The impact of land use on the provisioning of ecosystem services in the thicket biome of the Baviaanskloof, South Africa

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Table of Contents

1. Acknowledgements

2. Summary

3. Introduction

3.1 Background

Natural systems provide valuable resources of all kinds of goods and services for people. In some areas a certain good or service is recognised and is heavily exploited (like mining, deforestation or intensive tourism). Sometimes the area is transformed to an agricultural area, so it can provide more of a certain good. In both cases the natural system is heavily changed to provide more benefits for people. The degradation of natural systems caused by overuse of its goods and services is a global trend. Human activities have changed great proportions of the earth surface. The Millennium Ecosystem Assessment (MA, 2005) shows how the human use of ecosystem services is expanding worldwide while the condition of most of the services is decreasing (Carpenter et al., 2009; MA, 2005). Since the publication of the Millennium Ecosystem Assessment there has been a growing number of scientific papers on the subject of ecosystem services (Fisher et al., 2009). It is widely recognized that current land use activities cause benefits on the short term, but diminish the capacity of ecosystems to provide their services on the long term (Foley et al., 2005). The subject of ecosystem services is however still lacking in many policy tools (De Groot et al., 2010a). Also there is still no consensus on how to define and measure ecosystem services and to integrate this is in landscape planning, management and decision making (Fisher et al., 2009). There are many definition for ecosystem services described in literature. The definition that is used for this report is: "the benefits human populations derive, directly or indirectly, from ecosystem functions"(Costanza et al., 1997). Newer definitions of ecosystem services, such as defined by the Millennium Assessment and the TEEB (The Economics of Ecosystems and Biodiversity), are based on this definition (MA, 2005). So ecosystem services are defined by the relation between ecosystem functions and the benefits for the human population. In other words, the actual use of the capacity of a landscape is an ecosystem service.

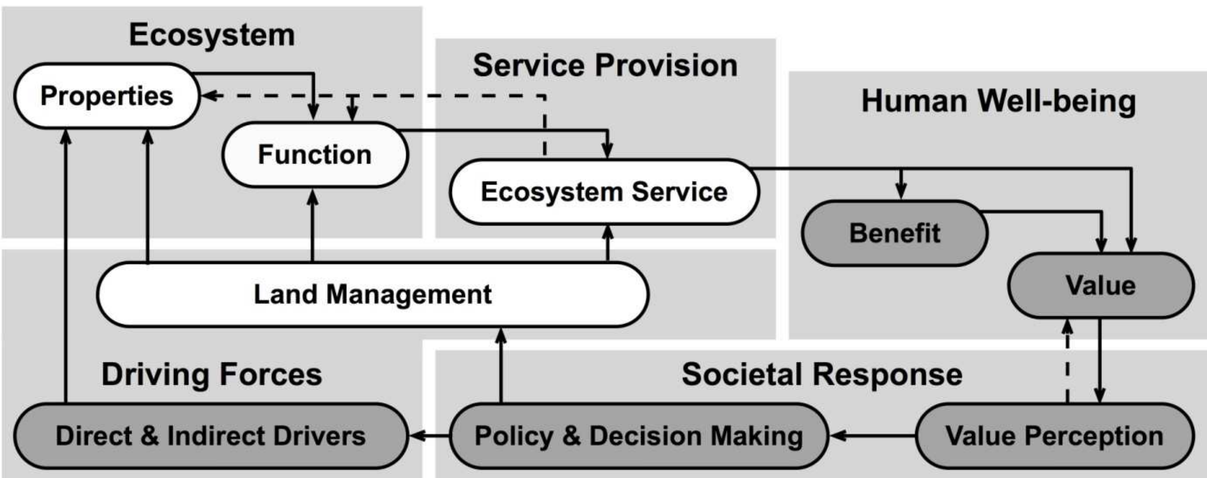

Figure 1. Framework that shows the stepwise cascade approach of linking ecosystems to human wellbeing, in a wider context connecting societal response and driving forces (Van Oudenhoven et al., 2011) ***submitted.***

The ecosystem properties, functions and services indicated in figure 1 can be used as steps to describe the relation between biophysical structures and processes and human benefits. The framework can be used to select indicators for describing the different steps when applied in a case study. Next to that, the framework puts this cascade relationship into context by adding societal response and driving forces such as ecosystem or landscape management.

Practically, when a landscape is valued for the goods and services it is providing, this framework can be a valuable tool. By searching for indicators for each of the steps in the framework, one can quantify and describe the steps and identify the flaws in reasoning. The step on ecosystem properties will provide information on the necessary structures and processes within the ecosystem that is needed for producing the ecosystem service, like information about the rainfall, altitude and vegetation. This is followed by the step on the ecosystem function describing the capacity of the landscape. In other words, the production potential that can be related to sustainable use. This can for instance be the potential production of maize, the amount of grazing animals or the tourism potential. And the step on ecosystem services describes the actual use by humans, like the harvest or the real amount of tourists visiting the area per year. Based on this information, the economic value of a certain good or service can be calculated. This whole system is subject to societal response expressed by the value perception of the different stakeholders and policy making. Also landscape management and other drivers influence the cascade relation between ecosystem properties, functions and services.

Indicators are used to describe and quantify the different steps. It differs per ecosystem service what type of indicator can be used to describe the area and its services. So in some cases it is possible to use indicators for both the ecosystem function as the service. For example the potential of maize production could be used as function indicator and the actual harvest of maize per year as service indicator. But in some cases it is not possible to quantify the service, so only a function indicator is used. This could be the case when the water regulation service needs to be described for a certain area. For quantifying the ecosystem service the actual measured data of water regulation indicators of the entire area are needed. When using a computer model where the water regulation is calculated based on the different ecosystem properties, a number of function indicators is used to describe the potential (the calculated) water regulation in the area. So it is essential to carefully choose the indicators in order to describe the situation as close as possible to the truth.

3.2 Problem Statement

In this research the framework is applied to a case study in the Baviaanskloof, a nature reserve in South Africa. Special focus in this study is on the thicket biome of the Baviaanskloof, the dominant biome in the study area. The area is known for its beauty and high numbers of endemic species (Vlok et al., 2003). This was internationally recognized when the Baviaanskloof Nature Reserve was declared a UNESCO World Heritage Site in 2004. However, within the Baviaanskloof there is also a privately owned area where several farmers live, this area is referred to as the Western Baviaanskloof. The main activity for the last three generations of farmers is the grazing of goats, sheep and cattle for meat and mohair production (pers com farmers). Currently 55% of the thicket biome in the Western Baviaanskloof is severely degraded (Vlok, 2010). There is increasing evidence that pastoralism is unsustainable and leads to a degradation typified by the loss of species, loss of soil nutrients and large scale erosion (Kerley et al., 1999; Le Maitre et al., 2007; Mander et al., 2010; Turpie, 2003). The problem of degradation also affects the farmers in return, by the loss of primary production there is also a decreased capacity to support herbivores (Kerley et al., 1999). So the farmers living in the Western Baviaanskloof are searching for new sources of income to be able to support their livelihoods on the long term (pers com farmers). Restoration efforts are currently based on the replanting of cut truncheons of the succulent *Portulacaria afra*, also named 'Spekboom', a key species of the semi-arid subtropical thicket. This species is a driver of the soil nutrient status and sequesters a considerable high amount of carbon (Lechmere-Oertel et al., 2005; Mills et al., 2005; Powell, 2009).

The Baviaanskloof has been subject of several research initiatives in the past few years. Several research projects has been done on Payment for Ecosystems, in which water services are investigated and valued (lit! Mander, Gull, Van der Burg). Also the *Portulacaria afra* species has been subject of several studies. In some studies the focus was on the sequestration capacity of the Spekboom plant (Mills and Cowling, 2006; Mills and Cowling, 2010; Mills et al., 2005; Powell et al., 2011). Also the use of Spekboom cut truncheons for restoration purposes has been studied (Mills and Cowling, 2006; Sigwela et al., 2009). Currently a monitoring plot is located in the Baviaanskloof for measuring hydrological processes in intact and degraded thicket. Most of the research is related to ecosystem services, although it is not always referred to it as such. Subsequently, most research is focussing on a small range of ecosystem services. There is a need for integrating the available information to get a better understanding of the impact of different management practices on the delivery of ecosystem services.

3.3 Objective and Research Questions

The objective of this study is to quantify and compare ecosystem services provided by the main land use types in the Baviaanskloof in South Africa.

The related research questions are as follows:

1. What are the main land use types in the thicket area of the Baviaanskloof and where are they located?
2. What are the main ecosystem services provided by each of the main land use types?
3. What are relevant indicators for the ecosystem services provided by each of the land use types and how can they be quantified?
4. What is the relation between the main land use types and the provisioning of ecosystem services?

The study gives insight in the relation between the main land use types and a wide range of services. Furthermore, it provides understanding on the relative difference in the provisioning of ecosystem services between the main land use types. The research integrates existing information and identifies the gaps in knowledge. Finally, the research can provide valuable information for the restoration of the Baviaanskloof.

3.4 Study area

3.4.1 Location

The Baviaanskloof is located in the Eastern Cape province of South Africa, and lies between the parallel east-west Kouga mountain ranges (Boshoff, 2005). It is known by its beauty, the highly diverse ecosystems and the high amount of endemic species (Cowling, 2007; Vlok et al., 2003). The Baviaanskloof is a nature reserve in South Africa, an example of an area exploited for different kinds of goods and services like meat, mohair and vegetable seeds. But also tourism is a growing source of income for the landowners in the area. Subsequently, the area functions as important water catchment for the city Port Elizabeth (Mander et al., 2010).

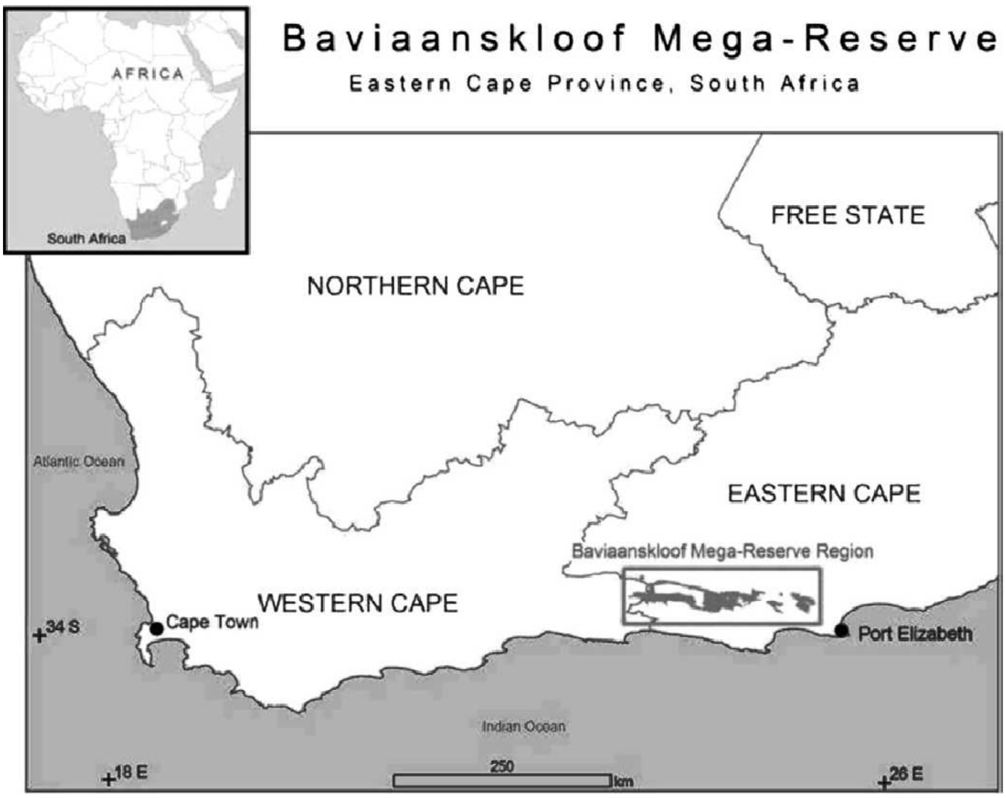

Figure X. Location of the Baviaanskloof Mega-Reserve Region in South Africa. **<u>(lit! Crane 2006)</u>**

The research is focussed on the thicket biome in the Baviaanskloof within the boundaries of the Western Baviaanskloof and the Baviaanskloof Nature Reserve (figure X next page). The Western Baviaanskloof is not part of the Nature Reserve as it is owned by 27 private landowners. The landowners with the largest properties use the land mainly for agricultural activities. The properties range from less than 1 to almost 10,000 hectares (Appendix 1). The total area in the Western Baviaanskloof is 46,543.4 hectares. The Baviaanskloof Nature Reserve is surrounding the private lands in the Western Baviaanskloof, and is managed by Eastern Cape Parks and Tourism Agency (ECPTA). In this report the Western Baviaanskloof and the Baviaanskloof Nature Reserve together are referred to as the 'study area'.

3.4.2 Subtropical thicket biome

There are eight different biomes in South Africa, seven of them can be found in the Baviaanskloof Mega-Reserve, namely Fynbos, Subtropical Thicket, Nama-Karoo, Succulent Karoo, Grassland, Savanna and Forest (Cowling et al., 2005). The subtropical Thicket biome is dominant in the research area and is shown in orange in figure X. This biome is depicted by its dense formation of evergreen and weakly deciduous shrubs and low trees (2-5 m). The thicket has a high biodiversity in flora, it is estimated at about 1.600 species, of which 20% are endemic to the biome (Vlok et al., 2003).

The thicket biome is dominant in the research area. However, in the last centuries the area is thoroughly transformed through agricultural activities and building of infrastructure (lit!). Only 25% of the original thicket cover is still in pristine state in the Nature Reserve. In the Western Baviaanskloof 55% of the surface is identified as severely degraded (Vlok, 2010).

