EFFECTS OF ECOSYSTEM CHANGE ON DECIDUOUS FRUIT FARMING IN THE LANGKLOOF IN SOUTH AFRICA

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MSc Thesis in Environmental Sciences
June 2015

Supervised by: Dr. Rudolf S. de Groot (ESA)

Course code: ESA - 80436

Environmental Systems Analysis

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Preface

This thesis emerges from my personal interest in human interactions with biodiversity and ecosystem services as potential drivers of ecosystem protection initiatives. As part of my quest for inspiring cases, I coincidentally came across Living Lands, a non-profit organization based in South Africa that works closely with local stakeholders in order to generate knowledge with the ultimate aim of restoring living landscapes. In their current initiatives, together with Commonland (Dutch foundation that aims at scaling up existing ecosystem restoration projects), they have also considered involving the business community in order to successfully restore ecosystems at a large scale. One of the most recent examples following this approach are the intentions to establish a partnership between Commonland, Living Lands, GIZ (Germany), Santam (insurance company, South Africa) and governmental bodies from South Africa.

As a contribution to the abovementioned initiatives, analysing climate change adaptation options for local activities and stakeholders including ecosystem restoration arose as an interesting research topic for Living Lands. Thus, this study was envisioned as part of two complementary theses under that overarching topic, and hence it has been written simultaneously with Arjan de Groot, student of MSc Climate Studies at Wageningen University. While he addressed interactions between climate change, stakeholders and ecosystem services, I focussed on the deciduous fruit farming sector and ecosystem services linkages.

As part of the collaboration with Arjan de Groot, we developed and applied the main data collection instruments (semi-structured interviews) together. Furthermore, the study area description has been conceived as a common chapter for both theses.

Living Lands provided material and logistic support for the fieldwork activities in South Africa that were essential for achieving our research objectives. During our stay we were based in the PRESENCE Learning Village, where we had the opportunity to get involved in diverse meetings and activities held by the organization, as well as sharing with other students conducting research in the area.

In addition to the fruitful interaction with other students and the organizations in South Africa, the continuous support and orientation provided by my supervisor, Rudolf S. de Groot, in the Environmental Systems Analysis group (Wageningen University) significantly contributed to the quality of this study and the communication of the results.

Conducting this thesis was made possible by the support of "*Becas Chile*" scholarship program from the Chilean National Commission for Scientific and Technological Research (CONICYT).

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Acronyms

BEE	Black Economic Empowerment
BHU	Broad Habitat Unit
BRC	British Real Consortium
CAPE	Cape Action Plan for People and the Environment
CFR	Cape Floristic Region
CICES	Common International Classification of Ecosystem Services
DAFF	South African Department of Agriculture, Forestry and Fisheries
DEAT	South African Department of Environmental Affairs and Tourism
DFF	Deciduous Fruit Farmer
DWAF	South African Department of Water Affairs and Forestry
EC	Eastern Cape Province
ECPTA	Eastern Cape Parks and Tourism Agency
ESR	Corporate Ecosystem Services Review
FAO	Food and Agriculture Organization of the United Nations
FPA	Fire Protection Association
GDP	Gross Domestic Product
GIB	Gamtoos Irrigation Board
GIS	Geographic Information Systems
GIZ	German Federal Enterprise for International Cooperation (*Deutsche Gesellschaft für Internationale Zusammenarbeit*)
GLOBALG.A.P.	Global Good Agricultural Practices
GMOs	Genetically Modified Organisms
IAPs	Invasive Alien Plants
IFC	International Finance Corporation
ITCZ	Inter-Tropical Convergence Zone
IUCN	International Union for the Conservation of Nature
MA	Millennium Ecosystem Assessment
NGO	Non-Governmental Organization
PRESENCE	Participatory Restoration of Ecosystem Services and Natural Capital
PS	Performance Standard
SAB	South African Breweries
SANBI	South African National Biodiversity Institute
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEP	United Nations Environment Program
UTM	Universal Transverse Mercator
WBCSD	World Business Council for Sustainable Development
WC	Western Cape Province
WfW	Working for Water
WRC	South African Water Research Commission
WRI	World Resources Institute

Summary

Future agricultural expansion and export persist in countries with high biodiversity, which are controlled by their thriving climatic and environmental conditions. South Africa is such a country and it currently emerges as one of the biggest African agricultural economies. As the world´s "biggest land manager", the agricultural sector affects biodiversity and ecosystems, and simultaneously benefits from ecosystem services. Additionally, the sector, biodiversity, ecosystems and their services are adversely affected by climate change. This consequently creates both risks and opportunities for agriculture, and can stimulate decision-makers to improve agricultural and ecological sustainability.

To explore these risks and opportunities, this thesis focuses on specific South African agricultural systems in the Langkloof area. This is an agricultural valley in the Kouga River catchment with deciduous fruit production as its main economic base. This valley is part of the Cape Floristic Region, which is one of the world´s biodiversity hotspots.

To examine the consequences of ecosystem change on deciduous fruit farming here, I evaluate the dependencies and impacts of local agriculture on ecosystems, determine key ecosystem services for deciduous fruit farming performance, describe the trends for key services and, finally, identify risks and opportunities arising from ecosystem change.

The business community has recently become concerned about ecosystem services and since the concerns appeared, guidelines and partnerships have been established to address the dependencies and impacts on ecosystems, and the consequences of changes in ecosystem services. The World Business Council for Sustainable Development, the World Resources Institute and the Meridian Institute, for example, provide guidelines for Corporate Ecosystem Services Reviews (ESR) and strategy development for business managers.

Most of the methods utilized in this thesis followed the stepwise ESR approach. The main interactions between each ecosystem service and deciduous fruit farming performance were classified along a three level impact and dependence scale. The services with the highest impact and dependence levels were selected as key ecosystem services for deciduous fruit farming and their current condition and probable future supply and demand trends were analyzed. These trends helped identify risks and opportunities, for which management and collaboration options were suggested. Most data for this analysis were obtained from the literature and interviews with farmers, stakeholders and experts. These interviews were conducted during a fieldwork period.

Regulating ecosystem services and, to a lesser extent, provisioning services defined the highest impacts and dependencies of deciduous fruit farming. Based on this analysis, four key ecosystem services were selected: water, water flow regulation, extreme events moderation and pollination. The current capacity of ecosystems to supply these services in the area was good because their supply currently exceeds their demand. However, the effects of alien species and water diversion currently threaten extreme events moderation in the study area. Additionally, other drivers of ecosystem change (e.g. land degradation, population growth and climate change) will likely cause future demand to exceed the supply of all key ecosystem services. This analysis shows that water and extreme events moderation should have a high priority to manage risks and opportunities.

Risks for deciduous fruit farming operations include reduced productivity, increased costs and disruption of normal production activities. Moreover, in legal and regulatory terms, risks of lawsuits, fines, increased fees and restrictions on the use of natural resources are tied to these ecosystem-change trends. Other risks include reputational, financing, and market and product consequences.

Opportunities to improve land and infrastructure management, increase efficiency in using production inputs, improve the sector's reputation and access to new markets, emerge from the changes in the provision of key ecosystem services for deciduous fruit farming.

Notwithstanding limitations in terms of the ESR (e.g. impact and dependence questionnaires), the data collection methods (e.g. in-depth interviews) and the number of interviews, the thesis´ results are consistent with other studies that analyze the interactions between ecosystems and major regional activities. However, this thesis provides additional insights by relating deciduous fruit farming to a broader group of ecosystem services and providing detailed information about the consequences for this sector.

Given the wide variety of risks and opportunities arising from changes in key ecosystem services, management options for deciduous fruit farming should be diverse. Additionally, the identified risks and opportunities involve multiple stakeholders that can be potential partners to implement these options. This would not only benefit deciduous fruit farming performance, but also would contribute to ensure the provision of ecosystem services to the entire landscape.

1 Introduction

1.1 Background

The global food demand is expected to rapidly increase as a consequence of population growth and per capita GDP predictions (Tilmans *et al.*, 2011). Influenced by food demand, future agricultural expansion is likely to follow the current trend, in which the main growths in cropland area have occurred in less developed countries (Balmford *et al.*, 2005). Since most biodiversity hotspots are found in such countries (Myers *et al.*, 2000), a growing agricultural sector is likely to affect valuable ecosystems worldwide (Baudron and Giller, 2014).

Agriculture can alter ecosystem processes (Baudron and Giller, 2014), thus affecting ecosystem services, which are the benefits people obtain from ecosystems (MA, 2003; 2005). Impacts of agriculture and other sectors alike include changes in quantity and quality of ecosystem services, both positive and negative (Hanson et al., 2012). However, agricultural activities do not only affect, but also depend on ecosystem services (Lockwood, 1999; TEEB, 2012). This dependence emerges from using ecosystem services as inputs that enable or enhance agriculture´s performance (Hanson et al., 2012).

Ecosystem degradation affects ecosystem services and, consequently, poses risks for different business sectors in terms of internal operations, legal restrictions, reputation, markets and products, and financial aspects (Hanson *et al.*, 2011; 2012). Other changes in ecosystems, however, can provide opportunities for business, such us entering new markets, attracting new customers and adding value, among others (TEEB, 2012). Minimizing risks and managing opportunities can thus stimulate environmental management practices and promote changes in value chains that address dependencies and impacts on ecosystem services (Delmas and Toffel, 2008; Winn and Pogutz, 2013).

Even though it may be rather predictable for the agricultural sector, acknowledging that business depend on and affect ecosystem services is a relatively recent process among the business community (Winn and Pogutz, 2013). Since ecosystem services became a corporate concern, guidelines to tackle this issue (e.g. IUCN *et al.*, 2006; Hanson *et al.*, 2011; TEEB, 2012) and partnerships between NGOs and business worldwide have been established (Winn and Pogutz, 2013).

In response to global concerns, the dependencies and impacts on ecosystems are currently part of the International Finance Corporation's Performance Standard (PS6), which aims to maintain the benefits from ecosystems through corporate biodiversity management (IFC, 2012). The United Nations (UN) Global Compact initiative and the International Union for the Conservation of Nature (IUCN) also provide a framework to incorporate biodiversity and ecosystem services into corporate sustainability (UN Global Compact and IUCN, 2012). Furthermore, on behalf of the business community, the World Business Council for Sustainable Development (WBCSD), the World Resources Institute (WRI) and the Meridian

Institute, provide guidelines for Corporate Ecosystem Services Reviews (ESR) and strategies to deal with changes in these services (Hanson *et al.*, 2011; 2012).

The relatively recent interest among corporations in actively protecting ecosystem services offers a broad range of possibilities to explore options to take responsibility for the interactions between business and nature (Winn and Pogutz, 2013). Since agriculture is considered the "biggest land manager in the world" (TEEB, 2012), the impacts (both positive and negative) and dependencies of this business sector on ecosystems can create risks and opportunities with potential effects on several landscapes and stakeholders worldwide. Consequently, it is likely that investments in sustainable agricultural development will significantly contribute to minimize the impacts on biodiversity caused by a high food demand in the future (Tilman *et al.*, 2011).

South Africa is an interesting case for this analysis because it is one of the biggest agricultural producers in Africa (FAOSTAT, 2015), it has a growing agricultural production value and more than half of its produce is exported (DAFF, 2014b). Increasing trends in food demand are thus likely to drive future agricultural development in the country (Tilman *et al.*, 2014). Therefore, additional agricultural impacts on ecosystem services can be expected to occur (Baudron and Giller, 2014).

The supply of ecosystem services in South Africa is supported by highly diverse and threatened biomes. With more than 30% of their vegetation types actually classified as threatened (Rouget *et al.*, 2005), South Africa's nine biomes contain over 20.000 plant species (Mucina and Rutherford, 2006; SANBI, 2014), which represent between 5% and 10% of all plant species on earth (Scotland and Wortley, 2003; Ungricht, 2004). Furthermore, two biodiversity hotspots, in terms of endemism and threat level (Myers *et al.*, 2000), and two centres of plant diversity are identified in the country (Barthlott *et al.*, 2005).

The combination between particularly diverse ecosystems and a growing agricultural sector immersed in the global market dynamics is remarkably in terms of potential linkages between ecosystem services and agriculture. Furthermore, South Africa is expected to become hotter and drier (Blignaut *et al.*, 2009), and extreme events in the country are likely to increase in frequency and magnitude as a result of climate change (Kusangaya *et al.*, 2014). These factors can lead to changes in ecosystem services provision, and these changes can ultimately pose additional risks and opportunities for agriculture (Calzadilla *et al.*, 2014).

To adapt to global market dynamics and changes in ecosystems, combining agricultural development and ecosystem services protection seems to be essential in South Africa. Management improvements and collaboration among stakeholders are therefore attractive options to meet future food demand whilst offering returns for biodiversity conservation (Tilman *et al.*, 2011; Baudron and Giller, 2014). Analysing risks and opportunities arising from ecosystem change, in turn, can help identifying potential incentives to improve management and establish collaboration partnerships (Hanson *et al.*, 2012).

1.2 Problem definition

The Cape Floristic Region (CFR) in South Africa is one of the 25 world biodiversity hotspots (Myers et al., 2000). However, it is exposed to ecosystem-change due to a growing agricultural sector (Goldblatt, 2010). The Langkloof, an agricultural valley in the CFR, is an example of this agricultural pressure. With almost 7,000 ha of intensive cultivation (Hortgro, 2013), this is one of the main deciduous fruit producer valleys in South Africa (DAFF, 2012a; Hortgro, 2013).

Since most Langkloof's fruit production is exported, coping with global food demand is likely to lead to farms' expansion and/or more intensive farming practices. This increased pressure, added to current alien plants invasion and unsustainable land use, are thus expected to keep degrading the ecosystems in this valley in the future (Skowno, 2007).

In addition to ecosystem degradation, regional effects of climate change (e.g. hotter and drier conditions) will potentially lead to water stress (Blignaut *et al.*, 2009) and increase unpredictability, frequency and intensity of extreme events (Jansen, 2008; Vromans *et al.*, 2010; Kusangaya *et al.*, 2014). Population growth in downstream areas (e.g. Port Elizabeth), on the other hand, is likely to increase water demand in the Kouga River catchment, which also supplies the Langkloof with freshwater (Jansen, 2008).

Farmers in the Langkloof depend on ecosystem services from the Kouga catchment to enhance farming performance (Hanson et al., 2012). However, deciduous fruit farming also affects (positively and negatively) water, soil and wildlife (Cerutti *et al.*, 2010; 2013), thus influencing trends in several of these ecosystem services' supply.

In combination with the already described pressures on ecosystems, negative impacts of farming activities in the Langkloof can pose risks for farmers and other stakeholders if ecosystem services for these activities are affected. On the other hand, maximizing positive impacts of farming activities and minimizing negative effects of ecosystem-change can provide opportunities for the farming business (Hanson *et al.*, 2012).

As managers of the upper Kouga River catchment, farmers in the Langkloof share a large responsibility in terms of ensuring the supply of services for downstream areas (Jansen, 2008). While dealing with the consequences of ecosystem change for their business (i.e. risks and opportunities), deciduous fruit farmers can, at the same time, help tackle the main issues threatening the benefits from ecosystems for local and downstream users. Therefore, these farmers are chosen as the focus of this analysis.

1.3 Aim of the study and research questions

Based on the main issues described in the previous section, this thesis aims to examine the main consequences of ecosystem-change for deciduous fruit farming in the Langkloof.

In order to achieve the research objective, four research questions are formulated:

1. What are the dependencies and impacts of deciduous fruit farming in the Langkloof on ecosystem services?
2. What are the key ecosystem services to be considered by deciduous fruit farmers?
3. What are the trends in key ecosystem services for deciduous fruit farming?
4. What are the risks and opportunities arising from changes in key ecosystem services for deciduous fruit farming in the Langkloof?

1.4 Outline of this thesis

This thesis is comprised of 10 chapters, including the introduction presented above (Ch. 1). Chapter 2 was written in collaboration with Arjan de Groot and presents detailed information about climatic conditions and biophysical structure of the ecosystems in the study area. Furthermore, it summarizes the current evidence of changes in these ecosystems.

Building upon the research questions, Chapter 3 organizes the main concepts to achieve the research objective. This chapter also details the methodological steps from the guidelines for ESR adapted to this thesis and the main instruments to collect and analyse data.

To introduce the results, Chapter 4 describes the most relevant aspects of deciduous fruit farming for the analysis. The interactions between deciduous fruit farming and the ecosystems in the study area (i.e. impacts and dependencies) are subsequently examined in Chapter 5, to select four key ecosystem services for this business sector. These services are investigated in detail in Chapter 6, which delves into supply and demand trends, and the main drivers of ecosystem change.

Chapter 7 relies on the results from chapters 5 and 6 to identify the main consequences (i.e. risks and opportunities) of ecosystem-change for deciduous fruit farming and prioritize them according to the most critical trends in key ecosystem services. Based on these results, Chapter 8 recommends options to deal with changes in ecosystems in the Langkloof from an integrated perspective, by combining farm management and stakeholder collaboration.

The discussion, presented in Chapter 9, addresses methodological limitations arising from: ecosystem services' typologies; the guidelines adapted in this thesis; and the obstacles in the fieldwork. However, it shows that despite these limitations, the results are robust and meaningful regarding the main issues in the study area. Consequently, Chapter 10 looks over the research questions to conclude that dealing with consequences of ecosystem change for deciduous fruit farming in the Langkloof would affect the entire landscape, benefiting several stakeholders that become potential partners for collaborative strategies.

2 Study area

This thesis focuses on the Langkloof, an agricultural valley situated in the Eastern Cape province of South Africa. The topography in this area is rugged and its spatial boundaries are naturally demarcated by mountain ranges (Haigh *et al.* 2004). The Langkloof belongs to the Kouga catchment area, which covers approximately 282,000 ha and extends from the township of Avontuur in the west up to the Kouga dam in the north-east (Mander *et al.*, 2010) (Figure 2-1). Despite the large extension of the Kouga river catchment, mountainous areas cover the majority of its surface (248,000 ha) (Mander *et al.* 2010).

Figure 2-1. Study area

Approximately 15,000 people live within the catchment, although the numbers are almost certainly higher today, due to expansion of various settlements (GOV 2, pers. comm.). Most of this population concentrates over a total of eleven settlements developing next to the different Kouga River tributaries in the Langkloof. These settlements are distributed from west to east in the following order: Avontuur, Haarlem, Ongelegen, Misgund, Apiesrivier, Louterwater, Krakeel, Joubertina, Ravinia, Twee Riviere and The Heights. Avontuur and Haarlem are part of the George Municipality in the Eden district, and thus fall under the jurisdiction of the Western Cape, whereas the other settlements belong to the Koukamma Municipality in the Sarah Baartmann district from the Eastern Cape. Figure 2-2 illustrates the main townships and the adjacent tributaries of the Kouga River in the Langkloof.

This thesis focuses on the section of the Langkloof that begins approximately 12 km to the west of the township of Haarlem, before reaching the town of Avontuur on the national route 62. From there and eastwards, the Tsitsikamma Mountains (in the south), and the Kouga and Suuranys Mountains (in the north), determine the study area boundaries. The settlement of The Heights demarcates the eastern border of this area, without being included in the analysis. For cartographical purposes, this study relies on the definition of Broad Habitat Units (BHU) provided by the Cape Action Plan for People and the Environment (CAPE) (Boshoff *et al.*, 2002; Younge and Fowkes, 2003) specifically defined as Langkloof Fynbos / Renosterveld Mosaic. This delimitation is only used as a surrogate for the estimation of areas, given the lack of more precise spatial representations of the valley. Based on this reference map and the boundaries of the Kouga catchment, the extension of the Langkloof in the study area is estimated in 42,274 ha.

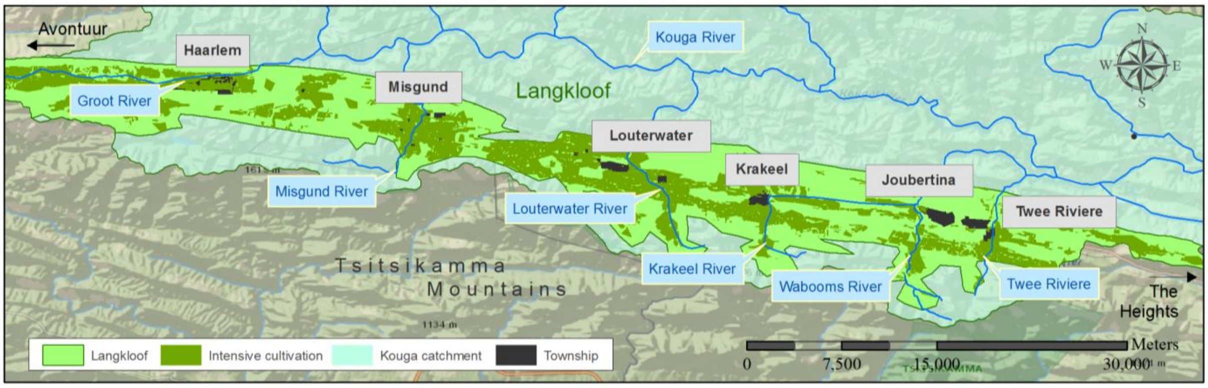

Figure 2-2. Main townships and tributaries of the Kouga River in the Langkloof

Although the valley´s extension in the Kouga catchment is relatively small, there is intensive agriculture and the soils and water, stemming from the tributaries of the Kouga River, represent valuable resources for the local livelihoods. The main agricultural crops in the Langkloof are deciduous fruits (Jansen, 2008), of which this is the second largest producer in the country (Hortgro, 2013). Only 4% of South Africa's GDP is attributed to agricultural production, but the agricultural sector still accounts for over 10 % of the total employment and one third of its production is exported (Calzadilla *et al.*, 2014 ; OECD, 2008).

Approximately 150 farmers are currently active in the Langkloof, with around 20 of them owning more than one farm (Veerkamp, 2013). Many of these farms have existed for generations already, and have often stayed within the family, being given from father to son. It is for this reason as well, that the farmers in the Langkloof know each other well and often share knowledge and information with each other, as they can draw on a generation-spanning experience of fruit farming in the Langkloof area.

While each farmer has its own irrigation dam for additional water storage, there are four larger dams in the area that supply water for the settlements and the agricultural practices. The irrigation boards of Haarlem and Louterwater own private communal dams, whereas the local municipality in Joubertina owns the dam in the Wabooms River.

Furthermore, the settlement of Misgund has recently finished the construction of its own dam, although pipelines from the dam to the settlement and farmers still have to be installed by the municipality. After the end of the apartheid in 1994, the municipal structure throughout South Africa began to change. In 2000, there was an act of dispensation issues by the national government. Throughout South Africa, the number of municipalities decreased from 800 to 200. In the Langkloof, the municipality of Joubertina was merged with the Kareedouw municipality to make up the larger municipality of Koukamma. Also, the Black Economic Empowerment (BEE) act, agreed upon in 2001, was launched by the national government in 2003 and promoted economic privileges for certain disadvantaged groups (Broad-Based Black Economic Empowerment Act No 57 of 2003). Through this act, about 80 emerging farmer projects were started in the Langkloof, although only a small number of those are still active and doing well today (EXP 4, pers. comm.). These emerging farmers receive assistance from the government in terms of financial support and start-up, and some have a more experienced, often retired commercial farmer as a mentor. These mentors often introduce the relatively inexperienced emerging farmers to fruit farming and share their expertise and knowledge (GOV 8, pers. comm.).

Figure 2-3. Overview of the three completed larger dams in the Langkloof valley. a) The Wabooms River dam, b) the Louterwater dam, and c) Haarlem dam

Even though this thesis focuses on activities in the valley, the contribution of the mountainous areas in the Kouga Catchment for the area of interest is undeniable. Therefore, some of the analyses presented in this report may refer to ecosystems from the entire Kouga catchment, as they are directly supporting the provision of specific services in the Langkloof.

The geology of the Kouga catchment determines relatively rich nutrient soils with high amounts of clay (Sandbrink, 2013; Veerkamp, 2013). Furthermore, the Tsitsikamma and the Kouga mountains influence wind patterns and act as a trap for rain clouds from the ocean (Sandbrink, 2013) and provide water to the valley. All these physical features of the landscape provide suitable conditions for the growing of deciduous fruit in the Langkloof, which benefits from fertile soils and the Kouga River tributaries.

As part of the CFR, the Kouga catchment contains a high number of endemic and threatened taxa (Low and Rebelo, 1996; Ojeda *et al.*, 2001). Most of them live in Fynbos vegetation types, which extend over more than 90% of the catchment (Mucina and Rutherford, 2006), supporting large mammals and diverse reptiles and birds (Veerkamp, 2013).

Besides the already presented information, the vegetation, fauna, climatic conditions, and biophysical structure of the landscape are thoroughly described in Appendix I, which provides a detailed overview to understand the diverse ecological interactions that are relevant for the provision of ecosystem services in the study area.

2.1 Current state of ecosystems

The current state of South African ecosystems was evaluated in the National Biodiversity Assessment in terms of protection level and threat status (Driver *et al.*, 2011). Based on the results of that assessment and the boundaries of the study area, the current state of the ecosystems in the Kouga catchment is presented in Table 2-1 and Table 2-2. In both cases, the respective categories of threat and protection levels represent the conservation status of each ecosystem according to its total distribution in the country. Therefore, this is a useful indicator to set conservation priorities, though it does not necessarily reflect the current condition of the catchment, which is described in the following sections of this chapter.

Table 2-1. National protection level of the ecosystems in the Kouga catchment

Protection level	Area (ha) in the Kouga catchment	% of Kouga catchment area	Criterion to determine protection level
Well protected	101,478	36%	More than 100% of the biodiversity target is met in formal protected areas.
Moderately protected	131,782	47%	Less than 100% of the biodiversity target is met in formal protected areas.
Poorly protected	44,777	16%	Less than 50% of the biodiversity target is met.
Not protected	4,265	2%	Less than 5% of the biodiversity target is met.
Total	282,303	100%	

Source: own elaboration based on data from Driver et al. (2011)

According to the information presented in Table 2-1, more than 80% of the ecosystems in the study area are moderately or well represented in formal protected areas in South Africa. Nevertheless, the 16% of the ecosystems in the catchment, which mainly belong to the Tsitsikamma Sandstone Fynbos vegetation type, are poorly protected in the country. The remaining 2% of the catchment, classified as not protected in South Africa, is entirely comprised of the Langkloof Shale Renosterveld vegetation type.

Table 2-2. Threat status of the ecosystems in the Kouga catchment

Threat status[1]	Area (ha) in the Kouga catchment	% of the Kouga catchment area	Criterion to determine protection level
Endangered	101,478	2%	Remaining natural habitat extent is larger than the biodiversity target, but it exceeds the target in less than 15%.
Vulnerable	131,782	14%	Remaining natural habitat is less than 60% of its original extent, but it is larger than the area to be considered endangered.
Least threatened	44,777	84%	Remaining natural habitat is more than 60% of its original extent.
Total	282,303	100%	

[1] No critically endangered ecosystems are found in the Kouga catchment

Source: own elaboration based on data from Driver *et al.* (2011)

In terms of threat status, most ecosystems represented in the study area (more than 80% of its surface) are classified as least threatened. However, the Tsitsikamma Sandstone Fynbos are vulnerable ecosystems at a national scale and they cover almost 40,000 ha in the catchment (14% of its total area). Categorised as endangered, the most threatened ecosystem in the catchment (in less than 2% of its surface) is Langkloof Shale Renosterveld (Table 2-2)

2.2 Main signs of ecosystem change

Land use types, invasive alien plant species (IAPs) and protected areas are described in this section as the main aspects denoting changes in the ecosystems in the study area. Current land use and invasion by alien plants indicate changes in the ecosystems' structure and processes, whereas protected areas can suggest a certain degree of control over human induced changes in the ecosystems in the study area.

While this section focuses on current conditions in the ecosystems in the study area, specific drivers of future ecosystem change are identified and described in Chapter 5, in terms of the key ecosystem services for deciduous fruit farming.

2.2.1 Land use

Due to its fertile soils and suitable climate for agriculture, the landscape in the Langkloof valley has undergone intensive change. The different land use types that are present in the valley include natural vegetation, protected areas, cultivated land, degraded vegetation, urban built up, and water bodies. Natural vegetation consists of areas untouched, or almost untouched, by human activities, with an abundance of native plant and animal species. Such vegetation is mainly found on the mountain hills of the Tsitsikamma Mountains and the Kouga mountains, or intermittently between settlements. A large portion of the land in the valley however has been changed into cultivated land to sustain agricultural productivity. As such, large parts of the landscape are characterised by widespread fruit orchards, and some grazing pastures for cattle and sheep. Degraded vegetation refers to a significant deterioration of natural vegetation, soil quality, or water resources, due to excessive human exploitation. It is thus a gradual destruction of natural vegetation and causes a reduction in the quality of the land. Urban built-up is considered as a removal of native vegetation and ecosystems in order to facilitate space for humans and their activities. This includes infrastructure such as industrial buildings, houses, and roads that are typically clustered around the various settlements in the Langkloof valley. Water bodies include both natural and human-made bodies of water, such as lakes, rivers and dams.

Table 2-3 shows an overview of the Kouga catchment and its land cover. This has been updated by the South African National Biodiversity Institute (SANBI) in 2009 for the entire country. Most of the catchment is covered by natural areas (about 90%), which also cover a large part of the Langkloof (roughly 60%). However, the latter has a larger proportion of intensively cultivated land (almost 40%), reflecting its importance as an agricultural area. The use of the land for agricultural purposes also explains why 0% of the land in the valley is considered to be degraded, as agricultural cultivation has less negative effects on land quality than for example mining activities. It should be noted that only 2% of the total surface area of the Langkloof is occupied by human settlements and structures. Similarly, only 1% of the area consists of water bodies. This table clearly highlights the importance and prevalence of agriculture for the Langkloof compared to its other land use types.

Table 2-3. Land cover in the study area

Land cover	Kouga River catchment		Langkloof	
	(ha)	(%)	(ha)	(%)
Natural	257,647	91	25,561	61
Cultivated	22,157	8	15,196	36
Degraded	106	0	-	0
Urban built-up	795	0	795	2
Waterbodies	1,596	1	535	1
Total	**282,300**	**100**	**42,087**	**100**

Source: own elaboration based on data from SANBI (2009)

2.2.2 Invasive alien plant species (IAPs)

Recognising its threat to ecosystem stability, many scientists have researched the impacts of IAPs throughout the world in recent decades (Vilà *et al.*, 2011; Powell *et al.*, 2011; Liao *et al.*, 2008). As such, it has become widely accepted that IAPs have a negative effect on local biodiversity, influence ecosystem stability such as provision of water and nutrients, and can have an impact on human well-being (Vilà *et al.*, 2011), as was already mentioned earlier.

Large parts of the Langkloof valley have recently become infested with IAPs, and this infestation is growing at an alarming rate (Richardson and Van Wilgen, 2004). More precisely, the spreading of IAPs is a cause for concern not only in the valley, but also in the surrounding Kouga catchment and the entirety of South Africa. Most of these invasive species originally came from Europe or Australia, during a time when people from those countries journeyed to South Africa and began to build settlements. They brought with them species that would grow fast and which would thus be well suited for the building of houses and structures. Other earlier uses of IAPs included the use as firewood, the provision of shade, for windbreaks, amongst others (Poynton, 1979; Moyo and Fatunbi, 2010). Since the middle of the seventeenth century, around 750 tree species and approximately 8,000 shrubby, succulent and herbaceous species have been introduced in South Africa (van Wilgen *et al.*, 2001). Out of these, a total of 161 species are regarded as invasive and are therefore a cause for concern for the rich bio-diversity. Many of these introduced species were used for commercial purposes, such as the softwood species *Pinus* spp., of which there exist approximately 700,000 ha of plantations in South Africa, and the hardwood species wattles, eucalypts and poplar, which occupy roughly 625,000 ha (Nyoka, 2003). Van Wilgen *et al.* (2001) record that an area exceeding 100,000 km^2 of natural vegetation in South Africa is currently invaded by IAPs. This area is more than 8% of the country's total surface. Many of these IAPs reproduce fast, grow rapidly and out-compete native species due to a lack of original predators (Richardson *et al.*, 2000; van Wilgen *et al.*, 2001). As a result, bio-diversity in infested areas is decreasing, and 750 native plant species are threatened with extinction due to IAPs (de Wit *et al.*, 2001). Due to its widespread occurrence and its fast spreading rate, the most concerning IAPs in the study area is *Acacia mearnsii* (black wattle) (Figure 2-4 and Table 2-4).

Figure 2-4. From left to right: (a) and (b) *Acacia mearnsii*, and (c) *Hakea sericea*

Table 2-4. Overview of *Acacia mearnsii*.

Genus/ Species	Origin	Characteristics	Ecological Impacts (Langkloof)
Acacia / *A. mearnsii*	Australia	• Fast spreading (large amounts of long-lived seeds with prolific and precocious seed dispersal • Fast growing • Bound to water ways • Increases height and biomass of vegetation	• Replaces native vegetation • Increases rainfall interception • Increases transpiration • Reduces soil moisture • Destabilizes stream banks • Reduces carrying capacity and profitability of agricultural land • Disrupts ecosystem stability

Source: Global Invasive Species Database (http://www.issg.org/).

While *A. mearnsii* is by far the most common and most worrying IAP in the Langkloof area (McConnachie, 2012), the spreading of another IAP most notably in the western part of the valley, needs to be mentioned. *Hakea* is a genus consisting of many shrub and small tree species, and is spreading at an alarmingly fast rate in the western Langkloof near the settlements of Misgund and Haarlem (Fugler, 1982). It was introduced to South Africa for its ornamental uses. Most prominent amongst the *Hakea* species in the western Langkloof is *H. sericea* (Gordon and Fourie, 2011; Figure 2-4), of which Table 2-5 provides a brief overview.

Table 2-5. Overview of *Hakea sericea*.

Genus/ Species	Origin	Characteristics	Ecological Impacts (Langkloof)
Hakea / *H. sericea*	Australia	• Highly branched, prickly shrub • Resistant to drought, wind and cold • Most commonly found on mountain hills • Large and prolific seed bank	• Replaces native vegetation • Increases fire hazards • Reduces soil moisture and water yields • Reduces surface runoff • Disrupts ecosystem stability

Source: Invasive Species Compendium (http://www.cabi.org/isc/).

There exist also other IAPs in the Langkloof area, such as *Eucalypts sp.* and *Pinus sp.* and *Opuntia sp.* (Veerkamp, 2013), whose ecological impact and distribution however is considerably less impactful than those of *A. mearnsii* and *H. sericea*.

IAPs have a considerable negative effect on the environment, as they have been shown to reduce surface stream flow, reduce the availability of water due to increased water uptake, increase soil erosion, contribute to a more rapid spreading of fires, affect soil nutrient status, affect habitat suitability for native species, and reduce bio-diversity. More precisely, studies have shown that IAPs reduce stream flows between 4.7 and 13% (Dye, 1995; Le Maitre *et al.*, 1996; Prinsloo and Scott, 1999, Le Maitre *et al.*, 2000), and use 10 % of the utilizable surface runoff annually (Le Maitre *et al.*, 2000). In a water-stressed country such as South Africa, this can potentially have devastating consequences in the future. But apart from their ecological effect, they also negatively affect the nation's economy. IAPs also reduce the amount of potentially arable land, reduce grazing potential, poison humans and livestock, increase the amount of imported water, and cause considerable costs in terms of fire control and clearing efforts. It is therefore not surprising that the spreading and analysis of IAPs has been a hot topic for research in the past decades (Le Maitre *et al.*, 1996; Prinsloo and Scott, 1999; Holmes and Marais, 2000; Le Maitre *et al.*, 2000; van Wilgen *et al.*, 2001).

Fynbos, the pre-dominant biome in the Langkloof and its surrounding, include the most heavily infested vegetation types. As such, the spreading of IAPs is one of the most pressing challenges in the area. For this reason, the nation's government has created the Working for Water (WfW) program as a means to combat the spreading of IAPs in 1995 (McConnachie *et al.*, 2012). The Kouga River catchment was chosen as the first area on which the WfW program would focus, due to its great ecological importance and its heavy infestation. The program has a spear-headed objective, as it aims to create work opportunities for the many unemployed people, while simultaneously controlling and eradicating IAPs. It has been called the world's most ambitious invasive alien plant control programme by Kader Asmal, a founding minister of the programme, but its success is disputed.

2.2.3 Protected areas

This section examines the protected areas with formal status according to the Protected Areas Act, 2003 (No 57 of 2003). Protected areas have been established in order to preserve the rich biodiversity of the natural habitat. In the Langkloof, the mountain hills of the Kouga Mountains are protected as part of the Baviaanskloof Nature Reserve, and the Formosa Nature Reserve near Joubertina protects part of the Tsitsikamma Mountains (Erlank *et al.*, 2009). Consistently, the formal protected areas in and around the Kouga catchment depicted in Figure 2-5 are taken from the National Biodiversity Assessment (Driver *et al.*, 2011). As presented in the figure, the Baviaanskloof Nature Reserve is the main protected area in the Kouga catchment (protecting approximately 80,000 ha in it). After this mega reserve, the Formosa Nature Reserve protects approximately 3,000 ha and the Garden Route National Park extends over around 1,000 ha in the Kouga catchment. In total, the Kouga catchment comprises almost 84,000 ha of formally protected areas (30% of the catchment area), whereas the Langkloof only includes a minimum part (roughly 300 ha) of the Formosa Nature Reserve (estimation based on Driver *et al.*, 2011).

