natural resources as the "private land owner get steward of his land" (Markham pers. comm. 2011). Local land owners and users might have to change their current land management but will find new sources of income by support of the government and eco-tourism according to the E2A Langkloof coordinator.

Figure 2: Proposed corridors from Eden to Addo by the E2A Initiative (more information www.edentoaddo.co.za)

Appendix VII - Fire events in the Baviaanskloof region during the period of 2000 – 2011

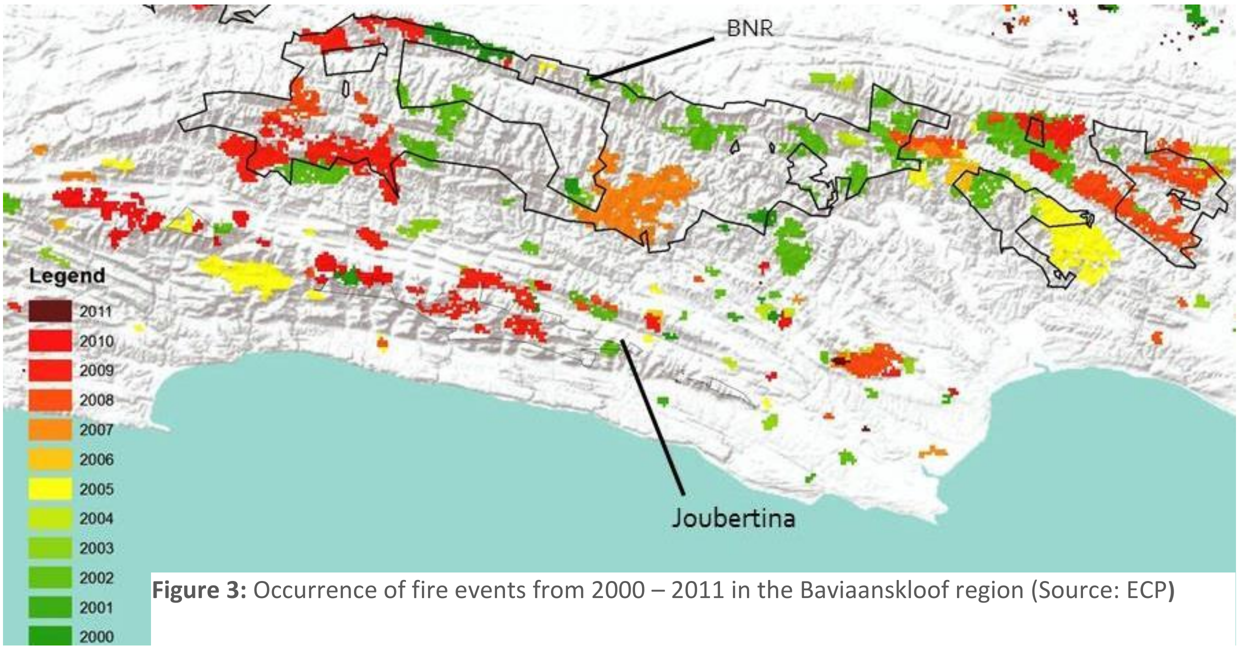


Figure 3: Occurrence of fire events from 2000 – 2011 in the Baviaanskloof region (Source: ECP**)**

Appendix VIII – Statistics on deciduous fruit farming in the Langkloof

Table 3: Deciduous fruit farming in the Langkloof (Source: Horgro Tree Census, 2011)

	Apple production area (ha)	Pear production area (ha)	Plum/pruim production area (ha)	Apricot production area (ha)	Peach production area (ha)
Langkloof East (EC)	4136	1556	200	141.5	154.03
Langkloof West (WC)	502	122	55	76.3	27.9
Langkloof total	**4638**	**1678**	**255**	**217.8**	**181.93**
Fruit production of total %	66.54	24.07	3.66	3.12	2.61
Total area deciduous fruit farming (ha)					**6970.73**

Appendix IX: Recommendation to improve biodiversity in orchards while maintaining agricultural production

Figure 4: Due to the aggressive spraying regime, grass and weed growth is limited in the orchards (left photo). Some farmers however started to reduce the chemical input in order to allow grass, clover and weed to grow (middle photo). This helped to prevent soil erosion, to keep the soil moisture and stimulate the growth of soil organism, which improves the soil productivity, according to one fruit farmer. This farming practice also increase the biodiversity level in the orchards. This farming practice is seen by more and more fruit farmers in the Langkloof and need to promote more as an sustainable from of agricultural production while improving biodiversity level in the orchards.