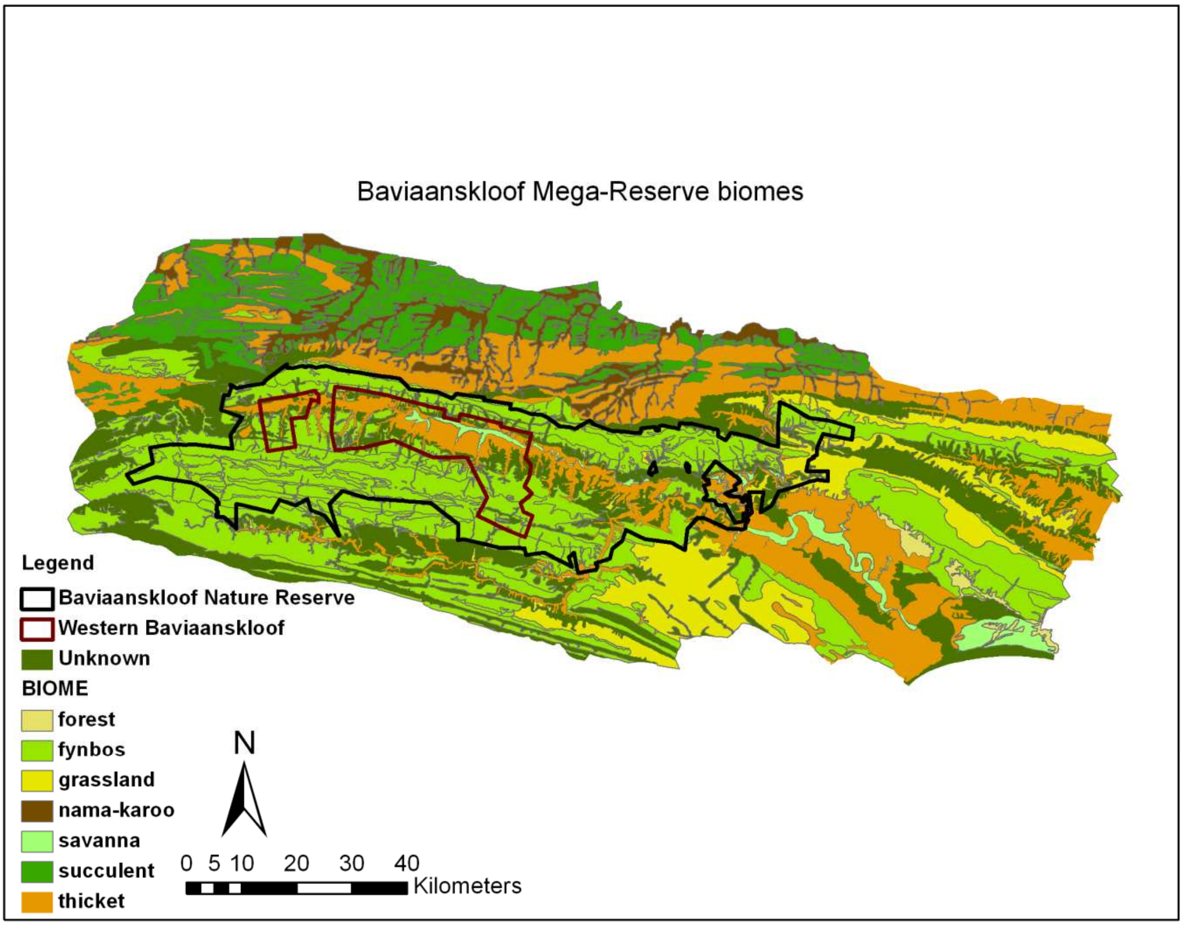

Figure X. Biomes in the Baviaanskloof Mega-Reserve (based on data (Skowno, 2008) The black line indicates the boundary of the Baviaanskloof Nature Reserve within the Mega-Reserve and the red line indicate the boundary of the private lands in the Western Baviaanskloof. The study area is the thicket biome (in orange) in the Baviaanskloof Nature Reserve and the Western Baviaanskloof.

3.4.3 Conservation and restoration programs

In 2004 the Baviaanskloof Natural Reserve was declared a UNESCO World Heritage Site. Since then the Baviaanskloof is object of several programs aiming to protect the biodiversity and to implement restoration management. The three most relevant programs are the Subtropical Thicket Ecosystem Planning (STEP), the Baviaanskloof Mega-Reserve Project (BMR) and the Subtropical Thicket Restoration Program (STRP). Living Lands is facilitating research in South Africa with the aim to restore degraded landscapes in the Baviaanskloof for the benefit of the local people. PRESENCE

(Participatory Restoration of Ecosystem Services and Natural Capital, Eastern Cape) is a network of both governmental as non-governmental organizations and institutes aiming to deliver research and technical expertise on restoration and to support poverty alleviation. The PRESENCE network is coordinated by Living Lands.

3.4.4 Land use

The main land use types in the study area are: arable land, grazing land, thicket restoration plots, old farmlands and intact thicket. The arable lands, grazing lands and old farmlands can only be found in the Western Baviaanskloof. Intact thicket is only still present in the Baviaanskloof Nature Reserve.

3.5 Outline of the report

4. Methods

4.1 Land use identification and mapping

The first step in this research was to identify the main land use types in the Western Baviaanskloof, as also described in research question 1. By talking with experts of the field (researchers, Living Lands) and farmers living in the Western Baviaanskloof, the 5 main land use types were identified: arable land, grazing land, restoration sites, old farmlands and intact thicket. The land use types 'arable land' and 'grazing land' represent the agricultural activities in the Baviaanskloof. The 'restoration sites' and 'old farmlands' represent a situation where agricultural activities are replaced for other purposes. And the 'intact thicket' is used as reference, assuming that the whole thicket biome in the Baviaanskloof was originally intact. Below the different land use types in the Baviaanskloof are further described.

The next step in the research was to locate the defined main land use types in a map. The land use management of the farmers is constantly changing. There were no maps available that represented the current situation in the Baviaanskloof. Therefore seven farmers living in the Western Baviaanskloof were interviewed and asked to make a drawing of their property. The total area of the properties of the seven farmers together was 24.424 hectares, 52% of the total area in the Western Baviaanskloof (Vlok, 2010). The drawing is done by using a printed aerial photograph of the farmers' cadastre (Appendix 2A). A semi-transparant paper is put over the photograph in a way that the landscape features on the photograph could still be seen. By using different colours the farmers were asked to draw the boundaries of the main land use types and the locations of tourist accommodations and water sources in cadastral maps of their properties. The farmers explained many things verbally while drawing. The interviews were recorded, so the drawings could be further completed after the interview. An example of a drawing can be found in Appendix 2B. The drawings were digitized by using arcGIS. Features such as water sources, hiking/4WD trails and houses were drawn as separate layers in arcGIS.

The land use type 'intact thicket' could not be drawn in a map, since this was the only land use type that is not present in the Western Baviaanskloof. Data from Vlok (2010) are used to locate this land use type in a map of the Baviaanskloof Nature Reserve.

Picture X. Arable land with Lucerne at Bokloof in the Baviaanskloof

Picture X. Arable land with a clear fence line contrast with the original vegetation.

Arable land

Arable land is one of the main land use types since the farmers are highly dependent on it. All farmers with livestock produce fodder for own use on these arable lands (picture X). Also the vegetable seed production (for potatoes and onions) is for some farmers a main source of income. All the studied farmers use fertilizers and pesticides, herbicides and fungicides. The fields are irrigated, since the Baviaanskloof is a relatively dry area. The arable lands are thoroughly transformed for this land use type by removing all original vegetation (picture X).

Grazing land

Livestock farming is the main source of income for most farmers in the Baviaanskloof, a major part in the Western Baviaanskloof is used for this land use type.

The most degraded lands in the Baviaanskloof are for a big part (historical) grazing lands, therefore the degradation problems are often attributed to grazing (Boshoff, 2006; Kerley et al., 1995). There is scientific evidence that heavy grazing has an impact on the biodiversity, the species richness is decreased when light grazing areas are compared with heavy grazing areas (Allsopp et al., 2007). A percentage of 71% of the grazing lands is defined as severely degraded (Vlok, 2010). The main livestock species that are kept are: Angora goats, boergoats, sheep, ostrich and cattle (pers com farmers).

Picture X. Grazing land with Angora goats at Rus en Vrede in the Baviaanskloof

Thicket restoration sites

The degraded fields of semi-arid subtropical thicket vegetation has a low regeneration through seedling recruitment. The thicket species Spekboom *(Portulacaria afra)* is a driver of the soil nutrient status, but is also largely lost in degraded lands (Powell, 2009). The sites are restored by replanting cut truncheons from Spekboom in degraded fields (picture X). The carbon stocks in subtropical thicket is exceptional high (Mills et al., 2005). The sequestration rates compete with those of temperate forests, although they receive far more water. There is high scientific evidence of the immense carbon losses through degradation of the thicket vegetation (Lechmere-Oertel et al., 2005; Mills et al., 2005). This creates opportunities for achieving carbon credits under the current rules of CDM (Clean Development Mechanism) when thicket vegetation is restored.

Picture X. Replanted Spekboom cut truncheons at Rus en Vrede in the Baviaanskloof

Old farmlands

A large amount of the lands of the farmers is not in use and defined as old farmlands. There are different motivations for the farmers why these areas are not in use. For some farmers it is based on a financial motivation not to use is. It

Figure X. Old farmland at Rus en Vrede in the Baviaanskloof.

would not be cost-efficient since some areas need water structures in order to use the land for grazing. Other farmers did not use the land because of the inaccessibility of the area caused by the steep slopes and cliffs in the area. And there are also farmers that switched to new sources of income such as tourism. Some farmers constructed Four Wheel Drive and hiking trails in these areas (figure X). Still an amount of 53% of the thicket biome at the old farmlands is defined as pristine-moderately degraded. However 32% is defined as severely and 14 % as moderate-severely degraded (Vlok, 2010). This is probably because large areas of the old farmlands have been overgrazed in the past.

Figure X. Old farmland with Four Wheel Drive trail and old Spekboom (on the right) at Rus en Vrede in the Baviaanskloof.

Intact thicket
Intact thicket is not present anymore in the private lands of the Western Baviaanskloof, but it can still be found in the Baviaanskloof Nature Reserve. A percentage of 25% of the thicket biome in the Nature Reserve is defined as pristine, 75% as pristine-moderately degraded. In this report intact thicket is defined as the area that is pristine or pristine-moderately degraded with an historical Spekboom density of 20-50% (Vlok, 2010). Intact thicket is used as reference, assuming that the thicket biome in the Baviaanskloof was originally intact.

Figure X. Intact thicket in the Baviaanskloof Nature Reserve

4.2 Ecosystem service quantification

4.2.1 Ecosystem Function Analysis

The Ecosystem Function Analysis is a method to translate ecological complexity into a limited number of ecosystem functions. Ecosystem functions describe the *capacity* of a landscape, while the ecosystem services describe the *goods and services* that are valued by humans (De Groot, 2006). The steps to go from ecological processes to ecosystem functions to ecosystem services are also described in the framework, figure X in the introduction (paragraph 3.1). In this research the classification for ecosystem functions and services of the Economics of Ecosystems and Biodiversity (TEEB) is used (De Groot et al., 2010b). The main service types as described by the TEEB are: Provisioning Services, Regulating Services, Habitat Services and Cultural Services. A table with all the subservices of the TEEB can be found in Appendix 3.

In this research the Ecosystem Function Analysis and the framework of figure X are used as basic approach to quantify the ecosystem services in the Baviaanskloof. The selection of ecosystem services for this research are based on the interviews and literature study (paragraph 4.2.2, 4.2.3). Indicators are needed to quantify the ecosystem services (or functions) as described in paragraph 3.1. The services are quantified by using different methodologies. In table X the selected ecosystem services, the used indicators and the used methodologies are listed. The methodologies are further described in paragraph 4.2.2, 4.2.3 and 4.2.4.

Ecosystem Service type	Ecosystem Service	Subservice	Land use type					Method
			Arable land	Grazing land	Rest. sites	Old farm-lands	Intact thicket	
Provisioning Services	Food provisioning	Meat		animals/yr				Interviews
		Plants	Kg/ha/yr					Interviews
		Honey	Kg/hive/yr					Interviews
	Water supply	Drinking water		l/animal/ day				Literature Interviews
		Irrigation	m^3/yr					Interviews
	Provision of raw materials	Mohair		Kg/ha/yr				Interviews
		Fodder	Kg/ha/yr					Interviews
Regulating Services	Climate regulation	C-sequestration	t C ha^{-1} of Spekboom	t C ha^{-1} of Spekboom	t C ha^{-1} of Spekboom	t C ha^{-1} of Spekboom	t C ha^{-1} of Spekboom	GIS analysis Literature Interviews
	Regulation of water flows	Water regulation		Multiple indicators*			Multiple indicators*	Literature Interviews
	Erosion prevention	Erosion prevention	Erosion prev. level	Erosion prev. level	Erosion prev. level	Erosion prev. level	Erosion prev. level	GIS analysis Literature
Habitat services	Protection of gene pool	Biodiversity protection		Species richness			Species richness	Literature Interviews
Cultural Services	Aesthetic information	Attractive landscapes	Scoring tourists	Scoring tourists	Scoring tourists	Scoring tourists	Scoring tourists	Literature

Table X. Overview of studied ecosystem services, indicators and used methodology.
*** Multiple indicators: drying after rainfall, moisture depth, moist topsoil, peaks after rainfall events, increase in moist after rainfall, stable soil moisture, infiltration speed, run-off.**

4.2.2 Interviews

For this research interviews are conducted with 3 types of interviewees: farmers, researchers and a representative of Eastern Cape Parks and Tourism Agency (ECPTA). The method used for the interviews with the farmers and representative of ECPTA was open questions by using a questionnaire. Different questionnaires were used for the two types of interviewees (Appendix 4A and B). Two researchers were interviewed: Mike Powell and Richard Cowling. The aim of these interviews was to get a better understanding of some regulating services, to verify some quantification methods and to find indicators for different services. For these interviews no questionnaires were used. All interviews were recorded. These recordings are used to better select the information said during the interviews and to verify the given information written down during the interviews.

The biggest group of interviewees were the farmers living in the Western Baviaanskloof, 7 of them were interviewed. Due to time limitation it was not possible to interview all landowners. Since the focus of this research is on the main land use types, it has been decided to interview the farmers in the area who live permanently in the Baviaanskloof and are (financially) dependent on the services provided by the area. The aim of the interviews with the farmers was to get a better understanding of the main land use types in the Baviaanskloof and to find indicators for ecosystem functions and services and quantify them if possible.

4.2.3 Literature study

The aim of the literature study was to gather indicators for the different ecosystem services and to quantify them if possible. The literature study is used for quantifying the following ecosystem services: climate regulation, regulation of water flows, erosion prevention, protection of gene pool, aesthetic information (table X). All used literature was specific for the Baviaanskloof, however the literature was not always peer-reviewed (for the services: regulation of water flows (Van Luijk, 2011), erosion prevention (Draaijer, 2010) and aesthetic information (Fousert, 2009). Since no peer-reviewed data was available for the Baviaanskloof on these services, and these data are very location specific, it is chosen to still use the data from the not peer-reviewed sources.

For the ecosystem service 'protection of gene pool' the data in the literature could be directly used for this research. For the service 'climate regulation' data from different sources were used to create a sequestration map of the Baviaanskloof in arcGIS, with which the average sequestration level of each land use type could be calculated (described in paragraph 4.2.4). For the service 'erosion prevention' an erosion risk map is used (Draaijer, 2010). The inverse of the erosion risk map in arcGIS is used as function indicator for 'erosion prevention' (described in paragraph 4.2.4).

For describing the ecosystem service 'aesthetic information', data from Fousert (2009) are used. The report describes the scoring of pictures by 35 tourists in the Baviaanskloof on the importance of how well the picture contributes to the experience of the Baviaanskloof. It is scored in a semantic scale from -4 until 4, with -4 meaning not important at all and 4 as very important. For this research pictures are selected from Fousert (2009) that show the main land use types (listed in Appendix 5). The scoring of the 35 tourists of the selected pictures is used for the quantification of 'aesthetic information'. The average rating per picture of each land use type is used as function indicator.

4.2.4 GIS Analysis

For the quantification of the ecosystem services 'climate regulation' and 'erosion prevention' the software ArcGIS (ArcMap version 9.3.1) is used for a GIS analysis (table X). Also for the calculation of the average degradation level per land use type, ArcGIS is used. The data on degradation rates is used for the description of the main land use types. It could be seen as an ecosystem property, indicated in the framework in figure X.

The used erosion risk map (Draaijer, 2010) describes the erosion risk for the Baviaanskloof watershed, overlapping a large area of the western Baviaanskloof. By extracting data from the erosion risk map to the land use map ('Extract by Mask' in Spatial Analyst Tool), the average erosion risk per land use type could be calculated. The erosion risk is quantified in a scale from 1 to 5, with 5 describing the highest risk. The inverse of the average erosion risk is used as function indicator for the ecosystem service erosion prevention. The same method is used for quantifying the average degradation rate of each land use type. The degradation map (Vlok, 2010) describes the degradation rate in a scale from 1 to 5, with 1 describing no degradation/pristine and 5 severely degraded.

For the quantification of the average carbon sequestration per land use type, two different data sources had to be combined (Mills and Cowling, 2010; Vlok, 2010). In the arcGIS-map of Vlok (2010) Spekboom degradation was defined as in table X below (Powell et al., 2011).