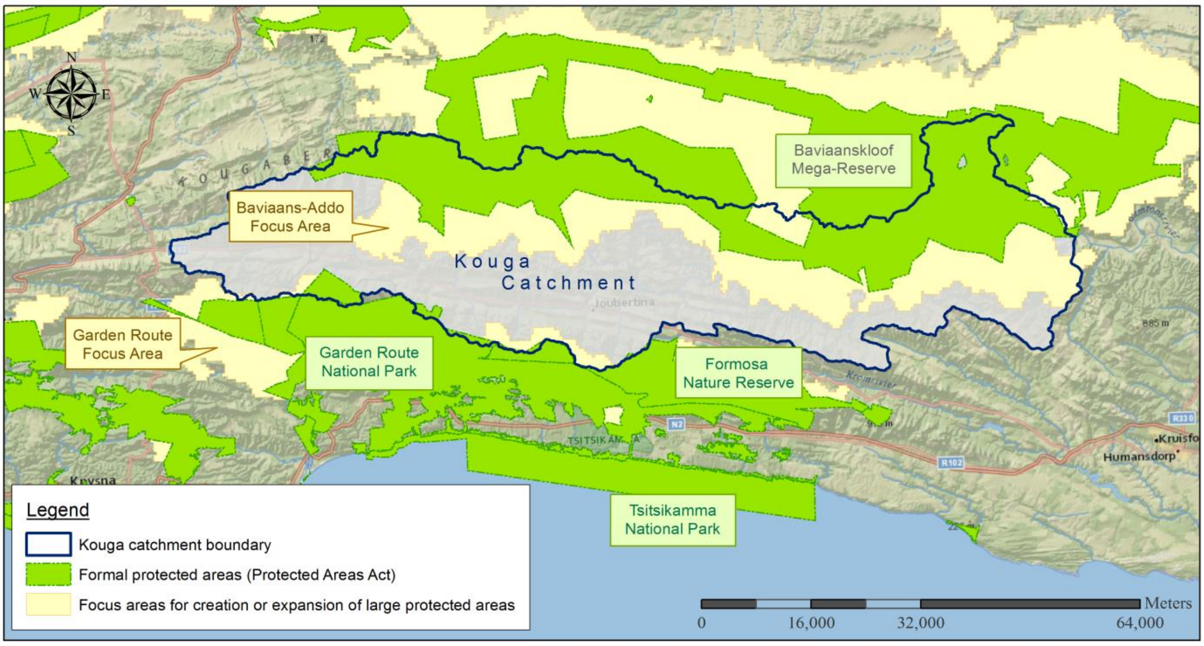

Figure 2-5. Formal Protected Areas (Driver *et al.*, 2011) and Focus Areas for expansion or creation of new large protected areas (Government of South Africa, 2008)

The cartographic analysis of the protected areas updated by Driver *et al.* (2011) and the vegetation (Mucina and Rutherford, 2006) in the Kouga catchment allows determining the main protected vegetation types in the study area. Most of the formally established areas protect Fynbos vegetation (88% of the protected area in the Kouga catchment), protecting 28% of all the vegetation from this biome in the catchment. Specifically the Kouga Sandstone Fynbos (65% of the protected area in the catchment) and Kouga Grassy Sandstone Fynbos (17% of the protected area) are the most represented types in protected areas in the Kouga catchment. Most of the remaining surface of these areas protects Groot Thicket vegetation, which covers approximately 10% of the area under protection in the catchment.

The CFR, which includes the Kouga catchment, is considered as one of the South Africa's nine priority conservation areas in the National Spatial Biodiversity Strategy (Rouget *et al.*, 2005). In order to narrow down this definition for fine-scale decision making purposes, the National Protected Areas Expansion Strategy (Government of South Africa, 2008) determined a list of 42 focus areas for creation or expansion of large protected areas. In the study area, around 65,000 ha of the Kouga Mountains are included in the Baviaans-Addo focus area and approximately 4,000 ha of the Tsitsikamma Mountains are considered in the Garden Route focus area for future expansion (Figure 2-5). As well as the currently protected areas, focus areas in the Kouga catchment are aimed at protecting Fynbos vegetation types. In fact, about a 90% of the surface considered for further expansion or creation of new protected areas in the Kouga catchment extends over the same currently protected vegetation types, namely Grassy Sandstone Fynbos and Sandstone Fynbos. On the other hand, despite being categorised as endangered in South Africa (Driver *et al.*, 2011), the Langkloof Shale Renosterveld is neither currently protected nor included in the focus areas for conservation in the Kouga catchment.

3 Research methods and literature review

This chapter provides the conceptual framework, and the methodological steps that are followed in order to achieve the research objective and answer the formulated research questions. Therefore, the interactions between the most relevant concepts for this study are firstly identified and the main methods chosen for this thesis are subsequently summarized. Finally, the specific data collection methods and analytical tools utilized to organize the information presented in this thesis are also explained.

3.1 Conceptual framework

This specific section explores the relationships between the main concepts addressed in this thesis. Based on the research questions a conceptual diagram is devised for establishing the main steps followed in the analysis. Figure 3-1 depicts the ecosystem services' role in supporting human activities such as deciduous fruit farming in the Langkloof. Ecosystem services represent a broad variety of interactions in which human development benefits from nature (MA, 2003) and, more precisely, from the ecosystems' biophysical structure, processes and function (de Groot *et al.*, 2010).

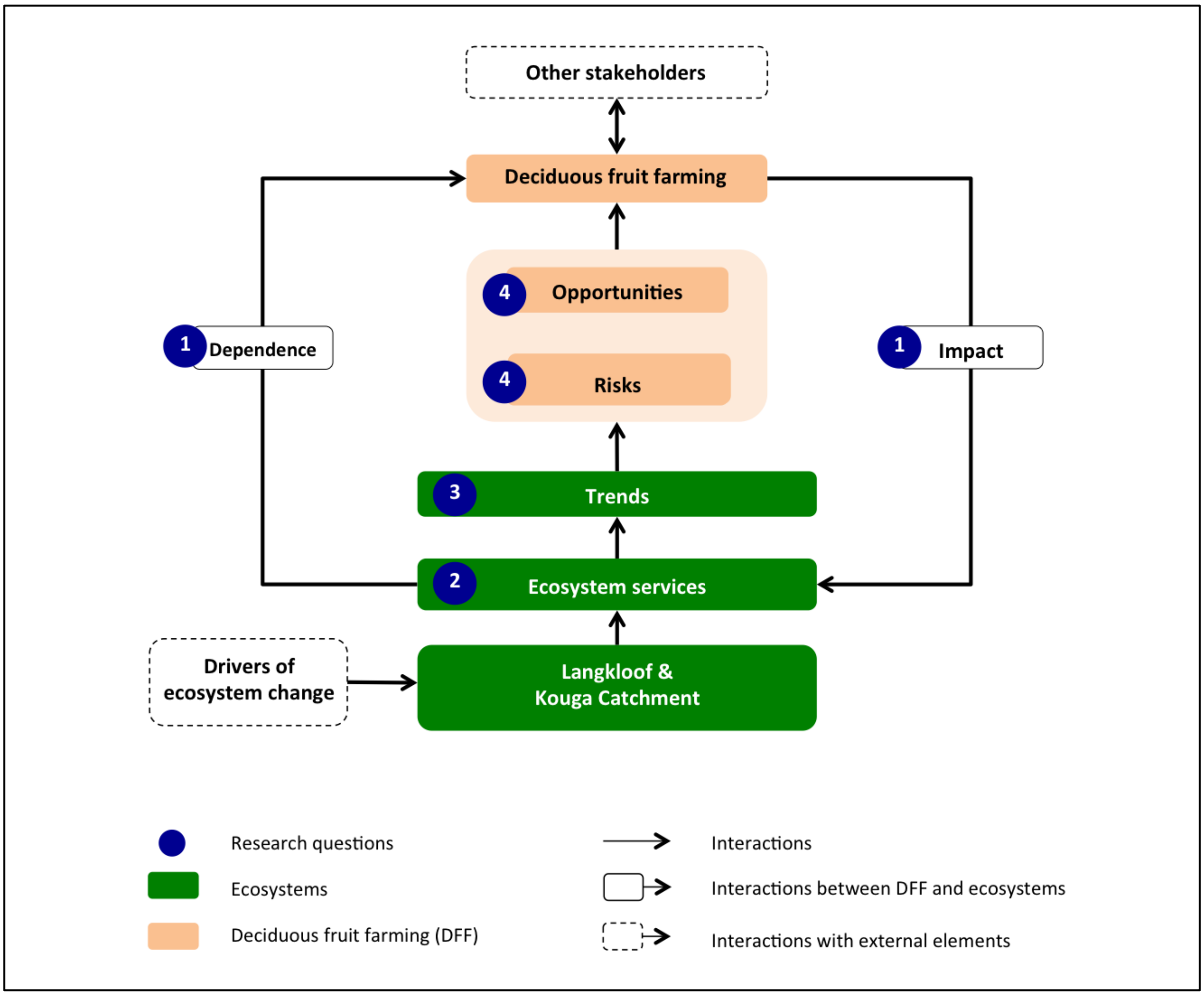

Figure 3-1. Conceptual framework of the thesis: Effects of ecosystem change on deciduous fruit farming in the Langkloof in South Africa.

As depicted in Figure 3-1, the ecosystems in the Langkloof and the Kouga catchment (see Chapter 2) provide several ecosystem services that affect deciduous fruit farming performance. However, climate change, land use change and land degradation, among other drivers, can lead to changes in these ecosystems (e.g. structure and processes) that can, in turn, influence the provision of services. Trends in ecosystem services on which deciduous fruit farming create impacts and depends are key services to identify risks and opportunities arising from ecosystem change. The latter can be ultimately dealt with through farm management and collaboration with other stakeholders.

The importance of connecting ecosystem services to diverse productive sectors was emphasized in the TEEB study (2010; 2012) to successfully implement ecosystem restoration strategies and conservation partnerships with business. However, carrying out this type of initiatives requires information about the interactions between such businesses and the ecosystems that support their activities (Hanson *et al.*, 2011).

As an effort to standardize and test methods to evaluate risks but also opportunities arising from changes in the provision of ecosystem services that support business activities, the WBCSD, the WRI and the Meridian Institute provide together guidelines to help businesses conducting ESR (Hanson *et al.*, 2012).

Unlike other frameworks to analyse impacts or dependencies on ecosystems of specific business sectors or human activities (e.g. Ecological Footprint Analysis and Life Cycle Assessment) the guidelines from Hanson *et al.* (2012) specifically address risks and opportunities for business, along with strategies to deal with them as a tool to be applied by business managers and decision makers. Furthermore, their flexibility in terms of input data (i.e. quantitative or qualitative data) allows performing rapid assessments and using existing results from previous analyses in order to provide a broad overview of the current business context along a complete list of ecosystem services.

Besides being proposed by WBCSD itself, the ESR is promoted by diverse international organizations, institutions and initiatives, which include IUCN and the UN (UN Global Compact and IUCN, 2012), TEEB (2012) and GIZ (Kosmus *et al.*, 2012), among others. Whereas this recently developed method can help guide adaptation strategies to ecosystem change, testing the ESR in different contexts may provide useful insights about its applicability and limitations.

In this thesis, the ESR (Hanson *et al.*, 2012) is applied in the study area to the case of deciduous fruit farming as an attempt to unveil the relationships, in terms of impact and dependence, between this business sector and the services provided by local ecosystems. Furthermore, as also conceived in the guidelines, it should allow identifying risks and opportunities for business, which can serve as a reference for future adaptation strategies to changes in ecosystems (i.e. structure, processes and function).

From the 5 steps proposed by Hanson *et al.* (2012) shown in Figure 3-2, the determination of the scope is not investigated in detail, since the extent of this thesis was determined by current interactions between stakeholders and environmental organizations in the study area that facilitated the fieldwork process. On the other hand, since the development of strategies is aimed at business managers and decision makers, this thesis only presents farm management and collaboration options in the Langkloof. Both, the scope selection and the management and collaboration options are explained below as part of the context of this thesis.

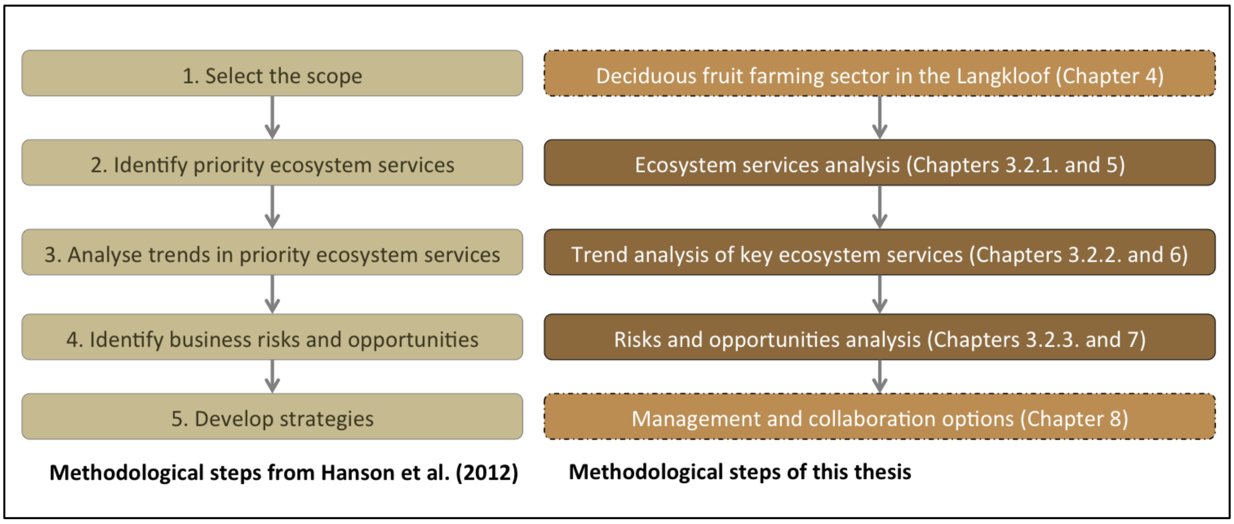

Figure 3-2. Methodological steps proposed by Hanson *et al.* (2012) adapted to this thesis.

The three middle steps from Hanson *et al.* (2012) presented in Figure 3-2 are adapted in this thesis as ecosystem services analysis, trend analysis, and risks and opportunities analysis. Each of these methods is explained in detail in Section 3.2.

3.1.1 Scope of this thesis

In order to keep clear boundaries to conduct the analysis and develop strategies, the determination of the scope of this type of study should consider a specific stage of the value chain, a specific group and the time limitations (Hanson *et al.*, 2011; 2012). In the case of this thesis, the scope is limited to the internal operations of deciduous fruit producers in the Langkloof, in which the interactions with ecosystems in the study area are most prominent. The specific limits of the activities considered and the main features of this business sector in the South African and local context are described in Chapter 4.

3.1.2 Management and collaboration options for deciduous fruit farming

Analysing options for management and collaboration strategies aims at providing background information to manage the identified risks and opportunities. Since this step was conducted in the Netherlands, after the fieldwork, the identified options are based on information from interviews and the outcomes from the ecosystem services analysis (Section 3.2.1), trend analysis (Section 3.2.2) and risks and opportunities analysis (Section 3.2.3). Besides climate and ecosystem change adaptation measures, current initiatives being developed by Living Lands and Commonland, in collaboration with other stakeholders in the landscape are also included as options for farmers. Since these options were not discussed with stakeholders after being identified, they are presented only as a reference for farmers and local organizations to guide their own strategies.

3.2 Research methods

The following sections describe the main research methods used in this thesis. The ecosystem services analysis to identify priorities for the deciduous fruit-farming sector is followed by the trends and the risks and opportunities analysis. Each section includes the main procedures followed and those steps that have been adapted in this thesis.

3.2.1 Ecosystem services analysis

The ecosystem services analysis focuses on interactions between the activities considered within the scope of this thesis and the ecosystems in the study area. Thus, this analysis includes the evaluation of impacts and dependencies of deciduous fruit farming on the ecosystems in the study area as the basis to identify key ecosystem services for this business sector (Hanson *et al.*, 2012).

Analysing impacts and dependencies firstly requires the selection of a meaningful list of ecosystem services to explain interactions between companies' operations and ecosystems. In that sense, the Millennium Ecosystem Assessment (MA, 2005) and The Economics of Ecosystems and Biodiversity (TEEB) (de Groot *et al.*, 2010) provide the most commonly used typologies of ecosystem services, which are classified primarily as provisioning, regulating and cultural services. Besides those categories, the MA (2005) includes supporting services (e.g. nutrient cycling and food chain dynamics), whereas TEEB (de Groot *et al.*, 2010) identifies habitat services (e.g. nursery and gene pool protection) as a separate group. In the latter classification the supporting services are left out for being considered as ecological processes instead of services with an economic (monetary) value.

The Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin, 2013) is aimed at providing inputs for integrated environmental and economic accounting, and as such it also includes its own ecosystem services classification. The CICES is consistent with TEEB in disregarding supporting services for the analysis. Consequently, it focuses on three main sections of services, namely provisioning, regulating and maintenance, and cultural. Within such sections, the habitat services defined in TEEB (de Groot *et al.*, 2010) are encompassed in a broader division (below the section regulating and maintenance) called regulation of biotic environment, which includes lifecycle maintenance, habitat and gene pool protection, next to pest and disease control (Haines-Young and Potschin, 2013). Thus, CICES offers more detailed categories for some services (e.g. it includes energy within the provisioning section) than TEEB, while some services considered in TEEB classification are embedded in broader groups (e.g. pollination) in CICES.

For the analysis of deciduous fruit farming in the Langkloof, considering supporting services would lead to unnecessary duplications when analysing the data for other services (e.g. soil fertility). In that sense, both CICES and TEEB would be appropriate classifications to follow in this thesis. Nevertheless, the ecosystem services defined at the most detailed level in the WRI, WBCSD and Meridian Institute guidelines for ESR (Hanson *et al.*, 2012) are comparable to the TEEB services (de Groot *et al.*, 2010). Based on these similarities, the ecosystem services typology proposed in TEEB (de Groot *et al.*, 2010) is complemented in this thesis with the sub set of services suggested for the ESR (Hanson *et al.*, 2012).

Combining TEEB and ESR ecosystem services typologies allows comparing the results of the analysis of deciduous fruit farming in the Langkloof with other cases in which the guidelines proposed by Hanson *et al.* (2012) were applied, and with the other thesis written simultaneously in the study area using the TEEB classification. Since some of the 22 ecosystem services from TEEB (de Groot *et al.*, 2010) are subdivided into more specific subcategories, which are suitable for the analysed case and consistent with Hanson *et al.* (2012), a list with a total of 30 ecosystem services (including subcategories) is considered in this thesis (Table 3-1).

Table 3-1. List of ecosystem services analysed in this thesis

Provisioning services	***Regulating services***	***Habitat services***
1. Food: 1.1.Crops 1.2. Livestock 1.3. Wild foods	7. Air quality regulation	16. Maintenance of life cycles of migratory species
	8. Climate regulation: 8.1. Global climate regulation 8.2. Regional/local climate regulation	17. Maintenance of genetic diversity
		Cultural & Amenity Services
2. Water	9. Moderation of extreme events	18. Aesthetic information
3. Raw Material: 3.1. Timber and other fibre 3.2. Fibres and resins 3.3. Animal Skins 3.4. Fodder 3.5. Fertilizer	10. Regulation of water flows	19. Opportunities for recreation & tourism
	11. Waste treatment: 11.1. Water purification 11.2. Waste treatment	20. Inspiration (culture, art and design)
		21. Spiritual experience
	12. Erosion prevention	22. Information for cognitive development
	13. Maintenance of soil fertility	
4. Genetic Resources	14. Pollination	
5. Medicinal Resources	15. Biological control	
6. Ornamental Resources		

Source: adapted from de Groot *et al.* (2010) and Hanson *et al.* (2012).

According to Hanson *et al.* (2011; 2012), companies can use specific ecosystem services as inputs, whereas in other cases they can enable or enhance the conditions for successful performance. Under such circumstances, a dependency on those specific services can be described. Similarly, business impacts on a specific ecosystem service can be understood as effects on that service's quality or quantity, either in a positive or a negative sense.

In this thesis, the degree of impact and dependence of deciduous fruit farming on ecosystem services are classified as low, medium and high through a questionnaire devised by Hanson *et al.* (2012) and presented in Section 3.4 (Table 3-6). Based on the results obtained after applying the questionnaire, ecosystem services are prioritized (see Table 3-7) to subsequently analyse the trends of those services from which business risks and opportunities may arise.

3.2.2 Trend analysis of key ecosystem services

The trends are analysed according to the current condition of key ecosystem services and the main drivers and stakeholders that are likely to contribute to future changes in the supply and demand for these services (Hanson *et al.*, 2012; Kosmus *et al.*, 2012).

Regarding the current condition of key ecosystem services, the guidelines proposed by Hanson *et al.* (2012) only provide descriptive orientation for their analysis. The GIZ, on the other hand, suggests a four categories scale (very good, good, bad, very bad) to differentiate between the present conditions of different ecosystem services in development planning (Kosmus *et al.*, 2012). Nevertheless, the lack of specific selection criteria to use the scale in these guidelines debilitates its practicality in this case. For these reasons, only two simplified categories are used in this thesis to summarise the current condition of key ecosystem services in the study area, namely sufficient (or good) and insufficient (or bad). Two criteria (C1 and C2) are proposed to decide on each of these categories (Table 3-2).

Table 3-2. Criteria to determine current condition of key ecosystem services

Current condition	**Criterion C1**	**Criterion C2**[1]
Sufficient / Good	Supply > demand for the ecosystem service	Capacity of local ecosystems to provide the service has not been degraded.
Insufficient / Bad	Supply ≤ demand for the ecosystem service	Degraded capacity of local ecosystems to provide the service.
[1] C2 is used if no information is available to determine current condition based on C1.		

Source: own elaboration.

From the criteria presented in Table 3-2, C1 the first selection criterion. Since C1 is based on supply and demand, it encompasses interactions between different stakeholders as well as the capacity of ecosystems to provide a particular service. If no indication is available to classify the current condition according to C1, then the decision is based on information about the state of the ecosystems providing that service as described in C2.

Likely future trends in demand and supply are expressed in three categories, namely stable, decreasing and increasing (Kosmus *et al.*, 2012; Table 3-3). Each ecosystem service is individually analysed according to available information about current condition, drivers and stakeholders that contribute to changes in that service's provision.

Table 3-3. Matrix for summarizing the trend analysis

Key ecosystem services	**Provision unit or ecosystem**	**Current condition** (+ good or sufficient, - bad or insufficient)	**Likely future trends** (➚ increasing, ➔ stable and ➘ decreasing)		**Drivers of change**
			Demand	**Supply**	
Key ecosystem service 1					
… Key ecosystem service N					

Source: adapted from Kosmus *et al.* (2012).

The main information sources for the trends analysis are peer-reviewed articles, scientific and institutional reports (e.g. government, NGOs, research centres, etc.) and interviews with experts and farmers. The results obtained from this analysis are summarised in a matrix adapted from Kosmus *et al.* (2012) (Table 3-3) and the results of the trends analysis is presented in Chapter 6.

3.2.3 Risks and opportunities analysis

Current and future changes in the provision of key ecosystem services can pose different types of risks and offer opportunities for the deciduous fruit farming sector in the Langkloof. Hanson *et al.* (2012) and IUCN *et al.* (2006) classify these risks and opportunities as follows:

a) Operational risks and opportunities that affect daily internal operation and processes of the business, as well as the main expenditures. They can emerge from scarcity of certain inputs, increased costs or disruptions to productive activities.
b) Regulatory and legal risks and opportunities that include laws, policies and court actions that can lead to additional costs for the business activities. Some examples include taxes, extraction moratoria, fines and user fees.
c) Reputational risks and opportunities that relate to the relationship with customers or stakeholders in terms of brand or image.
d) Market and product risks and opportunities that are influenced by customer preferences or changes in global or local markets.
e) Financing risks and opportunities refer to access to financial resources from investors and restrictions established by investors

The different risks and opportunities are grouped according to the abovementioned categories and the ecosystem service they emerge from. Furthermore, the trends and current condition of key ecosystem services are used to prioritize risks and opportunities in order to guide management strategies. Thus, risks and opportunities arising from ecosystem services with a bad or insufficient current condition and a likely future demand exceeding the supply are classified as the first (very high) priority for management. On the other hand, those risks and opportunities arising from ecosystem services with a good or sufficient condition and a likely future supply that is expected to exceed the demand are categorised as the lowest priority for management strategies (Table 3-4).

Table 3-4. Priorities for management of risks and opportunities according to trends in key ecosystem services

Likely future trends in key ecosystem services		**Supply**		
		↗	→	↘
Demand	↗	Medium priority	High priority	Very high priority
	→	Low priority	Medium priority	High priority
	↘	Low priority	Low priority	Medium priority
Key: ↗ increasing, → stable and ↘ decreasing trends.				

Source: own elaboration.

The results of the identification of risks and opportunities according to different categories, key ecosystem services and priorities is presented in Chapter 7, whereas management and collaboration options are described in Chapter 8.

3.3 Data collection methods

In order to facilitate the data collection, Living Lands provided supervision and information throughout the entire fieldwork period. This organization, based in South Africa, has previously gathered information in the area, mainly by facilitating other master theses, which provided secondary data, interview transcripts and useful contacts for achieving the research objective. Thus, the network that Living Lands created in the area has been useful to achieve a first contact and subsequently arrange meetings with farmers, stakeholders and experts for the primary data collection. The interviews and meetings were carried by over three months in South Africa, from September to December 2014. The activities during that period included interviews and meetings, deskwork (e.g. literature review, preparation of interviews, scheduling meetings and interviews, etc.) and collaboration in Living Lands' activities (e.g. workshops, meetings, presentations, etc.).

The primary data collection was designed and performed in collaboration with Arjan de Groot, student of MSc Climate Studies at Wageningen University, with the main goal of providing complementary results and recommendations. His focus on stakeholders and climate change offered useful insights to understand the study area and the interactions between climate change and ecosystem services in the catchment. On the other hand, my study contributed with a deeper understanding of the deciduous fruit-farming sector, which is one of the main businesses in the area and involves diverse stakeholders.

Different methods were used to collect the primary and secondary data. These included a literature review, interviews with farmers, stakeholder and experts, and participation in meetings. All these methods are presented in Table 3-5 according to the specific research question and the methodological steps they belong to. Moreover, they are further explained in the subsequent sections focusing on the relevant procedures for this specific thesis.

Table 3-5. Data collection methods and research questions

Research Question		Methodological steps	Data collection method
1.	What are the dependencies and impacts of deciduous fruit farming in the Langkloof on ecosystem services?	• Dependence and impact analysis.	• Interviews with farmers and experts • Literature review • Stakeholder meetings • Spatial data analysis
2.	What are the key ecosystem services to be considered by deciduous fruit farmers in the Langkloof?	• Dependence and impact analysis. • Ecosystem services prioritization	• Interviews with farmers and experts • Literature review • Stakeholder meetings
3.	What are the trends in key ecosystem services for deciduous fruit farming in the Langkloof?	• Trend analysis	• Interviews with farmers, experts and stakeholders • Literature review
4.	What are the risks and opportunities arising from changes in key ecosystem services for deciduous fruit farming in the Langkloof?	• Risks and opportunities analysis for strategies development	• Farmers and experts interviews • Stakeholder meetings

3.3.1 Literature review

An extensive and complete literature review is of crucial importance for this thesis. Given the large extent of the study area and the limited availability of time during the fieldwork period, biophysical measurements have not been included among the data collection methods. Thus, the analyses conducted to answer the research questions largely rely on secondary sources.

Peer-reviewed literature is the main source to bridge gaps of information. This includes from general scientific information, which can be used as an indicative framework, to specific case studies that are comparable to the study area. Additionally, technical reports from government institutions, research centres and Non-Governmental Organisations (NGOs) are also included. The South African National Biodiversity Institute (SANBI), the South African Water Research Commission (WRC) and the South African Department of Agriculture, Forestry and Fisheries (DAFF) are some examples of institutions that have conducted publicly available assessments that provide useful information at the national, regional and local scales. Working with support of Living Lands also allowed to access technical reports (e.g. previous theses in the area). Cartographic information has been obtained from Living Lands database and supplementary material from institutional assessments provided online.

A careful selection and verification of the sources of cartographic information and databases has allowed avoiding, or at least minimizing, problems associated to validity, reliability, availability or format compatibility (Kumar, 2011). Thus, incomplete datasets or information lacking valid sources or metadata is excluded from the analyses performed in this thesis.

3.3.2 Interviews with stakeholders, farmers and experts

In order to include locally relevant issues in the analysis, as well as gathering useful information for the impact and dependence, the trend, and the risks and opportunities analyses, interviewing is the main method to collect primary data in this thesis. In-depth interviews with farmers, stakeholders and experts were conducted over a three month period (from September to December 2014) in South Africa.

The interviews with farmers aimed at obtaining information about farming practices, agricultural inputs, farming costs, and dependencies and impacts of deciduous fruit farming on ecosystem services. A core topic list was firstly elaborated on the basis of the research questions and the impact and dependence questionnaire from Hanson *et al.* (2012). Given the amount of time that would have consumed the application of the latter instrument, which includes a set of five questions for each ecosystem service (approximately 22), these questions were preliminarily answered beforehand through a rapid assessment of the available sources of information. This allowed identifying information gaps and minimizing the number of topics to include in the list of questions, which was later on discussed with the other MSc student collaborating in the research and combined into one list. This list of topics was organized as an interview schedule (Kumar, 2011), with a list of organized open-ended questions (Appendix IV). The semi-structured nature of this instrument allowed obtaining uniform data while delving into topics that were not previously considered or were particularly relevant for specific interviewees (Kumar, 2011).

Since the interviews were conducted in collaboration with another student, the original list of core topics was narrowed down in order to keep the interview length within an acceptable range for the interviewees. Nevertheless, whereas some farmers limited their answers to specific facts, others provided very detailed information. Thus, the duration of the interview varied between 25 minutes to approximately 3 hours.

For the selection of farmers to be interviewed, a detailed examination of the Living Lands contact database was conducted. The information provided by the local NGO contained names, phone, settlement and general information about farms obtained from previous interviews. The farmers were firstly selected according to farm location to cover as many settlements and irrigation boards in the Langkloof as possible. Before conducting the interviews most of the farmers were visited to describe the interview contents, explain the research aim and set a date for the actual interview. All these interviews were conducted in English and most of them were jointly performed with Arjan de Groot (in collaboration described earlier in this chapter). In each case one of us led the discussion, while the other had the role of note taker. The interview answers were directly registered in a laptop or voice recorder, depending on each farmer's preference. Throughout the process, a third MSc student joined the interviews, and hence, the roles were adapted to this new scenario and questions of his interest were carefully incorporated into the original combined interview. During the entire fieldwork period a total of 13 farmers were interviewed (Appendix V).

Expert and stakeholder interviews aimed at obtaining information about the state of and trends in ecosystem services in the area, complementing the information about farming practices and gaining insights about potential impacts of farming activities on ecosystems. The interviews were specifically designed for each interviewee following the same structure as the farmer interviews, also in collaboration with Arjan de Groot. The selection of experts and stakeholders initially relied on the Living Lands contacts network and the interviews were performed under the same structure as the ones with farmers. A total of 15 experts and stakeholders were interviewed during the fieldwork period (Appendix VI)

After finalising the interview, each farmer, expert or stakeholder was asked to identify other individuals in the area that could be willing to participate in the research in order to include them in the interviews. The new interviewees were subsequently asked again about potential participants, until the maximum possible interviews covering most of the area and topics were already performed. Thus, this selection process followed the structure of a snowball sampling (Kumar, 2011).

3.3.3 Meetings and observation

Working in the field with the facilitation of local organisations allowed participating in stakeholders meetings and gaining knowledge about the landscape through visits to the area that were not planned as part of this thesis. Apart from several meetings with Living Lands, during the data collection period it was possible to participate in two workshops and one stakeholder meeting. In addition to that, visiting the area allowed recording personal observations from conspicuous features of the landscape. These meetings and the observation process are described below.

a) Water learning journey in the Langkloof (16 - 17 September 2014)

This workshop, facilitated by Living Lands, aimed at bringing stakeholders together to share experiences and learn about the water management in the Kouga catchment, specifically in the Langkloof, between Joubertina and Haarlem. The participants included deciduous fruit farmers involved in different irrigation boards in the area and their technical advisors, as well as representatives of the municipality, the DWAF and the Department of Rural Development and Land Reform. The activities included discussion meetings and visits to the dams in the Wabooms River, Louterwater and Haarlem. The participation in this workshop provided insights about water management and the main water related issues in the area.

b) SmartAgri workshop in Oudtshoorn (16 October 2014)

This workshop was facilitated by Living Lands and organized in the context of the Smart Agriculture for Climate Resilience (SmartAgri) project carried by in collaboration between the Western Cape Department of Agriculture, the Western Cape Department of Environmental Affairs and Development Planning and the University of Cape Town's African Climate and Development Initiative. The aim of this workshop was bringing stakeholders together to share knowledge and experiences around climate change adaptation and agriculture. Besides technical information, this workshop provided useful insights in terms of observed effects of climate change, the perception about agriculture vulnerability and potential adaptation strategies in the Western Cape.

c) Formosa meeting in Joubertina (21 October 2014)

This was part of the regularly scheduled meetings to address concerns and issues in and around the Formosa Reserve. Issues, such as fires, IAPs, tourism and existing and potential partnerships, were discussed. The participants included representatives from the Eastern Cape Parks and Tourism Agency, Eden to Addo, Fire and Disaster management departments of Koukamma Municipality, and Living Lands. The participation in this meeting provided orientation in terms of disaster management and on-going initiatives in the protected area.

d) Observations

During research meetings with Living Lands, field excursions with other students and also while interviewing farmers, personal observations were recorded in order to guide the research and incorporate valuable inputs. Even though, these observations were not structured under an observation frame and come from different sources, their relevance for prioritizing topics to cover during the data collection phase is worth being included. Specifically in cases when certain issues are particularly conspicuous and are unlikely to mislead the conclusions of this thesis, observations are incorporated in the results. However, the extent to which observations are deemed as main information sources in this case is very limited and it only complements specific results if needed.

3.4 Data analysis

The information gathered through the data collection methods described above is organised as explained in this chapter. The steps presented here are aimed at enabling the analyses described in the research methods (ecosystem services, trends, and risks and opportunities).

3.4.1 Geographic Information Systems (GIS) for spatial data analysis

The spatial information has been obtained from supplementary material from peer-reviewed articles, books, institutional reports and the Living Lands database in shape file (.shp) format to be processed with Geographic Information System (GIS) Software. Thus, it has been firstly filtered in terms of its metadata. Those layers of information without a source that could indicate how the information included in the failed are excluded from the analysis. Similarly, in case of missing spatial reference, unless indicated in an associated document, the layers of information are not considered in the results either.

Before being analysed and processed, all the shape file format vector data used for this thesis have been projected to Universal Transverse Mercator (UTM) zone 35 South and datum WGS84 (applying the respective transformations if needed) by using Arc Map (ESRI) software.

Since the use of spatial information in this thesis aims at providing insights about the ecosystems in the study area, its analysis comprises the identification of overlaps between different data layers that may be relevant for the provision of ecosystem services and elementary calculations based on the geometry of vector data (e.g. area and length).

3.4.2 Impact and dependence evaluation

In the context of the ecosystem services analysis, the impact and dependence evaluation is based on a limited set of close-ended questions about the interactions of deciduous fruit farming activities and the ecosystems in the study area. The combined answers to those questions, for each ecosystem service, allow deciding between a medium and a high dependence, and a medium and a high impact (Hanson *et al.*, 2012; Table 3-6). The low level suggested by Hanson *et al.* (2012) is replaced in this thesis by the categories "no impact" and "no dependence".

The questions presented in Table 3-6 are proposed to help managers evaluate the activities within their company (Hanson *et al.*, 2011; 2012). Despite being a limited set of questions, applying them for each of the 30 selected ecosystem services would have implied asking a total of 150 questions to farm owners or managers. Therefore, in order to avoid an overly extended questionnaire that could prevent the respondents from participating, a review of literature and reports was conducted for answering as many of these questions as possible beforehand. This allowed selecting fewer interview questions with the aims of filling in information gaps from the literature and describing specific farming practices in the Langkloof that could influence the results at this point in the study (see Section 3.3.2).

The results of the dependence and impact evaluation are summarized in a matrix (Hanson *et al.*, 2012), which includes the list of all the ecosystem services, the impact level, the impact's nature (i.e. positive or negative) and the dependence level. In addition to the classification of impact and dependence, the resulting tables for each analysis include columns indicating the main sources of supporting information.

The identification of positive ("+") and negative ("-") impacts is included in this thesis as suggested in the referred guidelines. However, it is relevant to clarify that such distinction is aims to determine if each impact of the analysed activities increases (i.e. positive) or decreases (i.e. negative) the provision of a particular service. Therefore, it has no further implications in terms of labelling either "good" or "bad" farming practices.

In some cases, the impacts of a business sector on an ecosystem service can be negative and positive at the same time. Such impacts are indicated as "+/-" (Hanson *et al.*, 2012). Some ecosystem services are broad in their extent (e.g. air quality regulation), and hence one activity can give rise to both increases and decreases in their provision (e.g. an activity can contribute to the regulation of specific gases, while decreasing the regulation capacity for others). Also in these cases, impacts are classified as negative and positive, but only to guide the selection of key ecosystem services, since analysing the absolute quantitative impact of deciduous fruit farming is not part of the aim of this thesis.