Degradation rate	**% of original Spekboom density remaining**
Pristine	50-100%
Moderate	20-50 %
Severe	<20%

Table X. Degradation rate defined by Powell (2011) about the data from Vlok (2010)

The data in this GIS map were not connected to a certain carbon sequestration rate. Mills (2010) however defined for different degradation rates a certain sequestration rate. In table X below the relation between the current Spekboom density and carbon sequestration are given.

Degradation rate	**Current thicket density**	**Carbon sequestration**
Intact	>70% canopy cover	104 t C ha^{-1}
Degraded	<30% canopy cover	33.7 t C ha^{-1}

Table X. Degradation rate defined by Mills (2010)

For this research it is assumed that the term 'severe' in Powell (2011) equals the term 'degraded' in Mills (2010), and 'pristine' in Powell (2011) equals 'intact' in Mills (2010). The carbon sequestration for the degradation level 'moderate' (as defined by Powell 2011) is calculated as the average sequestration between 'intact' and 'degraded' (Mills and Cowling, 2010). A linear relation between degradation rate and carbon sequestration is assumed. This results in table X below.

Degradation rate (Vlok 2010)	**% of original Spekboom density remaining**	**Carbon sequestration (t C ha^{-1}) *soil* (Mills 2010)**	**Carbon sequestration (t C ha^{-1}) *root* (Mills 2010)**	**Carbon sequestration (t C ha^{-1}) *total***	**Sequestration level**
Pristine	50-100 %	93	11	104	5
Prist-mod		77.5	8.925	86.425	4
Moderate	20-50 %	62	6.85	68.85	3
Mod-sev		46.5	4.775	51.275	2
Severe	<20%	31	2.7	33.7	1

Table X. Calculated total sequestration and sequestration levels by combining the degradation rate data from Vlok (2010) with the sequestration measured by Mills (2010).

The degradation rates in Vlok (2010) describe the percentage of the Spekboom density that is still remaining. By using these sequestration levels, an area with a low historical Spekboom density with currently the same Spekboom density, would be defined as pristine and attached to the highest sequestration level. This would result in a distorted outcome. Therefore the calculated sequestration levels cannot be directly connected to the degradation rates described in Vlok (2010). The data in table X need to be corrected with the historical Spekboom density (Vlok, 2010). The sequestration levels are defined by using a matrix combining degradation rate and the historical Spekboom density (table X).

Historical Spekboom density **Degradation rate**	**0%**	**5-10%**	**10-20%**	**20-30%**	**30-50%**
Pristine	NA	2	3	4	5
Pristine-moderate	NA	1	2	3	4
Moderate	NA	1	1	2	3
Moderate-severe	NA	1	1	1	2
Severe	NA	1	1	1	1

Table X. Matrix combining the degradation rate and the historical Spekboom density (both defined in data Vlok 2010) to define the sequestration levels from 1-5.

Table X is used to construct the carbon sequestration map of the Baviaanskloof. By extracting data from the sequestration map to the land use map ('Extract by Mask' in Spatial Analyst Tool), the average sequestration level per land use type is calculated.

4.3 Comparison and visualization of ecosystem services per land use type

The last research question is about the relation between the main land use types and the provisioning of ecosystem services. This is done by comparing and visualizing the difference in service provisioning between the main land use types, by using intact thicket as reference. In table X the studied ecosystem services with the used indicators is listed. Not all ecosystem services could be quantified for each land use type. This was the case for the ecosystem services 'regulation of water flows' and 'protection of gene pool'. These services were only quantified for the land use types 'grazing land' and 'intact thicket'. That does not mean that the other land use types don't have water regulation or protection of gene pool, but that no data were found to quantify the other land use types with comparable indicators. The ecosystem services for 'regulation of water flows' and 'protection of gene pool' are compared and visualized by plotting the data in a bar chart.

The services 'climate regulation' and 'erosion prevention' are both quantified by using arcGIS (paragraph 4.2.4). Next to the quantified numbers of the used indicators for these services, this resulted in a spatial map of the Baviaanskloof in which the services are indicated in a 1-5 scale. These maps are used to visualize these services for the Baviaanskloof.

The provisioning services were only quantified for the land use types 'arable land' and 'grazing land'. This was not because of lack of information for the other land use types, but because these are the only land use types that provide provisioning services for the farmers. For the services 'climate regulation', 'erosion prevention' and 'aesthetic information' the same indicators are quantified for all land use types, so these can be easily compared to each other. This is done by plotting these three services together with the provisioning services in a spider diagram. For doing this the data needed to be in the same scale. Therefore the data are recalculated to a 1-100 scale.

The provisioning services are only present at arable land and grazing land. Since the services for these two land use types have different indicators, they cannot be compared to each other. The aim of the spider diagram is to compare and visualize the different land use types. Therefore the provisioning services for arable land and grazing land both have the value '100' and the other land use types '0'.

For the service 'climate regulation' the average carbon sequestration level of Spekboom of each land use type was used as function indicator, and for the service 'erosion prevention' the inverse of the average erosion risk is used as function indicator. Both the sequestration level and the erosion prevention level were calculated in a 1-5 scale (described in paragraph 4.2.4). The recalculation of the carbon sequestration and erosion prevention level to a 1-100 scale is done by using formula 1. Y is the outcome in a 1-100 scale and X the average sequestration or erosion prevention level in a 1-5 scale.

(1) $Y = X/5 * 100$

The service ‘aesthetic information’ is quantified by using the average scoring by tourists of pictures of each land use type (described in paragraph 4.2.3). The scoring was done in a -4 until 4 scale. So first the average scoring per land use type is recalculated to a positive scoring from 0-8 by adding 4 to all outcomes. Then the outcome is calculated to a 1-100 scale. Formula 2 describes the formula for the recalculation, Y is the outcome in a 1-100 scale and X the average scoring in a -4 to 4 scale.

(2) $Y = (X+4)/8 * 100$

After recalculating the data for the provisioning services and the services ‘climate regulation’, ‘erosion prevention’ and ‘aesthetic information’, they could be plotted together in a spider diagram.

5. Results

5.1 Land use identification and mapping

The main land use types identified for the Baviaanskloof are: arable land, grazing land, thicket restoration sites, old farmlands and intact thicket. Figure X is the result of the drawings of seven farmers in the cadastre map of their lands. Intact thicket is not indicated in this map since it is only existent in the Baviaanskloof Nature Reserve. The map shows that both the grazing land and the old farmlands have the biggest areas, respectively 40 and 45% of the studied farmlands in the Western Baviaanskloof. A much smaller area is used as arable land or restoration sites, respectively 1 and 0.3% of the studied farmlands.

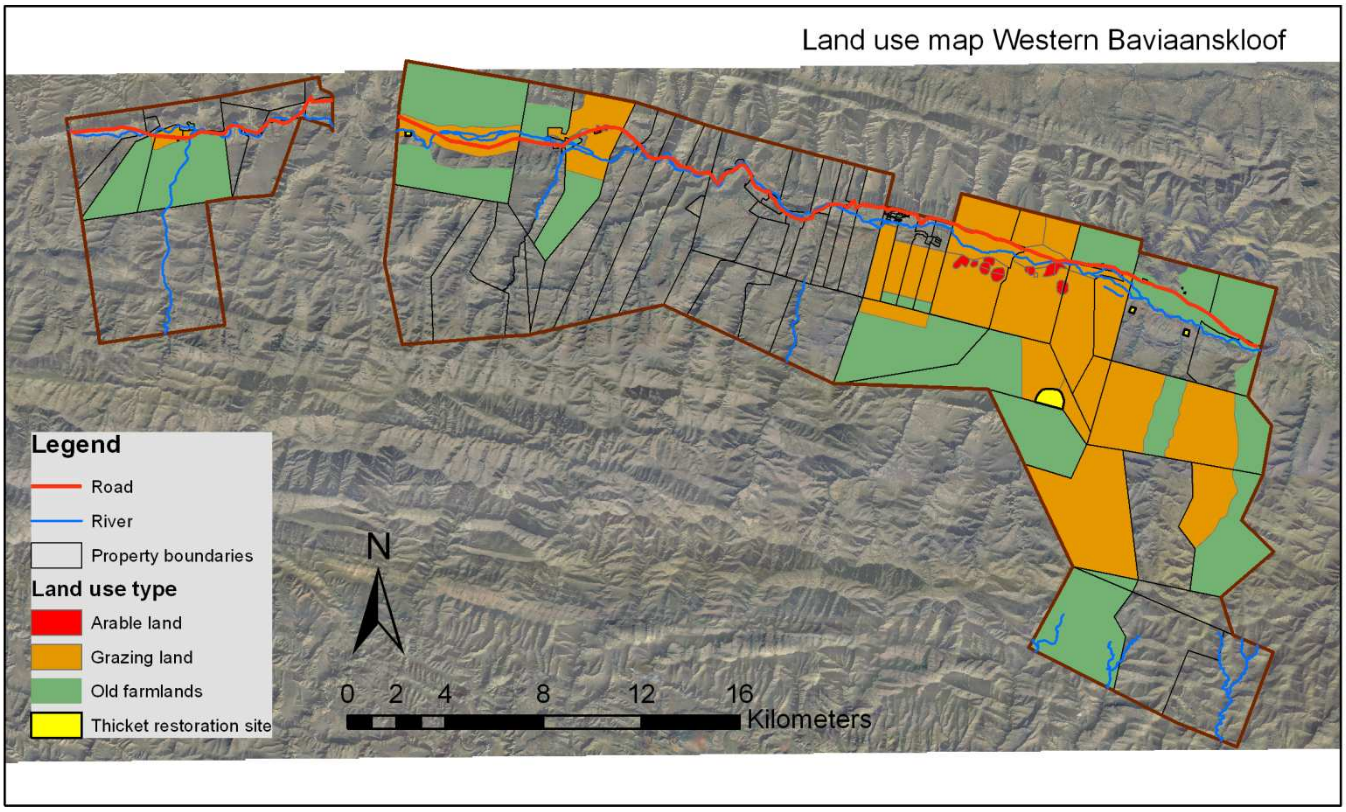

Figure X. Map of the main land use types of 7 farmers in the Western Baviaanskloof (based on drawings of the farmers)

The map shows that the old farmlands are mainly located on the outer sides of the Western Baviaanskloof. And the current grazing lands are found more in the middle and in the valley. The arable lands are located in the valley along the river in patches of 10 to 12 hectares. This map also shows the tourists' locations (lodges and campsites) are distributed along the entire valley of the Western Baviaanskloof. Although some concentrations of locations seem to be located in the far western part and in the eastern side, close to the entrance of the Baviaanskloof Nature Reserve. Most locations are also relatively closely located to the river. It also seems that most Four Wheel Drive and walking trails are located in the eastern part.

Intact thicket is not present in the Western Baviaanskloof, but can still be found in the Nature Reserve. In figure X all land use types, including the intact thicket, is indicated in the map. Because of the small areas of arable land and restoration sites, these are hardly visible on this map. Intact thicket is defined as the area that is pristine or pristine-moderately degraded with an historical

Spekboom density of 20-50%. Intact thicket is used as reference for the comparison of the different land use types (paragraph 5.3).

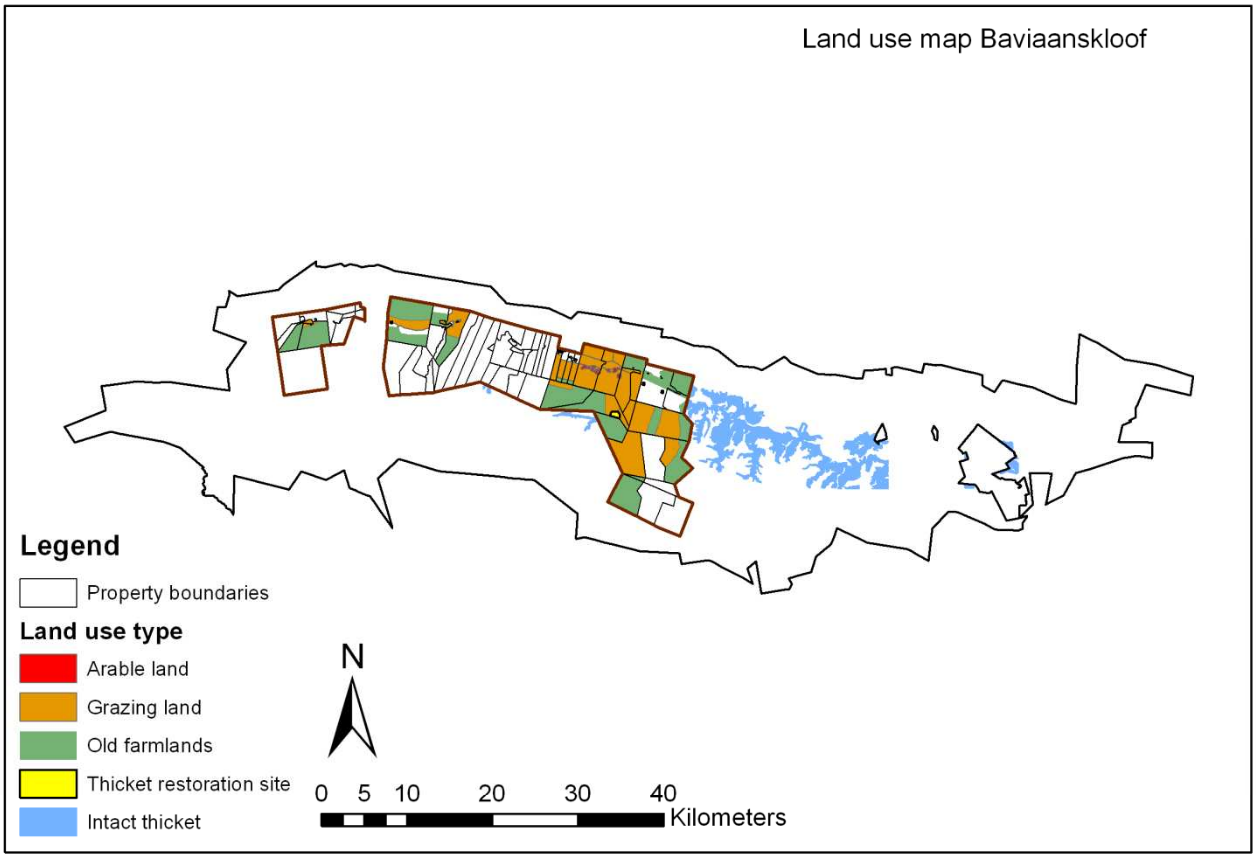

Figure X. Land use map of the Baviaanskloof Nature Reserve and the Western Baviaanskloof (based on drawings farmers and data Vlok 2010)

5.2 Ecosystem Service quantification

5.2.1 Arable land

Food Provisioning

For 3 of the interviewed farmers was seed production one of their main incomes. The total area for seed production in the study area (figure X) is estimated on 22 hectares, this is about 15% of the studied arable lands. The yield of seed production is used as service indicator for the food production. The yield is about 500 kg/ha/yr, and the total seed production of the 3 farmers together is estimated at 11,000 kg/yr.

Honey is produced by one of the studied farmers in the Western Baviaanskloof. Eastern Cape Parks and Tourism Agency (ECPTA) funded the farmer to produce honey to increase the pollination in the area (pers com representative ECPTA). Therefore the honey production is in this case related to arable lands. The farmer has 135 hives with a honey production of 20 kg/hive/yr, with a total honey production of about 2,700 kg/yr. So for this farmer the honey production is an important source of income. It is unknown what the effect of these hives is on the pollination in the area. Therefore the regulating service of 'pollination' could not be described in this research.

Provision of raw materials

An area of about 129 hectares is used for the production of fodder. The three types of fodder produced in the Baviaanskloof are lucerne, maize and wheat. Livestock farming is the main source of income in the study area, so all farmers that keep livestock produce fodder for own use. The area for fodder production per farmer range from 10 until 39 hectares. The yield of lucerne is 10,000 – 15,000 kg/ha/yr and for maize 8,000 kg/ha/yr. The yield of wheat in the Baviaanskloof is unknown. The production of lucerne and maize are used as service indicators for the provision of raw materials.

Water supply

The farmers in the Baviaanskloof have their own water sources on their land. This water is used for irrigation, drinking water for livestock and domestic use. Most of the farmers do not measure their water use, so their water consumption is unknown. One farmer estimated a total water use of 60,000 l/hour when using 50 sprayers for irrigation. The water use for this farmer is 525,600 m^3/yr. This is mainly used for irrigation and a negligible part is used for the water use of livestock (pers com farmer). In literature an average water use of 5,820 m^3/ha/yr for irrigation in the Baviaanskloof is described (De la Flor Tejero, 2008). These data are used as function indicator for the water supply for irrigation on arable lands in the Western Baviaanskloof.

Climate regulation

The carbon sequestration rate is calculated for Spekboom in the thicket biome (described in paragraph 4.2.4). The sequestration rate only represents 2% of the arable land, since only this percentage of arable land is located in the thicket biome. And 100% of this piece of area is defined as sequestration level 1, which equals a sequestration of 33.7 t C ha^{-1} for total root and soil carbon. The sequestration level is used as function indicator for climate regulation.

Erosion prevention

The erosion prevention rate is assessed by using the negative erosion risk as function indicator (Draaijer). The erosion prevention is determined in 5 levels, with 1 the lowest and 5 the highest prevention level. The erosion prevention for arable land is on average 3.4 with an almost even distribution over the erosion prevention levels 2 till 5, however 31% of the area was defined with erosion prevention level 2. No area of arable land is defined with the lowest erosion prevention level 1. Figure X shows the erosion prevention map of the Baviaanskloof.

Recreation and tourism

The pictures of arable land (Appendix 5) are rated negatively on average. The qualification of picture 1 by the tourists in the Baviaanskloof (n=35) was on average -0.8 ± 2, and picture 16 was rated -0.7 ± 2(Fousert 2009), so the average scoring of arable land is -0.75. Most interviewees rated these pictures negative. In the report (Fousert 2009) is described that nine interviewees stated that "This landscape doesn't add to the uniqueness of the Baviaanskloof, it's not the reason for visiting this area". And six interviewees stated that "Farming activity is in conflict with the nature image of the area ". However this report also describes that six interviewees expressed their beliefs on the importance of farming: "Farming is important to support local livelihoods in socio-economic needs". Two interviewees stated "Farming activity is nice to watch".

Summary table

Ecosystem service	Subservice	Indicators	Outcome	Unit
Food provisioning	Plants / vegetable food: seed production	Service indicator: yield/yr Function indicator: Area of crop land	500	kg/ha/yr
	Food: honey	Service indicator: yield/yr Function indicator: Nr of bee hives, honey per bee hive	2,700	kg/yr
Provision of raw materials	Fodder: lucerne, maize and wheat	Service indicator: yield/yr Function indicator: Area of crop land	Lucerne: 10,000 – 15,000 Maize 8,000	kg/ha/yr
Water supply	Irrigation water	Function indicator: Estimation farmer	525,600	m^3/yr for one farmer
		Function indicator: Average water use for irrigation in Baviaanskloof	5,820	m^3/ha/yr
Climate regulation	C-sequestration: Spekboom	Function indicators: C-sequestration level (root+soil)	1	Scale 1-5, (5 is highest seq. level)
Erosion prevention	Erosion prevention	Function indicator: Erosion prevention (inverse erosion risk)	3.4	Scale 1-5, (5 is highest prevention)
Regulation of water flows	Unknown	-	-	-
Protection of gene pool	Unknown	-	-	-
Opp. for recreation and tourism	Tourism	Function indicator: Qualification tourists	-0.8 ± 2 -0.7 ± 2	Scale -4 until 4 (-4 lowest importance)

Provisioning Services	Habitat Services
Regulating Services	Cultural Services

Figure X. Summary table for the ecosystem provisioning of arable lands in the Western Baviaanskloof

5.2.2 Grazing land

Food Provisioning
According to the majority of the farmers livestock farming is the main source of income for the farmers in the Western Baviaanskloof (pers com farmers). Most livestock is kept for meat production. The animals that are kept are sheep, goats (Angora goats and Boer goats), cattle and ostriches. The livestock is sold per animal. In table X the total number of animals of the study area is given, this is the function indicator. The amount of animals that is sold each year is the service indicator.

Livestock	Total nr in study area	Sold (average) (%)	sold (nr/yr)
Sheep	940	53	495
Angora goat	2900	16	465
Boer goat	270	60	162
Cattle	333	45	149
Ostrich	620	93	575

Table X. Total numbers of livestock animals of the studied farmers in the Western Baviaanskloof.

Provision of raw materials
The Angora goat is the main livestock animal in the Western Baviaanskloof. The goats are kept for the mohair, the whool-like hairs of the goat. From each goat an amount of 4 kg mohair per year is sold. Since there are 2900 Angora goats in the study area, the total yield of mohair is 3760 kg mohair/year (pers com farmers). The yield of mohair is used as service indicator for the provision of raw materials on grazing lands in the Baviaanskloof.

Water supply
The livestock in the Baviaanskloof need to be provided by drinking water. The water requirements of the livestock animals is used as function indicator for describing the water supply service in grazing land. The water requirements of the livestock depend on climate (Taddese, 1995). Since the research is done in the summer season, it is assumed that the climate was dry and hot with an average air temperature of 27 °C. In the table below the water requirements for the different livestock animals for this specific climate are given (Aganga et al., 2003; Taddese, 1995). The total water requirement of the livestock in the study area is 35121 l/day.

Livestock	Total nr in studied area	Water requirement l/animal/day	Total water requirement l/day
Sheep	940	5	4700
Goats	3170	5	15850
Cattle	333	27	8991
Ostrich	620	9	5580
total	*5063*		*35121*

Figure X. Total numbers of livestock animals in the Baviaanskloof and the water requirements of the different animals (Aganga et al., 2003; Taddese, 1995)

Climate regulation
The sequestration of Spekboom in the thicket biome in the Baviaanskloof is used as function indicator for climate regulion. 40% of the grazing land falls within the thicket biome and 83% of this land is classified in the lowest sequestration level and the remaining 17% is classified in sequestration level 4. On average the sequestration level for Spekboom (root+soil) of grazing land is 1.5 on a scale of 1-5 with 1 as lowest sequestration level.

Erosion prevention
The average erosion prevention level is 2.5 in a scale from 1 till 5. A major part of the grazing lands is defined with erosion prevention level 2 and 3, respectively 31 and 32% of the grazing land in the Baviaanskloof. Only 4% of the area was defined with the highest erosion prevention level 5.

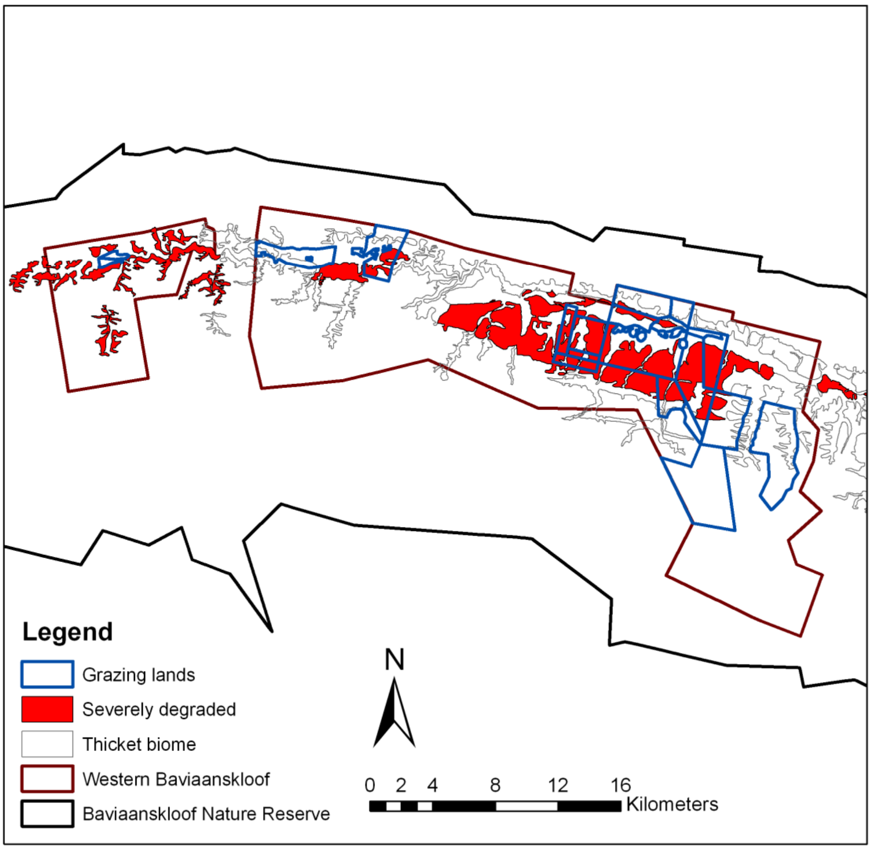

Figure X. Severely degraded thicket biome and the location of studied grazing lands. The map is based on the drawings of farmers and data Vlok (2010).

Regulation of water flows
The regulation of water flows is quantified for degraded thicket. In this research it is assumed that degraded thicket are the severely degraded areas at the grazing lands. In figure X the severely degraded areas in the thicket biome in the Western Baviaanskloof are indicated. The grazing lands are indicated with the blue lines.
The regulation of water flows can be described by several indicators. Long term measurements of water regulation indicators are not yet available for the Baviaanskloof. The data in table X are the results of a first survey at the monitoring plot in the Baviaanskloof (Van Luijk, 2011).

Indicators for regulation of water flows	
Drying after rainfall event	Dries quick
Moisture depth	40 cm
Moist topsoil	5-20%
Peaks after rainfall events	low
Increase in moist at topsoil after rainfall	4-16%
Soil moist after 9 days no rain	8%
Stable soil moisture (depth 50 cm)	10%
Infiltration speed	0.2 to 10 mm/hr
Run-off	high

Figure X. Preliminary data of service indicators for water regulation at grazing lands in the Baviaanskloof (Data Van Luijk 2011)

Protection of gene pool

Lechmere-Oertel (2005) compared the species richness between intact and transformed habitats of semi-arid succulent thicket. The species richness is measured at different locations (N=8) with a fence-line contrast between intact thicket and transformation through grazing (Lechmere-Oertel et al., 2005). The average amount of species in the transformed area was 15 ± 8 and a Shannon's diversity index (Zar, 1999) of 2,26 ± 0,71. The outcomes of this study are used as function indicator for the protection of gene pool for these two land use types.

Recreation and tourism

The pictures on degraded lands are rated relatively low by the interviewees, picture 4 was on average 0.1 ± 2.5 and picture 7 was rated on -0.3 ± 2 (Fousert, 2009), so the average rating for grazing land was -0.1. Three interviewees stated that "this landscape shows negative impact of human on the natural environment " and two interviewees stated "This landscape represents overgrazing, erosion and commercialized farming". But there were also two interviewees who had a more positive opinion: "This crisp Karoo (savannah) like landscape is appealing".

Summary table

Ecosystem service	Subservice	Indicators	Outcome	Unit
Food provisioning	Meat	Function indicator: Nr of animals Service indicator Nr of sold animals	Table X	Table X
Provision of raw materials	Mohair	Function indicator: Nr of Angora goats Kg mohair/goat/yr Service indicator: Kg mohair sold per year	 2900 4 3760	 Angora goats Kg mohair/goat/yr kg mohair/year
Water supply	Drinking water livestock	Function indicator: Water requirement livestock Service indicator: nr of livestock animals	 35,121 Table X	 l/day (total water requirement for all livestock animals in study area)
Climate regulation	C-sequestration of Spekboom	Function indicator: C-sequestration level (root+soil)	1.5	Scale 1-5, (5 is highest seq. level)
Erosion prevention	Erosion prevention	Function indicator: Erosion prevention (inverse erosion risk)	2.5	Scale 1-5, (5 highest prevention)
Regulation of water flows	Multiple	Multiple	Table X	Table X
Protection of gene pool	Biodiversity	Service indicator: species richness of thicket habitat	15 ± 8 2,26 ± 0,71	Nr of species Shannon's index H
Opp. for recreation and tourism	Tourism	Function indicator: Qualification tourists	0.1 ± 2.5 -0.3 ± 2	Scale -4 until 4 (-4 lowest importance)

(green)	Provisioning Services
(purple)	Regulating Services
(blue)	Habitat Services
(orange)	Cultural Services

Figure X. Summary table for the ecosystem provisioning of grazing lands in the Western Baviaanskloof

5.2.3 Thicket restoration site

Climate regulation

A percentage of 14% of the thicket restoration sites is located within the thicket biome. 99.8% of this area is categorized in the lowest sequestration level, so the average sequestration level of the thicket restoration sites is 1 which equals a sequestration of 33.7 t C ha^{-1} .

Erosion prevention

The average erosion prevention for the thicket restoration site is relatively low, it is 2.1 on a scale from 1-5. Almost all the thicket restoration sites in the Western Baviaanskloof have erosion levels 1, 2 or 3. Only 1% of the area has erosion level 5 and 4% level 4.

Recreation and tourism

Two pictures from the Fousert (2009) study describe the qualification of tourists for restoration sites (Appendix 5). Picture 24 is rated with 1.7 ± 2.2 and picture 25 was rated with 1.1 ± 2. A large majority of the interviewees rated these picture as a positive contribution to their experience of the Baviaanskloof. As four tourists stated “Conservation projects in the area are important to preserve its natural beauty for the next generations” and seven stated “Integrating tourism with rehabilitation is a nice opportunity to contribute to the natural environment”. However, four tourists had another opinion: “Conservation is good and to see the results but should happen out of tourists sight as it is not interesting”.

Summary table

Ecosystem service	Subservice	Indicators	Outcome	Unit
Food provisioning	None	-	-	-
Provision of raw materials	None	-	-	-
Water supply	Unknown	-	-	-
Climate regulation	C-sequestration: Spekboom	Function indicator: C-sequestration level (root+soil)	1	Scale 1-5, (5 is highest seq. level)
Erosion prevention	Erosion prevention	Function indicator: Erosion prevention (inverse erosion risk)	2.1	Scale 1-5, (5 highest prevention)
Regulation of water flows	Unknown	-	-	-
Protection of gene pool	Unknown	-	-	-
Opp. for recreation and tourism	Tourism	Function indicator: Qualification tourists	1.7 ± 2.2 1.1 ± 2	Scale -4 until 4 (-4 lowest importance)

Provisioning Services	Habitat Services
Regulating Services	Cultural Services

Figure X. Summary table for the ecosystem provisioning of thicket restoration sites in the Western Baviaanskloof

5.2.4 Old farmlands

Climate regulation

The average carbon sequestration level of the thicket biome in old farmlands is used as function indicator for climate regulation. It is calculated that 24% of old farmlands in the study area is located within the thicket biome. The average sequestration level is 2.4. A large area of the old farmlands (47%) is defined with the lowest sequestration level, however 34% of the area is defined with sequestration level 4.

Erosion prevention

The average erosion prevention for the studied old farmlands is 2.4. 83% of the old farmlands has an erosion prevention level of 1, 2 or 3. Only 2% has erosion prevention level 5.