Table 3-6. Questions to analyse dependence and impact on each ecosystem service

Dependence			
		2. "Does this ecosystem service have cost-effective substitutes?"	
1. "Does this ecosystem service serve as an input or does it enable/enhance conditions for successful company performance?"		**Yes**	**No**
	Yes	*Medium dependence*	*High dependence*
	No	*No dependence*	*No dependence*
Impact			
		4. "Does the company's impact limit or enhance the ability of others to benefit from this service?"	
		Yes	**No**
3. "Does the company affect the quantity or quality of this ecosystem service?"	**Yes**	*High impact*	*Medium impact*
	No	*No impact*	*No impact*
5. "Is the impact positive (+) or negative (-)?"		*(+) or (-) or (+/-)*	*(+) or (-) or (+/-)*

Source: Hanson *et al.* (2012)

Based on the results of the aforementioned evaluation, the ecosystem services, for which a certain level of impact or dependency is identified, are prioritized based on the criteria presented in Table 3-7. In cases where the impact and dependence on two or more ecosystem services are valued the same, those with negative impacts are assigned a higher priority than those with positive impacts. Ecosystem services with the highest values for both indicators (1^{st} priority) are selected as the key ones for deciduous fruit farming in the Langkloof.

Table 3-7. Criteria for ecosystem services prioritization

		Impact: High	Medium	No impact
Dependence:	**High**	*1st priority*	*2nd priority*	*3rd priority*
	Medium	*2nd priority*	*3rd priority*	*No priority*
	No dependence	*3rd priority*	*No priority*	*No priority*

Source: adapted from Hanson *et al.* (2012)

The results of this analysis are presented in Chapter 5 and in Appendix II and Appendix III.

3.4.3 Synthesis of interview findings

The use of semi-structured interviews as a research instrument implies that the gathered information is neither completely unstructured nor absolutely structured under a rigid frame (Kumar, 2011). Thus, this instrument allows gathering quantitative and qualitative data, which are analysed following different perspectives that are described below.

a) Quantitative data

Quantitative data include areas, costs, percentages and prices, among other topics that were discussed with farmers. However, the interviewed group was not a statistical sample of the farmers in the valley and some of them were reluctant to talk about costs or sensitive figures about their production. Consequently, synthetizing quantitative interview findings is limited to grouping and processing data to obtain comparable units (e.g. percentages versus absolute values) in order to present reference values (e.g. minimum and maximum) for the interviewed group.

b) Qualitative data

It represents the majority of the data gathered by interviewing experts, farmers and stakeholders in the Langkloof. It covers farming practices, use of inputs, farming impacts, dependence on ecosystems, trends in ecosystem services and main issues around farming in the area, among other topics. Processing qualitative data for this thesis aims at incorporating these different topics into a narrative format to describe the deciduous fruit farming sector in the Langkloof, as well as identifying relevant aspect of farming activities into the different analyses to perform (i.e. ecosystem services, trend, and risks and opportunities). Consequently, a content analysis is performed (Kumar, 2011) by carefully reviewing descriptive answers to classify them into main themes in the text.

4 Deciduous fruit farming in South Africa and the study area

This chapter examines the main characteristics of the deciduous fruit-farming sector in South Africa and the Langkloof. The scope of this thesis is also detailed in terms of farming activities and phases in the supply chain. Finally, the main farming practices and management issues in the Langkloof are presented on the basis of interviews with farmers and experts.

4.1 South African context of deciduous fruit farming

Deciduous fruit production in South Africa contributed with approximately 27% (12,815 million Rand) of the horticultural products income (47,806 million Rand) and 7% of the total farming income (182,987 million Rand) in 2013 (DAFF, 2014a). About 77% of the gross value of deciduous fruit that year was originated from exports (DAFF, 2014b) and approximately 49% of the total production volume was sold to the following export destinations: European Union (43% of total exports in 2012), West Africa and Southern Africa Development Community (23%), East Asia and Pacific (13%), Middle East (10%), Eastern Europe and Central Asia (4%), South Asia (3%) and others (4%) (DAFF, 2014b).

From all the deciduous fruit produced in the country, this chapter focuses on pome fruit (apples and pears) and stone fruit (apricots, peaches, nectarines and plums) (van Dyk and Maspero, 2004), since these are the main produce in the Langkloof. As previously described, the South African production of deciduous fruits (apples, pears and plums) is predominantly export oriented (Hortgro, 2014). However, the fruit that is not exported is processed for juice or canning (particularly peaches, nectarines and apricots) and a minor proportion (less than 30%) is sold in local markets (Hortgro, 2014; Figure 4-1).

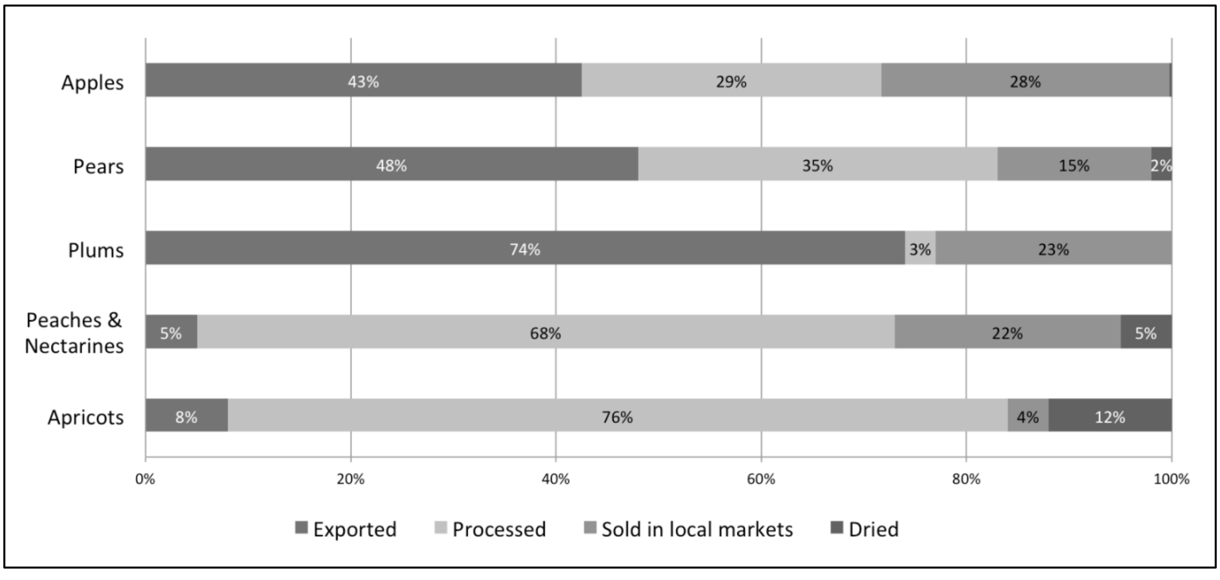

Figure 4-1. Average crop distribution 2003-2013 (Pome and stone fruit) in South Africa. Own elaboration based on statistics compiled by Hortgro (2014).

The following sections provide a brief overview of deciduous fruit farming in the South African economy and the main aspects that define the scope of the subsequent analysis.

4.2 Aspects of the deciduous fruit farming sector addressed in this thesis

In terms of production, the Western Cape and Eastern Cape are the main provinces under pome and stone fruit cultivation (Hortgro, 2014; DAFF, 2014b). As part of both provinces, the Langkloof is the second largest pear production area (covering 15% of the area under pears in South Africa) and the third largest apple production area (covering 20% of the area under apples) in South Africa (DAFF, 2012a; Hortgro, 2013). In total, the Langkloof encompasses 6,947 ha under deciduous fruit cultivation. This area represents about a 9% of the total 79,038 ha with deciduous fruit in South Africa (Hortgro, 2013; see Table 4-1).

Table 4-1. Deciduous fruit trees and production area in the Langkloof

	Apples	Pears	Plums	Peaches	Nectarines	Prunes	Total
Area (ha)	4,493	1,834	234	165	65	1	6,947 ha

Source: Hortgro Tree Census (Hortgro, 2013)

The different distribution channels for deciduous fruit produced in the Langkloof and other areas in South Africa, are depicted in the supply chain presented in
Figure 4-2 (DAFF, 2012a, b, c, d; van Dyk and Maspero, 2004; Cerutti *et al.*, 2010, 2011, 2013). This representation summarizes the various phases in the production process from the orchard to the final consumer of pome and stone fruit.

According to Cerutti *et al.* (2010; 2011; 2013), the specific phases of the deciduous fruit production process that entail input conversion and waste disposal into the landscape, and hence should be considered to analyse interactions with ecosystems, are: (1) nursery; (2) land preparation and orchard establishing; (3) farming and harvesting; and (4) removal and disposal of plants. Thus, the scope of this study is limited to those specific phases in which the most relevant impacts and dependencies on ecosystem services in the study area are expected to occur. The cold storage and packing phases are included in the analysis only if physically integrated to the other activities in the farm.

The first phase considered is the nursery, which includes the rootstock growth and plants propagation for the orchards. These activities use resources as soil, water, fertilizers and pesticides (Cerutti *et al.*, 2010; 2013). Particularly in the Langkloof, this phase is only observed in some farms, either for commercial purposes or for the farm needs. Only one of the interviewed farmers owns a nursery, which provides seedlings for internal use in the farm and also for the local market (DFF 12, pers. comm.). Other interviewees usually buy rootstocks or seedlings directly to suppliers in the valley or to nurseries from other areas in the Eastern and Western Cape.

For the orchard establishing, the area must be first cleared from other elements, such us previous orchards or natural vegetation. Then the land is prepared through fertilization and soil breakage to finally transplant the seedlings from the nursery (Cerutti *et al.*, 2010; 2013). According to farmer interviews these are common practices in the Langkloof, although its frequency depends on the financial capacity to expand or to re-establish an orchard.

Farming and harvesting is the phase in which the most commonly known practices are performed (Cerutti *et al.*, 2010; 2013). The field operations in this phase involve the management of trees, pest and diseases, and understorey, as well as irrigation and prevention of weather damage (Cerutti *et al.*, 2010). Most of these activities are organized in a yearly cycle according to the harvest seasons in South Africa, which differ for each fruit as follows: apricots from November to February; peaches from October to February; nectarines from November to April; plums from November to April; pears from January to July; and apples from March to September (van Dyk and Maspero, 2004).

Next to the described phases, the destruction of orchards occurs when the plants are in decline, after a production cycle. It includes the removal and disposal of trees and it can be followed by land preparation and establishing of a new orchard (Cerutti *et al.*, 2010).

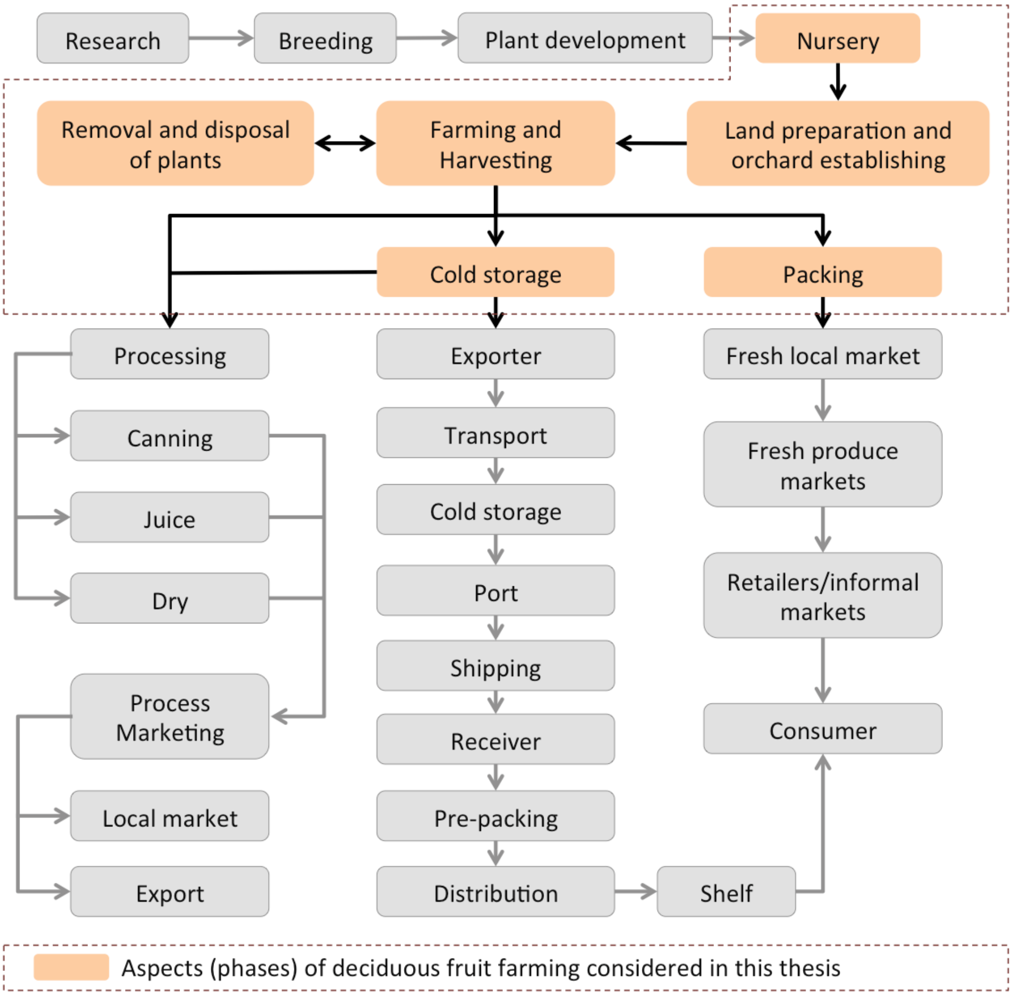

Figure 4-2. Supply chain of deciduous fruit in South Africa and aspects considered in this thesis. Own elaboration based on data from DAFF (2012a; 2012b; 2012c); van Dyk and Maspero (2004); Cerutti *et al.* (2010; 2011; 2013)

4.3 Farming practices and management in the Langkloof: results from interviews

Some particular findings in the study area and the deciduous fruit farming experiences of the interviewed farmers are summarized in this section. Farming practices and management in the Langkloof are described in this section based on the information gathered through interviews with farmers and, to a lesser extent, with experts and stakeholders in the study area. This overview of the farming activities in the Langkloof serves as a basis for analyses presented in the subsequent chapters.

During the period spent conducting fieldwork in the Langkloof, 13 farm owners and managers of deciduous fruit companies were interviewed (see Appendix V). In total, they managed approximately 3,394 ha of orchards, which represent a 49% of the 6,947 ha under deciduous fruit in the entire valley (Hortgro, 2013). The smallest orchard managed by an interviewee extended over 23 ha situated in one single farm, whereas the largest area occupied with deciduous fruit by one company was 945 ha distributed over 11 farms at different locations in the Langkloof. As explained in Section 3.3.2, farmers from the different sectors in the valley were interviewed. From East to West, three of them managed farms situated in Twee Riviere, two in Joubertina, three in Misgund, six in Louterwater, one in Ongelegen, three in Haarlem and two in Avontuur[1].

Next to the orchards, the remaining lands in farms in the Langkloof are sometimes used for cattle, sheep and honeybush tea production. Besides orchards, two of the interviewed farmers also own pack houses and one of them infrastructure for the nursery phase of production. As part of a diversification process of the family business, one farmer has recently started running a guesthouse and a bottle plant (DFF 8, pers. comm.).

Specifically on the deciduous fruit farming side, all the interviewed farmers mentioned apples and pears as their main products. These are accompanied by plums, peaches, apricots and nectarines. Consistently with the South African context, the production is sold in the fresh local or the processed fruit market (juice and canning) and exported to several different destinations. Europe is the main destination for most of the farms' production (12 farmers). Other frequent destinations markets include Far East, Middle East, United Kingdom, North America and Russia. Other countries in Africa were indicated as an upcoming market, given their fast growing economy (DFF 10, pers. comm.).

4.3.1 Farming practices

Farming practices in the Langkloof are largely determined by the international standards met in each farm (see complementary information about global environmental standards in Appendix VII). GLOBALG.A.P. sets a common basis of requirements met in most of the farms in the Langkloof, whereas other regulations influence more specific farming practices that differ among the interviewed farmers.

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[1] Some farmers managed more than one farm in the valley, and hence, they were counted separately for each location.

a) Pests and diseases management

In terms of pest and diseases management, the interviewed farmers share their concerns about the fruit scab caused by the fungus "fusi" (*Fusicladium sp.*). Consequently, they apply fungicides as a preventive measure. The fruit fly is also a national issue, and hence spraying against it is done individually or under fruit fly control programmes coordinated by Fruit Fly Africa and the Department of Agriculture, Forestry and Fisheries (DAFF) of South Africa.

During the interviews, farmers mentioned losses in the past that caused by codling moth, which affected apples and pears in particular. In order to prevent it from affecting the orchards, mating disruption was described as an effective measure that consists of several pheromones dispensers distributed over the orchard to inhibit mating success. Despite being expensive and adding labour cost for the farm (DFF 7, pers. comm.), 11 of the interviewed farmers use this method. Monitoring parasites and running prediction models to program the spraying, as well as mating disruption are perceived as means to reduce pesticides application and meet international standards.

Spraying less than in past years was also described as a practice to allow natural pest control. A specific example is that farmers have minimized the spraying against the red spider mite, because that keeps natural predators alive to control this pest. Other benefits alike are obtained from bats and birds (e.g. owls and falcons) that control rats, snails, beetles, moths and other secondary pests.

b) Fertilizer use

According to interviews, a broad variety of fertilizers are applied depending on prices and advisors' opinion about the type, amount and application method to select. The most common products mentioned by farmers include different forms of phosphate fertilizers, calcium ammonium nitrate (CAN or KAN), limestone ammonium nitrate (LAN), potassium chloride (KCL), as well as diverse concentrated nutrient solutions offered in the market (e.g. liquid fertilizers containing already available ammonium nitrogen combined with polyphosphate molecules). Most of these products are applied through the irrigation system.

Organic fertilizers are used as a complement to the conventional products and are incorporated by at least ten of the interviewed farmers (two farmers did not answer the question about organic fertilizer and another one do not use organic fertilizers because of their cost). Using only organic fertilizers was stated as financially unsustainable and therefore none of the interviewed farmers use exclusively organic products. Chicken manure pellets are in some cases applied during planting season on young trees, whereas compost tea is incorporated in the irrigation system in different phases of the orchard's life cycle.

In order to save water, preserve moisture and increase soil fertility and health, compost and mulch were also mentioned as regular practices in six of the interviews. Compost is commonly applied to young trees and made out of leftovers from farms (e.g. from cutting, pruning, clearing weeds, etc.), wood chips and material bought to dairy farms. Similarly, mulch is prepared with material from orchards and, in some cases, alien plant species cleared in the farms that are then chipped to apply them on top of the soil. Leaving pruning material and weeds that are cut next to trees is also practiced to preserve organic material.

c) Irrigation

The orchards are irrigated using micro sprinkler and drip irrigation with water from farm dams, which are filled with water from the Kouga River tributaries, communal dams and surface runoff. Farmers in the Langkloof are organized in irrigation boards for the water supply management from each river tributary. The irrigation boards in the study area are Wabooms River (Joubertina), Louterwater, Misgund and Haarlem. Except for Misgund, all these irrigation boards manage communal dams.

The water from communal dams is allocated to farmers and other users (e.g. municipality) either by turns organized in a schedule (Wabooms River) or by irrigable hectares (e.g. Haarlem). Regardless of the allocation system, most farmers pump the water from the dam or the river to their own smaller farm dams. The infrastructure maintenance is usually covered through the irrigation board and every six months a fee is paid to the government. However, according to the interviews, this fee is less significant than the electricity costs for pumping the water. Depending on the farm the fee can represent up to 7% of the production costs. During dry years, water is sometimes moved between private dams and some farmers pump water from boreholes that can reach 100 m deep (DFF 7, pers. comm.).

d) Water quality

In terms of quality, the water is monitored as part of the requirements to comply with global environmental standards (e.g. GLOBALG.A.P.) for specific markets. Depending on the results of water analyses, water purification systems are put place. However, at the time of interviewing, five farmers did not purify the irrigation water, five farmers filtered only big elements that interfere with the irrigation (e.g. twigs or sand) and only one farmer purified the water for irrigation (this topic was not discussed with the two remaining farmers). The proximity to mountains, the natural vegetation and the lack of activities upstream were mentioned as factors determining a suitable water quality for irrigation.

e) Prevention and mitigation of damage

Besides the already described practices, soil erosion prevention measures are regularly taken to avert damage in the orchards. Creating bumps on roads, contour farming and using cement and gabions increase resistance and help avoiding erosion due to rain or floods. IAPs clearing is also a habitual practice for most of the farmers (12 of the interviewed farmers clear IAPs) with the purpose of improving water availability or establishing a new orchard. The frequency of clearing varies depending on each farmer’s time and resources. According to interviews, it fluctuates from three times a year to a yearly basis. Similarly, the clearing methods differ for each case, but in general terms can be summarized as clearing, poisoning stumps, leaving them to dry and then burning (once a municipal permit is obtained). Alternatively to burning, the leftover material is sometimes chipped and used for mulch or simply disposed at specific areas in the farm.

4.3.2 Farming costs and financial risks

The interviewed farmers identify wages, packing material, chemicals, and fuel and electricity as their main production costs. Wages are considered the first or second main cost by all the interviewees, representing from 10% to 40% of the farming costs. Farmers who mentioned packing material stated that it could represent between 10% up to 25% of the farming costs. Chemicals include herbicides, pesticides and fertilizers that, added together, are estimated to account for 10% to 25% of the production costs. Two of the interviewed farmers estimated that fuel and electricity usually represent from 5% to 10% of the production costs.

Farmers coherently consider rising prices of fuel and electricity, chemicals, imported technology and other inputs (e.g. paper for packing) as main financial risks. Furthermore, global markets influencing fluctuations in costs, changes in the demand of deciduous fruit, and governmental decisions (e.g. wages rectification) were also stated as financial risks.

Additionally, another set of risks includes climate threats for the fruit production. Within this category hail damage was referred in interviews as the main risk, followed by potential impacts of other climate related events such as rainfall pattern fluctuations, thunderstorms, droughts and floods. One farmer expressed his concern about climate change as a potential risk, which can be minimized, in his opinion, by choosing appropriate tree varieties.

Among the climate threats, hail damage is the only peril covered by agricultural insurance in the Langkloof and 10 of the interviewed farmers deal with it by insuring part of or their entire orchards. Frost and wind damage may be also included in the insurance coverage, but these were not recognized as main financial risks in interviews. In order to cover the production costs in case of losses due to these events farmers indicated that up to 7% of their turnover is paid for the premiums. Therefore, there are farmers who choose minimizing these costs by insuring only the more productive trees or specific areas in their farms (e.g. orchards that were not previously damaged). The farmers that do not insure their orchards indicated that situating them in distant locations minimize the risk of being seriously affected by hailstorms, since these events are confined to specific areas.

Other financial risks (listed as secondary or only by one individual farmer) are: pests, failures in equipment, high tech management and political stability in South Africa.

4.3.3 Current management, financial and other issues

In addition to the financial risks, the main issues currently affecting farming activities in the area were also discussed in the interviews. In this regard, the main concerns for fruit farmers in the Langkloof are labour related issues, which include productivity, consistency and interest of workers, as well as problems such as alcoholism and access to basic services. In order to deal with labour matters, farm managers and owners mentioned communication with workers and direct management as effective solutions, yet still insufficient.

As well as financial risks, hail, rainfall patterns and water availability are current concerns. Hail is tackled by paying insurance premiums or by distributing orchards in different locations in the valley as mentioned in the previous section. Dealing with rainfall patterns is perceived also as a water storage issue, and hence, farmers have built dams according to the maximum allowed volume. Along the same lines, saving water by using more efficient irrigation systems and mulch are considered as alternatives to avoid water shortages.

Other issues concerning specific farmers are the lack of research, gender discrimination and debts. In terms of research, larger companies have the investment capacity to keep their own research department, which in one case in the area involves around 50 staff members. Nevertheless, smaller farms count only on occasional external advisory about chemicals and cultivars, but there is no funding for additional research about farming practices. Gender discrimination was mentioned as an issue in one interview concerning underestimated women’s leadership skills in a male dominated business. This, in that farmer’s opinion, renders an adverse scenario for female managers (DFF 9, pers. comm.). Finally, debts are a problem for one famer who perceives starting a BEE farm as an alternative to deal with the cash flows (DFF 4, pers. comm.).

4.3.4 Expected future changes in farming practices

Regarding future changes that farmers would like to make in their business, some of them focus on introducing new varieties or producing new fruits, given their increasing interest in new markets. Some examples from the interviews include producing smaller apples or trying with kiwifruit.

In order to have a better yield and improve the products quality, replanting or expanding the existing orchards are also among the plans for specific farms. Along with improving varieties and using better rootstock, farmers mentioned mulching and a more efficient water use as alternative means to improve the productivity of their farms. One farmer also perceives replanting shorter trees as an approach to maximize labour efficiency (e.g. during picking season).

Finally, other expected changes relate to infrastructure and equipment. Some examples are increasing the water storage capacity as far as possible, building their own pack houses and installing larger storage rooms. Infrastructure and equipment improvements are also perceived as means to increase energy efficiency.

5 Ecosystem services and deciduous fruit farming in the Langkloof

This chapter describes the dependence and impact of deciduous fruit farming on ecosystem services in the Langkloof. Dependence and impacts are described in two separate sections that summarize the answers to the questions from Table 3-6 according to the supporting information detailed in Appendix II and Appendix III. Based on these results, four key ecosystem services for deciduous fruit farming performance in the Langkloof are identified. As already described in the methods (Chapter 3.2.1), the typology of ecosystem services utilized in this chapter is adapted from TEEB (2010) and Hanson *et al.* (2012).

Given the heterogeneity of the ecosystem services included in the analysis, the sources of supporting information are diverse (Table 5-1 and Table 5-2). In some cases, the definition of an ecosystem service according to existing typologies and general scientific information about ecosystem processes (e.g. peer-reviewed articles and books) are sufficient to answer the questions. If that is the case, the source is referred to as literature (L). On the other hand, for specific services, the supporting information relies on case studies (C) conducted in other regions or countries that can be compared to the study area either because of biophysical processes alike or similar activities to deciduous fruit farming. Information from other theses and data provided by NGOs, research centres and governmental bodies are classified as technical information (T). Information about farm management and environmental issues that was collected by interviewing farmers (FI) and experts (EI), and recording observations in the study area (O), is also included. The observations are relevant for cases in which the type of interaction between deciduous fruit farming activities and specific ecosystem services was evident after visiting the study area. The number of sources is also presented in the corresponding tables, except for the field observations.

The selection of key ecosystem services described after the impact and dependence evaluation provides the basis for the analysis of trends, and risks and opportunities in the subsequent chapters.

5.1 Dependence of deciduous fruit farming on ecosystem services

The dependence on an ecosystem service is analysed according to the role of such service in the deciduous fruit farming performance. Based on Hanson *et al.* (2012), deciduous fruit farming is considered to be dependent on an ecosystem service if this is used as an input or enables or enhances the performance of this business in the area. Additionally, the magnitude of the dependence on a particular service is given by the substitutability of it. If substitutes are identified for a service on which deciduous fruit-farming depends, then this dependence is classified as medium. On the other hand, when substitutes are not identified or they are not cost-effective at the moment, then the dependence is high. The "no dependence" category includes those ecosystem services for which dependence is not currently identified and the services that affect the business sector activities only indirectly or to a limited extent. The supporting information and the reasoning behind the answers to the dependence questionnaire (Table 5-1) are presented in Appendix II.

Table 5-1. Dependence analysis of the deciduous fruit farming sector in the Langkloof

Ecosystem services	Q1[1]	Q2[2]	Dependence	Source[3]
Provisioning				
1. Food				
1.1.Crops	No	N.A.	N.D.	O
1.2. Livestock	No	N.A.	N.D.	FI (5)
1.3. Wild foods	No	N.A.	N.D.	T (1)
2. Water	Yes	No	High	FI (2)
3. Raw Material				
3.1. Timber and other wood fibre	Yes	Yes	Medium	FI (5)
3.2. Fibres and resins	No	N.A.	N.D.	O
3.3. Animal Skins	No	N.A.	N.D.	O
3.4. Fodder	No	N.A.	N.D.	FI (6)
3.5. Fertilizer	Yes	Yes	Medium	FI (5)
4. Genetic Resources	No	N.A.	N.D.	FI (6)
5. Medicinal Resources	No	N.A.	N.D.	T (1)
6. Ornamental Resources	No	N.A.	N.D.	O
Regulating				
7. Air quality regulation	Yes	Yes	High	L (6)
8. Climate regulation				
8.1. Global climate regulation	Yes	Yes	Medium	L (3)
8.2. Regional/local climate regulation	Yes	No	High	FI (11), L (3) & T (1)
9. Moderation of extreme events	Yes	No	High	FI (10), EI (1), L (1) & T (2)
10. Regulation of water flows	Yes	No	High	FI (3), EI (2) & T (1)
11. Waste treatment				
11.1. Water purification	Yes	Yes	Medium	FI (12)
11.2. Waste treatment	Yes	Yes	Medium	FI (5)
12. Erosion prevention	Yes	Yes	Medium	L (2)
13. Maintenance of soil fertility	Yes	Yes	Medium	FI (11) & L (3)
14. Pollination	Yes	No	High	FI (12) & EI (2)
15. Biological control	Yes	Yes	Medium	FI (6)
Habitat				
16. Maintenance of life cycles of migratory species	No	N.A.	N.D.	O
17. Maintenance of genetic diversity	No	N.A.	N.D.	O
Cultural & Amenity Services				
18. Aesthetic information	No	N.A.	N.D.	O
19. Opportunities for recreation & tourism	No	N.A.	N.D.	FI (1)
20. Inspiration for culture, art and design	No	N.A.	N.D.	O
21. Spiritual experience	No	N.A.	N.D.	O
22. Information for cognitive development	No	N.A.	N.D.	O

[1] Q1 = "Does this ecosystem service serve as an input or does it enable/ enhance conditions for successful company performance? (Hanson *et al.*, 2012).

[2] Q2 = "Does this ecosystem service have cost-effective substitutes?" (Hanson *et al.*, 2012)

[3] Supporting information sources classified as experts (EI) and farmers (FI) interviews, scientific literature (L) theses and technical reports (T), and personal observations (O). The number of sources is indicated within parenthesis for each category, except for (O).

Key: N.A. = Not applicable and N.D. = No dependence

Source: own elaboration based on data from literature review, interviews and observations presented in Appendix II.

The results summarised in Table 5-1, show that deciduous fruit farming depends on fourteen ecosystem services, which belong to the provisioning and regulating categories only. Six of these dependencies are high and the remaining eight are classified as medium dependencies.

Neither habitat nor cultural and amenity services are subject of dependencies of deciduous fruit farming in the study area.

5.1.1 Dependence on provisioning services

From the provisioning services, the deciduous fruit-farming sector is highly dependent on water, which is one of the main inputs for the production, it is not substitutable and it is directly obtained from the ecosystems in the area (i.e. surface runoff, Kouga River tributaries and groundwater). Farmers also obtain wood, (e.g. as a packing material) and organic matter (e.g. for fertilizing) from Fynbos, agricultural lands and other ecosystems in the study area. Nevertheless, since imported products can substitute organic fertilizers and wood as inputs for the production process, farming activities depend on them on a medium level.

5.1.2 Dependence on regulating services

Deciduous fruit farmers in the Langkloof depend on all the regulating services that are part of the analysis. A high dependence upon air quality regulation, local and regional climate regulation, extreme events moderation and the regulation of water flows is identified on the basis of the role that vegetation cover and topography play in their provision. Furthermore, these services cannot be substituted by cost effective alternatives or can be replaced only to a very limited extent. Pollination is another important (high dependence) and non-substitutable service for deciduous fruit farming. This is mainly provided by natural bee and bird populations, and enhanced by an additional input of bees from beehives supplied by beekeepers.

The dependence on other regulating services is classified as medium, because cost-effective substitutes exist. Waste treatment, erosion prevention, maintenance of soil fertility and biological control, for example, are susceptible of being replaced by technological, infrastructural or chemical inputs. In the case of global climate regulation, it enhances the conditions for successful performance, but the scale of this service renders local ecosystems as substitutable units in its provision.

Further details about dependence on ecosystem services are presented in Appendix II.

5.2 Impacts of deciduous fruit farming on ecosystem services

The deciduous fruit farming impacts are analysed according to the effects of field operations, and farming practices and management, on ecosystem services in the study area. According to Hanson *et al.* (2012), these impacts can be evaluated in terms of increases (positive impacts) and decreases (negative impacts) in quantity or quality of an ecosystem service. Furthermore, this analysis considers if farming activities affect the provision of each ecosystem service (i.e. medium impact), or they also influence the ability of other users (limiting or enhancing it) to obtain benefits from it (i.e. high impact) (Hanson *et al.* 2012). The "no impact" category is used when no effects or very limited effects on quantity or quality are identified. The supporting information and the rationale behind the answers to the questions to determine the impact on each ecosystem service (Table 5-2) are shown in Appendix III.

Table 5-2. Impact analysis of the deciduous fruit farming sector in the Langkloof

Ecosystem services	Q3[1]	Q4[2]	Q5[3]	Impact	Source[4]
Provisioning					
1. Food					
1.1.Crops	Yes	Yes	+	High	FI (13)
1.2. Livestock	Yes	No	+/-	Medium	FI (10), T (4)
1.3. Wild foods	Yes	Yes	+/-	High	FI (12), EI (2) & T (1)
2. Water	Yes	Yes	+/-	High	FI (2), EI (3), L (9) & T (1)
3. Raw Material					
3.1. Timber and other wood fibre	Yes	No	-	Medium	T (1)
3.2. Fibres and resins	No	No	N.A.	N.I.	O
3.3. Animal Skins	No	No	N.A.	N.I.	O
3.4. Fodder	No	No	N.A.	N.I.	O
3.5. Fertilizer	Yes	No	+	Medium	FI (6)
4. Genetic Resources	Yes	No	+/-	Medium	FI (6)
5. Medicinal Resources	No	No	N.A.	N.I.	O
6. Ornamental Resources	No	No	N.A.	N.I.	O
Regulating					
7. Air quality regulation	Yes	No	+/-	Medium	FI (10), EI (1) & C (9)
8. Climate regulation					
8.1. Global climate regulation	Yes	No	+/-	Medium	L (2) & C (6)
8.2. Regional/local climate regulation	Yes	No	?	Medium	L (2), C (5) & T (1)
9. Moderation of extreme events	Yes	Yes	+/-	High	FI (11), EI (2), L (3) & T (1)
10. Regulation of water flows	Yes	Yes	-	High	EI (2), L (1) & T (1)
11. Waste treatment					
11.1. Water purification	Yes	No	-	Medium	FI (11), EI (3), L (3) & T (1)
11.2. Waste treatment	Yes	No	+	Medium	FI (6)
12. Erosion prevention	Yes	Yes	+/-	High	FI (9), EI (2), L (1) & T (1)
13. Maintenance of soil fertility	Yes	No	+	Medium	FI (11)
14. Pollination	Yes	Yes	+/-	High	FI (13) & EI (3)
15. Biological control	Yes	No	-	Medium	FI (13)
Habitat					
16. Maintenance of life cycles of migratory species	No	No	N.A.	N.I.	L (2)
17. Maintenance of genetic diversity	No	No	N.A.	N.I.	L (2)
Cultural & Amenity Services					
18. Aesthetic information	Yes	Yes	+	High	O
19. Opportunities for recreation & tourism	No	No	N.A.	N.I.	FI (1)
20. Inspiration for culture, art and design	No	No	N.A.	N.I.	O
21. Spiritual experience	No	No	N.A.	N.I.	O
22. Information for cognitive development	No	No	N.A.	N.I.	O

[1] Q3 = "Does the company affect the quantity or quality of this ecosystem service?" (Hanson *et al.*, 2012).

[2] Q4 = "Does the company's impact limit or enhance the ability of others to benefit from this service?" (Hanson *et al.*, 2012).

[3] Q5 = "Is the impact positive or negative?" (Hanson *et al.*, 2012)

[4] Supporting information sources classified as experts (EI) and farmers (FI) interviews, case studies (C), scientific literature (L) theses and technical reports (T), and personal observations (O). The number of sources is indicated within parenthesis for each category, except for (O).

Key: + positive, - negative, +/- positive and negative, (?) unknown, N.A. = Not applicable and N.I. = No impact

Source: own elaboration based on data from literature review, interviews and observations presented in Appendix III.

The analysis that is summarized in Table 5-2 shows that deciduous fruit farming affects 19 out of 30 ecosystem services considered in the analysis. From these ecosystem services, eight are largely affected (high impact) and 11 are affected to a lesser extent (medium impact). Five ecosystem services are positively affected, four of them are negatively affected and nine services are positively and negatively affected at the same time. The nature of the impact is unknown only for one ecosystem service. The majority of the impacts of deciduous fruit farming on ecosystem services occur on provisioning and regulating services. No impacts are identified for habitat services and only one impact is recognized on a cultural and amenity service. The following sections include a brief description of the most relevant impacts organised in ecosystem service categories.

5.2.1 Impacts on provisioning services

The identified impacts of deciduous fruit farming on provisioning services occur on food, water, raw material and genetic resources. Apart from the high positive impacts on the quantity of fresh fruit produce from the ecosystems in the area, high impacts on wild foods are also identified. Medium to high negative impacts on wild foods can be attached to any agricultural activity occupying former natural areas where wild fruits were originally found. However, deciduous fruit farming in the Langkloof also influences the production of honey, thus determining also a positive large impact on food. In this case, by hiring beehives for the orchards during pollination season, fruit farmers offer new opportunities for other users (i.e. beekeepers) to benefit from a multipurpose business (i.e. pollination and honey production), which grows along with the demand for pollination services.