Recreation and tourism

The picture (appendix 5) for old farmlands is rated relatively positive by tourists in the Baviaanskloof (Fousert, 2009). The average rating is 2.9 ± 1.6. Six tourists commented to this with: "From the road one can experience a pristine and beautiful scenery". One other tourist stated: "The route through this area is unique as, except from the road itself, there was no human interference".

Summary table

Ecosystem service	Subservice	Indicators	Outcome	Unit
Food provisioning	None	-	-	-
Provision of raw materials	None	-	-	-
Water supply	Unknown	-	-	-
Climate regulation	C-sequestration: Spekboom	Function indicators: C-sequestration level (root+soil)	2.4	Scale 1-5, (5 is highest seq. level)
Erosion prevention	Erosion prevention	Function indicator: Erosion prevention (inverse erosion risk)	2.4	Scale 1-5, (5 highest prevention)
Regulation of water flows	Unknown	-	-	-
Protection of gene pool	Unknown	-	-	-
Opp. for recreation and tourism	Tourism	Function indicator: Qualification tourists	2.9 ± 1.6	Scale -4 until 4 (-4 lowest importance)

	Provisioning Services
	Regulating Services
	Habitat Services
	Cultural Services

Figure X. Summary table for the ecosystem provisioning of old farmlands in the Western Baviaanskloof

5.2.5 Intact thicket

Climate regulation
Intact thicket can sequester a high amount of carbon. On average the total stored carbon in soil and roots of Spekboom in intact thicket is 104 t C ha^{-1} (Mills and Cowling, 2010). The average sequestration level of intact thicket is 4. A percentage of 74% of the intact thicket falls in category 4, 13% of the area in level 3 and also 13% in level 5.

Erosion prevention
The average erosion prevention level for intact thicket is 3.4 in a 1-5 scale. This is a relatively high number, 65% of the intact thicket area in the Baviaanskloof Nature Reserve has an erosion prevention level of 4.

Regulation of water flows
The preliminary results of the research in Van Luijk (2011) are used as service indicators for water regulation for the land use types grazing land and intact thicket. Several indicators are used to measure the water regulation as indicated in figure X.

Indicators for regulation of water flows	
Drying after rainfall event	Takes long to dry
Moisture depth	20 cm
Moist topsoil	20-35%
Peaks after rainfall events	high
Increase in moist at topsoil after rainfall	15-45%
Soil moist after 9 days no rain	26%
Stable soil moisture (depth 50 cm)	30%
Infiltration speed	26 to 29 mm/h
Run-off	low

Figure X. Preliminary data of service indicators for water regulation at grazing lands in the Baviaanskloof (Data Van Luijk 2011)

Protection of gene pool
For the protection of gene pool service the species richness measured by Lechmere-Oertel (2009) is used as function indicator. In this research different sites (N=8) are measured where there was a fence-line contrast between intact and transformed (through grazing) land. The average species richness for intact thicket was 23 ± 7 and the Shannon's diversity index (Zar, 1999) 3,19 ± 0,84.

Recreation and tourism
The pictures of intact thicket are rated relatively high, with picture 3 rated 2.3 ± 2 and picture 5 as 1.9 ± 2 (Appendix 5) so the average rating was 2.1. Three tourists explained the rating by saying: "This landscape offers pristine and untouched nature". Three other tourists commented with: "This area should be preserved from human influences".

Summary table

Ecosystem service	Subservice	Indicators	Outcome	Unit
Food provisioning	None	-	-	-
Provision of raw materials	None	-	-	-
Water supply	Unknown	-	-	-
Climate regulation	C-sequestration: Spekboom	Function indicators: C-sequestration level (root+soil)	4	Scale 1-5, (5 is highest seq. level)
Erosion prevention	Erosion prevention	Function indicator: Erosion prevention (inverse erosion risk)	3.4	Scale 1-5, (5 highest prevention)
Regulation of water flows	Multiple	Multiple service indicators	Table X	Table X
Protection of gene pool	Biodiversity	Service indicator: species richness Spekboom habitat	23 ± 7 3,19 ± 0,84	Nr of species Shannon's index H
Opp. for recreation and tourism	Tourism	Function indicator: Qualification tourists	2.3 ± 2 1.9 ± 2	Scale -4 until 4 (-4 lowest importance)

(green)	Provisioning Services
(purple)	Regulating Services
(blue)	Habitat Services
(orange)	Cultural Services

Figure X. Summary table for the ecosystem provisioning of intact thicket in the Baviaanskloof Nature Reserve

5.3 Comparison and visualization of ecosystem services per land use type

The previous paragraph (5.2) explained the quantification for each land use type. This paragraph will put the information together in graphs and maps to integrate the information and to see the difference in service provision between the main land use types in the Baviaanskloof. By doing this new conclusion can be drawn on the impact of land use on the provisioning of ecosystem services.

Regulation of water flows
The regulation of water flows is described by the service indicators listed in table X, which are measured at a monitoring plot in the Baviaanskloof (Van Luijk, 2011). Although the results in this table are preliminary results of a long term research, it already shows a clear difference between the two land use types. The measured data at the intact thicket plot indicate a higher water retention and erosion prevention.

	Intact thicket	**Grazing land**
Drying after rainfall event	Takes long to dry	Dries quick
Moisture depth	20 cm	40 cm
Moist topsoil	20-35%	5-20%
Peaks after rainfall events	high	low
Increase in moist at topsoil after rainfall	15-45%	4-16%
After 9 days no rain	26%	8%
Stable soil moisture (depth 50 cm)	30%	10%
Infiltration speed	26 to 29 mm/h	0.2 to 10 mm/hr
Run-off	low	high

Figure X. Preliminary data of service indicators for water regulation at grazing lands in the Baviaanskloof (Data Van Luijk 2011)

Protection of gene pool
For the protection of gene pool is the average species richness and related Shannon's index used as function indicator for the subservice biodiversity (Lechmere-Oertel et al., 2005). These data were only available for intact and transformed thicket. The data for transformed thicket are used as function indicator for the subservice biodiversity for the land use type 'grazing land'.

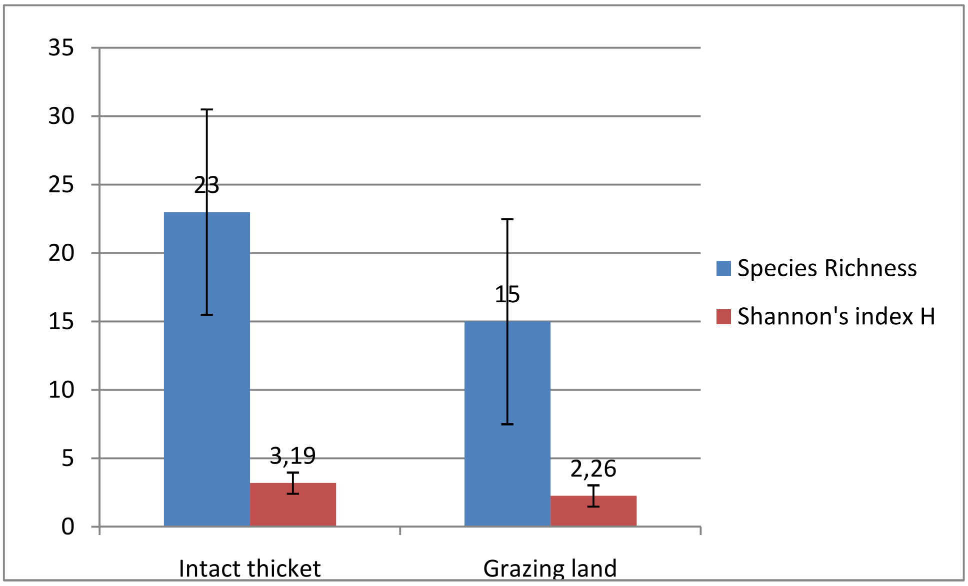

Figure X. Difference in species richness between intact and grazing land (based on data Lechmere-Oertel et al., 2005)

The graph shows a clear difference in species richness between the two land use types. The intact thicket as a higher species richness compared the transformed thicket by grazing (Lechmere-Oertel et al., 2005).

Climate regulation

For all the studied land use types the average carbon sequestration level is calculated (described in paragraph 4.1.4). This resulted in the carbon sequestration map in figure X (based on data from Mills 2010 and Powell 2011).

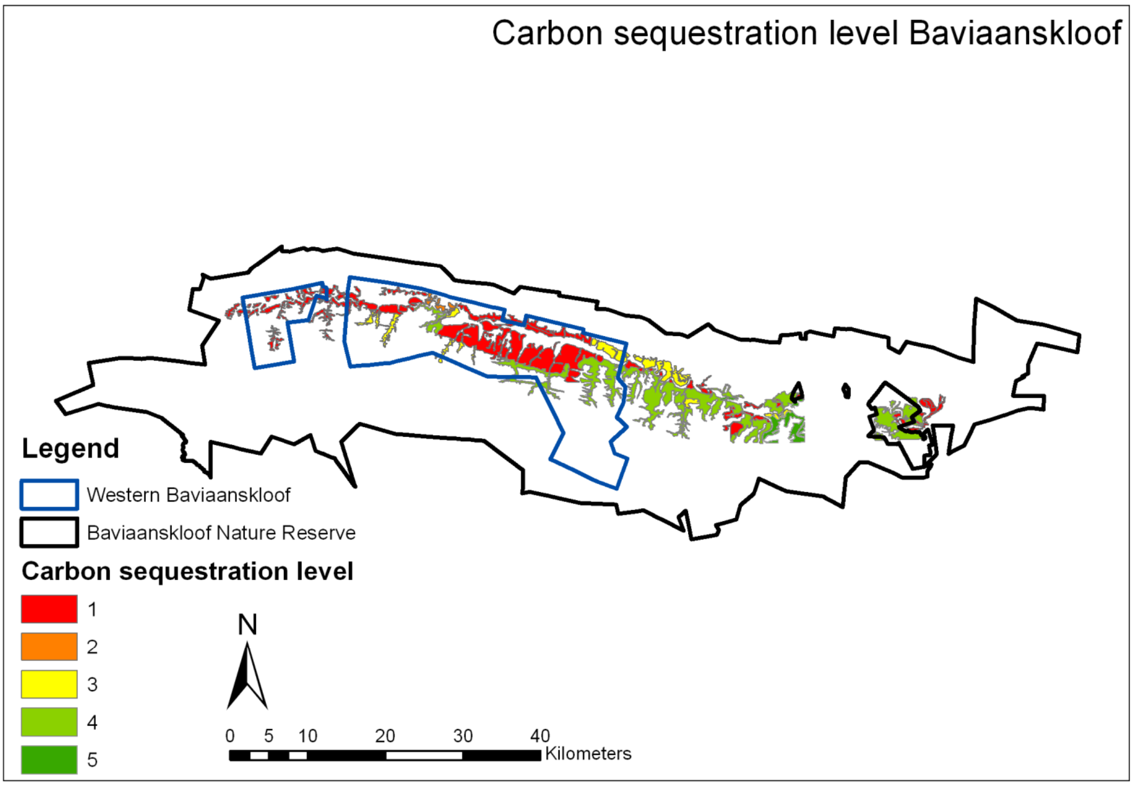

Figure X. Carbon sequestration map based on sequestration level of Spekboom in the thicket biome of the Baviaanskloof (based on data Mills and Vlok 2010)

The figure shows that the carbon sequestration level is the lowest within the private lands, compared to the thicket biome in the Nature Reserve. By comparing the average sequestration level of each of the land use types, it appears that Intact thicket has the highest sequestration rate, followed by the old agricultural lands (figure X).

The carbon sequestration is only calculated for Spekboom within the thicket biome. However not all land use types are located within the thicket biome. In table X below the percentages of each land use type that falls within the thicket biome are given. These data are based on map calculations. It shows that only 2% of the arable land is located within the thicket biome. It also shows that the restoration plots are located for only 14% within the thicket biome. This is probably the result of errors due to the used drawing methods to indicate the locations of the land use types (this is further described in the Discussion, paragraph 6.1).

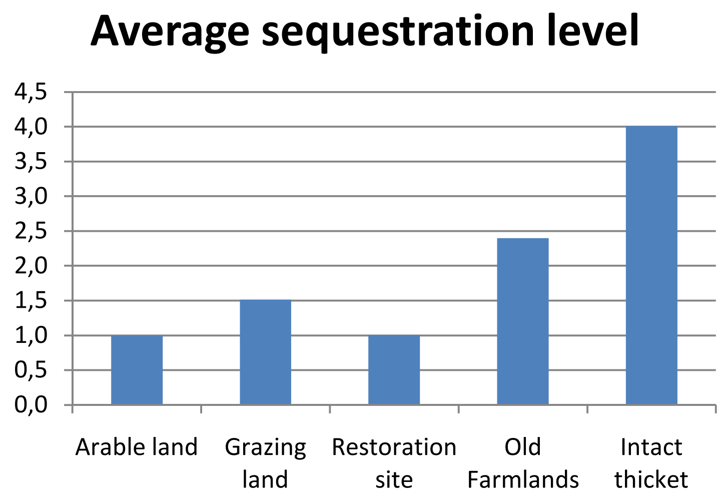

Figure X. The average sequestration levels for each of the land use types in the Baviaanskloof.

land use type	% of area in thicket biome
Arable land	2
Grazing land	40
Restoration plots	14
Old agricultural lands	24
Intact thicket	100

Figure X. Percentage of land use types located within the thicket biome

Erosion prevention

The average erosion risk is used as inverse function indicator to quantify the service erosion prevention. In figure X the erosion risk map of the Baviaanskloof watershed is given (Draaijer, 2010). The calculation of the erosion risk is based on the vegetation density, slope and rainfall.

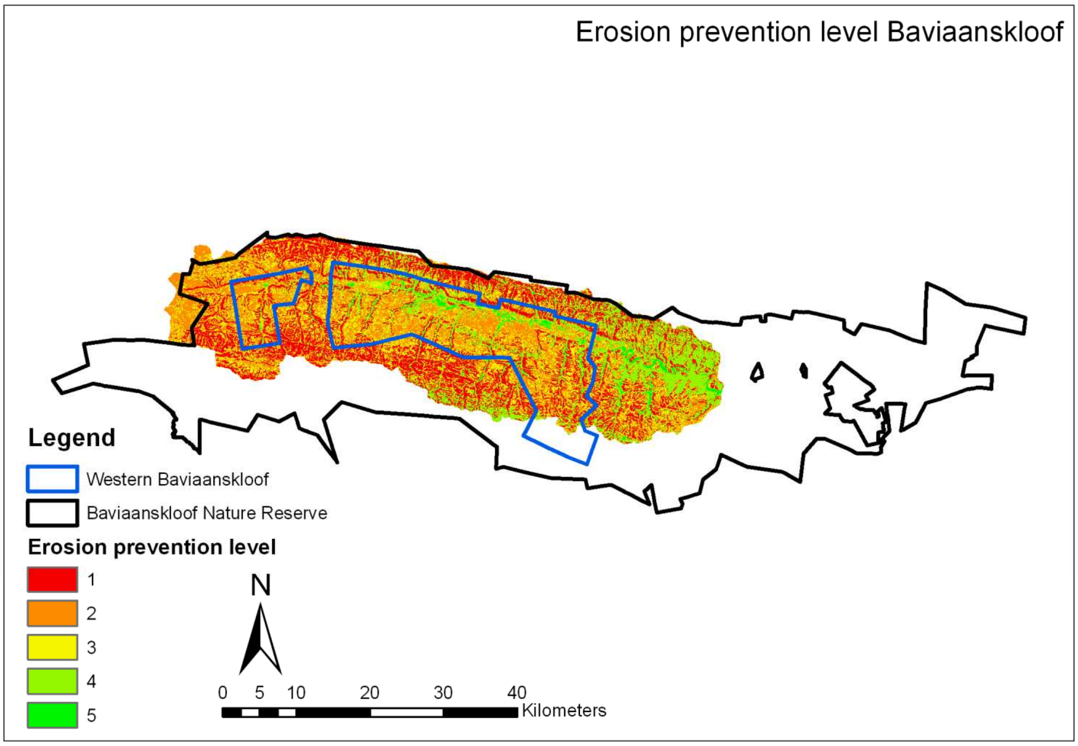

Figure X. Erosion prevention map for the Baviaanskloof Catchment (based on data Draaijer 2010)

In figure X below the average erosion prevention for each land use type is calculated. It shows that both grazing land and intact thicket have the highest erosion prevention level. Restoration plots seem to have the lowest erosion prevention.

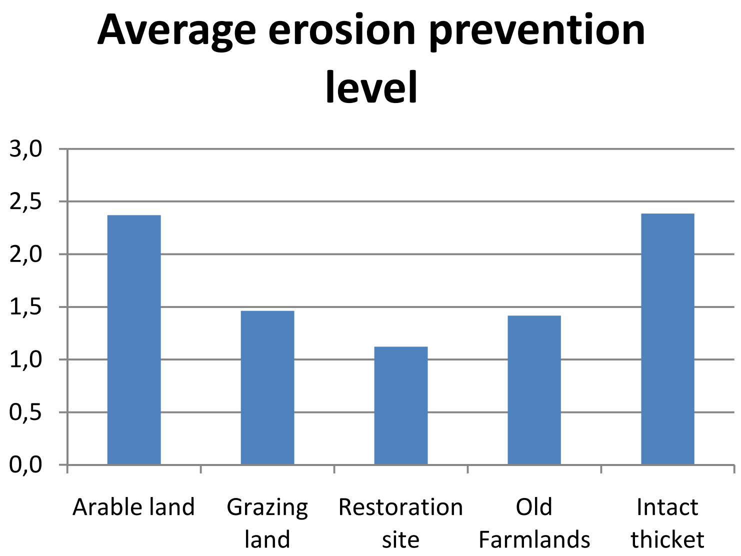

Table X. Average erosion prevention level for all land use types

Opportunities for recreation and tourism
The quantification of the attractiveness of landscapes by tourists is based on the qualification of tourists of different pictures of the land use types (Fousert, 2009). These data are used as function indicator. In figure X the quantified data are presented. It gives a clear indication that the agricultural lands are both qualified negatively on average. Old agricultural lands however are rated the highest.

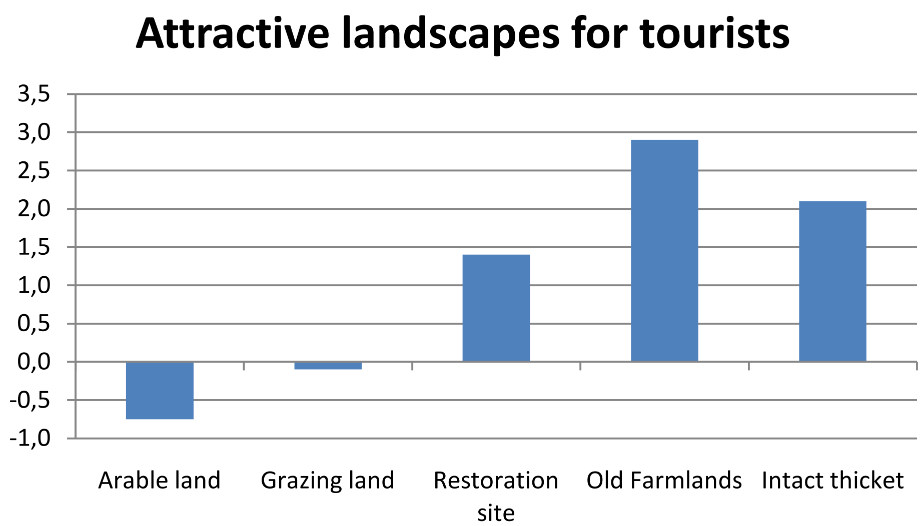

Table X. Average attractiveness of the land use types for tourists in the Baviaanskloof

During the interviews the farmers were asked to also indicate the tourist locations in the cadastre maps. It is asked how many tourist visit these places each year. Based on the data of three farmers the calculated average number of tourists per bed per year is between 50 and 100. The farmers with the most beds for tourists do not seem to have a higher average per bed per year. So based on these data it seems that tourists are distributed quite evenly over the different tourist locations in the Baviaanskloof. Even though the tourists qualified the agricultural land use types grazing land and arable land relatively low, the tourists do still go to the tourist locations at the farmers properties.

In figure X below the ecosystem services are indicated that could be described for all land use types. The provision services are grouped together to indicate the absence of this service type in three of the five land use types. The services on 'regulation of water flows' and 'protection of gene pool' are not indicated in this figure since these could not be recalculating to a 0-100 scale. The shape of the pentagon shows the relative difference in service provisioning between the different land use types. The pointed pentagon of 'carbon sequestration' shows the big difference in sequestration rate between intact thicket and grazing land. The relative circular pentagon of 'attractiveness' seem to have a more equal outcome for intact thicket, old agricultural lands and restoration plots and a relative low outcome for the arable and grazing lands, although these agricultural lands are the only land use types providing provisioning services.

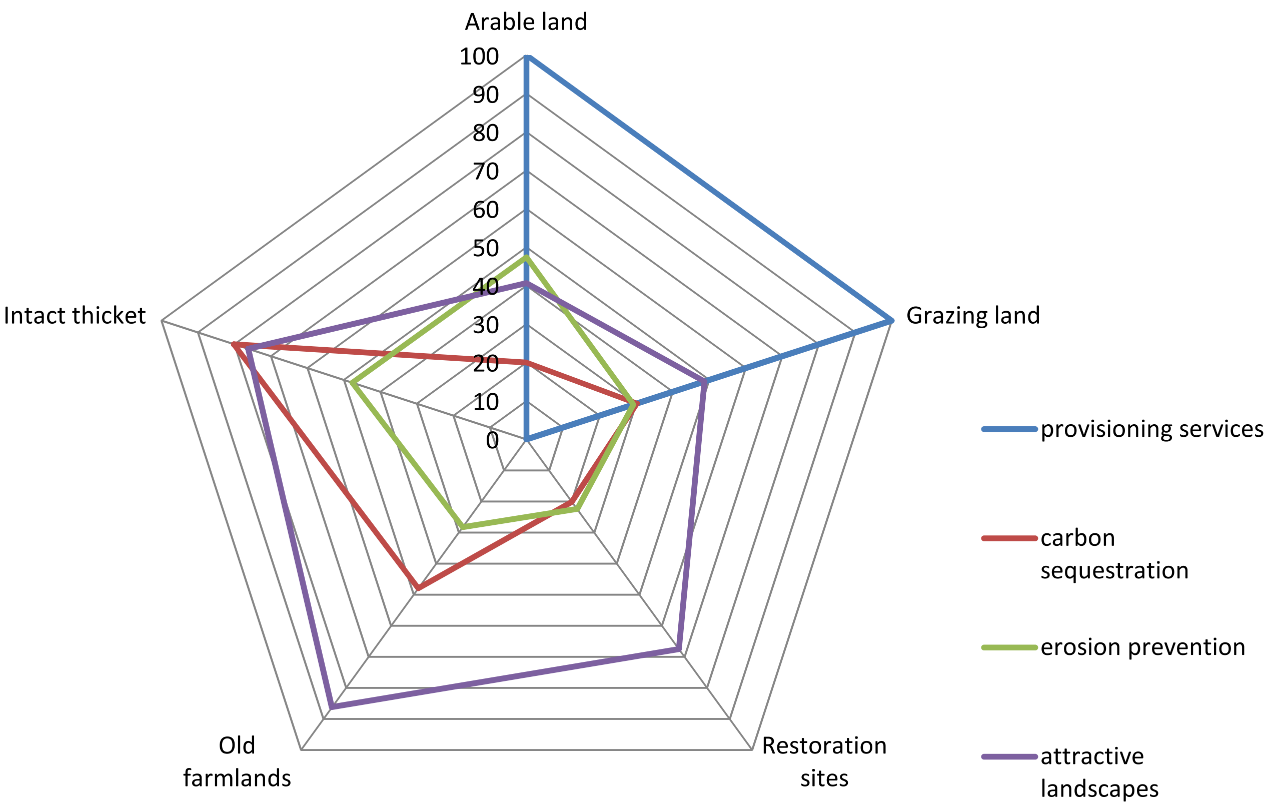

Figure X. Web diagram indicating the relative provisioning of ecosystem services by five land use types in the Baviaanskloof in a 0-100 scale.

6 Discussion

The discussion is divided in two parts, one on the used methods (paragraph 6.1) and the other on the results (paragraph 6.2) of the research. These two parts are discussed by using the same structure as used for the Methods (chapter 4) and Results (chapter 5). First the land use identification and mapping is discussed. After that the quantification of the different ecosystem services will be looked at. At last the comparison and visualization of the service provision of the land use types will be discussed.

6.1 On methods

Land use identification and mapping

The land use identification and mapping was an essential step for the quantification and understanding of the impact of land use management. The identification of the main land use types is based on interviews with farmers in the Western Baviaanskloof. This resulted in a list of the five main land use types: arable land, grazing land, thicket restoration sites, old farmlands and intact thicket. These land use types are broad groups since every land use type is a combination of different management intensities and activities. Because of time limitation and lack of information it was not possible to quantify ecosystem services for more specific land use types.

During the interviews the farmers were asked to draw their land uses in cadastre maps of the farmers. These drawings are used to digitize the main land use types in a map of the Baviaanskloof (example of drawing farmer in Appendix 2A,B). The methodology based on the drawings of farmers is a time intensive activity. After digitizing all the drawings in arcGIS, it appeared that there were some inaccuracies in the map. For example only 14% of the area of the drawn thicket restoration sites are located within the thicket biome. When assuming that the locations of these sites are planned within the thicket biome, the sites are not located right in the map. Subsequently there was a big difference in the level of detail between the drawings of the farmers. Some farmers made detailed drawings with all the land uses explained, other farmers explained everything more verbally and did not draw very detailed maps. So this resulted in a digitized land use map with a different level of detail per cadastre.

However, the methodology of drawing and mapping also provided another inside in the case study. Behind each ecosystem service there is a story. As also can be seen in the framework (figure X) ecosystem services are subject to policy, external driving forces, economic developments etcetera. By asking the farmers about some ecosystem services the farmers started to tell about the drivers that influence their production and choice of land use management. This appeared to be a valuable source of information of putting the ecosystem services more in perspective.

For the mapping it is chosen to limit the case study to the farmers, although there are also other stakeholders living in the Western Baviaanskloof. The farmers that were subject of this research are the biggest producers in the Baviaanskloof, since they own large areas of land with intensive crop and livestock production. Since the research was focussing on the impact of land use management, this was the most interesting stakeholder group to look at. However, it is essential to realize that some ecosystem services (of other stakeholders) were not taken into account in this study. It would be interesting to do a similar study for the communities living in the Baviaanskloof. As described in the report of Janssen (2008) this stakeholder group has different provisioning and cultural services compared to the farmers (Janssen, 2008). So ecosystem services are not objective, it depends from which stakeholder perspective the study is done for the selection of services and indicators. For example for the Eastern Cape Parks and Tourism Agency (ECPTA) the charismatic animals in the Baviaanskloof Nature Reserve are important indicators for tourism opportunities. But for the farmers some of these animals, like the Leopard and Caracal , is a threat for their livestock. So there is a trade-off between the ecosystem services between stakeholders.

Quantification of ecosystem services
The choice of indicators for quantifying ecosystem services is an essential step and determines the outcome of the quantification. Indicators can describe different components of the framework (figure X). When the calculated production potential is used as indicator, it is defined as function indicator. When the service itself is measured and quantified (e.g. the measured harvest as provisioning service) it is defined as service indicator. Indicators are per definition a partial description of the real situation. Therefore a number of indicators should be used for the quantification to give a more weighted outcome. All the data used for this research were based on existing literature and the available information of the farmers. So for this research it was not always possible to find multiple indicators. Subsequently, the quantification of ecosystem services implies a static description of a constantly changing environment. This does not fully correspond with the real situation in the Baviaanskloof, farmers are constantly adapting to environmental (such as flooding, rainfall events, predation on livestock etc.) and economic (e.g. changing market prices) developments. That is a consequence of the quantification method. These implications of the method should be realized when data are used and communicated to stakeholders.
For the quantification of the studied ecosystem services (table X) different methods are used for each of the ecosystem service types (provisioning, regulating, habitat and cultural). Below the methodology is discussed per ecosystem services type.

The provisioning services are quantified based on data given during the interviews with the farmers. During some interviews not all questions could be asked and consequently some data was missing. By assuming that the average production (for example the average lucerne harvest per hectare per year) was the same between the different farmers, the production could be calculated. In some cases the drawings were used to calculate the size of a land use type of a farmer. In some cases the size said by the farmer did not correspond with the drawn size. In these situations it is assumed that the farmers probably know the size of their land better than they can draw it, so the said area size was probably a better estimate.

The quantification of the regulating services is based on literature and a GIS analysis. In literature the land use type 'grazing land' is often not mentioned as such. In some literature data could be found for degraded lands caused by overgrazing. So these data are used as indicator for the most degraded areas in grazing land. This area is indicated in figure X.
For the ecosystem service 'climate regulation', the carbon sequestration by the succulent plant *Portulacaria afra*, also named 'Spekboom', is used as indicator. This is a key species of the semi-arid subtropical thicket biome. By focussing on just the carbon sequestration in this particular plant, the carbon storage in other plants is not taken into account. Also the livestock on the grazing land might have a negative impact on climate regulation because of the methane emission by some livestock. However for this research it is chosen to use the total carbon sequestration in the soil and roots of Spekboom as function indicator for the climate regulation. Spekboom can sequester a relative high

amount of carbon and has a positive influence on the water regulation (ref!). This plant is the key species for the current restoration activities in the Baviaanskloof, and it might create an economic incentive for restoration based on the carbon credit potential within the CDM (Clean Development Mechanism) regulations (Powell et al., 2011).
For the calculation of the average carbon sequestration per land use type existing GIS data (Vlok, 2010) and literature (Mills and Cowling, 2010; Powell et al., 2011) had to be combined (described in paragraph 4.2.4). For this calculation a linear relation between degradation category and sequestration rate is assumed. Based on this assumption the carbon sequestration could be calculated for all the categories. However the used historical Spekboom density data (Vlok 2010) do not have even intervals (table X). For this reason the sequestration rate is not presented in the unit t C ha^{-1} but in a scale from 1 till 5, with 1 indicating a low sequestration level. Since the sequestration by Spekboom is used as indicator, the calculations were focussing on the thicket biome within the land use type areas. However, only 2% of the arable land is located within the ticket biome and only 14% of the restoration sites. Old farmlands and grazing lands were located within the thicket biome respectively 24% and 40%. Obviously 100% of the intact thicket was located within the thicket biome.
The erosion prevention level is also calculated by using a GIS analysis. Yet, an existing erosion risk map (Draaijer, 2010) had first to be converted to an erosion prevention map, this is done by taking the inverse of the erosion risk map. The indicators used to make the erosion risk map were vegetation cover and slope. So the resulting map on erosion prevention is also based on these two indicators. It should be noted that erosion is caused by more factors than these two. In paragraph 6.1 the results of the quantification based on this map are further discussed.
For describing the water regulation service some preliminary measurements at a monitoring plot in the Baviaanskloof are used as service indicators (Van Luijk, 2011). Since no other data was available for different land use types, it is chosen to use these preliminary data.