Water provision is also largely affected in different dimensions, which include positive and negative impacts on the quantity of this service. IAPs management, fire prevention, and an efficient use of water in farming processes enhance the provision of water for other users in the catchment. Nevertheless, water diversion, through artificial reservoirs and canals, and groundwater extraction, negatively affect downstream water users.

Among the different raw materials, timber and other wood fibres are affected by the replacement of natural vegetation. However, fruit farming is not deemed as an activity that can limit or enhance the capacity of other users to benefit from this service. Therefore, this impact is classified as medium. Organic fertilizer preparations for the orchards also imply an enhanced provision of this service (i.e. positive impact), although a private use of it in farms determines a medium impact, since it does not benefit other users in the Langkloof.

In terms of genetic resources, new fruit tree varieties in farms increase the availability of genetic resources in the Langkloof. However, the intensive orchards cultivation minimizes the potential use of land for other crops or indigenous plant species, thus reducing genetic resources. Since the orchards surface is limited in comparison with other land uses and the utilization of new tree varieties is private, farming activities are unlikely to affect others in terms of genetic resources. Therefore, this impact is classified as medium, and simultaneously as positive and negative.

5.2.2 Impacts on regulating services

Regarding regulating services, the largest impacts are identified on extreme events moderation and water flow regulation. In both cases, the diversion of rivers, and the replacement of wetlands and other vegetation types affect the provision of these ecosystem services and potential benefits to others (i.e. high impact). While water flow regulation is only negatively affected by these factors, the moderation of extreme events can also be enhanced by the infrastructural improvements and prevention measures implemented by farmers in the area (i.e. positive and negative impact).

Fruit farming largely affect the erosion prevention capacity of ecosystems to a large extent (i.e. high impact). Farmers implement erosion prevention and mitigation measures that, in general, have positive effects in their farms and in other parts of the catchment as well. In contrast to these measures, the role of wetlands in the protection from soil erosion has been minimized with their replacement by orchards. Furthermore, specific cases of erosion associated to a negligent soil management have also affected the erosion prevention service. Thus, all these practices combined give rise to positive and negative impacts on soil erosion prevention in the study area.

In the case of pollination, the impacts are also high and positive, since the mere presence of orchards can attract pollinator species to the area. Furthermore, bringing beehives into farms further enhances this service. However, the application of pesticides has the potential to negatively affect pollinators. Therefore, the impacts are at the same time classified as negative. These impacts of farming management and practices affect the quality of the pollination service in the Langkloof, as well as other activities, such as beekeeping.

A medium impact was identified on all the other regulating services because deciduous fruit farming can affect their quantity or quality, but does not necessarily influence the benefits that others perceive from these services in the study area. In the case of regional and local climate regulation the nature of the impact (i.e. positive or negative) is unknown. Even though various case studies were found in the literature analysing effects of land use change on climate regulation, the specificity of this type of impacts regarding the geographical context do not allow extrapolating those results to the study area.

5.2.3 Impacts on cultural and amenity services

According to the impact analysis, from cultural and amenity services, deciduous fruit farming only affects aesthetic features of the landscape. Orchards are conspicuous elements in the area that contribute to define the national Route R62 as a scenic drive. Thus, deciduous fruit farming positively affects how others benefit from the aesthetic value of the Langkloof, either for visitors in the area or the development of the tourism sector (i.e. high positive impact).

Further information about impacts of deciduous fruit farming on ecosystem services in the Langkloof is presented in Appendix III.

5.3 Selection of key ecosystem services related to deciduous fruit farming

The combined analysis of impact and dependence is the basis to determine key ecosystem services in terms of the potential risks and opportunities that may arise from changes in their provision (Hanson *et al.*, 2012). Consequently, three priorities of ecosystem services for deciduous fruit farming are presented in Table 5-3. These priorities are assigned according to the criteria presented in Section 3.4 (Table 3-7).

Table 5-3. Impact-dependence matrix of the deciduous fruit farming sector in the Langkloof

Ecosystem services	Dependence	Impact	Priority
Provisioning			
1. Food			
1.1.Crops	N.D.	High (+)	3rd priority
1.2. Livestock	N.D.	Medium (+/-)	No priority
1.3. Wild foods	N.D.	High (+/-)	3rd priority
2. Water	High	High (+/-)	1st priority
3. Raw Material			
3.1. Timber and other wood fibre	Medium	Medium (-)	3rd priority
3.2. Fibres and resins	N.D.	N.I.	No priority
3.3. Animal Skins	N.D.	N.I.	No priority
3.4. Fodder	N.D.	N.I.	No priority
3.5. Fertilizer	Medium	Medium (+)	3rd priority
4. Genetic Resources	N.D.	Medium (+/-)	No priority
5. Medicinal Resources	N.D.	N.I.	No priority
6. Ornamental Resources	N.D.	N.I.	No priority
Regulating			
7. Air quality regulation	High	Medium (+/-)	2nd priority
8. Climate regulation			
8.1. Global climate regulation	Medium	Medium (+/-)	3rd priority
8.2. Regional/local climate regulation	High	Medium (?)	2nd priority
9. Moderation of extreme events	High	High (+/-)	1st priority
10. Regulation of water flows	High	High (-)	1st priority
11. Waste treatment			
11.1. Water purification	Medium	Medium (-)	3rd priority
11.2. Waste treatment	Medium	Medium (+)	3rd priority
12. Erosion prevention	Medium	High (+/-)	2nd priority
13. Maintenance of soil fertility	Medium	Medium (+)	3rd priority
14. Pollination	High	High (+/-)	1st priority
15. Biological control	Medium	Medium (-)	3rd priority
Habitat			
16. Maintenance of life cycles of migratory species	N.D.	N.I.	No priority
17. Maintenance of genetic diversity	N.D.	N.I.	No priority
Cultural & Amenity Services			
18. Aesthetic information	N.D.	High (+)	3rd priority
19. Opportunities for recreation & tourism	N.D.	N.I.	No priority
20. Inspiration for culture, art and design	N.D.	N.I.	No priority
21. Spiritual experience	N.D.	N.I.	No priority
22. Information for cognitive development	N.D.	N.I.	No priority
Key: + positive, - negative, +/- positive and negative, (?) unknown, N.D. = No dependence and N.I. = No impact. The light blue cells highlight the first priority or key ecosystem services.			

Source: own elaboration based on the results of the impact and dependence analysis.

As detailed in the results in Table 5-3 above, 10 ecosystem services are included in the third priority group, three ecosystem services are classified as second priority and four as first priority for deciduous fruit farming in the Langkloof.

The third priority services include food (crops and wild foods), raw material (timber and other wood fibres, and fertilizers), global climate regulation, waste treatment (water purification and waste treatment), soil fertility, biological control and aesthetic information. Deciduous fruit farming activities currently have a medium dependence and impact on part of these ecosystem services, and a high impact and no dependence on others. In any of these cases, third priority services do not represent sources of risks and opportunities regarding changes in the ecosystems in the area at the moment. Nevertheless, variations in the availability of cost effective substitutes (e.g. rising prices) for any of these ecosystem services would determine an increase in the dependence on that particular service. Similarly, and according to Hanson *et al.* (2012), a medium impact could turn high in any of the following cases: if the share of fruit farming impact compared to other activities in the catchment increased (e.g. water pollution caused by deciduous fruit farming becomes larger that pollution from other sources); if the supply of the service were short in comparison to demand (e.g. increase in the demand of any service negatively affected); or if the current quality or quantity of the ecosystem service were near a physical or regulatory threshold (e.g. poor water quality according to standards).

Air quality regulation and regional and local climate regulation are grouped as second priority services because the deciduous fruit-farming sector is highly dependent and has a medium impact on them. Although the dependence on these services is not modifiable unless cost effective substitutes existed, the negative impacts on these services can still be mitigated to minimize potential risks in the future (e.g. by adapting the application of fertilizers to reduce emissions). Erosion prevention is also included as a second priority service, but in this case with a medium degree of dependence and high impact (negative and positive). Changes in cost effective substitutes for this service (e.g. higher costs of erosion prevention measures) can increase the dependence level, and hence need to be monitored. On the other hand, the impact can be mitigated to minimize and avoid risks (e.g. by minimizing impacts on others with afforestation or other prevention measures).

The ecosystem services identified as first priority include water, moderation of extreme events, regulation of water flows and pollination. For all of these services a high dependence and impact were determined, and hence, changes in their provision are expected to generate the main risks and opportunities for deciduous fruit farming in the Langkloof. The following chapter focuses on trends for these key ecosystem services only. Thus, these ecosystem services are the basis for subsequent analyses and recommendations.

6 Trends in key ecosystem services for deciduous fruit farming in the Langkloof

This chapter aims at providing an overview of the current condition and trends in key ecosystem services that can eventually pose risks and opportunities for deciduous fruit farmers in the Langkloof. The current condition is described in terms of supply and demand for each key ecosystem service. Furthermore, the main drivers of change in key ecosystem services are identified, along with the main activities and stakeholders that are likely to influence ecosystem change in the study area. Table 6-1 summarizes the main results of this analysis, which is further described in the following sections.

Table 6-1. Summary matrix of the trend analysis of key ecosystem services

Key ecosystem services	**Provision unit or ecosystem**	**Current condition**	**Likely future trends**		**Drivers of change**
			Demand	**Supply**	
1a. Water (provision)	• Tsitsikamma and Kouga mountains (including Fynbos)	(+)	➚	➘	• IAPs • Fires • Land degradation • Population growth • Climate change • Land use change
1b. Water flow regulation	• Fynbos • Wetlands	(+)[1]	➔	➘[1]	• IAPs • Fires • Land degradation • Population growth • Climate change • Land use change
2. Extreme events moderation	• Fynbos • Wetlands	(-)	➚	➘	• IAPs • Land degradation • Climate change • Land use change
3. Pollination	• Fynbos • Thicket • Agricultural matrix • Alien plants	(+)	➚	➔	• Habitat degradation • IAPs • Alien pollinators, pests and diseases • Climate change • Land use change

Key: + good or sufficient, - bad or insufficient, ➚ increasing, ➔ stable and ➘ decreasing

[1] It is recommended to re-assess this service if quantitative information or indicators are made available.

Source: matrix adapted from Kosmus *et al.* (2012) and Hanson *et al.* (2012). Data obtained from interviews and literature review.

The current condition of water provision, water flow regulation and pollination is classified as good, because the ecosystems in the area present a favourable state to provide these services and/or the supply is sufficient in terms of the current demand. For extreme events moderation, on the other hand, the current condition is classified as insufficient on the basis of specific circumstances that affect the ecosystems in the study area (e.g. invasive alien species, soil erosion, etc.), and hence, hamper the moderation of these events to its full extent.

In terms of likely future trends, the demand for water provision and pollination is expected to grow. However, the supply of these services is likely to be stable. In the case of water the supply could decrease if climate change impacts become too severe in the future.

The demand for water flow regulation and extreme events moderation is likely to remain stable. However, the demand for the latter could also grow in the future if climate change affects the intensity and frequency of extreme events. For both services a decreasing trend in supply is determined. The main drivers influencing this trend are the limited effectiveness of alien plants clearing and the lack of soil erosion control in the Kouga catchment.

As shown in Table 6-1, water provision and regulation of water flows are classified as separate services (de Groot *et al.* 2010). Nevertheless, since the drivers of change in both ecosystem services are largely intertwined, their analyses have been combined in the following section in order to avoid unnecessary duplication of information.

6.1 Ecosystem change and trends in water provision and water flow regulation

Since the Kouga catchment does not only supply water resources to the Langkloof, but also to other regions, water use by deciduous fruit farming in this valley is usually targeted as a threat for the population and activities downstream. Thus, despite being situated in a privileged upstream location that mitigates potential water shortages at a local scale (Jansen, 2008); the activities in the Langkloof still share a large responsibility in terms of water use efficiency. Accordingly, legal limitations on water use have ultimately put pressure for an efficient management of this resource by farmers in the valley (EXP 4, pers. comm.). Water infrastructural development and water use efficiency in the catchment are thus driven by the need to maximize yields, whilst complying with legal and regulatory requirements.

The following sections summarize the currently available information about supply and demand for water and the regulation of water flows. Since future trends do not only depend on the current supply and demand (Table 6-2), the drivers of change and the interaction with other water users are also examined (Table 6-3).

Figure 6-1. Haarlem Dam (left) and IAPs in the riparian zone of a Kouga River tributary (right).

6.1.1 Current condition of water and water flow regulation

Water supply in the Kouga catchment is highly influenced by erratic rainfall patterns, which determine large variations in water discharge (Jansen, 2008). A mean annual runoff of 255 mm is calculated for the catchment (Hosking and du Preez, 2004) and the groundwater recharge in the Kouga and Baviaanskloof catchments together is estimated at approximately 150 million m^3 per year (Jansen, 2008).

The Kouga River is estimated to supply 125 to 135 million m^3 per year, from which 5% to 8% comes from the groundwater. In total, the river discharge provides almost 80% of the inflow to the Kouga dam (Jansen, 2008). This is particularly relevant because 30% of the water required by the Nelson Mandela Bay Municipality comes from that dam (Jansen, 2008).

The study area extends over areas upstream the Kouga dam. Therefore, water users in the Langkloof share a large responsibility in terms of protecting water provision and flow regulation. Besides downstream users, the water provided in the Kouga River catchment is utilised for agriculture and domestic users concentrated in the Langkloof (i.e. municipality).

Despite the lack of detailed figures of domestic water use in the Kouga catchment, Jansen (2008) estimates that domestic use only accounts for 1 or 2% of the irrigation requirements in the catchment. Deficient infrastructure maintenance and water losses, however, do not allow supplying enough water to domestic users. According to a representative of Koukamma municipality (GOV 1, pers. comm.), around 90% of the domestic demand is currently met. Furthermore, stakeholders agree on the fact that water losses for domestic supply are too high in the area[2]. In the worst cases, water losses are estimated at even 175% of the water use, thus exceeding the current domestic demand for water (EXP 2, pers. comm.).

Most of the water in the Kouga catchment and the Langkloof is used for agriculture. The net water use for irrigation is calculated between 25 and 30 million m^3 per year (Jansen, 2008). As described in Section 4.3, the water for irrigation is stored in communal dams and allocated to farmers either by turns in a schedule or by irrigable hectares. Together, the two main communal dams in Joubertina (Waboooms river) and Haarlem can store around 5 million m^3 (Jansen, 2008). This water is distributed to private weirs and farm dams through a network of canals and pipes, which stores around 26 million m^3 in total (Jansen, 2008).

Groundwater abstraction is another practice described during interviews. Some farmers pump water from boreholes during dry years (e.g. drought in 2008 and 2009), reaching 100 m deep in some cases (DFF 7, pers. comm.). In this regard, the DWAF estimated already in 2004 that natural mean annual runoff in the Kouga catchment had decreased partly due to such abstractions. All the information and indicators of the current demand and supply for water and water flow regulation are summarised in Table 6-2.

Information about **water provision** in the Kouga catchment (Jansen, 2008) indicates that farming activities in the area are not expected to currently face problems in terms of water assurance given their favourable position upstream the catchment and their significant water storage capacity. In this sense, cases of insufficient water supply can be more likely originated from the lack of storage capacity and infrastructure maintenance than from a bad condition of the ecosystems supplying this service. Thus, in spite of the current challenges in terms of infrastructure and water management (e.g. minimizing water losses), the condition

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[2] Based on meetings attended during the Water Learning Journey in Joubertina (partial transcript is provided in the supplementary material in the CD attached to this thesis).

of water provided as an ecosystem service can be deemed as **good or currently sufficient**, since it can currently cope with the water demand in the area (Criterion C1, Section 3.2.2).

Regarding **water flow regulation**, the available information does not allow quantitative estimations of its current condition. Nevertheless, the impacts of water diversion through pipes, canals and dams on this ecosystem service have been already described for the impact analysis in Appendix III. In the study area, such impacts include increased floods damage mainly arising from insufficient infrastructure or lack of maintenance (EXP 1, pers. comm.). Despite the occurrence of this type of events, the ecosystem's capacity to regulate water flows can be still considered to contribute to the aquifer recharge and filling dams to a large extent, since its supply is still sufficient compared to the demand in the area (Criterion C1, Section 3.2.2). Even though the condition of this ecosystem service is classified as **good or currently sufficient**, no information about current soil erosion levels or other quantitative indicators of water regulation in the study area are accessible for this thesis. Therefore, revising the current condition of water regulation in the study area is highly recommended if new information is made available in the future.

Table 6-2. Current condition of the supply and demand for water and regulation of water flows

Key Ecosystem Services	Main facts and indicators of the current condition	
	Supply	Demand
Water provision	• Mean Annual Runoff in the Kouga catchment equals 255 mm. • Water supply of Kouga River is between 125 and 135 million m3 per year. • Groundwater outflow is estimated to contribute with approximately 5 to 8% of the total river flow.	• Net water use for irrigation in the Kouga catchment is between 25 and 33 million m3 per year. • The Nelson Mandela Bay Metropolitan Municipality demands on average about 20 million m3 per year. The Kouga dam supplies 30% of such requirement. • Storage capacity of Haarlem and Joubertina (Waboom River) dams is 5 million m3. Farm dams are estimated to store 26 million m3. • Groundwater abstractions have affected natural mean annual runoff in the catchment.
Regulation of water flows	• Variations in the water discharge in the Kouga catchment arise from erratic rainfall pattern. • There is no available data about current erosion levels or quantitative indicators of water flow regulation.	• Farmers rely on a combination of the storage capacity of ecosystems and water infrastructure to counteract erratic discharges in the catchment.

Source: literature review and interviews with farmers and experts.

6.1.2 Drivers of change and contribution of others to water provision and water flow regulation

The drivers presented in Table 6-3 can lead to changes in future supply and demand for water and water flow regulation, thereby determining risks and opportunities for deciduous fruit farming and other stakeholders in the area. The main direct drivers of change affecting these ecosystem services include the spread of invasive alien plants, fires, land use change, land degradation, population growth and climate change (Appendix VIII).

Deciduous fruit farmers can contribute to the majority of these drivers in the study area. The WfW program and the DWAF contribute by implementing clearing programmes for invasive alien plants in the catchment. The municipal fire departments and their coordinated activities with farmers are also relevant for fire control and prevention. All the agricultural activities in the area relate to land use change and the influential municipalities in terms of population growth include Koukamma, George (in the case of Harleem) and Nelson Mandela Bay. Regarding climate change, the contribution of the stakeholders in the study area is not considered to determine future trends, given the scale of this thesis.

Table 6-3. Drivers and stakeholders influencing changes in water and water flow regulation

Driver	**Condition of the driver**	**Stakeholders influencing trends**
Alien plants invasion	• Invasive Alien Plants (IAPs) are estimated to currently reduce: - 1 billion m^3 of the mean annual runoff in Fynbos in South Africa. - 4 million m^3 of the groundwater recharge in South Africa. - 6% of the streamflow in the Eastern Cape Province. - 16% of the streamflow in the Western Cape Province. • A rate of spread of IAPs of 15% per year is estimated in the catchment. • Total clearing at current rates may take 35 to 85 years under favourable conditions • Farmers in the Langkloof identify weaknesses of WfW program (e.g. communication, follow up, clearing methods) that threaten its effectiveness in the area.	• Deciduous fruit farmers • WfW • DWAF
Fires	• Provide suitable conditions for invasive alien plants to establish. • Fynbos is a fire prone vegetation type. • Fire return period in Fynbos is between 12 and 15 years. • Control burns are coordinated between the municipality and farmers	• Deciduous fruit farmers • Municipal fire department
Land degradation	• Some farmers in the area take measures for soil erosion prevention. • There are cases of severe erosion caused by deficient farming practices in the Langkloof. • There are no coordinated actions in the Langkloof or the Kouga catchment to prevent or stop soil erosion.	• Deciduous fruit farmers
Population growth	• Preliminary estimates from Koukamma municipality representatives describe an increase in the local population of around 2.5%. • There are high water losses in domestic water supply in Koukamma municipality. • Population growth of 100%in 10 years is projected in the Nelson Mandela Bay Metropolitan Area. • The Kouga dam provides about 30% of the water demand to Nelson Mandela Bay Metropolitan Municipality.	• Koukamma municipality • Nelson Mandela Bay Municipality
Climate change	• Between 1997 and 2006 South Africa was 2% hotter and 6% drier than in the 1970s. • The Eastern Cape province became 3% hotter and 5% drier in the same years. • Case studies in Southern Africa estimate a decreasing streamflow caused by climate change in the region. • Changes in groundwater recharge and in timing, frequency and intensity of precipitation are foreseen in the country.	-
Land use change	• Agricultural expansion opportunities are limited in the Langkloof. • 30% of the Kouga catchment is formally protected • 28% of the Fynbos in the catchment are formally protected • 90% of the focus areas for expansion is planned on Fynbos	• Deciduous fruit farmers • Livestock farmers • Other farmers

Source: information from interviews and literature review presented in Appendix VIII

In terms of **water provision**, a combination between the spread of invasive alien plants, poor control of soil erosion and potential effects of climate change, can largely determine future trends in supply. Therefore, based on the information presented in Table 6-3 and Appendix VIII the **supply** of water in the area is likely to **decrease** in the future. On the other hand, despite the limited opportunities for agricultural expansion and increased water efficiency in this sector, the **demand** for water in the catchment is likely to **increase** as a result of population growth in local and downstream municipalities.

Regarding **water flow regulation**, the **demand** for this service is likely to remain **stable**, since further expansion of agriculture in the Langkloof is not expected to be significant (DWAF, 2004) and this service can be complemented with infrastructural improvement. Notwithstanding a large proportion of the catchment is under formal protection (see Section 2.2.3), water flow regulation can be still threatened as an ecosystem service in the future. A limited effectiveness of IAPs clearing programmes in the catchment (van Wilgen, 2009), along with the lack of coordinated actions for soil erosion control (EXP 2, pers. comm.), are the main drivers that can determine changes in the streamflow and groundwater recharge. Such impacts can be worsened by climate change, since changes in precipitation intensity and timing are foreseen in the country (Blignaut *et al.*, 2009; Kusangaya *et al.*, 2014; Calzadilla *et al.*, 2014). Even though the magnitude and extent of these processes in the future are largely uncertain, for the purposes of this thesis (e.g. identifying risks and opportunities) a likely **decreasing trend** in **supply** is assumed in the future for water flow regulation on the basis of the available information about drivers summarized in Table 6-3.

6.2 Ecosystem change and trends in extreme events moderation

As already described in Section 4.3, extreme events represent one of the main concerns for the future among deciduous fruit farmers in the Langkloof. Erratic rainfall patterns in the area represent a concern themselves (Jansen, 2008), but they can also affect the water discharge causing floods and damage to infrastructure. In addition to that, recent droughts and the frequent hailstorms described in interviews have caused major fruit production losses. Besides these climatic events, the Fynbos susceptibility to fires poses an extra risk, which is increased by alien plants invasion in the study area (van Wilgen, 2009; Figure 6-2).

Despite the limited availability of quantitative data about the moderation of extreme events, the sections below summarize the currently accessible information to assess the current condition of and future trends in this ecosystem service in the study area. Thus, Table 6-4 presents the main indicators of current supply and demand of this ecosystem service, whereas Table 6-5 sums up the direct drivers of change and the stakeholders and activities that are likely to influence future trends.

Figure 6-2. Fire impacts (Oct. 2014) on vegetation cover in the adjacent Kromme Catchment (left) and infrastructure damage in Haarlem dam caused by floods (right).

6.2.1 Current condition of extreme events moderation

As a regulating service, the quantification of the supply and demand for moderation of extreme events is not direct. Consequently, quantitative information to determine these conditions is scarce. For the purpose of this thesis, however, the supply of moderation of extreme events is qualitatively described in terms of the biophysical features and state of the ecosystems that enhance or limit the provision of this service. On the other hand, the magnitude and frequency of extreme events in the study area is presented as an indication of the current need (or demand) for moderation of such events (Table 6-4; Appendix IX).

The information summarised in Table 6-4 presents the large proportion of natural ecosystems and the absence of degraded areas (SANBI, 2009) as current conditions of the catchment that can contribute to the moderation of floods and droughts. Nevertheless, the loss of wetlands and riparian vegetation loss, and the soil erosion described in the Kouga catchment limit the supply of this service, particularly in terms of flood moderation.

The susceptibility of Fynbos to fires is exacerbated by the spread of alien plants, which increase the availability of biomass and create drier conditions (van Wilgen, 2009; GOV 3, pers. comm.). Therefore, the natural regulation capacity of the frequency and magnitude of fires in the study area is also limited.

Hailstorms are also presented in Table 6-4 in order to cover all the extreme events that occur in the Langkloof and the damage they can frequently cause to the agricultural sector in the valley. However, regardless of their state, local ecosystems do not exert direct influence in the moderation of hailstorms. Therefore, the capacity to moderate these events is not considered to determine the current condition of this ecosystem service's provision in the study area.

Determining the current condition of an ecosystem service, as described in the methods (Section 3.2.2), firstly requires the comparison between demand and supply. In the case of floods, droughts and fires, it is likely that as far as they occur, there will be demand for their moderation. Therefore, the supply would meet this demand only if these events were totally avoided. However, there could be cases in which ecosystems provide this service to their maximum capacity, thus minimizing the damage of extreme events, yet not necessarily preventing them from happening. For this reason, the current condition of extreme events moderation is evaluated in this thesis focusing only on the state of certain traits of ecosystems that determine its capacity to moderate extreme events, but not directly in the supply of this service (Criterion C2, Section 3.2.2). Consequently, since wetlands and riparian vegetation have been replaced in the study area, soil erosion is not tackled at a catchment scale and invasive alien species have spread over certain ecosystems, the current condition of this ecosystem service is deemed as currently **insufficient**.

Table 6-4. Current condition of the moderation of extreme events in the Langkloof

Moderation of extreme events	**Main facts and indicators of the current condition of the ecosystem service**	
	State of ecosystems and biophysical features	**Magnitude and frequency of extreme events and damage in the study area**
Moderation of floods	• 91% of the Kouga catchment and 61% of the Langkloof are classified as natural. • No degraded areas are identified in the catchment in the national land cover classification. • Orchards have replaced wetlands and riparian vegetation, though the extent is unknown. • Soil erosion processes are not tackled at a catchment scale.	• Exceptional peak flows in the catchment and adjacent areas have been registered in 1981, 1983, 1996 and 2006. • Flood in 2006 had the highest registered flows since measurements started in 1995. • During flood in 2006 water level in the Kouga Dam raised 24.5 metres in one day. • A smaller flood affected the Langkloof in 2007. • Floods with a magnitude of the one in 2006 have a return period of 50 years. • Floods with a magnitude of the one in 2007 have a return period of 5 years. • Combined damage of 2006 and 2007 floods included infrastructure and production losses.
Moderation of fires	• Fynbos contain fire prone species. • Alien plants invasion provide additional biomass and creates drier conditions. •Alien plants invasion increase risks and unpredictability of fires	• Fire return period in Fynbos is between 12 and 15 years. • 7 major fires have occurred in the catchment in recent years. • Biggest recent fire occurred in 2007 in the Heights and Tsitsikamma mountains. • Fires favour alien plants invasion.
Moderation of droughts effects	• 91% of the Kouga catchment and 61% of the Langkloof are classified as natural. • Natural areas are mainly Fynbos • No degraded areas are identified in the catchment in the national land cover classification. • Orchards have replaced wetlands and riparian vegetation, though the extent is unknown.	• From 2008 to 2011 insufficient rainfall caused droughts in the Langkloof. • Damaged infrastructure (from floods) did not allow saving enough water to cope with droughts. • Restrictions in the use of water were implemented in 2011.
Moderation of hailstorms damage	• Local ecosystems are not expected to directly influence frequency, magnitude or damage of hailstorms.	• Hailstorms are frequent (every year) and unpredictable in the Langkloof. • Hail damage is localised (e.g. specific farms). 10 out of 13 interviewed farmers have been affected by hailstorms. • Losses in the Langkloof include from few trees to the entire production of a farm.

Source: interviews and literature review presented in Appendix IX.

6.2.2 Drivers of change and contribution of others to extreme events moderation

Potential drivers of change in the moderation of extreme events include alien plants invasion, land use change, land degradation and climate change (Table 6-5; Appendix IX). Deciduous fruit farming is one of the main activities contributing to likely future trends in the provision of this ecosystem service. Different farming practices can influence invasion by alien plants and land degradation trends. Furthermore, the projections for deciduous fruit farming and other agricultural sectors in the Langkloof will most likely determine land use change and degradation in the future.

The WfW and the DWAF are currently in charge of controlling invasive alien plants. Consequently, they share a large responsibility regarding the effects of clearing practices on floods or other extreme events moderation. The fire department also plays a role in terms of coordinating and approving control burn, which minimizes the risks of fire and indirectly contribute to alien plants clearing. The contribution of the stakeholders in the study area to climate change is not considered to be of a major influence on this driver, given the scale of this thesis.

Table 6-5. Drivers and stakeholders influencing changes in extreme events moderation

Driver	Driver condition in the study area	Activities and stakeholders
Alien plants invasion	• Invasive alien plants (IAPs) provide additional biomass and drier conditions in sites where they establish. • Certain IAPs (e.g. *Acacia mearnsii*) grow in the riparian zone, but they are not adapted to floods, which increases damage. • A rate of spread of IAPs of 15% per year is estimated in the Kouga catchment. • Total clearing at current rates may take 35 to 85 years under favourable conditions. • Farmers in the Langkloof identify weaknesses of WfW program (e.g. communication, follow up, clearing methods) that hamper clearing goals achievement.	• Deciduous fruit farmers • WfW • DWAF • Fire department, Koukamma municipality
Land degradation	• Certain practices in farms in the Langkloof can help minimize soil erosion and flood damage. • There are cases of severe erosion caused by deficient farming practices in the Langkloof. • No measures are currently taken to control various observed cases of soil erosion around the Kouga River. • There are no coordinated actions to prevent or stop soil erosion at a catchment level.	• Deciduous fruit farmers • Livestock farmers
Climate change	• Between 1997 and 2007 the Eastern Cape Province became 3% hotter and 5% drier than in the 1970s. • Exacerbated cold and warm extremes are foreseen in Southern Africa as a result of climate change. • Less rainfall in winter and more rainfall in summer are expected in the Kouga catchment.	-
Land use change	• Future agricultural expansion is expected to be limited. • 30% of the catchment is formally protected, and hence it is not susceptible to changes in land use.	• Deciduous fruit farmers • Livestock farmers • Other farmers

Source: information from interviews and literature review presented in Appendix IX.

Regarding the most relevant drivers of change, invasive alien plants can increase the vulnerability of riparian zones to flash floods (Hosking *et al.*, 2002) and the unpredictability and magnitude of fires in the area (van Wilgen, 2009). At current expansion and clearing rates of invasive alien plants, it can be expected that they will remain as a main driver of change in trends in the moderation of extreme events (van Wilgen, 2009). Land degradation can be aggravated by alien plants invasion, but also by certain farming practices in the Langkloof. In spite of soil erosion prevention efforts by some farmers, cases of deficient land management (GOV 4, pers. comm.) and lack of soil erosion control are still likely to affect part of the catchment (EXP 2, pers. comm.). A combination of invasive alien plants impacts and land degradation is thus likely to determine a **decreasing trend** in the moderation of extreme events as an ecosystem service (supply).

Projections in terms of land use change in the study area show that this phenomenon would be limited in the future. Despite its potential effects on magnitude and frequency of extreme events, land use change is thus not considered to be a main driver of change in the moderation of these events.

Climate change is expected to exacerbate extreme temperatures and rainfall in Southern Africa in the future (Kusangaya *et al.*, 2014; Jansen, 2008). In general, hotter and drier conditions are currently experienced in the Eastern Cape province in comparison to the 1970s (Blignaut *et al.*, 2009). These changes could lead to an increase in the frequency and magnitude of extreme events such as floods, droughts and fires (Kusangaya *et al.*, 2014). Under such circumstances, the **demand** for extreme events moderation is likely to show an **increasing trend** in the next years, although it depends on the actual effects of climate change in the study area.

6.3 Ecosystem change and trends in pollination

Pollination was estimated to contribute with more than 9% of the world value of crops for direct human use in 2005 (Gallai *et al.*, 2009). As described in Chapter 5, deciduous fruit farming is not an exception, given its high dependence level on pollination. Indeed, a review of available information for 124 worldwide leading crops determined that animal pollinators could increase from 40% to 90% the production of the deciduous fruits considered in this thesis (Klein *et al.*, 2007). Benefits of this kind normally originate from two different types of pollinators, namely wild (e.g. wild insects and birds) and managed pollinators (e.g. honeybees) (Klein *et al.*, 2007; Garibaldi *et al.*, 2013; Melin *et al.* 2014).

Even though there is no consensus about considering managed pollinators as part of pollination as an ecosystem service, honeybees (the most common managed pollinator) are included in this thesis, because they are indigenous in South Africa (Melin *et al.*, 2014). Furthermore, research on honeybees' interactions with wild pollinators has shown that they do not necessarily substitute each other in their tasks, but instead they act as supplementary pollination agents (Garibaldi *et al.*, 2013). For these reasons, the following sections deal with the current condition and trends in pollination, including both pollinator types (wild and managed pollinators) in the Langkloof. The possible changes in pollination are addressed in terms of direct and indirect drivers, and the different factors with potential influence on such drivers.

Figure 6-3. Beehives in the Langkloof (Joubertina).

6.3.1 Current condition of pollination

Deciduous fruit farming in the Langkloof relies on both, managed and wild pollinators, in order to enable its successful performance. Consistently, 12 out of 13 interviewed farmers in the study area own or hire beehives during pollination season (Figure 6-3), which occur from August to November in the case of deciduous fruit (Melin *et al.*, 2014; Beekeeper 1, pers. comm.; Beekeeper 2, pers. comm.).

Honeybees (*Apis mellifera scutellata and A. mellifera capensis, both indigenous to South Africa*), bumble bees (*Bombus sp*.) and solitary bees (*Andrena sp*., *Anthophora sp*., *Osmia cornifrons*, *O. lignaria propinqua* and *O. rufa*) are common pollinator species of all deciduous fruit. Flies (*Eristalis sp.*) also contribute especially to stone fruit and pear pollination, whereas hover flies (*Eristalis cerealis* and *E. tenax*) are particularly relevant for apple (Klein *et al.*, 2007). Other insect pollinators are butterflies (Potts *et al.*, 2010), although their influence on deciduous fruit pollination in the Langkloof is not investigated in the references reviewed in this thesis. Among vertebrates, sugarbirds are also suggested as deciduous fruit pollinators in the study area (Melin *et al.*, 2014). Other bird or bat species are known to be relevant for the pollination of various crops (Klein *et al.*, 2007), but they have not been researched in cases with deciduous fruit that can be compared to the Langkloof context. Even though wild pollinators are more effective than managed bees for the pollination of several crops (Garibaldi *et al.*, 2013), specific information about the wild populations playing this role in the study area is scarce.

In terms of habitat, the Fynbos vegetation types represent the main indigenous floral resources for wild and managed pollinators (Melin *et al.*, 2014). Fynbos vegetation types are important nectar and pollen sources for beekeepers because of the long flowering season of their species (Beekeeper 1, pers. comm.). Wild bee populations in the mountains are thus considered to be still large, since travelling swarms are often seen in the Langkloof (Beekeeper 1, pers. comm.; DFF 9, pers. comm.). Additionally, specific crops, such as canola (*Brassica napus*), and some invasive alien tree species (e.g. *Eucalyptus sp.*) are effective in attracting swarms when other floral resources are limited (Melin *et al.*, 2014).

Trapping wild or migrating swarms is one of the most common practices to start a new beehive in South Africa (Melin *et al.*, 2014) and even if they are bought, swarms are originally obtained by this method (Beekeeper 2, pers. comm.). In spite of not being preferred by the beekeepers in the study area, trapping wild swarms from the mountains is described as an increasingly common practice that can potentially threaten wild bee populations (Beekeeper 1, pers. comm.; Beekeeper 2, pers. comm.). An alternative in this regard, if no migrating swarms are caught, is to divide a swarm after breeding a new queen. However, the last practice is less common than swarm trapping in the study area (Beekeeper 2, pers. comm.)

Once the beehives are established, beekeepers move them through different crops, around alien gum trees (*Eucalyptus sp*.) or in the Fynbos in order to provide foraging opportunities for honeybees throughout the year (Turpie *et al.*, 2003; Melin *et al.*, 2014). During off season in the Langkloof, bees are moved to the Western Cape or the Northern Cape provinces for honey production, since there are carrots, onions and other crops that serve as pollen and nectar sources for bees (Beekeeper 2, pers. comm.). In addition to that, pollination is also provided as a service to canola farms, because pollination season in that case occurs earlier than in deciduous fruits (Beekeeper 1, pers. comm.).

To provide an approximation of the demand for honeybee pollination in the Langkloof, two different estimations of the beehives and the direct pollination costs for deciduous fruit-farmers are presented in Table 6-6. The differences in these estimates arise from two different sources utilised as a reference for the calculations, which are all described in Appendix X. Since these calculations aim at providing only a rough idea of the demand for managed pollination, the table below presents approximate numbers. The exact results of the calculations are included in the appendix. The estimates based on interviews with farmers represent the number of beehives actually hired by the interviewed group of farmers. On the other hand, the information provided by beekeepers specifies the optimum number of beehives expected in one hectare in order to maximize the productivity of each deciduous fruit. Therefore, the second estimate reflects the demand for pollination under a scenario in which every farmer utilizes the recommended number of beehives in each orchard. The number of honeybees needed for pollination is included as a reference to quantify the magnitude of the pollination agents involved in the provision of this service. Furthermore, the number of pollinations from beehives required in a year is presented to make these results comparable with other studies conducting similar estimations (e.g. Melin *et al.*, 2014)

Table 6-6. Estimation of the demand for managed pollination in the Langkloof

	Estimates based on Interviews with farmers	**Estimates based on Interviews with beekeepers**
Estimated number of beehives needed in a year	7,000	13,000 to 28,000
Estimated pollinations needed in a year	12,000	21,000 to 47,000
Estimated number of honeybees required in a year	220 to 360 million	600 million to 1 billion
Direct costs of managed pollinators for deciduous fruit farming in the Langkloof in a year	3 million ZAR	5 to 13 million ZAR

Source: literature review and interviews with farmers and beekeepers.

Although there are no particular estimates of the supply of pollination services in the Langkloof, approximations to the total number of operating hives in the country quantify them between 90,000 and 110,000, and in some cases even up to 250,000 (NAMC, 2008). More specifically, the hives in the Western Cape are estimated approximately between 45,000 (NAMC, 2008) and 73,000 (Turpie *et al.*, 2003). According to beekeepers interviewed in the Langkloof, an important part of the hives for pollination in deciduous fruit in the study area come from the Western Cape, since this business is better developed there than in Eastern Cape areas around the Langkloof (Beekeeper 1, pers. comm.; Beekeeper 2, pers. comm.).

The Western Cape Province alone requires on average 42,000 pollinations in a year and since each beehive is estimated to account for 1.7 pollinations (Melin *et al.*, 2014), almost 25,000 beehives are needed to provide this service to the province. Nevertheless, the Langkloof has an estimated demand between 7,000 hives (from farmers' answers) and 21,000 hives (average calculated from interviews with beekeepers). Since the Langkloof demand is partly covered by the Western Cape, the demand for beehives in the Western Cape Province and this valley together is estimated between 32,000 and 46,000 beehives per year. This means that in a pessimistic scenario with no supply of beehives in the Eastern Cape, the surplus would reach a maximum of around 30%, if the supply (45,000) presented by NAMC (2008) were considered, or approximately 50%, if the supply (73,000) expressed by Turpie *et al.* (2003) were used for the calculations.

Despite the large differences in the surplus estimates arising from the use of different data sources, these results seem to support that the supply, including Western Cape, can currently cope with the demand for pollination in the Langkloof, and it is thus classified as a **sufficient or good current condition** (Criterion C1, Section 3.2.2). Information provided by beekeepers, however, shows that the **demand** currently follows an **increasing trend** that might continue in the future. According to them, there are still cases in which pollination comes from a place 300 km away from the farm and it might still take time to locally meet that growing demand for pollination in the Langkloof (Beekeeper 1, pers. comm.). Based on that, they perceive the need for developing beekeeping in the valley in order to cope with the deciduous fruit farming growing needs (Beekeeper 2, pers. comm.).

6.3.2 Drivers of change and contribution of others to pollination

Even though managed honeybees in South Africa have remained stable compared with the declines experienced in North America and Europe (Melin *et al.*, 2014), there are still many factors that can lead to changes in their populations and in wild pollinators number. The direct drivers of change in pollination include land use change, habitat degradation, invasive alien species, alien pollinators and climate change (Klein *et al.*, 2007; Potts *et al.*, 2010; Melin *et al.*, 2014). These drivers of change in pollination are detailed in Appendix XI and summarised for the study area in Table 6-7, along with other activities or stakeholders contributing to the trends in pollination that are also mentioned below.

Based on the information obtained from interviews in the Langkloof, deciduous fruit farming may particularly contribute to land use change, habitat degradation and invasive alien species control. In the case of land use change, the orchards extension is usually according to water storage capacity and current restrictions in that regard may eventually prevent large-scale expansions in the future (EXP 4, pers. comm.). In case it occurs, the expansion of orchards or other agricultural crops expansion can be actually beneficial for pollination services in terms of providing new foraging sources (Potts *et al.*, 2010; Melin *et al.*, 2014). Nevertheless, deciduous fruit farming may also have a main influence in habitat degradation for pollinators in the Langkloof, since all the interviewed farmers mentioned chemical pesticides. Even though some farmers take preventive measures to protect managed bees that include specific times for spraying or reducing concentrations (Beekeeper 1, pers. comm.), these practices do not prevent them from spraying. Therefore, they can still affect wild pollinators' abundance and diversity (Potts *et al.*, 2010). Regarding alien plant species, farmers contribute to clearing, although this is done without following common guidelines. This can negatively affect pollinators, since clearing all the alien species, even if they are not considered invasive or degrading the ecosystems in the area, may unnecessarily reduce foraging resources for wild and managed pollinators (de Lange *et al.*, 2013).

Table 6-7. Drivers and stakeholders influencing changes in pollination

Driver	**Condition of the driver**	**Stakeholders influencing trends**
Habitat degradation	• Use of chemical pesticides is a common practice in orchards in the Langkloof. • Deciduous fruit farmers take preventive measures regarding managed honeybees, but spraying can still affect wild pollinators.	• Deciduous fruit farmers
Invasive Alien Species	• Alien species in the study area, especially gum tree species (*Eucalyptus sp.*) are beneficial for wild and managed pollinator species. • Clearing strategies can reduce foraging resources for pollinators, although other species can potentially serve as a substitute.	• WfW
Alien pollinators and disease and pests spreading	• Wax moth larvae affect honeybee colonies in the Karoo, but it is controlled in the Langkloof. • Imported pests and diseases are currently controlled. • Regional varieties are not moved to other areas in order to avoid interferences in pollination arising from specific traits. • High colony losses are observed. These are attributed, in the scientific literature, to moving colonies and social parasitism.	• Beekeepers
Climate change	• Colony losses associated to cold winters and rainy periods are observed. • Frost hampers establishing new swarms.	-
Land use change	• Agricultural expansion rates in the Langkloof are constrained by water storage capacity. • At least 30% of the Fynbos (habitat for wild and managed pollinators) is not susceptible to land use change, since it is officially protected. • The agricultural matrix can also provide a habitat for pollinators (e.g. canola, deciduous fruit and vegetables).	• Deciduous fruit farmers • Livestock farmers • Other farmers

Source: information from interviews and literature review presented in Appendix XI.

The WfW program may also influence pollination trends in terms of controlling invasive species that serve as forage for pollinators, because an appropriate management of these species may avoid significant losses in terms of pollination supply in the area (de Lange *et al.*, 2013).

Beekeepers in the study area play an important role in terms of controlling alien pollinators and disease spreading, since they move beehives through different forage sources and regions in South Africa. Imported pests that have affected honeybees in the past have been controlled and beekeepers take preventive measures in terms of the management of different honeybee species varieties. However, high colony losses, which can threaten pollination supply, remain a challenge for beekeeping, since these loss rates have been partly attributed to the practice of moving beehives in combination with social worker parasitism by *Apis mellifera capensis* (Melin *et al.*, 2014).

Even though the current condition of pollination as an ecosystem service in the Langkloof has been categorised as sufficient and a **growing demand** is likely to be observed in the future (see previous section), the supply of this service is not necessarily expected to increase. High colony losses, climatic threats and the use of chemicals, among others, can prevent pollinator populations from growing in the future, despite the availability of foraging resources and the current prevention measures taken by farmers and beekeepers. For these reasons, the likely future trend in **supply** is classified as **stable**.

7 Risks and opportunities for deciduous fruit farming in the Langkloof

This chapter relies on the results of the ecosystem services analysis (Chapter 5) and the trends analysis (Chapter 6) to identify the main risks and opportunities for deciduous fruit farming arising from ecosystem change in the Langkloof. The information presented below is aimed at giving a general overview to guide future management strategies in the study area.

In order to provide a scale of reference for management strategies, a priority is assigned to the identified risks and opportunities according to the current condition and trends of the key ecosystem services that originate them (see Section 3.2.3; Table 3-4). Thus, the risks and opportunities emerging from changes in extreme events moderation are the first in importance with very high priority. This priority for management is based on the currently insufficient condition of this ecosystem service, which can be worsened considering the likely future trends in supply (decreasing) and demand (increasing) in the Langkloof.

In spite of the currently sufficient condition of water provision in the study area, risks and opportunities arising from possible trends in this service are also categorised as a very high priority for management. The management of this ecosystem service is deemed as increasingly relevant on the basis of an increasing demand and a decreasing supply, which is likely to be determined by climate change impacts.

The risks and opportunities arising from changes in water flow regulation and pollination are categorised as high priority for management. This lower category compared to the previous services is assigned on the basis of a likely stable demand or supply.

The results presented in Table 7-1 are organized following this priority scale (from top to the bottom of each group). Furthermore, risks and opportunities are grouped by their corresponding key ecosystem services and within one of the main categories suggested by Hanson *et al.* (2012). The results for each of those categories are summarised as follows:

a) Operational risks and opportunities

Identified risks in this category include disruption to farming activities, reduced productivity and increased costs for deciduous fruit farming as a result of changes in key ecosystem services. On the other hand, opportunities can contribute to cope with changes in these key ecosystems services, whilst enhancing farming performance by implementing new farming practices, developing infrastructure and improving management. The majority of the operational risks and opportunities originate from changes in extreme events moderation or water provision.

Table 7-1. Risks and opportunities for deciduous fruit farming arising from ecosystem change

Type	Risk	Opportunity
Operational	• Disruption to farming due to floods or fires. • Reduced productivity due to droughts (water scarcity) or floods (damage to trees). • Increased costs of water infrastructure (e.g. building, repairing or maintaining infrastructure). • Increased costs of pumping water (e.g. in droughts).	• Improved land management practices (e.g. preventing extreme events damage and soil erosion). • Improved water infrastructure. • Improved fire management (e.g. preventing and controlling fires efficiently).
	• Reduced productivity due to water scarcity. • Increased costs of pumping water (e.g. transferring water to and among farm dams). • Increased costs of water due to insufficient supply to meet the growing demand.	• Increased efficiency in irrigation systems. • Improved water saving practices.
	• Increased costs of pumping water (e.g. reduced groundwater recharge).	• Improved land management practices
	• Increased costs of managed pollinators.	• Improved pest and disease management.
Regulatory and legal	• Lawsuits due to liabilities in flood or fire damage. • Fines as a result of control burns without permit. • Fines for liabilities in wildfires. • Emergency restrictions on water use (e.g. droughts).	-
	• Restrictions on storage capacity to assure water provision to downstream users. • Increased user fees for water due to growing demand.	-
	• Restrictions on groundwater extraction (e.g. due to effects on the catchment discharge).	-
Reputational	• Damaged relationship with other stakeholders due to liabilities in flood or fire damage.	• Improved image among local stakeholders (e.g. collaboration in the FPA).
	• Damaged image in case of insufficient water provision (e.g. downstream water users).	• Improved relationship with downstream water users (e.g. saving water upstream).
	• Damaged image due to effects of water diversion or groundwater extraction on availability for other users (e.g. downstream water users).	• Improved relationship with downstream water users (e.g. by upstream infrastructure maintenance).
	• Damaged image and relationship with local stakeholders in case of pollinators decline.	• Improved brand (e.g. organic farming).
Market and product	-	• Payments for ecosystem services (e.g. protecting water source).
	-	• Payments for ecosystem services.
	• Changes in customer preferences (e.g. favouring organic or specific farming practices).	• Access to market for certified products (e.g. organic farming).
Financing	• Increased costs of insurance premiums.	-

🟥 Risks and opportunities related to **extreme events moderation** (very high priority)
⬜ Risks and opportunities related to **water provision** (very high priority)
🟦 Risks and opportunities related to **water flow** regulation (high priority)
🟧 Risks and opportunities related to **pollination** (high priority)

Source: own elaboration based on information presented in chapters 5 and 6.

b) Regulatory and legal risks and opportunities

In the case of deciduous fruit farming, risks of fines or lawsuits can emerge from liabilities in extreme events, particularly floods or fires. Furthermore, legal restrictions or increased fees on water use can arise as a regulatory response to a growing demand or decreasing availability. Changes in pollination are not considered to generate risks under this category. No legal or regulatory opportunities are identified.

c) Reputational risks and opportunities

Damaged relationship with local stakeholders is identified as a risk in cases of liabilities in extreme events or pollinators decline. Similarly, damage to deciduous fruit-farming image in the Langkloof can arise from impacts of farming activities on water provision, water flow regulation and pollination. In terms of the reputation of this agricultural sector in the study area, there are opportunities for collaboration with the fire protection association (FPA), in which some farmers currently contribute to fight and prevent fires in the area, while obtaining advise, training and legal assistance. Furthermore, there are also opportunities for improving image and relationship with downstream users if water is saved and infrastructure maintained by farmers in the Langkloof. Regarding pollination, tackling impacts on pollinators by adapting farming practices provides opportunities for brand improvement.

d) Market and product risks and opportunities

The main risk in this category relates to potential changes in customer preferences limiting access to specific markets. This risk may arise from customers becoming more concerned about fruit farming impacts on pollinators or favouring environmentally friendly practices over conventional intensive farming, among other reasons. Thus, minimizing impacts on pollinators would potentially provide opportunities to access specific markets, for instance, for certified products. The implementation of payment schemes for ecosystem services also represents a potential opportunity for fruit farmers, given their responsibility in terms of water provision and flow regulation to downstream users. In spite of not being currently implemented in the area, payment schemes could benefit fruit farmers and other stakeholders in the Langkloof depending on their share in the protection of strategic ecosystems in the area.

e) Financing risks and opportunities

Changes in frequency and magnitude of extreme events can lead to increased costs of insurance premiums if those perils are included in the coverage. Even though insurance premiums are not part of the main costs of farming, they can still be significant. Furthermore, an increase in insurance premiums could lead farmers to avoid agricultural insurance and face big losses if damage occurred.

8 Management and collaboration options to deal with risks and opportunities in the Langkloof

This chapter provides a general overview of alternatives for deciduous fruit farming management and partnerships in the Langkloof arising from the risks and opportunities identified in the previous chapter. Thus, the sections below summarize options, identified during the fieldwork and provided in the literature, for tackling the consequences of changes in key ecosystem services for farmers in the Langkloof. These options are summarized in Table 8-1, which also presents the type of risks and opportunities and key ecosystem services these options would potentially address. Management alternatives are aimed at deciduous fruit managers and farmers associations, whereas collaboration options additionally refer to NGOs, municipalities and other activities in the study area.

Table 8-1. Management and collaboration options to deal with risks and opportunities

Management and collaboration options	Risks and opportunities					Key Ecosystem services			
	Operational	Regulatory and legal	Reputational	Market and product	Financing	Extreme Event moderation	Water	Water flow regulation	Pollination
Farm management options									
a) Diversification	✓				✓	○	○		
b) Intensity of production	✓		✓	✓					○
c) Resource management	✓	✓	✓		✓	○	○	○	
d) Monitoring and information systems	✓	✓	✓			○			○
e) Agricultural insurance	✓					○			
f) Other management options	✓				✓	○			
Collaboration options									
a) Ecosystem restoration partnerships	✓	✓	✓	✓	✓	○	○	○	○
b) Biodiversity conservation in the catchment	✓	✓	✓	✓	✓	○	○	○	○
c) Resource management programs	✓	✓	✓		✓	○	○	○	
d) Disaster management collaboration	✓	✓	✓		✓	○			
e) Monitoring programs	✓	✓	✓			○			○
Key: ✓ Type of risk and opportunity, and ○ key ecosystem service addressed with each option									

Source: own elaboration based on information from Chapter 7, interviews and literature review.

8.1 Farm management options for deciduous fruit farming

Internal options for deciduous fruit farming to deal with the identified risks and opportunities (Table 8-1) include management improvements for individual farms, particular deciduous fruit producers or the entire sector in the Langkloof. Each of the six categories of farm management options is explained below:

a) Diversification

It refers to incorporating new crop varieties or types that are heat tolerant, or well adapted to droughts (Smit and Skinner, 2002). Diversifying crop varieties and types can potentially minimize operational risks arising from changes in the moderation of extreme events and water provision. According to interviews with farmers in the Langkloof, replanting or expanding orchards is among their future expectations. Even though the selection of fruit types or varieties is usually driven by market factors, such as consumer preferences (DFF 2, pers. comm.), minimizing operational risks could also arise as an incentive to consider other traits (e.g. drought or heat tolerance) in species to expand or replant.

b) Intensity of production

Changing the intensity of certain inputs application (e.g. types, timing and quantity) could also contribute to face ecosystem change (Smit and Skinner, 2002). Certain farmers in the Langkloof currently adapt the timing of pesticides application in order to minimize impacts on honeybees during pollination season (Beekeeper 1, pers. comm.). This would contribute to manage operational, reputational, and market related risks and opportunities emerging from changes in pollination.

c) Resource management

Alternatives to manage risks and opportunities identified in the Langkloof can include water and soil management. The use of efficient irrigation systems (e.g. drip irrigation) and mulch are examples of reductions in water use by some farmers (EXP 4, pers. comm.). Besides reducing water use, this can contribute to manage operational, regulatory and legal, and reputational risks and opportunities emerging from water provision and water flow regulation. In terms of soil management, erosion prevention at the farm level can help minimize operational risks associated to changes in the moderation of extreme events (particularly floods), water provision and water flow regulation.

d) Monitoring and information systems

Organized information about weather, climate, pests and other factors influencing the deciduous fruit farming productivity can contribute to manage certain risks and opportunities. Generating daily weather and seasonal climate information can help forecasting specific climatic events and particular conditions associated to climate change (Smit and Skinner, 2002). In the Langkloof, this can additionally contribute to minimize operational risks emerging from changes in extreme events moderation (e.g. moderation of droughts and floods) and water provision. Monitoring pests and diseases can lead to a more efficient and organized application of pesticides as an option to manage operational and reputational risks and opportunities emerging from changes in pollination. According to interviews with farmers, systems to monitor weather, climate, pests and diseases are currently implemented in some of the farms in the Langkloof in order to comply with global environmental standards. However, improving current systems, implementing them in new farms and monitoring more elements (e.g. pollinators) are still options to improve farm management regarding changes in key ecosystem services.

e) Agricultural insurance

Purchasing agricultural insurance can partly contribute to minimize operational risks that entail production losses caused by disruption to farming activities or reduced productivity.

That can stabilize the income from fruit production in the area in terms of certain climatic risks (Smit and Skinner, 2002), yet it would depend on the available coverage. According to information provided by a big insurance company in South Africa, crop insurance in the area is available for wind, hail and frost damage (Santam, pers. comm.), and leaves droughts, floods and fires out of the insurable perils.

f) Other management options

For some deciduous fruit producers in the Langkloof distributing their farms in different geographical contexts in the valley help minimize risks of decreased productivity caused by hail or floods damage, given the localized impacts of these events (DFF 6, pers. comm.; DFF 13, pers. comm.). Nevertheless, this option seems to be feasible only for large companies, but not necessarily for smaller producers (e.g. BEE farms) in the Langkloof.

8.2 Collaboration options in the Langkloof

In addition to internal management, engaging with stakeholders, other business sectors or policy makers can also help address risks and opportunities (Hanson *et al.*, 2012). Different collaboration options are explained below according to the categories presented in Table 8-1.

a) Ecosystem restoration partnerships

Ecosystem restoration may include assisting the recovery of damaged ecosystems, preventing land degradation, regenerating native species, recovering ecosystems productivity, rehabilitating habitat and indirectly restoring ecosystem services (Ferweda, 2012). One of these options in the Kouga catchment is the restoration of water resources though IAPs clearing, particularly in riparian areas (Marais and Wannenburgh, 2008). This has been so far implemented by the WfW program (Turpie *et al.*, 2008). However, while some of the farmers in the area work in direct collaboration with the program, others do it independently. Sharing practical knowledge and coordinating efforts to successfully clear IAPs is essential in the area, since this issue extends beyond individual farm boundaries. Stakeholders that can be involved in this process include the already mentioned WfW program and potentially DWAF, DAFF, downstream water users (e.g. municipalities or other business sectors) and NGOS such as Living Lands and Commonland, among others. These two NGOs currently work in the area to establish a partnership involving Santam (insurance company), GIZ and government bodies. This partnership can also provide opportunities for collaboration with the deciduous fruit farming sector in the Langkloof for addressing issues such as extreme events and water provision. Working in ecosystem restoration partnerships can be a long term process, but if their goals are met, they can contribute to deal with operational, regulatory and legal, reputational and market related risks and opportunities arising from changes in all 4 key ecosystem services for deciduous fruit farming identified in the Langkloof. It means that, depending on the approach that is followed, ecosystem restoration can improve water provision and regulation, moderate impacts of floods and drought, and provide habitat for pollinators.

b) Biodiversity conservation in the Kouga catchment

The expansion of protected areas in the Kouga catchment needs to involve farmers as part of the main landowners in the area. Incentives to become involved in this type of initiatives may include, for instance, tourism development and payments for ecosystem services (e.g. water provision for downstream users), among others. Even though payments for ecosystem services such as water in the area may not represent a financial incentive to prevent farmers from doing intensive agriculture (Mander *et al.*, 2010), information from interviews in the Langkloof confirms that areas under fruit are in many cases only small portions of the entire farms. Since other locations in their farms are not suitable for cultivation, conservation efforts to maximize water provision and other ecosystem services may still focus on ecosystem restoration, erosion control and IAPs clearing in those areas. Potential partners in this regard include ECPTA, DAFF, WfW, DWAF, Formosa Nature Reserve, Eden to Addo and NGOs. Engaging in biodiversity conservation can help deal with operational, regulatory (e.g. restrictions or user fees on water use) and reputational risks from changes in all key ecosystem services. Furthermore, engaging in biodiversity conservation may enable farmers to access to benefits from payments for ecosystem services in the future and improve their image and relationship with other stakeholders.

c) Resource management programs

Tackling soil erosion in coordinated initiatives in the Kouga catchment can minimize operational risks for deciduous fruit farming in terms of extreme events moderation, water provision and water flow regulation. Since deciduous fruit farmers are among the main landowners in the catchment, they must be involved in soil erosion control and prevention initiatives. Several farmers in the Langkloof work as partners with the WfW program in order to clear their farms from IAPs (EXP 5, pers. comm.). As direct participants in the clearing process, farmers can define, in collaboration with the program, the specific practices that will be considered in order to avoid soil erosion caused by deficient clearing practices. This and other potential partnerships to control and prevent soil erosion (if successful) can improve the capacity of ecosystems to provide water, moderate extreme events and regulate water flow, and hence minimize operational risks for farming. In terms of water management, engaging with other stakeholders such as the municipality or the DWAF can help build or maintain water infrastructure and distribute water among different users. This type of collaboration can address operational, regulatory and legal, and reputational risks arising from changes in extreme events moderation, water provision and water flow regulation.

d) Disaster management collaboration

Engaging with municipal departments (e.g. disaster management) and government bodies (e.g. DAFF) can provide orientation and support for farmers in terms of disaster relief fund. This support can ultimately contribute to mitigate loses caused by extreme events, among others. Furthermore, engaging with the municipal fire departments through the FPA offers training, and technical and legal assistance about fires (GOV 3, pers. comm.). Thus, this type of collaboration can be useful to deal with the disruption of farming activities caused by fires and floods, regulatory and legal risks arising from liabilities in wildfires, and reputational risks and opportunities arising from changes in the moderation of extreme events, particularly in terms floods and fires.

e) Monitoring programs

Involvement in monitoring programs with NGOs, the municipality (e.g. Disaster management department) or government bodies such as the DAFF, DWAF or DEAT, can provide additional information to improve weather predictions or seasonal forecasts. Furthermore, biodiversity-monitoring programs carried by in collaboration with others can supply information about the state and potential threats to pollinators in order to inform strategies to cope with potential risks for farming activities. Thus, engaging in monitoring programs can help deciduous fruit farmers dealing with operational, regulatory and legal, and reputational risks and opportunities emerging from changes in extreme events moderation and pollination.

9 Discussion

This thesis integrated information from diverse disciplines to explore the main consequences of ecosystem change for deciduous fruit farming in the Langkloof. In order to achieve the research objective, the guidelines for corporate ecosystem services review (ESR) (Hanson *et al.*, 2012) were used as a reference to structure the analysis. Focusing on the methods, the following section discusses the suitability of different ecosystem services typologies for this case, the main limitations of the ESR guidelines, and the strengths and weaknesses of the data collection. On the other hand, the discussion of the results addresses the implications of uncertainties and compares the results with those from other studies.

9.1 Discussion of the methods: strengths, weaknesses and assumptions

9.1.1 Ecosystem services typology suitability

A meaningful ecosystem services typology is the basis for the analysis presented in this thesis, which relies on a combination of the TEEB typology (de Groot *et al.*, 2010) and the one from the guidelines for ESR (Hanson *et al.*, 2012). These were chosen over other typologies to obtain comparable results with other cases in which ESR was conducted and other theses in the study area. The TEEB typology is also comparable to the MA (2005). However, the TEEB includes categories to distinguish between ecological processes and ecosystem services and avoid duplication arising from the MA (2005) classification.

Another more recent classification is CICES (Haines-Young and Potschin, 2013), which is coherent with TEEB (de Groot *et al.*, 2010) and the MA (2005) in some broad categories of ecosystem services. Nevertheless, CICES organizes these services in different detail levels, which do not include services such as pollination and extreme events moderation explicitly. The connection between these two services and farming activities in South Africa could be intuitively identified before conducting any analysis. In this case, it was confirmed by the results, since high impacts and dependencies were identified on both services. Therefore, using CICES was less suitable than building upon the TEEB typology, which provided a meaningful classification to represent interactions in the Langkloof.

Despite the strengths of the proposed list of ecosystem services, some weaknesses were found in terms of the detail level of ecosystem categories and the scale of the ecological processes supporting the provision of several services. This is discussed below:

a) Detail level of ecosystem services categories

The detail level of ecosystem services categories is one of the main aspects to consider when choosing a specific typology for the ESR. Particular ecosystem services may include subcategories that differ in their interactions with specific business activities, and hence, assigning impact and dependence levels can be ambiguous in such cases. For example, the lists of services used in this thesis divides food provision in crops, livestock and wild foods, on which deciduous fruit farming has different dependencies and impacts. However, wild foods also include honeybush, honey, among other specific products that were not considered in the list despite being differently affected by farming activities. In this, and other cases alike, negative and positive impact (+/-), and the highest impact among different wild foods, were assigned to the ecosystem service. Thus, assigning the highest impact and including both types of impact (i.e. negative and positive) together was useful to cover all the relevant interactions for subsequent analyses and avoid missing substantial information.

b) Scale of ecological processes

The time and spatial scales of ecological processes involved in the provision of services are also relevant aspects to deal with when using a particular typology. Ecosystem services such as global climate regulation involve processes that do not necessarily correspond to the scale of the analysis. This was the case in this thesis, since dependence and impacts were only evaluated considering ecosystems in the study area. In such case, to analyse dependence on global climate regulation, other ecosystems were considered as substitutes of the local ones. Similarly, it was deemed as unlikely that farming activities in the Langkloof were able to affect the ability of others to benefit from this service directly, since the impacts of local practices on climate regulation would be limited in a global context. In order to deal with this limitation, selecting the scale for the analysis beforehand and identifying the processes involved in the provision of each service helped improve the robustness of the results and avoid contradictions among dependencies and impacts on different services.

9.1.2 Limitations arising from the corporate ecosystem services review (ESR) guidelines

The ESR guidelines are aimed at specific firms (Hanson *et al.*, 2012), and hence, analysing a business sector represents a deviation from their original purpose. However, the advantages and disadvantages of this approach that are discussed in the following paragraphs are still applicable to cases in which the analysis focuses on single firms, given the clear boundaries and homogeneity of the deciduous fruit farming sector in the Langkloof.

a) Questionnaire design

To evaluate impact and dependence on ecosystem services, Hanson *et al.* (2012) provide a questionnaire with five close-ended questions for each service. Even though the simplicity of this instrument may be regarded as an advantage for business managers, the broad formulation of the questions requires additional specific criteria to avoid over- or underestimation of impact or dependence. The existence of cost effective substitutes for an ecosystem service that benefits business activities, for example, is the only criterion to decide between a medium and a high dependence on such service. This can be a rather simple decision if no substitutes are identified. However, the guidelines for ESR do not provide orientation for cases in which partial substitutes exist or information about substitute's effectiveness is not available. In those cases, the information gaps and uncertainties were explicitly stated in the supporting information provided in each answer to the questionnaire. Furthermore, the impacts and dependencies obtained from these answers were completed with experts' interviews to fill in gaps of information and avoid excluding ecosystem services from subsequent steps.

b) Nature and availability of information

Besides the questionnaire formulation, the nature and availability of supporting information can also influence the outcomes of the impact and dependence evaluation. In this thesis, the supporting information was obtained from diverse secondary (i.e. books, peer reviewed articles, theses and technical reports) and primary sources (i.e. interviews and personal observations). As expected, the information from secondary sources was neither homogeneous nor necessarily focused on the Langkloof. Therefore, assumptions were made in terms of comparability of secondary information and different case studies.

In spite of the limitations in terms of nature and availability of information, secondary sources were contrasted and complemented with interviews with farmers and experts in order to compensate for the lack of data about certain services at a local scale. Furthermore, the supporting information and the rationale behind each answer to the questionnaire were included in the appendices, which provide clarity in terms of information gaps, uncertainties and the criteria that were used to decide on each answer.

c) Lack of common tools and indicators (for trend analysis)

The lack of common analytical tools and indicators to analyse trends has been identified as a challenge for several ecosystem services (Carpenter *et al.*, 2006; Carpenter *et al.*, 2009; Feld *et al.*, 2009). Indeed, neither the guidelines for ESR (Hanson *et al.*, 2012) nor other guidelines for similar purposes (e.g. Kosmus *et al.*, 2012) provide specific indications to determine likely future trends or current condition of key ecosystem services.

Methods to deal with the lack of tools for trend analysis were not elaborated in this thesis. However, the aspects recommended by GIZ (Kosmus *et al.*, 2012) were used as a reference in addition to general criteria to determine trends and current condition in key services. This provides comparable results among key ecosystem services, despite their particularities.

d) Dealing with limitations of the guidelines (ESR)

The impact and dependence evaluation and the trend analysis are perhaps the most essential and complex steps to identify risks and opportunities arising from ecosystem change. It is therefore predictable to find most of the methods’ weaknesses in these specific sections. The integration of large amounts of information to analyse different ecosystem services, their particularities in a local context and the lack of criteria to establish comparisons, were common limitations for both steps. These issues were addressed in this thesis by: establishing general criteria for comparisons, organizing the supporting information in a common structure, and filling in information gaps with data from interviews. Although these strategies may not deal with all the weaknesses and complexities in the analysis, they contributed to the robustness of the results and their potential applicability to management strategies, by providing clear indication of the assumptions and potential uncertainties.

9.1.3 Data collection methods: problems and solutions

The data collection methods of this thesis aimed to provide sufficient information to support the identification of risks and opportunities on the basis of potential changes in key ecosystem services. Nevertheless, collecting data for a broad variety of services was limited by diverse obstacles during the fieldwork. These obstacles are discussed below:

a) Obstacles for collecting data

As explained in the methods section, the direct use of the impact and dependence questionnaire (Hanson *et al.*, 2012) to interview farmers, stakeholders and experts, was not feasible because of the large number of questions required to the application of this instrument and the time limitations in the field. Besides these restrictions, logistic constraints (e.g. distance between farms and to the research station) did not allow interviewing a representative sample of deciduous fruit farmers in the Langkloof either. This consequently hampered the chances to obtain sufficient input data for quantitative analyses. However, despite the lack of quantitative data, in-depth interviews with carefully selected experts and different types of farmers (e.g. big and small, and from different settlements) provided abundant information to evaluate impacts and dependencies.

b) Limitations of in-depth interview

Based on the fieldwork obstacles, questionnaires were not suitable for interviewing farmers in the study area. Therefore, in-depth interviews were chosen as an appropriate option to obtain information about farming practices and interactions with ecosystems. Compared to a structured interview, in-depth interviews allow identifying particularities (e.g. farming techniques) and gaining additional insights from relevant actors (e.g. farmers) with specific knowledge about certain topics (e.g. pollination, water management, management, etc.). Nonetheless, the answers obtained with this instrument are generally less comparable than those potentially obtained with a questionnaire (Kumar, 2011).

The obstacles to quantitatively integrate the information from in-depth interviews reduced the possibilities to analyse to what extent different farming practices were actually performed in the Langkloof (e.g. controlling erosion, using fewer pesticides, using compost, etc.). Therefore, the outcome of the impact evaluation does not account for these issues with quantitative indicators. However, contrasting the information about farming practices with that obtained from experts was therefore used in this thesis as an approach to provide an indication of the extent of these practices and compensate for this weakness.

c) Lack of a representative sample

One of the main shortcomings of the data collection arose from the inability to interview BEE (emerging) farmers due to language and logistic barriers. This weakness was compensated by using snowball sampling, since it offered access to key informants that provided information not only about their own farms, but also about others, including BEE farms in which they were mentors. Despite obtaining general information about their practices from mentors, interviewing these farmers directly could have provided more detailed data to analyse impacts and dependence on ecosystem services, to identify risks and opportunities, and to identify specific management options for farmers.

Despite a small group of farmers was interviewed and BEE farms were not directly represented, the information from interviews likely still represent the general situation in terms of management practices in the study area at the time of interviewing, because the interviewed farmers were responsible for managing almost half of the area with deciduous fruit in the Langkloof. Furthermore, their farms were diverse in size and extent, and covered all the main tributaries of the Kouga River in the valley.

d) Collaboration with other students

Besides the already discussed problems during the data collection, conducting interviews jointly could have also influenced the quality and quantity of the information obtained with this instrument. However, although conducting interviews with another student (and in some cases a third student) restricted the number of questions to address our topics of interest, it also provided additional contextual information for this research and improved the access to contacts. Hence, this is not considered a main limitation for this thesis.

9.2 Discussion of the results: implications of uncertainties and comparison with literature

In spite of the weaknesses of the methods discussed in the previous section, this study produced several interesting results that are supported by other research in various aspects. The main results of this and other studies, and the implications of the assumptions described in Section 9.1 are discussed below.

9.2.1 Key ecosystem services and available information in the study area

Previous theses (Veerkamp, 2013; Sandbrink, 2013) and technical reports (Jansen, 2008) confirm the importance of water provision and regulation of water flows for deciduous fruit farming in the Langkloof. Similarly, pollination, extreme events moderation and other services classified as second or third priority in this thesis are also identified among the most relevant services for agriculture and biodiversity conservation in the Kouga catchment (Veerkamp, 2013).

In spite of the weaknesses of the methods (Section 9.1), the key ecosystem services that were selected in this thesis are relevant in the landscape context. These services cover the main benefits obtained from nature that were mentioned by farmers and experts, and the main environmental issues described in studies in the Kouga Catchment (Jansen, 2008; Haigh *et al.*, 2004) and neighbour areas in South Africa (e.g. pollination in the Western Cape analysed by Melin *et al.* (2014)).

9.2.2 Trends in key ecosystem services versus global and local projections

The increasing demand and decreasing supply of extreme events moderation presented in this thesis is comparable to trends in natural hazard regulation projected in the MA (2005). Similarly, the strained condition of water supply indicated by van Jaarsveld *et al.* (2005) corroborates the decreasing trend in the supply of this service anticipated in the Langkloof. For water flow regulation, no comparable studies were found, since trends in its supply depend on local conditions (MA, 2005). In terms of pollination, declining trends are generally observed in the USA and Europe (Potts *et al.*, 2010), but the scarce evidence about this service in South Africa do not suggest decreasing trends in its supply (Melin et al, 2014).

9.2.3 Comparison with corporate ecosystem services review (ESR) from other studies

More than 300 firms have conducted ESR since 2008 (WRI, 2012). The results of these analyses are often part of internal strategies, and hence, not publicly available, which hinders the possibility of comparing different initiatives in detail. However, the guidelines for ESR (Hanson *et al.*, 2012) present examples from five companies that tested the method and the WRI website summarizes additional case studies. Some key findings are discussed below:

a) Key ecosystem services

Water provision is identified as a key ecosystem service for diverse business examples (Hanson *et al.*, 2012; WRI, 2012), which include mining, packaging and paper, meat and dairy, electricity, cement and paint companies. Other key ecosystem services identified by firms conducting ESR are diverse, yet several of these key services are common for a broad variety of cases in the agricultural sector (e.g. regulation of water flows, pollination, maintenance of soil fertility, erosion prevention and climate regulation). Therefore, other examples of ESR in agriculture are comparable to the deciduous fruit farming case. A particular difference with other studies include that farmers in the Langkloof were considered to be able to substitute the maintenance of soil fertility and erosion prevention under normal circumstances, and hence, the impacts of deciduous fruit farming were classified as medium. This particular reasoning assigned a second or third priority to these services, whereas in other studies were chosen as key ecosystem services (first priority).

b) Common risks and opportunities and options to deal with them

Although the risks and opportunities arising from ecosystem change are diverse among different business sectors, risks driven by climate change and IAPs are common in the agricultural sector and others such as paper production. The risks and opportunities identified in other examples of ESR in the agricultural sector are comparable to those presented in this thesis, especially in terms of interactions with climate change and IAPs.

In the Western Cape Province, the South African Breweries (SAB) adopted a similar approach to the ESR and obtained comparable results to the ones of this thesis. This company identified water scarcity, driven by climate change, IAPs and urban development, as the main risk for business performance (Kissinger, 2013). Similarly, SAB also considered stakeholder partnerships, IAPs clearing and ecosystems restoration as options to deal with water issues.

These different cases show that comparable drivers of change, and similar risks arising from ecosystem change, currently affect diverse business sectors (including deciduous fruit farming in the Langkloof). Thus, the potentially shared interest in these issues provides a significant opportunity to combine efforts at enhancing the provision of ecosystem services and benefiting a broad range of actors.