Biodiversity is an important ecosystem services since it is a widely used term in policy and mentioned by stakeholders. The word is interpreted in many ways, for some it is a function indicator for tourism and for others a high biodiversity means a healthy ecosystem. Yet it is hard to find the right indicators for describing biodiversity for the right interpretation. Since this research was limited by the available data for selection of indicators, it is chosen to describe biodiversity based on the study of Lechmere-Oertel (2005). In this research the species richness is counted in intact and in degraded thicket. These data give an indicator of the impact of degradation on the biodiversity in the thicket biome. Obviously this is interesting data and quantifies the impact of a certain management. But it is also a limited set of data for drawing conclusions for the entire Baviaanskloof.

Tourism opportunities is an important ecosystem service for the farmers in the Baviaanskloof. All the studied farmers have tourist accommodations and activities, it is a growing source of income for many farmers. However, cultural services are generally hard to quantify and to find the right indicators for. Two methods are used for the quantification. During the interviews the farmers were asked to draw the tourist location (such as lodges and campsites) in the cadastre maps. Also data was gathered about the average amount of tourists visiting the locations. After gathering these data it appeared to be hard to relate these data to the specific land use types, although these were interesting data. So other data was needed to describe this service for each land use type. Since tourism opportunities is such a subjective service, it would be interesting to include some data based on a survey with questionnaires. Data from Fousert (2009) are used which describes the qualification of tourists of different pictures of the Baviaanskloof. For this research those pictures were selected that showed the main land use types of the Baviaanskloof. The limitation of this method is that a certain qualification of a picture does not have to correspond with the real qualification of the land use types by the tourists. The results of this methodology are further discussed in paragraph 6.1.

Comparison and visualization
The comparison of the ecosystem services per land use type is put together by making a web diagram (figure X). The ecosystem services that could not be quantified for all the land use types (like biodiversity and water regulation) could not be indicated in the diagram. The web diagram has only one scale, so all the values of the ecosystem services had to be recalculated to a 1-100 scale. This was possible to do since the data on carbon sequestration, erosion prevention and tourism opportunities were already in a scale without a unit. It is decided to also include the provisioning services as a group in the diagram, although these are indicated through a different methodology. The outcomes of the production units (such as the mohair or seed production per year) could not be compared between grazing land and arable land since they describe different products and use different units. The aim of the web diagram is to compare the different land use types. So the land use types that do provide provisioning services for the farmers is put on 100 and the land use types without provisioning services on 0.

6.1 On results

Land use identification and mapping
An older version of a land use map of the Baviaanskloof (Janssen, 2008) shows some differences with the map based on the drawings (Appendix 6). The map of Janssen (2008) gives more detailed categories of grazing lands, but does not indicate arable land and old farmlands. Based on the data of Janssen (2008) a much bigger area could be assumed of active grazing. One of the most remarkable results of the land use map based on the drawings (figure X) is that 45% of the land of the farmers is defined as old farmlands. It was known before that farmers do not use parts of their land, but it was not indicated as such in a map before. Yet, there are several reasons why farmers do not use part of their lands and it is not known for how long these areas are not in use.
The Eastern Cape Parks and Tourism Agency (ECPTA) initiated a mechanism, the Biodiversity Stewardship Programme, in which land within the Western Baviaanskloof can be protected through contract agreements with private landowners. There are several levels of agreements depending on the level of commitment between the farmer and ECPTA. The large area in the Western Baviaanskloof defined as old farmland can be seen as potential areas for the Biodiversity Stewardship Programme.

Quantification of ecosystem services
In this report only the carbon sequestration data on the current storage of carbon per hectare are described. It would be interesting to also calculate the carbon accrual potential for the future. However there is no consensus about which number to take. The carbon accrual rate of 4.2 t C ha^{-1} yr^{-1} and 2.4 t C ha^{-1} yr^{-1} are measured at Krompoort in South Africa and the figure 0.4 t C ha^{-1} yr^{-1} is measured at the Fish River Nature Reserve (Powell et al., 2011). It is not known which are the most realistic estimates to adopt and whether there is a relation between current carbon storage and the accrual rates. Therefore these numbers are not used as indicators for climate regulations. Yet, when

more is known about the carbon accrual potential in the Baviaanskloof, it would be valuable to use it as indicator for the service 'climate regulation'.

The results of the quantification of the erosion prevention level shows that both arable land and intact thicket have the highest levels compared to the other land use types. However the high prevention level of arable lands do not correspond with observation of experts in the Baviaanskloof (pers com). As described in the discussion on methods (paragraph 6.1) the indicators used for the erosion prevention map are limited, it is based on slope and vegetation density. These indicators were originally used for making the erosion risk map. But for describing the erosion prevention level, these indicators are not sufficient.

For the service Aesthetic information the average qualification of 35 tourists of pictures of the Baviaanskloof is used as indicator. For each of the land use types two pictures are selected from Fousert (2009) (Appendix 5). Both arable and grazing land have a negative average qualification, old farmlands have the highest qualification. By looking at the pictures it appears that for grazing land pictures are used in which a highly degraded field is shown. And for the land use type 'old farmlands' a picture is selected that shows a Four Wheel Drive car driving in the mountains. Since not the entire grazing land is as degraded as shown on the pictures and not all old farmlands looks like the scene on the picture, the used methodology does not fully describe the qualification of the specific land use types but rather the scenes shown in the pictures. In addition, the farmers were asked to draw the tourist locations in the cadastre map and asked about the number of tourists visiting these places. It appeared that even though the tourists rate the agricultural services (arable and grazing land) relatively low, they still go to the farms where these land use types are. The farmers were also asked to draw the hiking and Four Wheel Drive trails in the cadastre maps. These drawings show that many of these trails are located at the old farmlands. This indicates that the tourists have a preference for certain land use types, but still go to the places where the facilities are. However, since many farmers start to construct hiking and Four Wheel Drive trails on their lands, the old farmlands seem to have a high potential for this purpose.

Another feature of the Baviaanskloof that is highly understudied, is the existence of the many rock paintings. These are remains of the former presence of the San and Khoekhoen tribes in the Baviaanskloof. More than 200 heritage sites have been discovered in the area, for which is estimated that it only represents 10% of those in existence (Boshoff, 2005). This cultural heritage has a high tourism potential and might become an important indicator for the cultural services in the Baviaanskloof.

Comparison and visualization

The web diagram (figure X) is a useful figure for comparing different land use types for a wide range of services. However it is also a figure that is easy to misinterpret. Since all the ecosystem services are put in the same scale, it can be misinterpreted that the figure can be used to compare the ecosystem services. This is not the case since the data are based on different indicators and different scales. For example, the carbon sequestration is higher than the erosion prevention in intact thicket, no conclusion can be drawn based on this. In the web diagram the ecosystem services can only be compared between the land use types.

The results of this research may seem to suggest that there is direct relation between land use and the provision of ecosystem services. However, these data illustrate the difference in service provisioning between the services. By using 'intact thicket' as reference site, the results could be compared and a conclusions can be drawn on the impact of land use. However, it should be realised that the underlying factors in the complex biophysical system supporting the landscape properties are not studied for this research. Therefore the outcomes should be interpreted as an indication of the impact of land use.

7. Conclusions

The objective of this research was to compare ecosystem services provided by the main land use types in the Baviaanskloof in South Africa. Based on this comparison a few conclusions can be drawn. The study shows that 'grazing land' and 'arable land' are the only land use types with provisioning services. The studied provisioning services have a direct connection with the market, and with this it provides revenue for the farmers. But the results also show a decrease in regulating services when arable and grazing lands are compared with the reference site 'intact thicket'. Especially intensive grazing lands show a strong decrease in regulating services (for carbon sequestration, erosion prevention and water regulation). Since the regulation of a landscape influences the provisioning services, these data support the theory that worldwide current land use activities cause benefits on the short term, but diminish the capacity of ecosystems to provide their services on the long term (Foley et al., 2005).
The results also suggest that old farmlands have a relatively high tourism potential compared to the other land use types. Tourism is a growing source of income for the farmers, and some farmers are using their old farmlands for tourism activities. However, when looking at the numbers of tourists visiting the lodges and campsites of the farmers, it seems that the tourists are distributed relatively even over the location in the Western Baviaanskoof. So tourists seem to have a priority for certain land use types or landscapes, but stay at the places where the facilities are. Another remarkable outcome of this research is the high percentage of land that is defined as 'old farmland', 45% of the study area. This can be seen as potential areas for Biodiversity Stewardship agreements between the farmers in the Western Baviaanskloof and Eastern Cape Parks and Tourism Agency (ECPTA).
Still a minor area in the study area is defined as restoration sites. It is expected that these areas will grow in the future, since more and more farmers are willing to restore parts of their lands by replanting Spekboom truncheons. This replanting can create revenue for the farmers in the future when they will be able to sell carbon credits under the CDM (Clean Development Mechanism) regulations.
The restoration sites have still a relatively low outcome in the provision of ecosystem services. It is assumed that these areas will be restored to an area comparable to intact thicket. These data show that the restoration does not seem to provide more service yet. But these are potential intact thicket areas for the future. So by restoring the thicket biome, also the regulation functions of these areas will be restored.

Except from the results also some conclusions can be drawn based on the used methodology for this research. The mapping based on the drawings of farmers appeared to be of great help of locating all land use types, but also to put the ecosystem services in context. Each ecosystem service is subject of landscape management, external drivers and economic developments, which is also indicated in the conceptual framework (figure X). When farmers are asked about the ecosystem services, they talk about these factors. This makes the situation more complex, but it helps to understand the system and the motivations of the farmers to chose for certain management. When only looking at literature for quantification of the services, these different factors will be missed. So by combining the literature study with the talking with farmers a connection is created between literature and reality. Based on the experiences acquired in this research it is concluded that this is an essential step in an applied study on ecosystem services.

Another result of the interviews was the land use map based on the drawings of the farmers. Also this seemed to be very useful for the further quantification of the ecosystem services. There are quite some GIS data available on the Baviaanskloof. When combining and overlaying these data with land use maps, new conclusions can be drawn on the existing data. Ecosystem services are not only result of the land use management but also of the ecosystem properties (as indicated in the conceptual framework). When using spatial data, ecosystem properties can be taken into account. The web diagram is used for showing the differences in the provisioning of a broad range of services between the different land use types. This figure is a nice way to present the results and to integrate all the research. However, it is also a risky figure because it can easily be misinterpreted. The figure can be used for comparing the different land use types, but it is not possible to compare the different ecosystem services in this figure. Therefore it is important that this figure is explained when it is used for whatever purpose.

Indicators are needed for quantifying ecosystem services. However, indicators do per definition not describe the ecosystem service entirely, it is an indication of the ecosystem service. For that reason preferably multiple indicators should be used for describing an ecosystem service for giving a more weighted outcome. Because of time limitation and limitation of data it was not possible to find multiple indicators for each ecosystem service for this research. It is essential to realize that outcomes of ecosystem service studies are defined by the choice of indicators. These play a central role in the quantification and thus in the outcome. An example in this research is the quantification of erosion prevention. The erosion prevention map is based on the indicators slope and vegetation density. This is a limited number of indicators and does not fully cover all the factors that prevent erosion. In this research the results show a high erosion prevention at arable land, although it is experienced that there is a high erosion around these arable lands in the Baviaanskloof. So apparently some key indicators are not taken into account for describing this ecosystem service. When communicating quantified ecosystem services, it is of high importance to communicate the underlying indicators.

This research has been limited to the farmers in the Baviaanskloof. The land use types are identified based on the land uses of the farmers, and also the ecosystem services are related to the farmers. When the research would for example have been limited to the communities in the Baviaanskloof, other land use types and other ecosystem services would have been selected.

One of the objectives of this research was to identify the gaps in knowledge. During the research it was realized that some main ecosystem services in the Baviaanskloof could not be quantified because of lack of data. An important ecosystem service in the Baviaanskloof is the moderation of extreme events like flooding and fires. However, it was hard to find indicators for these services and even harder to find quantifiable data. Erosion prevention has been quantified for this research, but the underlying indicators are very limited. At this moment there is no more data available on this services. Since erosion is such a big problem in the Baviaanskloof is this also one of the major gaps in knowledge. Another important ecosystem service is biodiversity. Also this ecosystem service is quantified in the research, but this was limited to the land use types intact thicket and grazing land (degraded thicket). Biodiversity is an important ecosystem services since it says something about the state of the ecosystem but is also an important factor for tourism. So quantified data on biodiversity (preferably in maps) was also one of the major gaps in knowledge.

8. Recommendations

- Detailed land use map entire Baviaanskloof
- Missing data on biodiversity – more data on the biodiversity in the Baviaanskloof. If indicated in a map it would be very interesting data! So challenge is to find the right indicators for describing this ecosystem service.
- More research on old farmlands
- Expand to more stakeholders in the Baviaanskloof, such as the communities and other landowners
- Expand to other areas in the BMR .
- Use of web diagram for communication – always with an explanation
- Describe the ecosystem service trade-offs between stakeholders (describe the subject of conflicts between farmers and ECPTA in terms of ecosystem service and use conceptual framework)
    - Charismatic predators
    - Fire policy for burning Fynbos
    - Stewardship and restoration activities

Gaps in knowledge

- Land use of communities
- Quantified ecosystem services of communities
- Same study for more specific land use types (for example on the land use management intensities in relation with ecosystem services.)
- More indicators for the same ecosystem services (give some examples)
- Indicators for (better) describing moderation of extreme events (erosion, flooding, fires)

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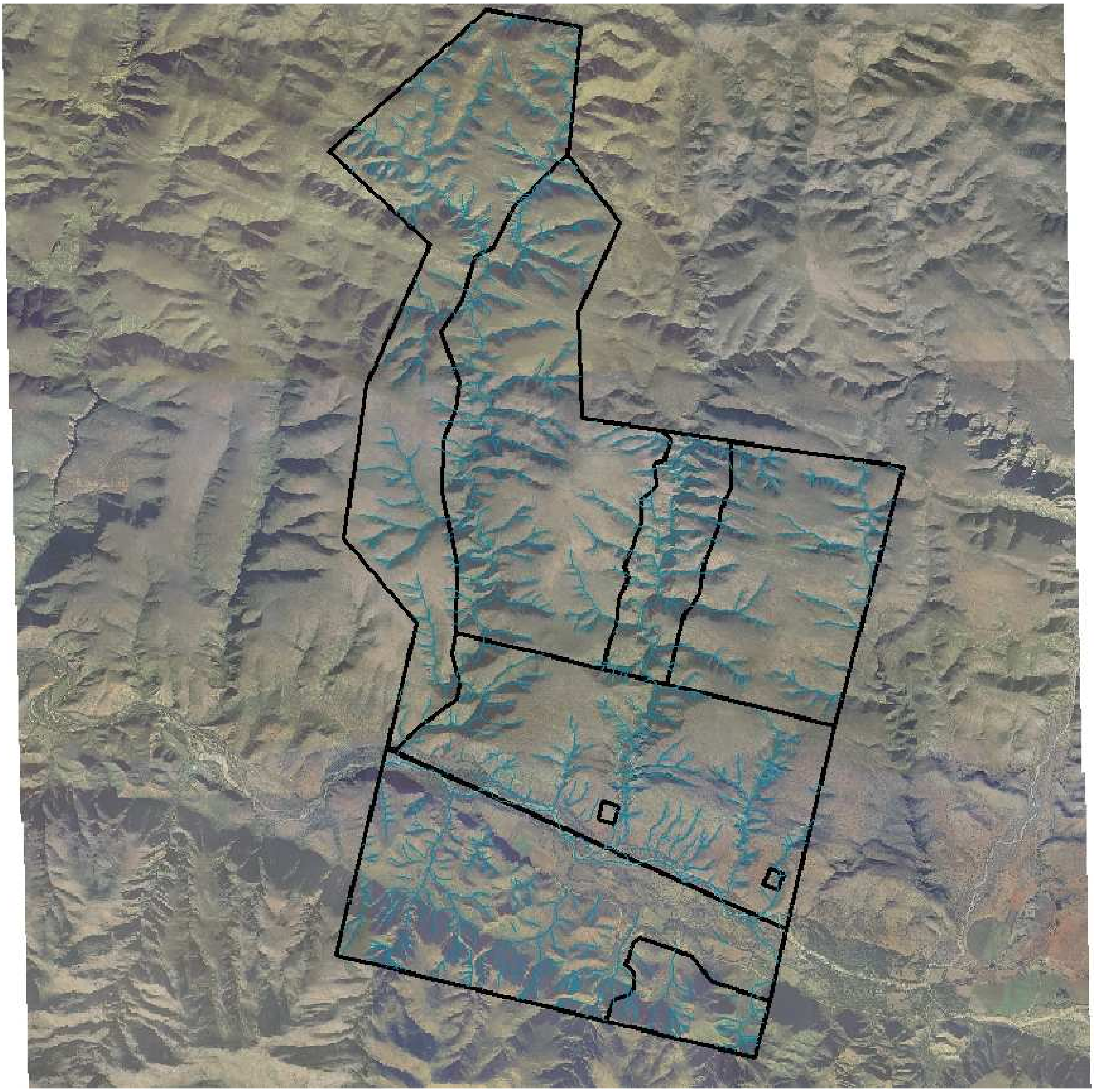
Appendix 1: Summary of degradation per property in Western Baviaanskloof (Vlok 2010)