10 Conclusions

This thesis presented the main consequences of ecosystem change on deciduous fruit farming in the Langkloof based on the evaluation of impacts and dependencies on ecosystem services and in-depth analysis of trends in the most relevant services for this business sector. Current and potential changes in ecosystems that could affect the provision of ecosystem services were therefore presented as sources of risks and opportunities for deciduous fruit farming performance. The main findings are presented below:

RQ1. Impact and dependence of deciduous fruit farming on ecosystem services

The highest impacts and dependencies of deciduous fruit farming on ecosystem services were the basis to select key ecosystem services to take into account in farm management and collaboration strategies in the Langkloof. The highest impacts and dependencies were identified on regulating ecosystem services, as follows:

a) Highest dependencies on ecosystem services

The highest dependencies of deciduous fruit farming were found on five regulating services for which there are no available cost effective substitutes despite their importance to provide conditions for the optimal growth of trees, enable their reproduction and minimize natural hazards. These services correspond to: air quality regulation, regulation of regional and local climate, regulation of water flows, moderation of extreme events and pollination. Besides regulating services, farming activities in the Langkloof depend on three provisioning services, but from these, a high dependence was only identified on water provision.

b) Highest impacts on ecosystem services

The highest impacts of deciduous fruit farming were found on four regulating services. This implies that this business sector affects the quantity or quality of these services and also the ability of others to benefit from them. Among these services, the regulation of water flows is negatively affected by water diversion and land conversion associated to farming activities. The other three services are negatively and positively affected at the same time. Farmers in the area prevent and mitigate extreme events, but the lack of infrastructure maintenance, water diversion and land conversion can increase the intensity and damage of these events due to a reduced moderation capacity of ecosystems. Similarly, soil erosion prevention can be either hampered or enhanced depending on specific practices. In the case of pollination, the chemicals use negatively affects wild pollinators. However, deciduous fruit farms contribute to the development of, and attract, managed pollinators for which farmers have also increased spraying efficiency in order to protect honeybees and wild pollinators.

Three provisioning services (i.e. crops, wild foods and water provision) and one cultural and amenity service (i.e. aesthetic information) are also largely affected by deciduous fruit farming. Impacts on wild foods and water provision are both positive and negative, while the impacts on food crops are only positive. Furthermore, orchards in the Langkloof benefit tourists and visitors as an aesthetically appealing landscape element.

RQ2. Key ecosystem services for deciduous fruit farming

Based on the impact and dependence of deciduous fruit farming, 17 out of 30 ecosystem services were classified as first (four ecosystem services), second (three services) or third priority (ten services) for farming. From this group, only first priority services were taken into account as key ecosystem services for management and collaboration strategies.

The third priority ecosystem services (i.e. crops, wild foods, timber and other wood fibre, fertilizers, global climate regulation, water purification, waste treatment, maintenance of soil fertility, biological control and aesthetic information) are not sources of major risks, but specific conditions could turn them into a higher priority for deciduous fruit farming. The second priority services (i.e. air quality regulation, regional and local climate regulation, and erosion prevention) are not sources of main risks either, but changes in their substitutes or increasing impacts on them would pose new risks for deciduous fruit farming performance.

The first priority ecosystem services (i.e. water, water flow regulation, extreme events moderation and pollination) were chosen as key ecosystem services, because their current condition and trends are likely to pose risks and provide opportunities for deciduous fruit farming based on the high impacts and dependencies on them.

RQ3. Trends in key ecosystem services

The analysis of the condition of key ecosystem services showed that the capacity of the ecosystems in the Kouga catchment is sufficient to cope with the demand for water, regulation of water flows and pollination in the Langkloof. However, the moderation of extreme events is currently affected by the invasion by alien plants.

Analysed trends in key ecosystem services suggest that the demand for all key ecosystem services will exceed the supply of these services in the study area in the future.

a) Current state and trends in water provision and regulation of water flows

The demand for water in the Langkloof is likely to increase mainly due to population growth. However, the supply would decrease depending on the future effects of climate change. Despite the regulation of water flows is also expected to decrease, a stable demand is foreseen. Thus, the demand will likely exceed the supply of these services in the future.

b) Current state and trends in extreme events moderation

The evidence presented for extreme events moderation shows a currently reduced capacity of the ecosystems in the area to moderate extreme events such as floods, fires and droughts. This is a result of IAPs, loss of riparian vegetation and wetlands, and to a lesser extent soil erosion. Future effects of climate change can determine a growing demand for this service because extreme events are expected to become more frequent and intense. However, the supply of this service is likely to decrease if alien plants keep spreading over the study area.

c) Current state and trends in pollination

Despite the limited evidence about wild pollinators, the results suggest that the pollination service is overall in a good condition in the study area. Regarding managed pollinators, the Langkloof currently requires 7,000 - 28,000 beehives per year and this demand is likely to keep increasing. The pollination supply, by contrast, is likely to remain stable.

d) Drivers of ecosystem change and stakeholders

Invasion by alien plants and climate change are likely to influence future trends in all the key ecosystem services in the Langkloof. At current clearing rates, IAPs are expected to remain an issue in the study area. This would negatively affect surface runoff (water), groundwater recharge (water flow regulation), fires regime and flood damage (moderation of extreme events). However, pollinators can benefit from IAPs, given the additional floral resources these plants provide. In addition to the effects of IAPs, climate change is also expected to influence changes in ecosystems by: decreasing streamflow; changing the timing, frequency and intensity of precipitation; exacerbating extreme events; and altering pollinators' dynamics. Other drivers of ecosystem change include fires, land degradation, population growth, habitat degradation, alien pollinators, pest and diseases, and land use change.

Besides deciduous fruit farmers, other stakeholders that can influence these trends include the WfW program, the DWAF, livestock farmers, beekeepers, municipal fire departments, and Koukamma, George and Nelson Mandela Bay municipalities.

RQ4. Risks and opportunities arising from ecosystem change

A total of 27 risks and 14 opportunities for deciduous fruit farmers were identified as consequences of ecosystem change. The highest priority for management was assigned to changes affecting extreme events moderation and water.

The risks and opportunities were classified in four categories, namely operational (nine risks and seven opportunities), regulatory and legal (seven risks), reputational (four risks and four opportunities), market and product (one risk and three opportunities) and financing (one risk). No opportunities were identified in the regulatory and legal, and financing categories.

a) Risks arising from ecosystem change

Operational and regulatory risks mainly arise from changes in water provision and the moderation of extreme events. A limited capacity to moderate extreme events and changes in pollination can additionally pose risks in terms of markets, products and financial aspects. Besides that, changes in any of the key ecosystem services can affect farmer's reputation (e.g. by damaging their relationship with other stakeholder).

b) Opportunities arising from ecosystem change

Alternatives to develop the internal operations of deciduous fruit farms (e.g. improvements in management practices and increased efficiency in the use of inputs) arise from expected changes in extreme events moderation and water provision. In terms of market and products (e.g. payment schemes for ecosystem services and access to new markets), there are opportunities to deal with changes in water, regulation of water flows and pollination, while improving business performance. Furthermore, dealing with changes in any of the key ecosystem services would give rise to opportunities in reputational terms (e.g. improved image, relationship or brand).

c) Options to deal with risks and opportunities

Strategies to cope with risks and maximize the opportunities were not investigated in detail, although options for management and collaboration were compiled. Internal management options include diversification, intensity of production, resource management, monitoring and information systems and agricultural insurance, among others. On the other hand, collaboration options include ecosystem restoration partnerships, biodiversity conservation, resource management programs, disaster management partnerships and monitoring programs.

Operational risks and opportunities can be addressed through all the internal management options. Regulatory and legal risks can be dealt with through different resource management strategies and monitoring and information systems. Reputational risks and opportunities can be managed through the same options, but also with changes in the intensity of production. All the collaboration options would be appropriate to manage operational, regulatory and legal, and reputational risks and opportunities, yet in different aspects and extents.

Regarding market and products, the risks and opportunities can be managed through changes in the intensity of production. Collaboration options in this case include ecosystem restoration partnerships and biodiversity conservation in the catchment. These alternatives, in addition to resource management programs and disaster management collaboration, are also appropriate to deal with financing risks, which can be also internally managed through diversification and resource management, among others.

Overall conclusion

As shown in the results, the effects of ecosystem change on deciduous fruit farming in the Langkloof are diverse and embrace a broad range of interactions with ecosystem services. This thesis examined in depth only part of these consequences (i.e. risks and opportunities) and provided farm management and collaboration options to deal with them. Besides the expected results, this thesis showed that potential changes in the provision of key ecosystem services for this business sector are (or may become) also a concern for a larger group of stakeholders, which includes government bodies, municipal departments, local towns, downstream cities and local NGOs, among many others. Consequently, not only farm management alternatives should be considered as strategies to deal with ecosystem change, but also the diverse range of collaboration options in which management improvements can fit in. Thus, combining efforts in this regard arises as a promising strategy to enhance farming performance and protect, at the same time, the provision of ecosystem services for local and downstream users in the entire landscape.

References

Anderson-Teixeira, K. J., Snyder, P. K., Twine, T. E., Cuadra, S. V., Costa, M. H., & DeLucia, E. H. (2012). Climate-regulation services of natural and agricultural ecoregions of the Americas. *Nature Climate Change, 2*(3), 177-181.

Balmford, A., Green, R. E., & Scharlemann, J. P. W. (2005). Sparing land for nature: exploring the potential impact of changes in agricultural yield on the area needed for crop production. *Global Change Biology, 11*(10), 1594-1605.

Barthlott, W., Mutke, J., Rafiqpoor, D., Kier, G., & Kreft, H. (2005). Global centers of vascular plant diversity. *Nova Acta Leopoldina, 92*(342), 61-83.

Baselmans, D. (2011). *Preliminary study of the Kouga catchment. Farmers' water and land use and their perceptions on nature restoration and alien invasive species.* (BSc), Hogeschool Zeeland, Vlissingen.

Baudron, F., & Giller, K. E. (2014). Agriculture and nature: Trouble and strife? *Biological Conservation, 170*(1), 232-245.

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

Bond, W.J., Midgley, G.F., & Woodward, F.I. (2003). What controls South African vegetation - climate or fire? *South African Journal of Botany, 69*(1), 79-91.

Boshoff, A. F., Kerley, G. I. H., & Cowling, R. M. (2002). Estimated spatial requirements of the medium- to large-sized mammals, according to broad habitat units, in the Cape Floristic Region, South Africa. *African Journal of Range & Forage Science, 19*(1), 29-44.

Brantley, H. L., Hagler, G. S. W., J. Deshmukh, P., & Baldauf, R. W. (2014). Field assessment of the effects of roadside vegetation on near-road black carbon and particulate matter. *Science of The Total Environment, 468–469*, 120-129.

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. S. J., & Ringler, C. (2014). Climate change and agriculture: Impacts and adaptation options in South Africa. *Water Resources and Economics, 5*(1), 24-48.

Carpenter, S.R., De Fries, R., Dietz, T., Mooney, H. A., Polasky, S., Reid, W. V., & Scholes, R.J. (2006). Millennium Ecosystem Assessment: Research Needs. *Science, 314*(5797), 257-258.

Carpenter, S. R., Mooney, H. A., Agard, J., Capistrano, D., De Fries, R. S., Díaz, S., Dietz, T., Duraiappah, A. K., Oteng-Yeboah, A., Pereira, H. M., Perrings, C., Reid, W. V., Sarukhan, J., Scholes, R. J., & Whyte, A. (2009). Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. *Proceedings of the National Academy of Sciences, 106*(5), 1305-1312.

Cerutti, A. K., Bagliani, M., Beccaro, G. L., & Bounous, G. (2010). Application of Ecological Footprint Analysis on nectarine production: methodological issues and results from a case study in Italy. *Journal of Cleaner Production, 18*(8), 771-776.

Cerutti, A. K., Beccaro, G. L., Bagliani, M., Donno, D., & Bounous, G. (2013). Multifunctional Ecological Footprint Analysis for assessing eco-efficiency: A case study of fruit production systems in Northern Italy. *Journal of Cleaner Production, 40*(1), 108-117.

Cerutti, A. K., Bruun, S., Beccaro, G. L., & Bounous, G. (2011). A review of studies applying environmental impact assessment methods on fruit production systems. *Journal of Environmental Management, 92*(10), 2277-2286.

Cowling, R. (1992). *The ecology of Fynbos: nutrients, fire and diversity*. Cape Town: Oxford University Press.

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

DAFF (Department of Agriculture, Forestry and Fisheries). (2012a). *A Profile of the South African apple market value chain*. Pretoria: DAFF.

DAFF (Department of Agriculture, Forestry and Fisheries). (2012b). *A Profile of the South African Plum market value chain*. Pretoria: DAFF.

DAFF (Department of Agriculture, Forestry and Fisheries). (2012c). *A Profile of the South African Pear market value chain*. Pretoria: DAFF.

DAFF (Department of Agriculture, Forestry and Fisheries). (2012d). *A Profile of the South African Peach market value chain*. Pretoria: DAFF.

DAFF (Department of Agriculture, Forestry and Fisheries). (2014a). *Economic review of the South African agriculture 2013*. Pretoria: DAFF.

DAFF (Department of Agriculture, Forestry and Fisheries). (2014b). *Trends in the agricultural sector*. Pretoria: DAFF.

De Groot, R.S., Wilson, M.A., & Boumans, R.M. J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics, 41*(3), 393-408.

De Groot, R.S., Fisher, B., Christie, M., Aronson, J., Braat, L., Haines-Young, R., Gowdy, J., Maltby, E., Neuville, A., Polasky, S., Portela, R. & Ring, I. (2010). Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation.

In P. Kumar (Ed.), *The Economics of Ecosystems and Biodiversity (TEEB): Ecological and Economic Foundations* (pp. 9-40). London: Earthscan.

De Lange, W. J., Veldtman, R., & Allsopp, M. H. (2013). Valuation of pollinator forage services provided by *Eucalyptus cladocalyx*. *Journal of Environmental Management, 125*(1), 12-18.

De Wit, M.P., Crookes, D.J., & van Wilgen, B.W. (2001). Conflicts of interest in environmental management: estimating the costs and benefits of a tree invasion. *Biological Invasions, 3*(2), 167-168.

Delmas, M. A., & Toffel, M. W. (2008). Organizational responses to environmental demands: opening the black box. *Strategic Management Journal, 29*(10), 1027-1055.

Dougherty, T.C., & Hall, A.W. (1995). Environmental Impact Assessment of irrigation and drainage projects *FAO Irrigation and Drainage Paper 53*. Rome: Food and Agriculture Organization of the United Nations, Overseas Development Administration of the United Kingdom.

Draugelytė, E. (2012). *Dissonance in social learning. Towards maintenance of natural resources in the Kouga catchment, South Africa.* (MSc), Wageningen University and Research Centre (WUR), Wageningen.

Driver, A., Sink, K., Nel, J., Holness, S., van Niekerk, L., Daniels, F., Jonas, Z., Majiedt, P., Harris, L. & Maze, K. (2011). *National Biodiversity Assessment 2011: An assessment of South Africa's biodiversity and ecosystems*. Pretoria: South African National Biodiversity Institute and Department of Environmental Affairs.

Dye, P. J., & Poulter, A. G. (1995). A field demonstration of the effect on streamflow of clearing invasive pine and wattle trees from a riparian zone. *South African Forestry Journal, 173*(1), 27-30.

Dye, P., & Jarmain, C. (2004). Water Use by Black Wattle (*Acacia mearnsii*): Implications for the link between removal of invading trees and catchment streamflow response. *South African Journal of Science, 100*(1), 40-44.

Du Toit, A. L., & Haughton, S. H. (1954). *The geology of South Africa.* London: Oliver and Boyd.

DWAF (Department of Water Affairs and Forestry). (2004). *Fish to Tsitsikamma Water Management Area: Tsitsikamma to Coega internal strategic perspective*. Cradock: DWAF, Directorate National Water Resources Planning. Pretoria: DWAF.

DWAF (Department of Water Affairs and Forestry). (2009). *Blue Drop Report 2009: Version 1. South African drinking water quality management performance.* Pretoria: DWAF.

Emberson, L. D., Ashmore, M. R., Murray, F., Kuylenstierna, J. C. I., Percy, K. E., Izuta, T., Zheng, Y., Shimizu, H., Sheu, B. H., Liu, C. P., Agrawal, M., Wahid, A., Abdel-Latif, N. M., van Tienhoven, M., de Bauer, L. I., & Domingos, M. (2001). Impacts of air pollutants on vegetation in developing countries. *Water, Air, and Soil Pollution, 130*(1-4), 107-118.

Enright, W. D. (2000). The effect of terrestrial invasive alien plants on water scarcity in South Africa. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere, 25*(3), 237-242.

Erlank, W., Zake, P., Eloff, G., Thanyani, J., Mjali, F., & Venter, J. (2009). *Strategic management plan Baviaanskloof cluster. Integrated reserve management plan*. East London: Eastern Cape Parks.

Fairtrade International. (2011). *Fairtrade standard for fresh fruit for hired labour*. Fairtrade International, Bonn.

FAO (Food and Agriculture Organization of the United Nations). (1997). Irrigation potential in Africa: A basin approach *FAO Land and Water Bulletin 4*. Rome: Food and Agriculture Organization of the United Nations.

FAOSTAT. (2015). Statistics Division Database. Food and Agriculture Organization of the United Nations. Retrieved on 26-03-2015, from http://faostat.fao.org

Feld, C. K., Martins da Silva, P., Paulo Sousa, J., De Bello, F., Bugter, R., Grandin, U., Hering, D., Lavorel, S., Mountford, O., Pardo, I., Pärtel, M., Römbke, J., Sandin, L., Bruce Jones, K., & Harrison, P. (2009). Indicators of biodiversity and ecosystem services: a synthesis across ecosystems and spatial scales. *Oikos, 118*(12), 1862-1871.

Ferweda, W. (2012). *Organising ecological restoration by partners in business for next generations. Nature Resilience*. Rotterdam: Rotterdam School of Management, Erasmus University i.a.w. IUCN Commission on Ecosystem Management.

Foley, J. A., De Fries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C., Patz, J. A., Prentice, I. C., Ramankutty, N. & Snyder, P. K. (2005). Global consequences of land use. *Science, 309*(5734), 570-574.

Fugler, S. R. (1982). Infestations of three Australian *Hakea* species in South Africa and their control. *South African Forestry Journal,* 120 (1), 63-68.

Gallai, N., Salles, J. M., Settele, J, & Vaissière, B. E. (2009). Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics, 68*(3), 810-821.

Garibaldi, L. A., Steffan-Dewenter, I., Winfree, R., Aizen, M. A., Bommarco, R., Cunningham, S. A., Kremen, C., Carvalheiro, L. G., Harder, L. D., Afik, O., Bartomeus, I., Benjamin, F., Boreux, V., Cariveau, D., Chacoff, N. P., Dudenhöffer, J. H., Freitas, B. M., Ghazoul, J., Greenleaf, S., Hipólito, J., Holzschuh, A., Howlett, B., Isaacs, R., Javorek, S. K., Kennedy, C. M., Krewenka, K. M., Krishnan, S., Mandelik, Y., Mayfield, M. M., Motzke, I., Munyuli, T., Nault, B. A., Otieno, M., Petersen, J., Pisanty, G., Potts, S. G., Rader, R., Ricketts, T. H., Rundlöf, M., Seymour, C. L., Schüepp, C., Szentgyörgyi, H., Taki, H., Tscharntke, T., Vergara, C. H., Viana, B. F., Wanger, T. C., Westphal, C., Williams, N. & Klein, A. M. (2013). Wild pollinators enhance fruit set of crops regardless of honey bee abundance. *Science, 339*(6127), 1608-1611.

GLOBALG.A.P. (2013). Integrated Farm Assurance. Control points and compliance criteria. All Farm Base, Crop Base, Fruit and Vegetables. Cologne: GLOBALG.A.P.

Goldblatt, P. (1997). Floristic diversity in the Cape flora of South Africa. *Biodiversity & Conservation, 6*(3), 359-377.

Goldblatt, P., & Manning, J. C. (2002). Plant diversity of the Cape Region of Southern Africa. *Annals of the Missouri Botanical Garden, 89*(2), 281-302.

Goldblatt, A. (2010). Agriculture: Facts and trends. South Africa. In T. von Bormann (Ed.). Cape Town: WWF.

Gordon, A. J., & Fourie, A. (2011). Biological control of *Hakea sericea* Schrad. & J.C. Wendl. and *Hakea gibbosa* (Sm.) Cav. (Proteaceae) in South Africa. *African Entomology, 19*(2), 303-314.

Görgens, A. H. M., & van Wilgen, B. W. (2004). Invasive alien plants and water resources in South Africa: Current understanding, predictive ability and research challenges. *South African Journal of Science 100*(1), 27-33.

Government of South Africa. (2008). *National protected area expansion strategy for South Africa 2008. Priorities for expanding the protected area network for ecological sustainability and climate change adaptation*. Pretoria: DEAT.

Haigh, E., Bosman, L., Jones, R., & Illgner, P. (2004). *Wetland mapping and assessment in selected metropolitan water supply catchments in the Eastern Cape*. Grahamstown: Institute for Water Research, Rhodes University.

Haines-Young, R., & Potschin, M. (2013). *Common International Classification of Ecosystem Services (CICES): Consultation on Version 4*, August-December 2012. *EEA Framework Contract No EEA/IEA/09/003*. Nottingham: Centre for Environmental Management, University of Nottingham.

Hanson, C., van der Lugt, C., & Ozment, S. (2011). Nature in Performance. *Initial recommendations for integrating ecosystem services into business performance systems*. Washington, D.C.: World Resources Institute (WRI).

Hanson, C., Ranganathan, J., Iceland, C, & Finisdore, J. (2012). The Corporate Ecosystem Services Review. *Guidelines for identifying business risks and opportunities arising from ecosystem change*. Washington, D.C.: World Resources Institute (WRI), Meridian Institute & World Business Council for Sustainable Development (WBCSD).

Ho, C. H., Park, S. J., Jeong, S. J., Kim, J., & Jhun, J. G. (2012). Observational evidences of double cropping impacts on the climate in the northern China plains. *Journal of Climate, 25*(13), 4721-4728.

Holmes, P. M., & Marais, C. (2000). Impacts of alien plant clearance on the vegetation in the mountain catchments of the Western Cape. *Southern African Forestry Journal, 189*(1), 113-117.

Hortgro. (2013). Hortgro tree census. Retrieved on 17-12-2014, from http://www.hortgro.co.za/

Hortgro. (2014). *Key deciduous fruit statistics 2013*. Paarl: SASPA, DFTS & SAAPPA.

Hosking, S. G., du Preez, M., Campbell, E. E., Wooldridge, T. H., & du Plessis, LL. (2002). *Evaluating the environmental use of water - Selected case studies in the Eastern and Southern Cape Report No 1045/1/02*. Port Elizabeth: University of Port Elizabeth, Water Research Commission.

Hosking, S. G., & du Preez, M. (2004). A cost-benefit analysis of the Working for Water Programme on selected sites in South Africa. *Water SA, 30*(2), 143-152.

IFC (International Finance Corporation). (2012). Performance Standard 6. Biodiversity conservation and sustainable management of living natural resources. Washington, D.C.: IFC.

Iqbal, J., Lin, S., Hu, R., & Feng, M. (2009). Temporal variability of soil-atmospheric CO2 and CH4 fluxes from different land uses in mid-subtropical China. *Atmospheric Environment, 43*(37), 5865-5875.

Iqbal, J., Lin, S., Hu, R., & Zhao, J. (2013). CH4 oxidation potentials of different land uses in three gorges reservoir area of central subtropical China. *Pedosphere, 23*(5), 609-619.

Iqbal, J., Ronggui, H., Lijun, D., Lan, L., Shan, L., Tao, C., & Leilei, R. (2008). Differences in soil CO2 flux between different land use types in mid-subtropical China. *Soil Biology and Biochemistry, 40*(9), 2324-2333.

IUCN, WRI, Earthwatch, & WBCSD. (2006). *Business and Ecosystems. Issue brief Ecosystem Challenges and Business Implications.* Gland: IUCN.

Jansen, H. C. (2008). *Water for food and ecosystems in the Baviaanskloof Mega Reserve. Land and water resources assessment in the Baviaanskloof, Eastern Cape Province, South Africa*. Wageningen: Alterra.

Jury, Mark R. (2002). Economic impacts of climate variability in South Africa and development of resource prediction models. *Journal of Applied Meteorology, 41*(1), 46-55.

Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences, 274*(1608), 303-313.

Kosmus, M., Renner, I., & Ullrich, S. (2012). *Integrating Ecosystem Services into Development Planning. A stepwise approach for practitioners based on the TEEB approach.* Eschborn: GIZ, BMZ.

Kotze, D., & Ellery, W. (2009). *WET-OutcomeEvaluate. An evaluation of the rehabilitation outcomes at six wetland sites in South Africa.* TT 343/09. Pretoria: Water Research Commission.

Kröner, A., Hegner, E., Wendt, J. I., & Byerly, G. R. (1996). The oldest part of the Barberton granitoid-greenstone terrain, South Africa: evidence for crust formation between 3.5 and 3.7 Ga. *Precambrian Research, 78*(1–3), 105-124.

Kruger, A. C., & Shongwe, S. (2004). Temperature trends in South Africa: 1960–2003. *International Journal of Climatology, 24*(15), 1929-1945.

Kumar, R. (2011). *Research Methodology: A step-by-step guide for beginners* (Third edition ed.). London: SAGE.

Kusangaya, S., Warburton, M. L., van Garderen, E. A., & Jewitt, G. P. W. (2014). Impacts of climate change on water resources in southern Africa: A review. *Physics and Chemistry of the Earth, 67-69*, 47-54.

Le Maitre, D. C., Van Wilgen, B. W., Chapman, R. A., & McKelly, D. H. (1996). Invasive plants and water resources in the Western Cape Province, South Africa: Modeling the consequences of a lack of management. *Journal of Applied Ecology, 33*(1), 161-172.

Le Maitre, D., Versfel, D.B., & Chapman, R.A. (2000). The impact of invading alien plants on surface water resources in South Africa: A preliminary assessment. *Water SA, 26*(3), 397-408.

Le Maitre, D. C., van Wilgen, B. W., Gelderblom, C. M., Bailey, C., Chapman, R. A., & Nel, J. A. (2002). Invasive alien trees and water resources in South Africa: case studies of the costs and benefits of management. *Forest Ecology and Management, 160*(1–3), 143-159.

Liao, C., Peng, R., Luo, Y., Wu, X., Fang, C., Chen, J., & Li, B. (2008). Altered ecosystem carbon and nitrogen cycles by plant invasion: a meta-analysis. *New Phytologist, 177*, 706-714.

Lin, S., Iqbal, J., Hu, R., & Feng, M. (2010). N2O emissions from different land uses in mid-subtropical China. *Agriculture, Ecosystems & Environment, 136*(1–2), 40-48.

Loarie, S.R., Lobell, D.B., Asner, G.P., Mu, Q., & Field, C.B. (2011). Direct impacts on local climate of sugar-cane expansion in Brazil. *Nature Climate Change, 1*(2), 105-109.

Lockwood, J. A. (1999). Agriculture and biodiversity: Finding our place in this world. *Agriculture and Human Values, 16*(4), 365-379.

Low, A.B., & Rebelo, A.G. (eds.) (1996). *Vegetation of South Africa, Lesotho and Swaziland*. Pretoria: DEAT.

MA (Millennium Ecosystem Assessment). (2003). *Ecosystems and Human Well-Being: a framework for assessment*. Washington D.C.: Island Press.

MA (Millennium Ecosystem Assessment). (2005). *Ecosystems and Human Well-being: Current State and Trends* (Vol. 1). Washington D.C.: Island Press.

Mander, M., Blignaut, J., van Niekerk, M., Cowling, R., Horan, M., Knoesen, D., Mills, A., Powell, M. & Schulze, R. (2010). *Baviaanskloof - Tsitsikama. Payment for ecosystem services: A feasibility assessment.* Everton: Future Works.

Marais, C., & Wannenburgh, A. M. (2008). Restoration of water resources (natural capital) through the clearing of invasive alien plants from riparian areas in South Africa — Costs and water benefits. *South African Journal of Botany, 74*(3), 526-537.

McCarthy, T., & Rubidge, B. 2005. *The Story of Earth & Life. A Southern African perspective on a 4.6-billion-year journey*. Cape Town: Struik Publishers/Johnnic Publishing Group.

McConnachie, M. M., Cowling, R. M., Van Wilgen, B. W. & McConnachie, D. A. (2012). Evaluating the costs-effectiveness of invasive alien plant clearing: A case study from South Africa. *Biological Conservation, 155*, 128-135.

Meadows, M. E., & Sugden, J. M. (1993). The late quaternary paleoecology of a floristic kingdom: the southwestern Cape South Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology, 101*(3–4), 271-281.

Meert, J. G., & Van Der Voo, R. (1997). The assembly of Gondwana 800-550 Ma. *Journal of Geodynamics, 23*(3–4), 223-235.

Melin, A., Rouget, M., Midgley, J. J., & Donaldson, J. S. (2014). Pollination ecosystem services in South African agricultural systems: review article. *South African Journal of Science, 110*(11 & 12), 25-33.

Middleton, J. T., Darley, E. F., & Brewer, R. F. (1958). Damage to vegetation from polluted atmospheres. *Journal of the Air Pollution Control Association, 8*(1), 9-15.

Middleton, J. T., Emik, L. O., & Taylor, O. C. (1965). Air quality criteria and standards for agriculture. *Journal of the Air Pollution Control Association, 15*(10), 476-480.

Monaghan, J. M. (2006). United Kingdom and European approach to fresh produce food safety and security. *HortTechnology, 16*(4), 559-562.

Moyo, H. P. M., & Fatunbi, A. O. (2010). Utilitarian perspective of the invasion of some South African biomes by *Acacia mearnsii*. *Global Journal of Environmental Research,* 4 (1), 6-17.

Mucina, L., & Rutherford, M. C. (2006). *The vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19.* Pretoria: South African National Biodiversity Institute.

Myers, N., Mittermeier, R.A., Mittermeier, C. G., da Fonseca, G. A. B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature, 403*(6772), 853-858.

NAMC (National Agricultural Marketing Council of South Africa). (2008). The South African beekeeping industry. A section 7 Committee Investigation. Pretoria: NAMC.

Nyoka, B.I. (2003). *Biosecurity in Forestry: A Case Study on the Status of Invasive Forest Tree Species in Southern Africa: Working Paper FBS/1E*. Rome: Forest Research Centre, Zimbabwe, in collaboration with Food and Agriculture Organization of the United Nations.

OECD (Organisation for Economic Co-operation and Development). (2006). *Review of agricultural policies: South Africa*. Paris: OECD.

Ojeda, F., Simmons, M.T., Arroyo, J., Marañon, T., & Cowling, R.M. (2001). Biodiversity in South African Fynbos and Mediterranean heathland. *Journal of Vegetation Science, 12*(6), 867-874.

Pielke, R. A., & Avissar, R. (1990). Influence of landscape structure on local and regional climate. *Landscape Ecology, 4*(2-3), 133-155.

Potts, S. G., Biesmeijer, J. C., Kremen, C., Neumann, P., Schweiger, O., & Kunin, W. E. (2010). Global pollinator declines: trends, impacts and drivers. *Trends in Ecology & Evolution, 25*(6), 345-353.

Powell, K.I., Chase, J.M., & Knight, T.M. (2011). A synthesis of plant invasion effects on biodiversity across spatial scales. *American Journal of Botany*, 98, 539-548.

Poynton, R.J. (1979). *Tree Planting in Southern Africa. Volume 2. The pines.* Pretoria: Department of Forestry.

Prinsloo, F.W., & Scott, D.F. (1999). Streamflow responses to the clearing of alien invasive trees from riparian zones at the three sites in the Western Cape. *South African Forestry Journal, 185*(1), 1-7.

Rai, P. K., & Panda, L. S. (2014). Dust capturing potential and air pollution tolerance index (APTI) of some road side tree vegetation in Aizawl, Mizoram, India: an Indo-Burma hot spot region. *Air Quality, Atmosphere & Health, 7*(1), 93-101.

Ramdani, F., Moffiet, T., & Hino, M. (2014). Local surface temperature change due to expansion of oil palm plantation in Indonesia. *Climatic Change, 123*(2), 189-200.

Rebelo, A. G., & Siegfried, W. R. (1990). Protection of Fynbos vegetation: Ideal and real-world options. *Biological Conservation, 54*(1), 15-31.

Richardson, D. M., Pyšek, P., Rejmánek, M., Barbour, M. G., Panetta, F. D., & West, C. J. (2000). Naturalization and invasion of alien plants: concepts and definitions. *Diversity and Distributions, 6*(2), 93-107.

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

Rouget, M., Reyers, B., Jonas, Z., Desmet, P., Driver, A., Maze, K., Egoh, B., Cowling, R.M. (2005). *South African national spatial biodiversity assessment 2004: Technical Report* (Vol. 1: Terrestrial Component). Pretoria: South African National Biodiversity Institute.

Rowlings, D. W., Grace, P. R., Scheer, C., & Kiese, R. (2013). Influence of nitrogen fertilizer application and timing on greenhouse gas emissions from a lychee (*Litchi chinensis*) orchard in humid subtropical Australia. *Agriculture, Ecosystems & Environment, 179*, 168-178.

SANBI (South African National Biodiversity Institute). (2009). *Updating national land cover.* Pretoria: South African National Biodiversity Institute.

SANBI (South African National Biodiversity Institute). (2014). Red list of South African plants. Retrieved on 24-02-2015, from http://redlist.sanbi.org/index.php

Sandbrink, M. (2013). *Kouga catchment in bad waters? A resilience study of fruit farmers' water management practices in the Kouga catchment, South Africa.* (BSc), Wageningen University and Research Centre (WUR), Wageningen.

Scotland, R. W., & Wortley, A. H. (2003). How many species of seed plants are there? *Taxon, 52*(1), 101-104.

Shone, R. W., & Booth, P. W. K. (2005). The Cape basin, South Africa: A review. *Journal of African Earth Sciences, 43*(1–3), 196-210.

Skowno, A. (2007). Baviaanskloof Mega-Reserve Biodiversity Assessment: Project Management Unit, Baviaanskloof Mega-Reserve. East London: Eastern Cape Parks, the Wilderness Foundation.

Smit, B., & Skinner, M. W. (2002). Adaptation options in agriculture to climate change: a typology. *Mitigation and Adaptation Strategies for Global Change, 7*(1), 85-114.

Sofo, A., Nuzzo, V., Palese, A. M., Xiloyannis, C., Celano, G., Zukowskyj, P., & Dichio, B. (2005). Net CO2 storage in Mediterranean olive and peach orchards. *Scientia Horticulturae, 107*(1), 17-24.

Soon, J. M., & Baines, R.N. (2013). Public and private food safety standards: Facilitating or frustrating fresh produce growers? *Laws, 2*(1), 1-19.

Stohlgren, Thomas J., Chase, Thomas N., Pielke, Roger A., Sr, Kittel, Timothy G. F., & Baron, JilL S. (1998). Evidence that local land use practices influence regional climate, vegetation, and stream flow patterns in adjacent natural areas. *Global Change Biology, 4*(5), 495-504.

TEEB (The Economics of Ecosystems and Biodiversity). (2010). *The Ecological and Economic Foundations.* London: Earthscan.

TEEB (The Economics of Ecosystems and Biodiversity). (2012). *The Economics of Ecosystems and Biodiversity in Business and Enterprise*. London and New York: Earthscan.

Tesco. (2006). Tesco NURTURE Scheme. Protocol and Code of Practice. Tesco.

Tilman, D., Balzer, C., Hill, J., & Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences, 108*(50), 20260-20264.

Turpie, J. K., Heydenrych, B. J., & Lamberth, S. J. (2003). Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies. *Biological Conservation, 112*(1–2), 233-251.

Turpie, J. K., Marais, C., & Blignaut, J. N. (2008). The working for water programme: Evolution of a payments for ecosystem services mechanism that addresses both poverty and ecosystem service delivery in South Africa. *Ecological Economics, 65*(4), 788-798.

Ungricht, S. (2004). How many plant species are there? And how many are threatened with extinction? Endemic species in global biodiversity and conservation assessments. *Taxon, 53*(2), 481-484.

UN Global Compact & IUCN. (2012). *A framework for corporate action on biodiversity and ecosystem services*. New York: Global Compact Office.

Van Dyk, F.E., & Maspero, E. (2004). An analysis of the South African fruit logistics infrastructure. *OriON, 20*(1), 55-72.

Van Wilgen, B. W., Richardson, D. M., Le Maitre, D. C., Marais, C., & Magadlela, D. (2001). The economic consequences of alien plant invasions: examples of impacts and approaches to sustainable management in South Africa. *Environment, Development and Sustainability, 3*(2), 145-168.

Van Wilgen, B.W. (2009). The evolution of fire and invasive alien plant management practices in Fynbos. *South African Journal of Science, 105(*Sep/Oct*)*, 335-342.

Van Wilgen, B.W., Reyers, B., Le Maitre, D. C., Richardson, D. M., & Schonegevel, L. (2008). A biome-scale assessment of the impact of invasive alien plants on ecosystem services in South Africa. *Journal of Environmental Management, 89*(4), 336-349.

Veerkamp, C. (2013). *Agriculture and Biodiversity Conservation in the Water-Stressed South African Kouga Catchment.* (MSc), Wageningen University and Research Centre (WUR), Wageningen

Vilà, M., Espinar, J. L., Hejda, M., Hulme, P. E., Jarošik, V., Maron, J. L., Pergl, J., Schaffner, U., Sun, Y., and Pyšek, P. (2011). Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. *Ecology Letters, 14*(7): 702-708.