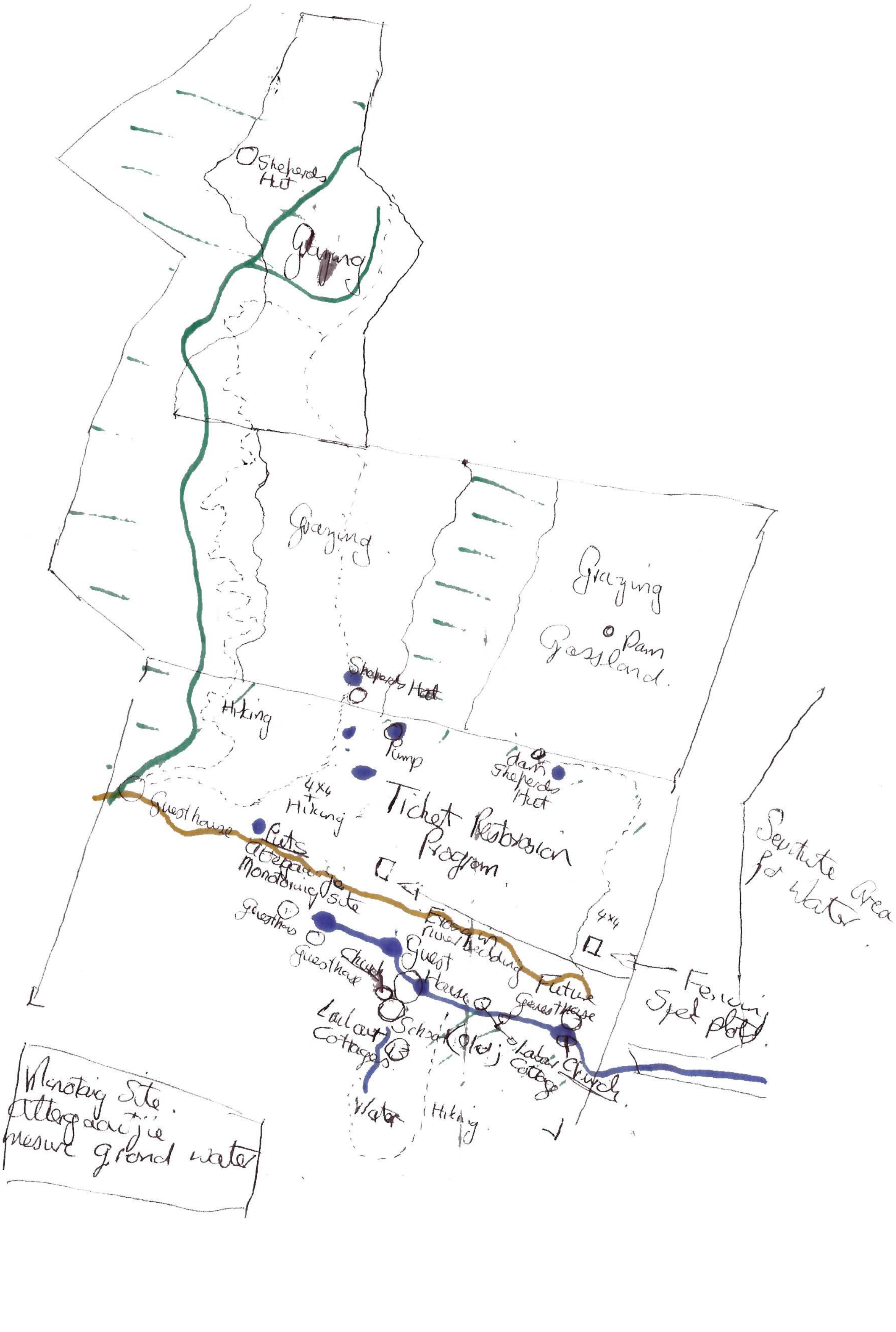
Landowner Details	Farm	TOTAL Hectares	Pristine-Moderate	% of Total Spekboomveld	Moderate	% of Total Spekboomveld	Moderate-Severe	% of Total Spekboomveld	Severe	% of Total Spekboomveld	TOTAL Spekboom Veld
BIDDULPH	BEAKOS NEK	985.3	120.2	66.5%	60.6	33.5%	0.0	0.0%	0.0	0.0%	180.8
CONGREGATIONAL CHURCH - WILLOWMORE	RIET RIVIER	29.5	0.0	0.0%	0.0	0.0%	0.0	0.0%	16.5	100.0%	16.5
CREATIVE FUTURES COMMUNITY TRUST	DE KLIP FONTEIN	614.9	34.7	17.1%	0.0	0.0%	0.9	0.4%	167.5	82.5%	203.1
DREAM WORLD INV 127 PTY LTD	ROCKSAND	347.6	0.0	0.0%	0.0	0.0%	0.0	0.0%	82.2	100.0%	82.2
DU PREEZ	VERLAATEN RIVIER	325.7	0.0	0.0%	0.0	0.0%	0.0	0.0%	86.8	100.0%	86.8
DU PREEZ FAMILY TRUST	RIET RIVIER	572.6	0.0	0.0%	0.0	0.0%	0.0	0.0%	112.0	100.0%	112.0
EDUCATIONAL TRUSTEES	DE KLIP FONTEIN	0.4	0.0	0.0%	0.4	100.0%	0.0	0.0%	0.0	0.0%	0.4
ERJEE TRUST	ZAND VLAKTE	518.8	251.5	100.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	251.5
HONEY	UITSLAG	2985.0	89.8	23.2%	0.0	0.0%	126.1	32.5%	171.8	44.3%	387.7
INITIATIVE S A INV 71 PTY LTD	DE KLIP FONTEIN	2171.7	154.5	18.3%	0.0	0.0%	0.0	0.0%	689.0	81.7%	843.5
LAMPRECHT - TRUSTEES	BEAKOS NEK	9886.8	871.5	21.1%	69.1	1.7%	419.8	10.1%	2776.9	67.1%	4137.3
LEZMIN 2087 C C	MATJESFONTEIN	2603.6	0.0	0.0%	0.0	0.0%	0.0	0.0%	186.3	100.0%	186.3
NED GER KERK - WILLOWMORE	KLIP FONTEIN	3.1	0.0	0.0%	0.0	0.0%	2.2	100.0%	0.0	0.0%	2.2
NORTJE	KOUD NEKS RANTE	4096.1	104.1	100.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	104.1
UNKNOWN	ZAND VLAKTE	1.0	0.3	100.0%	0.0	0.0%	0.0	0.0%	0.0	0.0%	0.3
REYNEKE	DE KLIP FONTEIN	500.3	0.0	0.0%	48.4	37.3%	81.2	62.7%	0.0	0.0%	129.6
ROOIKLOOF C C	ZAND VLAKTE	578.2	296.2	94.4%	0.0	0.0%	0.0	0.0%	17.6	5.6%	313.8
SEWEFONTEIN GEMEENSKAPSBOERDERY TRUST	DE KLIP FONTEIN	1410.2	6.5	1.2%	117.5	22.2%	82.1	15.5%	323.2	61.1%	529.3
SMITH D	RIET RIVIER	547.6	0.5	0.1%	0.0	0.0%	121.9	22.9%	410.3	77.0%	532.7
SMITH N	KLEIN POORT	3927.7	0.0	0.0%	0.0	0.0%	0.0	0.0%	87.1	100.0%	87.1
TERBLANCHE	RIET RIVIER	1473.9	0.0	0.0%	0.0	0.0%	0.0	0.0%	270.8	100.0%	270.8
UNITED CONGREGATIONAL	DE KLIP FONTEIN	179.0	0.0	0.0%	0.0	0.0%	33.7	73.4%	12.2	26.6%	45.9

CHURCH OF SOUTH A											
VAN DER WAT	BEAKOS NEK	1023.0	250.3	77.8%	44.1	13.7%	0.0	0.0%	27.3	8.5%	321.7
VAN RENSBURG MG	KLIP FONTEIN	800.6	0.2	0.0%	0.0	0.0%	1.2	0.3%	450.7	99.7%	452.1
VAN RENSBURG RJ	VERLOREN RIVIER	5155.0	337.3	31.8%	0.0	0.0%	436.8	41.2%	286.7	27.0%	1060.8
VORSTER	ROCKSAND	688.8	0.0	0.0%	0.0	0.0%	59.8	31.2%	132.0	68.8%	191.8
ZANDVLAKTE BOERDERY TRUST	SAND RIVER	5117.0	1261.8	69.9%	0.0	0.0%	103.6	5.7%	440.2	24.4%	1805.6
TOTALS		**46 543.4**	**3 779.4**		**340.1**		**1 469.3**		**6 747.1**		**12 335.9**

Appendix 2A: Example of aerial photograph of cadastral farmland



Appendix 2B: Example of drawing farmer on a cadastral map of his farmland



Appendix 3: Ecosystem Services TEEB

	Main service-types
	PROVISIONING SERVICES
1	**Food** (e.g. fish, game, fruit)
2	**Water** (e.g. for drinking, irrigation, cooling)
3	**Raw materials** (e.g. fiber, timber, fuel wood, fodder, fertilizer)
4	**Genetic resources** (e.g. for crop improvement and medicinal purposes)
5	**Medicinal resources** (e.g. biochemical products, models & test organisms)
6	**Ornamental resources** (e.g. artisan work, decorative plants, pet animals, fashion)
	REGULATING SERVICES
7	**Air quality regulation** (e.g. capturing (fine)dust, chemicals, etc.)
8	**Climate regulation** (incl. C-sequestration, influence of vegetation on rainfall, etc.)
9	**Moderation of extreme events** (e.g. storm protection and flood prevention)
10	**Regulation of water flows** (e.g. natural drainage, irrigation and drought prevention)
11	**Waste treatment** (especially water purification)
12	**Erosion prevention**
13	**Maintenance of soil fertility** (incl. soil formation)
14	**Pollination**
15	**Biological control** (e.g. seed dispersal, pest and disease control)
	HABITAT SERVICES
16	**Maintenance of life cycles of migratory species** (incl. nursery service)
17	**Maintenance of genetic diversity** (especially gene pool protection)
	CULTURAL SERVICES
18	**Aesthetic information**
19	**Opportunities for recreation & tourism**
20	**Inspiration for culture, art and design**
21	**Spiritual experience**
22	**Information for cognitive development**

Appendix 4A: Questionnaire farmers Western Baviaanskloof

Interview Baviaanskloof

Date:
Landowner:

General questions

1. What are the main land use activities in the Baviaanskloof?
2. What are you farming/producing on your land?
3. Could you draw the boundaries of the land use types in the cadastral maps?
4. For how long have you been performing these activities?
5. What where previous land use types?
6. Do you still have thicket species on your field?

Landscape properties

7. What is the average rainfall on your land (mm/yr)
8. Do you have any problems on your land with alien species/erosion/decreased soil fertility?
9. Are there other grazers on your land except livestock? If yes, how much?
10. Do you have any irrigation? Do you know how much water you use annually?
11. Do you use fertilizers? If yes, how much?
12. Do you use pesticides/herbicides? If yes, what kind? And how much?
13. Do you keep hydrological measurements? If yes, what kind? What are outcomes? Such as: water retention (m3/ha) or water infiltration speed (mm/hr)

Provisioning

14. Do you have livestock/animals? If yes, #/ha?

15. How many are you selling per year?

16. How much are you producing on your land?

Arable land	**Area**	**Yield**

Livestock	**Nr of animals**	**Selling**

Tourism

17. Do you have holiday locations on your land? If yes, how much and where (GPS)?

18. Do you have tourism activities on your land? If yes, how many tourists/yr?

19. Do you also have eco-tourism activities? What kind of activities are that?

20. What makes you decide to place the locations at these specific locations?

21. Where would you not locate a holiday location on your land? And why not?

Appendix 4B: Questionnaire representative Eastern Cape Parks and Tourism Agency (ECPTA)

Date:
Name:

Nature reserve

1. Are there quantified ecosystem services of the Baviaanskloof Nature Reserve?

2. Are there provisioning services in the Nature Reserve? Do you harvest anything from the area (like honeybush)? Do people hunt in the area?

3. Is there any negative impact of the natural grazers in the Nature Reserve?

4. Are there erosion problems? What is the cause of that?

5. Are there restored areas in the Nature Reserve (indicated in maps)?

6. What helps against fire/flooding? Do you have data or information about that?

7. Do you have data on biodiversity (in the Nature Reserve or the farmers areas)?

Tourism

8. What tourism activities are present in the Nature Reserve? Is it mapped?

9. How many tourists visit the Nature Reserve per year?

10. What makes an area attractive for tourism?

11. What is the motivation for ECP to increase tourism in the area? (creates income for nature conservation?)

Farmers

12. Which areas of the farmers are potential stewardship areas? What is that based on?

13. How is the biodiversity going to be determined for the Stewardship?

14. Can farmers still grow things like honey bush in Stewardship areas?

15. Do farmers activities create negative trade-offs for the Nature Reserve?

16. How do you see the future of the farmers in the Baviaanskloof?

Appendix 5: Pictures used for quantification of aesthetic information

(Fousert 2009)

<u>Arable land:</u>

Valley view, farm lands, gravel road and surrounding mountains

Modern farm fields with irrigation and ostriches

<u>Grazing land:</u>

Dry valley floor, open view with mountains aside

Degraded mountain with very little vegetation

<u>Restoration sites:</u>

Sign about the thicket rehabilitation project at research plots in nature reserve

Local communities planting in the mountains with volunteers

Old farmlands:

Mountain landscape with gravel road and 4x4 vehicle on the foreground

Intact thicket:

Pristine mountain scenery, different heights and unspoiled vegetation cover

Mountain ranges with dense vegetation cover

Appendix 6: Older version of land use map Baviaanskloof (Janssen, 2008)