Vromans, D.C., Maree, K.S., Holness, S., Job, N., & Brown, A.E. (2010). The Garden Route Biodiversity sector plan for the southern regions of the Kouga and Koukamma Municipalities. *Supporting land-use planning and decision-making in critical biodiversity areas and ecological support areas for sustainable development.* Knysna: Garden Route Initiative, South African National Parks.

Walker, N. D. (1990). Links between South African summer rainfall and temperature variability of the Agulhas and Benguela Current systems. *Journal of Geophysical Research: Oceans, 95*(C3), 3297-3319.

Winn, M. I., & Pogutz, S. (2013). Business, ecosystems, and biodiversity: New Horizons for management research. *Organization & Environment, 26*(2), 203-229.

Winter, T.C., Harvey, J.W., Franke, O.L., & Alley, W.M. (1998). *Ground water and surface water: A single resource U.S. Geological Survey Circular 1139.* Denver: U.S. Geological Survey.

World Bank. (2008). *Sustainable land management sourcebook*. Washington D.C.: World Bank Publications.

WRI (World Resources Institute). (2012). The Corporate Ecosystem Services Review. Retrieved 07-03-2015, from http://www.wri.org/publication/corporate-ecosystem-services-review

Younge, A., & Fowkes, S. (2003). The Cape Action Plan for the Environment: overview of an ecoregional planning process. *Biological Conservation, 112*(1-2), 15-28.

Appendices

Appendix I. Detailed overview of the study area

This appendix presents a detailed overview of the most prominent features of the study area in terms of climatic conditions, biophysical structure of the landscape, vegetation and fauna. As well as Chapter 2 (study area), this appendix was written in collaboration with Arjan de Groot.

1. Climatic conditions

Despite the fact that South Africa is situated between the 22°S and 35°S latitudes, and therefore falls within the Southern Hemisphere's subtropical zone, its average temperatures throughout the year are comparatively lower than those of other regions of similar latitude. A reason for that is the high elevation of South Africa's landscape. Summer in South Africa begins in October and ends in March, with highest temperatures usually in January and February. Temperatures in summer generally vary between 15 degrees at night and up to 35 degrees in the early afternoon, although more extreme temperatures are also possible (Kruger and Shongwe, 2004). Winter starts in April and lasts until September, with July and August being the coldest months of the year. Lowest temperatures are ordinarily around 0 degrees at night and up to 20 degrees during the day (Official weather reports). Annual rainfall in South Africa is around 460 mm, which compared to the global average of 860 mm defines the country as semi-arid according to the Köppen climate classification. Timing and amount of rainfall is also highly variable, both in terms of spatial and temporal variation, although in most areas of South Africa, most of the rain falls during the summer when the Inter-Tropical Convergence Zone (ITCZ) moves southwards (Jury, 2002). However, not only rainfall is highly variable in South Africa, also the climate itself is heterogeneous. This is largely due to the influence of the Indian Ocean to the east and the Atlantic Ocean to the west (Walker, 1990). Thus, South Africa is situated between high pressure zones in the east and the west. Depending on the prevailing global winds, the weather in each region is therefore subjective to large inter-annual variations, which is the reason for South Africa's very diverse climates and explains why the country is frequently experiencing periods of severe droughts or heavy rainfall. The Agulhas current of the Indian Ocean transports warm water and humid air along the eastern coast of the country and thus leads to a humid and warm climate, whereas cold water of the Benguela current from the Atlantic Ocean flows northwards along the western coastline of South Africa and causes drier conditions (Walker, 1990). As a result, temperatures and humidity differ between the western and the eastern parts of the country.

The Eastern Cape measures an annual rainfall of 550 to 700 mm, which is therefore higher than in most other parts of South Africa (Blignaut *et al.*, 2009). The Langkloof itself experiences large variations in rainfall even within the valley. The settlements of Haarlem and Avontuur to the west receive approximately 800 mm of rain per year, whereas only around 300 mm of rain fall annually near the eastern border of the valley in The Heights (Haigh *et al.*, 2004). Rainfall records stemming from Joubertina place the annual rainfall at 476 mm (Sam van der Merwe, 2014, pers. comm.). Overall, the average annual rainfall in the valley is around 500 to 550 mm, which is above the South African average (DWAF, 2009). Another characteristic of the study area is that it experiences a bimodal rainfall pattern (Cowling and Pierce 2009; Mander *et al.* 2010). Hence, most of the rain falls in autumn or spring, whereas most other regions in South Africa, with the exception of the Western Cape, receive the majority of rainfall in summer. According to the Köppen classification, the climate in the Langkloof can be described as a mild Mediterranean climate.

Summers in the Langkloof are warm and dry, and temperatures above 40°C can be recorded occasionally. Average daily sunshine is around 7 to 8 hours (official weather stations). Another reason apart from the influences of the Indian Ocean and the prevailing global winds for the variability in climate within the Langkloof valley is its topography. The Tsitsikamma Mountains in the south and the Kouga mountains in the north each influence the wind patterns and can act as a trap for rain clouds from the ocean (Sandbrink, 2013). Average midday temperatures in summer are around 25 degrees and around 16 – 18 degrees in winter, highlighting the mild climatic conditions in the Langkloof valley. Snow can be found on higher altitudes in the Langkloof in winter, and the valley also commonly experiences frost days (Haigh *et al.*, 2004), which can pose risks for the local agriculture.

Overall, the climate in the Langkloof makes it very suitable for the growing of deciduous fruits.

2. Biophysical structure of the landscape

This section discusses the most prominent biophysical structures of the Kouga catchment and, more specifically, the Langkloof. The geologic formation of the landscape and its significance for the soil composition and the hydrology are addressed, as well the vegetation and fauna of the area. The aim is to give the reader a comprehensive foundation of the underlying geologic and biologic history, in order to better understand aspects of the later discussed findings.

a) Geology and Geomorphology

The geology of South Africa is quite old compared to many other countries on Earth. What is known today as South Africa used to be a part of the former supercontinent Gondwana. The supercontinent Gondwana formed already during the beginning of the Cambrian (~850 million years ago) and was completed well into the Ordovician (approximately 570 to 510 million years ago) (Meert and Van der Voo, 1997). However, even older rocks, dated at 3,700 million years ago can be found in South Africa today (Kröner *et al.*, 1996). These are some of the oldest rocks still found today on Earth and highlight South Africa's long geologic history. Eventually, Gondwana joined with another supercontinent called Laurasia to build a third, and larger supercontinent: Pangaea. After Pangaea started to break up in the Early-Middle Jurassic period 175 million years ago, the former continent of Gondwana also started to break up and was subjected to a range of long-lasting geologic processes, such as tectonic rifting, the formation of crevasses, volcanic activity, erosion and rocks deposition. The next 10 - 25 million years of geologic activity have shaped the land and turned it into the rugged and highly elevated landscape that can be observed in present-day South Africa. Large deposits of gold, diamond and ore, amongst others, have resulted in a rich mining history in South Africa. Because of the hard rock geology in South Africa, groundwater availability is limited and highlights the importance of surface water as a primary water source (Calzadilla *et al.*, 2014).

The Langkloof is embedded between the Kouga mountains to the north and the Tsitsikamma mountains to the South and was formed during an uplifting event around 20 million years ago (Cowling and Pierce, 2009). The valley itself is situated roughly 300 meters above sea level and contains relatively nutrient rich soils due to the local geology, although a large portion of the land has been degraded (Sandbrink, 2013). The Kouga Mountains are higher and reach their highest point on top of the Hoosberg at an elevation of 1,705 meters, whereas the highest point of the Tsitsikamma Mountains is at an elevation of 1,500 meters above sea level. Both are part of the much larger complex of the Cape Fold Belt, which formed during the late Paleozoic approximately 300 to 250 million years ago (Shone and Booth, 2005). This fold and thrust belt covers most of the southern parts of South Africa and is heavily folded and deformed (Du Toit and Haughton, 1954). Generally, most of the area around the Langkloof is dominated by quartzitic sandstones of the Table Mountain Group. However, approximately 400 million years ago, during the Devonian period, fine-grained sediments of the Bokkeveld shale formation were deposited in the area, containing mainly mudstones. This group survived in the valley of the Langkloof, although it has been eroded from the surrounding mountaintops (McCarthy and Rubidge, 2005).

b) Soil Composition and Hydrology

The mountainsides surrounding the Langkloof valley are demarcated by acidic, nutrient poor and dry soils. However, the soft mudstones of the Bokkeveld group in the valley itself form very fertile soils due to their larger capacity to retain water and clay minerals (McCarthy and Rubidge, 2005). The soil in the Langkloof is generally fertile as it contains a high amount of clay and nutrients, which are derived from the shales of the Bokkeveld group (Veerkamp, 2013). This is one of the main reasons for the extensive agriculture in the Langkloof.

The hydrology around the Langkloof is of vital importance to the valley for its agriculture and human use, but it plays a far bigger role for the whole of the Eastern Cape. As previously stated, the Langkloof valley is part of the Kouga catchment. The mountains around the Kouga catchment act as a water trap, and transport water from the mountains down into the valley into the rivers. The largest of those is the Kouga River, which also drains the catchment. It flows eastwards through the Langkloof valley, during which it is joined by smaller tributaries. Eventually it turns northwards, where it flows in between the Kouga and Suuranys mountains. Finally, the Kouga River is joined by the Baviaanskloof River and afterwards ends in the Kouga dam, where the water is being accumulated. From there, the Kouga River joins the Groot River to form the Gamtoos River, which flows southwards towards the ocean.

Due to the already mentioned low rainfall in South Africa and the limited groundwater resources, the Kouga catchment is of vital importance for the Eastern Cape, as South Africa is highly dependent on its catchments for water. Ultimately, the Kouga catchment, through its accumulation of water, not only supplies the largest share of water resources for the Langkloof, but also for many regions located downstream. The Gamtoos valley and its settlements obtain their water from the Gamtoos River, which is fed by the Kouga River. Also, the Nelson Mandela Bay Metropolitan region, of which the city of Port Elizabeth is a part of, receives the majority of their water from the Kouga catchment and the Kouga River.

Wetlands have also formed in many occasions in the Langkloof valley and in the neighbouring Kromme catchment, although the wetlands in the area have been largely converted by humans for other purposes (Haigh *et al.*, 2004). Due to the fact that groundwater resources are limited, rainfall plays a crucial role in upholding the water supply of the Kouga catchment. It is for this reason that the variability in rainfall and future climate change can cause great problems for the whole of the Eastern Cape, as many different regions are depending on these water resources.

3. Vegetation

One of the main reasons for the high biodiversity in South Africa is the existence of different vegetation biomes. Approximately 20,000 plant species can be found in South Africa (SANBI, 2014), which accounts approximately to 5% up to nearly 10% of all estimated plant species for the Earth (Scotland and Wortley, 2003; Ungricht, 2004). Almost half of the plant species in the country (roughly 9,000) are found around the southern tip of South Africa, in the Eastern and Western Cape, with approximately 70% of its flora being endemic to the area (Goldblatt, 1997; Goldblatt and Manning, 2002). This area is called the Cape Floristic Region (CFR) and its floristic particularities (e.g. endemism and richness) make it even comparable to a unique floral kingdom (Meadows and Sugden, 1993; Low and Rebelo, 1996; Goldblatt, 1997). As such, the CFR contains nearly 20% of the African continent's flora in approximately 5% of its surface (Goldblatt and Manning, 2002), it is deemed as one of the world's biodiversity hotspots (Myers *et al.*, 2000) and recognised by UNESCO as a World Heritage Site. The CFR extends eastwards from the south-western tip of the country into the Eastern Cape and encompasses Mediterranean-climate dominated areas, as well as a broad diversity of landscapes that include different biomes and vegetation types (Goldblatt and Manning, 2002).

The currently accepted classification of South African vegetation includes nine biomes (Mucina and Rutherford, 2006), from which 6 are represented in the CFR. Based on the spatial analysis of the vegetation map provided by Mucina and Rutherford (2006), one azonal vegetation type and three biomes are found in the Kouga catchment. Fynbos is by far the dominant biome in the area (93% of the catchment), followed by Albany Thicket (6.6% of the catchment) and Forest (0.03% of the catchment) (see Table I-1 and Figure I-1).

Table I-1. Main biomes, bioregions and vegetation types in the study area

Biome – Bioregion – Vegetation type	Area (ha) Kouga catchment	% (Kouga catchment area)	Area (ha) in the Langkloof[1]	% (Langkloof area)
Fynbos Biome				
Eastern Fynbos-Renosterveld bioregion				
Kouga Grassy Sandstone Fynbos	116,710	41.3%	11,802	28.0%
Kouga Sandstone Fynbos	96,025	34.0%	909	2.2%
Tsitsikamma Sandstone Fynbos	38,779	13.7%	23,576	56.0%
Eastern Inland Shale Band Vegetation	5,454	1.9%	703	1.7%
Eastern Coastal Shale Band Vegetation	1,787	0.6%	1,291	3.1%
Langkloof Shale Renosterveld	4,265	1.5%	3,813	9.1%
Albany Thicket biome				
Albany Thicket				
Groot Thicket	14,984	5.3%	-	-
Gamtoos Thicket	3,715	1.3%	-	-
Azonal vegetation				
Alluvial vegetation				
Albany Alluvial Vegetation	497	0.2%	-	-
Forests				
Zonal & intrazonal forests				
Southern Afrotemperate forest	88	0.03%	-	-
Total	282,303	100%	42,094	100%
[1] Based on the Langkloof's area estimated for this thesis				

Source: based on spatial analysis of the vegetation map provided in Mucina and Rutherford (2006).

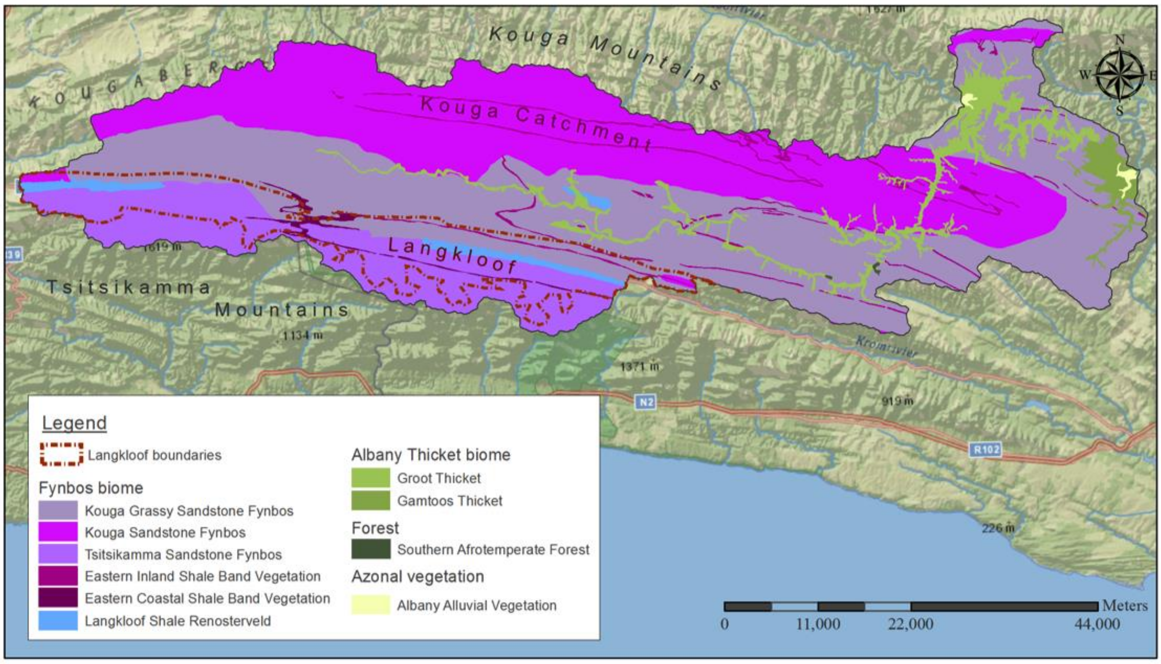

Figure I-1. Vegetation types in the study area (Mucina and Rutherford, 2006)

In addition to the abovementioned vegetation types, wetlands represent another form of azonal vegetation largely modified by human activities in the area. The wetlands identified in the catchment include remnants of palmiet wetlands in the eastern part of the Langkloof and the Tsitsikamma mountains, and seeps occurring in riparian and occasional floodplains in the Kouga Mountains (Haigh *et al.*, 2004).

In order to provide a more specific idea of the most prominent features of the landscape in terms of vegetation, the following sub sections present the main characteristics of Fynbos and Albany Thicket, since both biomes together extend over more than 99% of the catchment's surface.

c) Fynbos biome

Fynbos biome refers to two main vegetation groups, Fynbos and Renosterveld, and it is generally characterized by high plant species richness and high numbers of endemic species in relatively confined areas or centres of endemism (Low and Rebelo, 1996; Ojeda *et al.*, 2001). Despite representing less than 7% of the total country's total area, according to national statistics for South Africa (SANBI, 2014), Fynbos is the biome with the highest number of threatened taxa (approximately 1,800 taxa) and the highest number of endemic taxa of conservation concern at the national level (around 3,150 taxa).

Poor and well-leached soils, such as sandstones, granites and shale, serve as support for Fynbos vegetation, whereas more fertile fine-grained soils sustain the Renosterveld type (Rebelo and Siegfried, 1990; Low and Rebelo, 1996). These soil aspects in the surrounding Tsitsikamma and Kouga mountains explain why the majority of the mountains and slopes in the Kouga catchment are covered with Fynbos vegetation (Veerkamp, 2013).

The Fynbos is a sclerophyllous shrubland (Cowling, 1992) composed by three main categories of plants: shrubby grasses on nutrient-poor soils with winter rainfall (e.g. Restionaceae); a majority of plants with small leaves with thick-walled cells on the upper surface and hairs on the lower surface (e.g. Ericaceae, Asteraceae, Fabaceae, etc.); and a final group of broad leaves plants (e.g. Protaceae). On the other hand, Renosterbos (*Dicerothamnus rhinocerotis*) dominates the Renosterveld type, along with other species, which also belong to the Asteraceae Family (Low and Rebelo, 1996).

Fires are important events for Fynbos plant communities' development and establishment (Low and Rebelo, 1996; Bond *et al.*, 2003; van Wilgen, 2009). Since many of the species in Fynbos regenerate from seeds after fires (Low and Rebelo, 1996), the frequency of fires necessary to sustain the community has been estimated between a minimum of 10 years and a maximum of 45 years (Low and Rebelo, 1996; van Wilgen, 2009). For this reason, prescribed burning, conducted in the right season (e.g. late summer) and frequency, is currently regarded as an effective management strategy for the vegetation types in this biome (van Wilgen, 2009; GOV 3, pers. comm.) in order to avoid the invasion of other vegetation elements (e.g. alien plants or Thicket species) (Low and Rebelo, 1996).

The Kouga catchment is almost entirely classified within this biome (93% of its area) and the entire Langkloof is part of it. The Kouga Grassy Sandstone Fynbos is the best represented vegetation type in the Kouga catchment (41% of its area) and it covers 28% of the Langkloof area (Table I-1). This vegetation type is situated in the lower slopes of the Kouga Mountains on acidic lithosol soils derived from sandstones in areas with mean annual precipitation of approximately 540 mm. It is described as a low shrubland with sparse, emergent tall shrubs (e.g. *Aspalathus kougaensis, A. nivea, Dodonaea viscosa* var. *angustifolia*) and succulent shrubs species (e.g. *Aloe ferox*) (Mucina and Rutherford, 2006)

Kouga Sandstone Fynbos is the second best represented type in the study area (34% of the catchment), although it only covers approximately a 2% of the Langkloof (Table I-1). This specific type extends along the Kouga Mountains at higher altitudes than the Grassy Sandstone Fynbos, and in a confined band next to the lower Langkloof (towards the eastern portion of the valley in the study area) on southern slopes of the Suuranysberg (Figure I-1). This type occurs in acidic lithosol derived from sandstones areas, where the mean annual precipitation reaches around 600 mm. It includes low Fynbos in high altitudes, and Protaceae tall shrubs in intermediate slopes (Mucina and Rutherford, 2006).

In spite of covering roughly a 14% of the catchment, the Tsitsikamma Sandstone Fynbos more than half of the Langkloof's surface (56%) extends over this vegetation type (Table I-1). This is due to its distribution over low altitude coastal mountains with moderately undulating plains that neighbour the valley to the south (Figure I-1). Occurring on acidic soils from Ordovician sandstones and in areas with a mean annual precipitation of approximately 850 mm, this vegetation type is described as a medium dense, tall shrubland (e.g. *Leucadendron conicum* and *L. eucalyptifolium*), over a dense lower shrubland (e.g. *Erica discolor* var. *speciosa*, *E. sparsa* and *Ursinia scariosa* subsp. *scariosa*), which mixes with Fynbos thicket in wetter areas (e.g. *Pterocelastrus tricuspidatus*) (Mucina and Rutherford, 2006).

The Eastern Inland Shale Band Vegetation, Eastern Coastal Band Vegetation and the Langkloof Shale Renosterveld cover, altogether, only a 4% of the catchment. Nevertheless, the latter type is almost entirely represented in the Langkloof over approximately the 10% of its area (Table I-1). The Langkloof Shale Renosterveld occurs over a narrow distribution in localized areas with clays and loams derived from shales at lower slopes with mean annual precipitation of around 500 mm (Figure I-1). As indicated in the type classification, it is dominated by renosterbos in a shrubland with cuppressoid-leaved species and a stratum of graminoid species (Mucina and Rutherford, 2006).

Most of the vegetation types mentioned for the Fynbos biome have been largely affected by a widespread occurrence of IAPs in the Kouga catchment and the Langkloof.

d) Albany Thicket biome

The Albany Thicket biome is characterized for its types that are usually understood as transitional ones, since many of their floristic components are shared with other biomes. In general terms, it can be described as a dense thorny shrubland or low forest with little herbaceous cover that includes dominant evergreen and sclerophyllous elements, as well as high covers of succulent shrubs and trees (Low and Rebelo, 1996; Mucina and Rutherford, 2006).

This biome is found in the Eastern Cape and the Western Cape, in semi-arid areas, mainly across the Cape Fold Belt on a broad variety of soils (Mucina and Rutherford, 2006). In the

Kouga Catchment it is represented in almost 18,000 ha (less than 7% of the catchment) (Figure I-1). This biome is not represented in the Langkloof, but it extends over the catchment from west to east next to the Kouga River and around the northeast boundaries of the catchment, where the Kouga dam is located.

The Groot Thicket type covers almost 15,000 ha in the catchment (around 5% of its total area) (Table I-1). It can be found in the Kouga River and the boundaries of the Baviaanskloof in the Kouga catchment, occupying ridges with moderate to steep slopes in an altitude range from 200-1100 m and with medium annual precipitation between 250-450 mm. Spekboom (*Portulacaria afra*) is characteristic of this vegetation type under favourable conditions, as well as succulent trees such as *Aloe ferox* and *Euphorbia tetragona* (Mucina and Rutherford, 2006).

Covering around 1% of the Kouga catchment in a constrained area northwest of it (Table I-1; Figure I-1), the Gamtoos Thicket is distributed over an altitude range from 0-700 m on low ridges and steep areas of low mountains, which are protected against fires. With a low differentiation of strata, shrubs, trees and succulent are dominant (Mucina and Rutherford, 2006).

4. Fauna

As previously mentioned, the Langkloof and its surroundings are exposed to large variations in climatic conditions and are subjected to a number of so-called microclimates. As a result, the different biomes in the area provide a habitat for a number of animal species. Since Fynbos is the dominant biome in the catchment, its vegetation types determine the presence of specific wild animals in most of the area. According to Low and Rebelo (1996) a main distinction in terms of fauna can be done between Fynbos and Renosterveld types within the biome. Whereas the Fynbos vegetation types support most of the endemic amphibian, bird and mammal species, the Renosterveld types used to support the majority of larger animals in the region (Low and Rebelo, 1996).

Among the large mammals that used to exist in the Renosterveld types are Cape Mountain Zebra, Lion, Elephant, Black Rhino, Hyena and Leopard (Low and Rebelo, 1996). Nevertheless, with exceptions such as Leopard (which survives in the mountains), most of these animals became extinct in the biome, being introduced from other regions into protected areas (e.g. reserves, national parks, game safaris and game hunting grounds) (Low and Rebelo, 1996). Consequently, Cape Mountain Zebra, Cape Buffalos, Eland, Kudus, Red Hartebeest, Mountain Reedbuck and Bushbuck, can be still found in some of the mountainous areas (Veerkamp, 2013).

A large variety of birds and small reptiles can also be observed in Fynbos in the Kouga catchment and the Langkloof. Swallows, sunbirds, kingfisher, African black eagles, amongst other birds, and reptiles such as the Leopard Tortoise and small lizards are a common occurrence in the area (Veerkamp, 2013).

Of particular interest for humans are large wild bee populations, which are essential for the deciduous fruit production, as they pollinate the flowers (Beekeeper 1, pers. comm.). On the other hand, moths and other insects can affect agricultural production negatively, which is why many farmers have to use pesticides in their orchards. Large and widespread families of baboons are also characteristic throughout the study area. They sometimes pick fruits from orchards and are attracted by organic waste, and are thus a concern for the farmers and inhabitants of the area (DFF 9, pers. comm.).

Appendix II. Supporting information for the dependence analysis

Questionnaire for dependence analysis (Hanson et al 2012):
Question 1 (Q1): "Does this ecosystem service serve as an input or does it enable/ enhance conditions for successful company performance?" [1]
Question 2 (Q2): "Does this ecosystem service have cost-effective substitutes?"

Ecosystem services	**Q1**	**Q2**	**Supporting information**
Provisioning			
1. Food			
1.1.Crops	No	N.A.	In this case crops are products of the activities performed by the business sector. Therefore it is not enabling the conditions for successful company performance.
1.2. Livestock	No	N.A.	According to the interviews the fruit farming activities in the Langkloof do not depend on livestock to enhance or enable a successful performance. Five of the interviewed farmers have sheep or cattle in other areas of their farms, but mainly for personal consumption or small business, which are not related to fruit farming.
1.3. Wild foods	No	N.A.	Although wild foods (e.g. meat from game animals or wild fruits) were identified in the area in previous technical studies (Veerkamp, 2013), the deciduous fruit farming activities do not benefit from it. Therefore, wild foods are neither enabling nor enhancing the conditions for a successful business performance.
2. Water	Yes	No	Deciduous fruit farming business performance is directly related to the water provided by the Kouga catchment ecosystems. The water from the surface runoff and tributaries of the Kouga river is stored in private dams for irrigation from September or October until the beginning of winter (DFF 10, pers. comm.). In dry years, when there is not enough water accumulated in the dams, farmers need to tap to the groundwater, drilling in some cases 100 m deep to obtain the water from boreholes (DFF 7, pers. comm.). Water obtained with any of these systems is also used as drinking water for the farm workers. At the moment there are no further cost – effective substitutes to this service.
3. Raw Material			
3.1. Timber and other wood fibre	Yes	Yes	Wooden pallets and bins for fruit packing were bought from providers in the Kouga catchment by seven of the interviewed farmers. According to them, the wood is obtained from alien species (e.g. pine trees) (DFF 7, pers. comm.) and distributed mainly by two manufacturers and providers in the area (DFF 2, pers. comm.). Sawdust, loose bark and wood chips (for compost and mulching) are locally provided as well (DFF 1, pers. comm.; DFF 13, pers. comm.). Nonetheless, despite enhancing and enabling the conditions for successful business performance, agricultural supplies shops and providers from other regions also offer all these products, as well as substitutes such as paper made packing boxes (DFF 5, pers. comm.). In those cases imported inputs serve as cost-effective substitutes for the locally provided service. Source: Interviews
3.2. Fibres and resins	No	N.A.	Neither fibres nor resins that were locally obtained were identified as inputs for the deciduous fruit-farming sector in the Langkloof.

Questionnaire for dependence analysis (Hanson et al 2012):
Question 1 (Q1): "Does this ecosystem service serve as an input or does it enable/ enhance conditions for successful company performance?" [1]
Question 2 (Q2): "Does this ecosystem service have cost-effective substitutes?"

Ecosystem services	**Q1**	**Q2**	**Supporting information**
3.3. Animal Skins	No	N.A.	Animal skins were not identified as an input for the deciduous fruit-farming sector in the Langkloof.
3.4. Fodder	No	N.A.	Even though there are deciduous fruit-farmers in the Langkloof who raise cattle and other livestock (six of the interviewed farmers), these are considered separate activities in their farms. Therefore, the use of fodder for the farm animals does not enable or enhance the company performance.
3.5. Fertilizer	Yes	Yes	As described in Section 4.3, organic material obtained in the area is applied directly to the soil or used for composting (at least 5 of the interviewed farmers apply it as compost or mulch with organic material from their farms). Furthermore, there are farmers who buy locally produced fertilizers (DFF 3, pers. comm.). In that sense, the organic material provided in the local ecosystems and used as fertilizer enhances conditions for successful business performance. At the time of the interviews, however, the major fertilizer inputs were chemicals or imported organic products (all the farmers), such as pelletized chicken manure and compost tea. Consequently, these products are considered to be cost-effective substitutes for fertilizers provided in the ecosystems in the study area.
4. Genetic Resources	No	N.A.	According to the interviews, deciduous fruit-farming activities do not directly benefit from genetic resources found in the study area. New fruit varieties are imported, as well as any technology or practices for crop improvement (six interviewed farmers). Notwithstanding the indirect benefits in terms of pollination or natural pest control arising from the genetic diversity in the area, this is not considered in the analysis in order to avoid double counting. Therefore genetic diversity in the ecosystems in the Langkloof or the Kouga catchment do not serve as an input that enhances or enable conditions for successful company performance.
5. Medicinal Resources	No	N.A.	Medicinal resources identified in the Kouga catchment through interviews and earlier by Verkaamp (2013) are Aloe and Honeybush. Nevertheless, none of them serves as an input for deciduous fruit-farming activities.
6. Ornamental Resources	No	N.A.	Ornamental resources do not serve as an input for deciduous fruit farming activities in the Langkloof.
Regulating			
7. Air quality regulation	Yes	No	Air pollution impacts on food crops and agriculture have been long ago identified and reported in the scientific literature (Middleton *et al.*, 1958; Middleton *et al.*, 1965). Productivity losses caused by the effects of chemicals in the atmosphere (Middleton *et al.*, 1965) are likely to be experienced in rapidly developing countries given increasing emission levels of air pollutants such as SO_2, NO_X, O_3 and Suspended Particulate Matter (SPM) (Emberson *et al.*, 2001). Ecosystems can influence the levels of chemicals and particulate matter by extracting them from the atmosphere (MA, 2003; de Groot *et al.*, 2010; Hanson *et al.*, 2012). At the moment, this ecosystem service does not enable the farming activity in the area itself, but the literature shows that farming productivity is enhanced by the provision of this service. Since no air purifying options (e.g. technology) as a replacement of this service are found for the scale of the farming business in the area, the ecosystems from the Kouga Catchment can be deemed as non-substitutable in this regard.

Questionnaire for dependence analysis (Hanson et al 2012):
Question 1 (Q1): "Does this ecosystem service serve as an input or does it enable/ enhance conditions for successful company performance?" [1]
Question 2 (Q2): "Does this ecosystem service have cost-effective substitutes?"

Ecosystem services	**Q1**	**Q2**	**Supporting information**
8. Climate regulation			
8.1. Global climate regulation	Yes	Yes	The provision of this service includes the influence of ecosystems in the atmosphere gas concentrations, in which case the effects are cumulative and benefits provided to human beings can be quantified at large scales (MA, 2003; de Groot *et al.*, 2002). Farming productivity in South Africa is exposed to the effects of variations in atmospheric gas concentrations causing climate change, which can induce changes in precipitation, surface runoff, soil moisture, temperature and local climate, among others (Calzadilla *et al.*, 2014). Nevertheless, from a global perspective the local influence of the ecosystems in the Langkloof and the Kouga catchment in the absorption of global greenhouse or other gases can be substituted by this service's provision in other ecosystems in South Africa or the rest of the world. Therefore, global climate regulation enhances the conditions for successful business performance, but it is not exclusively provided by the ecosystems under analysis (i.e. other ecosystems can serve as substitutes), since it occurs at broader scales than the one used for this study.
8.2. Regional/ local climate regulation	Yes	No	According to the South African Department of Agriculture, Forest and Fisheries (DAFF, 2012a) declines in the gross value of apples during different production seasons (i.e. 2004-2005, 2005-2006 and 2009-2010) were caused mainly by unfavourable weather conditions (e.g. heat waves). In this context, local topography, land cover and, more particularly, vegetation cover can determine temperature and rainfall levels that are suitable for specific human activities (MA, 2003; de Groot *et al.*, 2002; Hanson *et al.*, 2012). Farmers in the Langkloof identified the local climate as an important benefit they obtain from nature. Sunlight, temperature (i.e. enough cold units) and precipitation were identified as key climatic treats for farming productivity (11 farmers identified at least one of these climatic conditions). Consequently, mountains proximity and vegetation cover were described as influential factors to provide favourable conditions regarding those key characteristics for deciduous-fruit farming. As such, local and regional climate regulation enables as well as enhances the conditions for successful company performance. In terms of substitutes, hail nets were identified as a measure to regulate sunlight (DFF 10, pers. comm.) and changes in the application of awakening oil were performed to deal with years when cold units were insufficient (DFF 2, pers. comm.). Nevertheless, these measures were not cost effective for every farmer in the Langkloof, but only for a minority of them, as mentioned in interviews. Even though, such alternatives could help dealing with specific changes in some of the aforementioned climatic treats, cost effective substitutes for general rainfall levels or temperature in the area have not been identified.

Questionnaire for dependence analysis (Hanson et al 2012):
Question 1 (Q1): "Does this ecosystem service serve as an input or does it enable/ enhance conditions for successful company performance?" [1]
Question 2 (Q2): "Does this ecosystem service have cost-effective substitutes?"

Ecosystem services	**Q1**	**Q2**	**Supporting information**
9. Moderation of extreme events	Yes	No	In the past, South African plums have faced export volumes declining up to 30% compared to previous years because of droughts (DAFF, 2012b). Similarly, these events have affected the country's apple production with declines of even 14% of its gross value (DAFF, 2012a). In the Langkloof, droughts (2008-2009) have affected in some cases even up to 30% to 40% of one farm's produce (DFF 7, pers. comm.). In one case, droughts combined with floods in subsequent years led to losses equivalent to the total company's turnover (DFF 4, pers. comm.). Major floods affected the Langkloof in 2006 and 2007, damaging infrastructure (e.g. dams, roads and pipes) and orchards. Besides that, 10 out of 13 farmers who participated in this study have faced hailstorms (in 2007 and every year from 2011 to 2013), which have damaged their orchards with losses of 80% and the entire production in the worse cases. Vegetation cover in the Langkloof and the Kouga catchment mountains can help minimizing the intensity of and damage caused by floods and droughts in particular. Nevertheless, according to a representative of the fire department of Koukamma municipality, the vegetation types found in the area and the alien plant species invasion increase the risks of fires (GOV 3, pers. comm.). Fynbos is a fire prone vegetation type for which a mean of 15 years fire return period has been estimated (van Wilgen, 2009). IAPs do not only increase the unpredictability of fire frequency, but also spread after fires causing additional impacts associated to these extreme events (GOV 3, pers. comm.; van Wilgen, 2009). Moderation of extreme events plays a relevant role enabling conditions for deciduous fruit farming and even though infrastructural and technological measures are able to mitigate the impacts of some extreme events on farming activities, they do not substitute the provision of this service to its full extent.
10. Regulation of water flows	Yes	No	As mentioned in Section 4.3, water for irrigation and domestic use in farms in the Langkloof is obtained from communal dams, tributaries of the Kouga River or directly from the surface runoff. The water is stored in private dams and then utilized over the year. Even though storing the water in private and communal dams allow farmers regulate the water flows for irrigation, the storage capacity is limited, and hence, they rely on regular water flows in order to fill in these dams (Veerkamp, 2013; GOV 2, pers. comm.; EXP 1, pers. comm.). During the interviews they described years in which most of the rainfall was observed in one short period of time. This poses risks for the water provision during the rest of the year in cases of insufficient storage capacity (DFF 6, pers. com; DFF 5, pers. comm.). Under such circumstances, the water storage potential of the ecosystems in the area plays a relevant role enabling the conditions for successful fruit farming. Filling the dams depends on natural water flow regulation in order to avoid overflowing or water shortages. Furthermore the aquifer recharge is fundamental for dry years, during which farmers pump groundwater for their activities (DFF 7. pers. comm.). For these reasons, current infrastructure or technology cannot be identified as a cost effective substitute for this service.

Questionnaire for dependence analysis (Hanson et al 2012):
Question 1 (Q1): “Does this ecosystem service serve as an input or does it enable/ enhance conditions for successful company performance?”[1]
Question 2 (Q2): “Does this ecosystem service have cost-effective substitutes?”

Ecosystem services	**Q1**	**Q2**	**Supporting information**
11. Waste treatment			
11.1. Water purification	Yes	Yes	Except by one of the interviewed farmers, water for irrigation is generally filtered for big particles in order to meet global environmental standards for agriculture (12 farmers’ interviews). That implies that deciduous fruit farming in the Langkloof largely relies on the natural capacity of ecosystems to purify the water and decompose organic matter and other pollutants. Nevertheless, up to certain impurities or pollution levels this service could be substituted by technological solutions devised for agriculture and other uses (e.g. purifying plants and other water treatment systems).
11.2. Waste treatment	Yes	Yes	According to interviews organic wastes from different phases in the orchards’ life cycle (e.g. pruning, thinning) are returned to the soil in order to obtain benefits from its degradation through natural processes (e.g. compost or direct organic matter degradation as fertilizer) (five of the farmers participating in this thesis). Despite being an input that enhances farming performance, other products (e.g. chemical fertilizers) can be used as substitutes of the degraded organic waste provided by the natural ecosystems. Furthermore, the waste can be treated with alternative systems.
12. Erosion prevention	Yes	Yes	As the capacity of replenishing and holding soil (Hanson *et al.*, 2012), as well as preventing landslides (de Groot *et al.*, 2002), the soil erosion prevention service is fundamental for farming activities. Notwithstanding its importance for deciduous fruit farming in the Langkloof, several measures to prevent soil erosion are implemented by farmers in the area (e.g. cement, gabions, bumps on the roads and contour agriculture). These measures substitute up to a certain extent the provision of this service by the ecosystems in the area.
13. Maintenance of soil fertility	Yes	Yes	The ecosystems’ role in maintaining the biological activity and productivity (Hanson *et al.*, 2012) enhances the conditions for the maintenance of crop productivity (de Groot *et al.*, 2002), and hence for a successful business performance. According to de Groot *et al.* (2010) soil formation is part of this process, although it occurs over a span of hundreds of years (de Groot *et al.*, 2002), which is not meaningful in terms of this analysis, since farming activities are already constrained to areas where fertile soils currently exists. In this sense, whereas no substitutes can be found for soil formation, the ecosystems capacity of maintaining soil fertility could be substituted by a combination of farming practices (e.g. composting, mulching, application of organic fertilizers, etc.). According to interviews, several of such practices are already cost effective in the Langkloof (at least 11 interviewed farmers mentioned one or a combination of those practices) in order to boost this particular ecosystem service.
14. Pollination	Yes	No	According to farmers interviews natural bee populations (i.e. from the nearby mountains or other ecosystems around the area) and certain bird species are in charge of pollinating orchards in the Langkloof. Therefore, farmers take bees and other pollinators into consideration for scheduling their spraying programs, and they incorporate flowers, among other measures to attract them to the orchards. In addition to that, and in order to enhance the pollination process, 12 out of 13 interviewed farmers bring beehives into their farms. For some beekeepers in the area the pollination business is currently more attractive than producing honey, mainly due to the deciduous fruit farming activities and the lack of substitutes to pollinate (Beekeeper 2, pers. comm.; Beekeeper 1, pers. comm.).

Questionnaire for dependence analysis (Hanson et al 2012):
Question 1 (Q1): “Does this ecosystem service serve as an input or does it enable/ enhance conditions for successful company performance?” [1]
Question 2 (Q2): “Does this ecosystem service have cost-effective substitutes?”

Ecosystem services	**Q1**	**Q2**	**Supporting information**
15. Biological control	Yes	Yes	Deciduous fruit farmers in the Langkloof mentioned natural predators for the red spider mite, as well as bats, and birds (e.g. falcons and owls) that control rats, snails, beetles and moths, among other secondary pests (six of the interviewed farmers). Despite the fact that natural pest control enhances the conditions for fruit farming, controlling the main pests and diseases for commercial purposes still relies on chemical pesticides or other alternative methods, such as mating disruption. These are both substitutes to biological control.
Habitat			
16. Maintenance of life cycles of migratory species	No	N.A.	Maintenance of life cycles of migratory species does not enhance or enable the conditions for successful fruit farming in the Langkloof.
17. Maintenance of genetic diversity	No	N.A.	Maintenance of genetic diversity in the Langkloof and the Kouga catchments ecosystems was not identified as a factor influencing the deciduous fruit farming activities in the area.
Cultural & Amenity Services			
18. Aesthetic information	No	N.A.	Aesthetic information does not serve as an input or enhance the conditions for deciduous fruit farming in the Langkloof.
19. Opportunities for recreation & tourism	No	N.A.	Among the activities of one of the interviewed farmers is included a guesthouse for tourists (DFF 8, pers. comm.). Although he benefits from the opportunities for recreation and tourism offered by the ecosystems in the area, this is an independent business from deciduous fruit farming, and hence not considered for the dependence valuation.
20. Inspiration for culture, art and design	No	N.A.	Inspiration for culture, art and design does not enhance or enable the conditions for successful fruit farming in the Langkloof.
21. Spiritual experience	No	N.A.	Spiritual experience does not enhance or enable the conditions for successful fruit farming in the Langkloof.
22. Information for cognitive development	No	N.A.	Information for cognitive development does not enhance or enable the conditions for successful fruit farming in the Langkloof.

[1] If the answer to question 1 was No, then question 2 was not applicable (N.A.), since it was already known that there was no dependence on that ecosystem service.

Appendix III. Supporting information for the impact analysis

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): “Does the company affect the quantity or quality of this ecosystem service?”
Question 4 (Q4): “Does the company’s impact limit or enhance the ability of others to benefit from this service?”
Question 5 (Q5): “Is the impact positive or negative?”

Ecosystem services	Q3	Q4	Q5	Supporting information
Provisioning				
1. Food				
1.1.Crops	Yes	Yes	+	Deciduous fruits are food crops, and hence the activities performed for their production directly affect the quantity and quality of this ecosystem service in the Langkloof. Deciduous fruit farming directly influence the ability of others to benefit from this ecosystem service by supplying their products to the local fresh, processed fruit and juice, and export markets (13 interviewed farmers). Fruit availability in the market can be seen as a positive impact that enhances the ability of others to benefit from cultivated plants for food.
1.2. Livestock	Yes	No	+/-	Fruit farms might compete with livestock for the available land in the area and therefore influence the quantity or quality of this ecosystem service. Nevertheless, livestock farming is still predominant in the catchment, where it covers about 14,020 ha (Veerkamp, 2013) versus the approximately 6,950 ha of orchards (Hortgro, 2013). According to previous research (Baselmans, 2011; Draugelytè, 2012; Veerkamp, 2013) and interviews in the Langkloof, farmers usually combine fruit farming with other practices. Indeed, from the farmers who provided information about the size of their entire farm and cultivated area (nine of them) it was estimated that they used between 4% and 43% of their land for orchards, while the rest is under other uses. Additionally, five of the interviewed farmers mentioned cattle and sheep as a complementary business or for domestic use. Based on this information, deciduous fruit farming in the Langkloof can either increase or decrease the quantity or quality of this service, but its impacts do not necessarily determine the ability of others to benefit from it.

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): “Does the company affect the quantity or quality of this ecosystem service?”
Question 4 (Q4): “Does the company’s impact limit or enhance the ability of others to benefit from this service?”
Question 5 (Q5): “Is the impact positive or negative?”

Ecosystem services	Q3	Q4	Q5	Supporting information
1.3. Wild foods	Yes	Yes	+/-	According to Veerkamp (2013) and farmers interviews conducted during fieldwork, honey, honeybush, wild fruits and meat from game animals are among the wild foods obtained in the Kouga catchment, where the Langkloof is located. Orchards can occupy part of the area where some of these wild foods (e.g. game animals, wild fruits, honeybush) are found and hence, it can affect the quantity of this service, but not necessarily others’ ability to benefit from it. On the other hand, planted fruit trees represent an additional source of pollen, which is fundamental for bee populations’ subsistence. Indeed, 12 of the 13 interviewed farmers perform activities that can affect the quantity or quality of the honey produced in the area, either by attracting bees with flowers to the orchards or by bringing beehives for pollination that are later on used for honey production. In this specific case, deciduous fruit farming enhances the ability of beekeepers to generate income from honey extraction (Beekeeper 2, pers. comm.; Beekeeper 1, pers. comm.). For those reasons, depending on the specific food, fruit farming impacts on wild foods production can be positive or negative. On this particular ecosystem service the impact can be medium (benefits for others are not affected) and negative for honeybush, game animals and other wild fruits, whereas it is deemed as high (ability of others to benefit from it is affected) and positive for honey production. The latter impact level is the one used in other sections of this report, next to a positive and negative sign to prevent the reader from neglecting the other impacts identified before.

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): "Does the company affect the quantity or quality of this ecosystem service?"
Question 4 (Q4): "Does the company's impact limit or enhance the ability of others to benefit from this service?"
Question 5 (Q5): "Is the impact positive or negative?"

Ecosystem services	Q3	Q4	Q5	Supporting information
2. Water	Yes	Yes	+/-	Deciduous fruit farming activities can currently affect the fresh water supply in the Langkloof in, at least, four different dimensions: invasive alien plants management, efficient use of water in farming processes, water infrastructure development (e.g. canals and reservoirs) and groundwater extraction. The main threats for water supply in the Langkloof, as well as in other regions in South Africa, are fires (van Wilgen 2009) and Invasive alien plants (IAPs) (Prinsloo and Scott, 1999; Enright, 2000; Le Maitre *et al.*, 2000; Le Maitre *et al.*, 2002; Dye and Jarmain, 2004; Görgens and van Wilgen, 2004; Marais and Wannenburg, 2008; van Wilgen, 2009). At the time of interviewing, 12 farmers described practices to clear IAPs in order to increase water yields. Similarly, fruit farmers have implemented fire prevention measures in their farms (e.g. fire breaks) and they actively contribute to municipal fire management with equipment and human resources (GOV 3, pers. comm.; DFF 11, pers. comm.). In addition to that, the efficient water use by most the deciduous fruit farmers in the area was highlighted during workshops and expert interviews (EXP 2, pers. comm.; EXP 4, pers. comm.). Reducing water demand is achieved by increasing the organic matter content in the soil (e.g. with mulch application to enhance water retention), and also by selecting efficient irrigation systems (e.g. drip) (EXP 4, pers. comm.). In contrast to the positive effects of deciduous fruit farming activities on this ecosystem service, the diversion of water through artificial reservoirs and canals for irrigation may have negative impacts on downstream users (e.g. municipality and other farms), who can experience a reduction in the water supply (Dougherty and Hall, 1995; FAO, 1997). Coherently, water for irrigation has been regulated and limited to municipal use in drought years in neighbour catchments (DFF 10, pers. comm.). The use of groundwater during dry years described in farmers' interviews may also have negative impacts on water supply, specifically in cases of over extraction (FAO, 1997). In this context, the deciduous fruit farming sector in the Langkloof affects the quantity of this ecosystem service and it can limit or enhance the ability of others to benefit from it. Therefore, the impacts are qualified as both, positive (e.g. clearing alien plants and efficient use) and negative (e.g. diverting water and groundwater extraction).
3. Raw Material				
3.1. Timber and other wood fibre	Yes	No	-	The replacement of natural vegetation, as well as clearing invasive alien plants, can decrease this service's provision. Nevertheless, the conversion of natural vegetation (mainly Fynbos) for orchards establishment has occurred predominantly on wetlands and floodplains (Haigh *et al.*, 2004), which do not represent major sources of timber in the area in comparison with the mountainous areas, where fruit farming is not feasible. Therefore, deciduous fruit farming does not prevent others to benefit from this service in the Langkloof or the Kouga catchment.

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): “Does the company affect the quantity or quality of this ecosystem service?”
Question 4 (Q4): “Does the company’s impact limit or enhance the ability of others to benefit from this service?”
Question 5 (Q5): “Is the impact positive or negative?”

Ecosystem services	Q3	Q4	Q5	Supporting information
3.2. Fibres and resins	No	No	N.A.	Impacts on this ecosystem service have not been identified in the Langkloof.
3.3. Animal Skins	No	No	N.A.	Impacts on this ecosystem service have not been identified in the Langkloof.
3.4. Fodder	No	No	N.A.	Impacts on this ecosystem service have not been identified in the Langkloof.
3.5. Fertilizer	Yes	No	+	Deciduous fruit farmers in the Langkloof use remainder organic material from the activities in the farm to prepare mulch or compost, which are applied as fertilizers in their orchards (six interviewed farmers). This practice do not affect the ability of others to benefit from this service, since it’s not provided to other activities and it does not imply the extraction of organic material from other ecosystems in the area.
4. Genetic Resources	Yes	No	+/-	Introduction of new cultivars (mentioned in six interviews) affects the genetic plant diversity in the Langkloof. Whereas new varieties may increase diversity at a sub specific level (deemed as a positive impact), monocultures minimize the potential of other crops or natural plant communities to develop in the valley (represented as a negative impact). Since orchards only cover a relatively small area in the Kouga catchment (approximately 3% of it) and new plant varieties generate only private benefits, fruit farming activities are currently unlikely to affect the ability of others to benefit from this service.
5. Medicinal Resources	No	No	N.A.	Impacts on this ecosystem service have not been identified in the Langkloof.
6. Ornamental Resources	No	No	N.A.	Impacts on this ecosystem service have not been identified in the Langkloof.

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): “Does the company affect the quantity or quality of this ecosystem service?”
Question 4 (Q4): “Does the company’s impact limit or enhance the ability of others to benefit from this service?”
Question 5 (Q5): “Is the impact positive or negative?”

Ecosystem services	Q3	Q4	Q5	Supporting information
Regulating				
7. Air quality regulation	Yes	No	+/-	The potential of plants to capture dust particles (e.g. from roads) has been described and tested in field studies (Brantley *et al.*, 2014; Rai *et al.*, 2014). Consistently, orchards in the Langkloof can be considered as a contribution to dust particles retention. Additionally, permanent structures of deciduous fruit trees (e.g. peach trees) have been deemed as capable of fixing important amounts of CO_2 from the atmosphere, a process that can be enhanced by management practices, such us using green manure or increasing water use efficiency (Sofo *et al.*, 2005). In the study area green manure is applied by at least five of the interviewed farmers, whereas the implementation of efficient irrigation systems is a generalized practice in the Langkloof (EXP 1, pers. comm.). On the other hand, soil holds organic carbon that can be released to the atmosphere depending on management practices (Iqbal *et al.*, 2009). Comparative case studies in subtropical regions of the world (Iqbal *et al.*, 2008; 2009) have shown that soils in orchards can have important CO_2 emission levels when compared to other land uses (e.g. woodlands). Similarly, orchards have been identified as an important source of N_2O emissions (Lin *et al.*, 2010; Rowlings *et al.*, 2013). Specific farming practices (Lin *et al.*, 2010), which are also performed in the Langkloof, can largely influence N_2O emission levels related to N fertilizers application (at least six of the interviewed farmers), burning of agricultural residue (mentioned by four farmers), animal manure composting (described by five farmers) and tilling (not covered in interviews). Whereas CO_2 fixation and dust captures are evaluated as positive impacts of deciduous fruit farming on air quality regulation, NO_2 and CO_2 emissions, mainly dependent on soil management, are deemed as negative. Differences in the balance between CH_4 production and consumption in orchards (Rowlings *et al.*, 2013; Iqbal *et al.*, 2008; 2009; 2013) can either positively or negatively contribute to air quality, given the ecosystem specificity and seasonality of such equilibrium (Iqbal *et al.*, 2013). Although deciduous fruit farming activities can affect air quality regulation, it is not considered to limit or enhance the ability of others to benefit from it.
8. Climate regulation				
8.1. Global climate regulation	Yes	No	+/-	Orchards have the capacity to absorb CO_2 and CH_4 (among other gases) from the atmosphere (Lin *et al.*, 2010; Rowlings *et al.*, 2013), but on the other hand management practices can influence emissions of those gases in addition to NO_2 (Lin *et al.*, 2010; Iqbal *et al.*, 2008; 2009; 2013; Rowlings *et al.*, 2013). Thus, deciduous fruit farming in the Langkloof affects global climate regulation, but it does not limit or enhance itself the capacity of others to benefit from this service. This is given by the cumulative nature of the provision of this ecosystem service, which can be quantified at larger scales (MA, 2003; de Groot *et al.*, 2002), and hence, in interaction with other activities and land uses. Given the dual nature of deciduous fruit farms, as sinks and sources of greenhouse gases, their impacts on global climate regulation are deemed to be both positive and negative.

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): "Does the company affect the quantity or quality of this ecosystem service?"
Question 4 (Q4): "Does the company's impact limit or enhance the ability of others to benefit from this service?"
Question 5 (Q5): "Is the impact positive or negative?"

Ecosystem services	Q3	Q4	Q5	Supporting information
8.2. Regional/local climate regulation	Yes	No	?	Land use change as part of agricultural expansion, among other drivers, can affect the albedo, evapotranspiration, surface runoff and, hence, surface temperature (Pielke and Avissar, 1990; Foley *et al.*, 2005; Loarie *et al.*, 2011). Such localized changes can, at the same time, influence weather and climate at local or regional scales (Pielke and Avissar, 1990). Case studies have demonstrated associations between changes in surface temperature and natural vegetation replacement. Increased temperatures in surface air and soil influenced by crop expansion have been registered by Loarie *et al.* (2011) in sugarcane, Ho *et al.* (2012) in double crops and Ramdami *et al.* (2014) in oil palm plantations. Similarly, Stohlgren *et al.* (1998) corroborated previous projections on lower summer temperature in the Rocky Mountains in Colorado due to natural vegetation replacement by agriculture and urbanization in the adjacent plains. In a general dimension of local climate regulation a comparison between agricultural use and natural ecosystems, carried by simultaneously in North America and Brazil, revealed much higher climate regulation capacity in natural than agro ecosystems, specifically in terms of greenhouse gases storage, along with local temperature and evapotranspiration regulation (Anderson-Teixeira *et al.*, 2012). Based on the information provided by the literature and case studies, deciduous fruit farming affects the local and, potentially the regional climate regulation. Nonetheless, orchards represent approximately a 3% of the Kouga catchment area, which is a relatively small share compared to other land uses that can exert a greater effect on regulation of climate in the area. In fact, almost 90% of the Kouga catchment extends over mountainous areas with natural vegetation (Veerkamp, 2013). Thus, deciduous fruit farming is not deemed in this thesis as limiting or enhancing the ability of others to benefit from local or regional climate regulation. Information provided by case studies and literature may suggest, in a broad sense, that impacts of agriculture on climate regulation at this scale may be negative. Nonetheless, the attachment of these impacts to each particular geographical context, along with the lack of cases in the scientific literature analysing the effects of natural vegetation replacement by orchards on climate, do not allow to determine the specific nature of the impact in the analysed case in the Langkloof. Therefore, for this thesis it has been classified as unknown (indicated as "?").

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): “Does the company affect the quantity or quality of this ecosystem service?”
Question 4 (Q4): “Does the company’s impact limit or enhance the ability of others to benefit from this service?”
Question 5 (Q5): “Is the impact positive or negative?”

Ecosystem services	Q3	Q4	Q5	Supporting information
9. Moderation of extreme events	Yes	Yes	+/-	Extreme events in the Langkloof include floods, droughts, hailstorms and fires. Regarding floods, a preventive approach in the management of dams and reservoirs storage capacity can positively help regulate them and minimize their damage (Dougherty and Hall, 1995; FAO 1997). At the time of interviewing, farmers stated their awareness in terms of water infrastructure maintenance for flood prevention, particularly given past events (e.g. overflowing dam and infrastructural damage in the Haarlem dam) in which flood infrastructural damage was intensified by insufficient storage capacity and a lack of preventive actions (described in six interviews with farmers; EXP 1, pers. comm.). Similarly, farmers have progressively improved the management of clearing material from alien plants, which used to be in some cases disposed in areas that were highly exposed to floods, thus increasing the damage of these events (DFF 13, pers. comm.; DFF 4, pers. comm.). According to interviews, corrective actions have been taken regarding infrastructure and mitigation measures are individually implemented in some farms. These measures include, among others, bumps on roads and the use of cement or gabions, which contribute to the moderation of these events in particular (from nine interviews with farmers). In contrast, the riparian vegetation and wetlands capacity to mitigate floods (Winter *et al.*, 1998) has been altered in the Langkloof by orchards, which have replaced part of those ecosystems in the area (Veerkamp, 2013). Water storage in dams and reservoirs contributes to moderate the impacts of droughts on farms (from five farmer interviews) and in severe cases also on municipal use (GOV 2, pers. comm.). On the other hand, groundwater extraction during dry periods may potentially worsen the situation, although neither current nor past conflicts around this issue were stated during interviews. In terms of fires, farming practices in the area include the use of firebreaks. Furthermore, specific farmers assist the municipality with equipment and fire management capacity in order to extinguish and maintain the natural frequency of fires in susceptible areas, such as Fynbos (GOV 3, pers. comm.). Moderation of hailstorms is beyond the capacities of farmers in the area, yet some impacts can be minimized with the use of agricultural screens (i.e. nets covering the orchards and protect them from sun and hail). Nonetheless, this type of measure is rarely implemented in the area (DFF 10, pers. comm.). In this context, deciduous fruit farming in the Langkloof affects the moderation of extreme events and it can either limit or enhance the benefits perceived by others in the area in the various modes described above. Impacts on moderation of floods are positive and negative. In the case of droughts are mainly positive, whereas in the moderation of fires are positive.

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): “Does the company affect the quantity or quality of this ecosystem service?”
Question 4 (Q4): “Does the company’s impact limit or enhance the ability of others to benefit from this service?”
Question 5 (Q5): “Is the impact positive or negative?”

Ecosystem services	Q3	Q4	Q5	Supporting information
10. Regulation of water flows	Yes	Yes	-	Diverting rivers through dams, canals and pipes can greatly affect the timing of water flow (FAO, 1997). Accordingly, storing water in both private artificial reservoirs and communal dams in the Langkloof (as explained in Section 4.3) alter regular flows in the catchment. Thus, the provision of this ecosystem service in the area is partly replaced by either holding or releasing water according to a timing set by different allocation mechanisms. The allocation of water stored in communal dams in the Kouga catchment is estimated either by turns organized in a schedule (in Wabooms River) or by irrigable hectares entitled to specific users (in Haarlem) (GOV 2, pers. comm.; EXP 1, pers. comm.). During specific extreme events in the past dams have overflown due to an insufficient storage capacity, management, maintenance or design (EXP 1, pers. comm.). This type of situations has altered the timing and flow in which water would be provided otherwise. Additionally, replacing wetlands by orchards (Haigh *et al.*, 2004) also hampers the water regulation capacity of the ecosystems in the area. In this setting, deciduous fruit farming affects the provision of this ecosystem service and the ability of other users to benefit from it (e.g. municipality or downstream users). This impact is classified as negative (i.e. reduction in the provision of the ecosystem service), since water regulation capacity is already constrained in the study area.

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): "Does the company affect the quantity or quality of this ecosystem service?"
Question 4 (Q4): "Does the company's impact limit or enhance the ability of others to benefit from this service?"
Question 5 (Q5): "Is the impact positive or negative?"

Ecosystem services	Q3	Q4	Q5	Supporting information
11. Waste treatment				
11.1. Water purification	Yes	No	-	Farmers and other stakeholders described high quality surface water at the time of interviewing. Indeed, 10 out of 13 of the interviewed farmers only filter bigger particles or do not need to filter the water for irrigation. Accordingly, a technical advisor of the Langkloof's Farmers Association indicates that the low emphasis in purification technology in the area is due to the high quality runoff water, which is then stored for irrigation (EXP 4, pers. comm.). In order to comply with global environmental standards deciduous fruit farmers need to regularly monitor water quality (indicated by four farmers) and they have subsequently have started using pesticides that persist for shorter periods in the environment (EXP 1, pers. comm.). A water and sanitation manager at Koukamma municipality describes groundwater quality as an issue, but related to iron concentrations, which originate from other sources different to fruit farming (GOV 1, pers. comm.). Notwithstanding major water quality issues directly targeting deciduous fruit farming were not mentioned in interviews, intensive agriculture practices can still affect the water purification service provided by the ecosystems in the area. Leaching nutrients and chemicals to groundwater and rivers can pollute water and cause algal blooms (World Bank, 2008; Goldblatt, 2010). In fact, N and P fertilizers are commonly used in the Langkloof and, as one farmer indicated they run off during floods into streams or rivers near the farms (DFF 8, pers. comm.). Similarly, another farmer described the use of specific pesticides against fruit fly that could kill fish and other organisms if applied near dams or reservoirs (DFF 13, pers. comm.). Since wetlands play an important role in water purification (Winter *et al.*, 1998; de Groot *et al.* 2002), their conversion into orchards reveals another impact on the provision of this ecosystem service. In this context, deciduous fruit farming in the Langkloof affects in quality and quantity the water purification service and this impact can be considered as negative, since it reduces the capacity of provision of this service. Nevertheless, based on the information provided by experts in the area, fruit farming activities do not currently limit or enhance the ability of others to benefit from this service.
11.2. Waste treatment	Yes	No	+	Farming practices related to mulching and composting (mentioned in five interviews) maximize the provision of this service in the Langkloof. Therefore it can be deemed as a positive effect, but it does not necessarily affects the ability of others to benefit from it, because these practices are limited to each farm.

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): “Does the company affect the quantity or quality of this ecosystem service?”
Question 4 (Q4): “Does the company’s impact limit or enhance the ability of others to benefit from this service?”
Question 5 (Q5): “Is the impact positive or negative?”

Ecosystem services	Q3	Q4	Q5	Supporting information
12. Erosion prevention	Yes	Yes	+/-	Since deciduous fruit farming benefits from this service in the area, actions to protect and ensure its provision are commonly undertaken. Measures such as applying cement and disposing gabions to prevent landslides (four interviewed farmers), or changes in the road network inside the farms are implemented for avoiding erosion due to floods (three interviewed farmers). Covering the soil with organic matter also helps to prevent soil erosion (at least five of the interviewed farmers). Nevertheless, other practices can also hamper the provision of this service. For instance, an expert in water developments in the area described how in specific cases farmers have cleared species that were in fact holding the soil in their farms, starting soil erosion processes that can only be stopped with major investments (EXP 2, pers. comm.). Similarly, a representative of the Department of Economic and Environmental Affairs provided specific examples of roads built up the hill, which changed surface runoff consequently causing soil erosion in a farm and neighbouring area. Similarly, cases in which machines are used to clear the invasive plants in the river have also increased risks of floods because of the removal of the vegetation cover without follow up actions (GOV 4, pers. comm.). Along with those particular practices the replacement of wetlands and other vegetation types that has occurred in the Langkloof (Haigh *et al.*, 2004) can also reduce the protection against soil erosion (Winter *et al.* 1998). In spite of existing mitigation and prevention measures that have been implemented by farmers in the area (at least nine of the interviewed farmers), the information provided by other stakeholders and experts reveals that specific practices without a proper management can still can affect others’ capacity to benefit from the erosion prevention service. Accordingly, the impacts on soil erosion prevention are deemed as positive and negative, since the interviews have shown that different practices among farmers can increase or decrease the quality of this ecosystem service in each specific case.
13. Maintenance of soil fertility	Yes	No	+	11 out of 13 interviewed farmers in the Langkloof mentioned at least one practice or a combination of them that can improve the ecosystems capacity to maintain soil fertility in the area (e.g. composting, mulching and application of organic fertilizers). Since these effects are constrained to the area where these measures are implemented, it does not necessarily limit or enhance the ability of others to benefit from this service.

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): "Does the company affect the quantity or quality of this ecosystem service?"
Question 4 (Q4): "Does the company's impact limit or enhance the ability of others to benefit from this service?"
Question 5 (Q5): "Is the impact positive or negative?"

Ecosystem services	Q3	Q4	Q5	Supporting information
14. Pollination	Yes	Yes	+/-	Deciduous fruit farming in the Langkloof can affect pollination either by attracting bees and other pollinator species or with the adverse effects of chemicals use. In the case of the latter, farmers in the area have moved to the application of chemicals that are less persistent in the environment (EXP 1, pers. comm.) and they have changed the application rates and timing to avoid disturbances on natural bee populations, among others (two of the interviewed farmers have done it specifically to protect pollinators, whereas seven have done it, but for other reasons). One example is to spray only at night and minimize the pesticides application during seasons in which pollinators are more active (DFF 9, pers. comm.). Since such practices are driven by the necessity to comply with global environmental standards, economic incentives of this kind are generally limited to export oriented farmers (the majority of small and big farmers in the Langkloof). Nonetheless, farmers also recognize pollinators as environmental assets (at least seven of the interviewed farmers) that allow them producing and contribute to obtain a higher productivity (DFF 7, pers. comm.). Accordingly, in an attempt to bring more natural pollinators to the orchards (e.g. bees and birds), farmers incorporate flowers that make the orchards more attractive to certain species (DFF 12, pers. comm.). Additionally, farmers bring beehives to their orchards (12 out of 13 interviewed farmers) during pollination season, which generally lasts from August until November (Beekeeper 1, pers. comm.; Beekeeper 2, pers. comm.). For example, one of the interviewed beekeeper supplies more than 2,000 beehives for pollination in every season to one of the largest farming companies in the area (Beekeeper 2, pers. comm.). Thus, deciduous fruit farming intensifies the provision of this service in the Langkloof, and hence is deemed as a positive impact that can also affect the ability of other to benefit from this service (e.g. benefits on wild fruits production, and other orchards and crops). Nevertheless, deciduous fruit farming has also the potential to negatively affect pollinator populations in the area with uncontrolled chemicals application, which can limit the ability of others to benefit from pollination in the Langkloof.
15. Biological control	Yes	No	-	Pests in deciduous fruit farms in the Langkloof are controlled by using of chemical pesticides (all the interviewed farmers) and, in the specific case of the codling moth, with mating disruption methods (11 interviewed farmers). Acknowledging the effects on other species (mentioned in four interviews), farmers have stopped spraying against specific pests (e.g. red spider mite) to allow natural predator populations to control it. Additionally, personal concerns and interest in bringing back predators to the farms have led specific farmers to try methods (e.g. building bird houses or banning actions that can damage certain species) to attract and keep them in the farm (DFF 8, pers. comm.; DFF 2, pers. comm.). In this context, fruit farming activities in the Langkloof affect the quality and quantity in which this ecosystem service is provided, but do not affect the ability of others to benefit from it at the moment. The impacts of deciduous fruit farming on biological control are thus deemed as being primarily negative in the area, since the attempts to attract natural predators has not shown successful results according to farmers experiences (DFF 8, pers. comm.) and other implemented measures (e.g. lower of pesticides application rates) only act as mitigation actions, which do not increase the quantity or quality of this ecosystem service.

Questionnaire for impact analysis (Hanson et al 2012):
Question 3 (Q3): "Does the company affect the quantity or quality of this ecosystem service?"
Question 4 (Q4): "Does the company's impact limit or enhance the ability of others to benefit from this service?"
Question 5 (Q5): "Is the impact positive or negative?"

Ecosystem services	Q3	Q4	Q5	Supporting information
Habitat				
16. Maintenance of life cycles of migratory species	No	No	N.A.	Based on the information presented in Chapter 2 deciduous fruit farming has no current impacts on life cycle of migratory species particularly in the Langkloof.
17. Maintenance of genetic diversity	No	No	N.A.	Based on the information presented in Chapter 2 deciduous fruit farming does not currently affect the maintenance of genetic diversity in the area.
Cultural & Amenity Services				
18. Aesthetic information	Yes	Yes	+	Orchards are conspicuous elements that can be seen along almost the entire length of the Route 62 in the Langkloof. This national route is considered as scenic route connecting the Eastern Cape and Western Cape provinces (e.g. by the official website of Route 62) and orchards are part of the aesthetic elements considered in this definition. Thus, deciduous fruit farms positively affect others (e.g. visitors and tourism sector) in benefiting from this ecosystem service.
19. Opportunities for recreation & tourism	No	No	N.A.	Deciduous fruit farming neither represent an opportunity nor affect other's alternatives for developing tourism or for recreation. Except for the orchards' aesthetic value, which was already considered in the previous ecosystem service under analysis, no other features that may affect this ecosystem service are identified. Only one of the interviewed farmers owned a guesthouse, which is, as most of them in the area, aimed at recreational activities in the Kouga and the Tsitsikamma Mountains (DFF 8, pers. comm.).
20. Inspiration for culture, art and design	No	No	N.A.	Impacts on this ecosystem service in the Langkloof have not been identified.
21. Spiritual experience	No	No	N.A.	Impacts on this ecosystem service have not been identified in the Langkloof.
22. Information for cognitive development	No	No	N.A.	Impacts on this ecosystem service have not been identified in the Langkloof.
Key: positive impact (+); negative impact (-); positive and negative impact (+/-); not applicable (n/a); and unknown (?).				

Appendix IV. Interview structure for farmers, experts and other stakeholders

1. Interview structure for deciduous fruit farmers

Table IV-1 below provides an example of the structure of an interview with a deciduous fruit farmer in the Langkloof conducted in collaboration with other students.

Table IV-1. Example of an interview with a deciduous fruit farmer in the Langkloof

Date of interview:		**Time of interview:**	
Organization or Stakeholder:			
Interviewee name:		**Role in organization:**	
Interviewers:			
Primary note-taker:		**Translator:**	

	Question	Keywords/Themes
1.	What is the size of your farm(s)?	Background
2.	How many hectares do you have for the production of fruits?	Background
3.	What fruit(s) do you farm?	Background
4.	Other farming practices? (vegetables, livestock, honeybush, bees)	Background
5.	How many employees do you have? How many permanent / seasonal?	Background
6.	Where is your main market located?	Business
7.	Do you also export internationally?	Business
8.	Do you need to meet any international standards? (Which one? how do they affect you? Do you meet Global GAP?)	Business
9.	What are you spending the majority of your business' budget on?	Business
10.	What kind of changes would you like to make in your business in the future?	Business
11.	Do you use any local products for farming?	Inputs
12.	What kind of fertilizers do you use? Do you use any natural / organic fertilizers?	Inputs Fertilizers
13.	What percentage of your budget goes to the purchase of fertilizers?	Inputs and costs
14.	Do you use pesticides? Which types?	Inputs Pest control
15.	What percentage of your budget goes to the purchase of chemicals?	Inputs Costs
16.	Do you use any kind of technology to improve your crops?	Crop improvement
17.	Do you use any environmentally friendly farming practices? What kind? (e.g. mulching, less chemicals, green labels, water saving practices, IAP clearing, etc.)	Environmentally friendly practices
18.	What compelled you to use them? What would need to happen for you to use them?	Environmentally friendly practices
19.	In your opinion, what is it that you get from nature and that benefits you? (i.e. what are the benefits of nature for you?)	Ecosystem Dependence Ecosystem Services
20.	What are the main issues that you and your business are dealing with on a regular basis? (e.g. water shortages, IAPs, climate change …)	Concerns and issues
21.	How do you deal with these issues?	Concerns and Issues
22.	Have you observed any changes in these issues? How do you expect these issues to develop in the future?	Future
23.	What are the biggest financial risks of your business?	Business risks
24.	How do you deal with it?	Business risks
25.	Have you ever been affected by floods, droughts, fires, water shortage and hailstorms? To what extent was your production affected?	Risks Extreme events
26.	How did you cover those costs? How do you deal with these events?	Insurance Strategy

27.	Are you insured against extreme events?	Insurance
28.	If yes, do you perceive any gaps in your insurance cover in this regard?	Insurance
29.	Do you perceive any dependence of your business on natural pollinators? (How?)	Ecosystem dependence Trends in ES Pollination
30.	Do you perceive any dependence of your business on any kind of natural pest control (e.g. bats, snakes, …)?	Natural Pest control
31.	Is soil erosion a problem for you? Do you know of any soil erosion prevention measures? Have you ever invested in these measures, and, if yes, how much?	Soil Erosion
32.	What do you think about tourism in the Langkloof? Do you think you could benefit from them?	Tourism
33.	How do you deal with IAPs? Part of WfW? Do you clear your land?	IAPs
34.	If part of WfW, what do you think about it?	WfW
35.	What is your opinion on biological control methods for IAPs (e.g. seed-feeding weevil, release of fungal pathogen, …)	Biological control methods
36.	Do you depend on any kind of technology to obtain and purify water?	Ecosystem dependence Water purification
37.	In what way do you think Climate Change could affect your business in the future? (e.g. production losses? Damages from adaptation? Water shortages? more IAP, human health issues?)	Climate change
38.	What do you think are measures to deal with these concerns?	Climate change
39.	How dependent is your production on weather and weather variability?	Climate change
40.	Have you observed any changes in the weather in the past years and/or decades?	Climate change
41.	Are you a member of a local farming organization (e.g. FA, Irrigation Board, BEE…)	Partnerships and collaboration
42.	How often do you meet and what topics are discussed?	Partnerships and collaboration
43.	How are these results (if they are) communicated to the authorities?(municipalities/government)	Partnerships and collaboration
44.	How would you describe the communication with other stakeholders in the area?	Communication
45.	Do you think the issues around communication are going to improve?	Communication
46.	Are you involved in any other kind of partnership? (e.g. WfW, municipalities, other government actors, NGOs, Universities)	Partnerships and collaboration
47.	With whom do you think a partnership could be beneficial and successful in the future, and why? (government, other farmers, NGOs, universities, other industries, …)	Partnerships and collaboration
48.	Feedback? Is there anything that we have not covered and you would like to mention?	Feedback

2. Interview structure for experts and stakeholders

Table IV-2 provides an example of the structure of an interview with an expert or a stakeholder (e.g. government actors) in the Langkloof. These interviews were conducted in collaboration with other students. The questions presented below were adjusted beforehand for each interviewee depending on his/her knowledge and expertise. The specific structure of each interview and the summaries of interview answers are provided in the supplementary material in the CD attached to this thesis.

Table IV-2. Example of an interview with an expert or stakeholder in the Langkloof.

Date of interview:		**Time of interview:**	
Organization or Stakeholder:			
Interviewee name:		**Role in organization:**	
Interviewers:			
Primary note-taker:		**Translator:**	

	Question	Keywords/Themes
1.	What is your role in the organization?	Background Personal Information
2.	Can you tell us about your responsibilities?	Background Personal Information
3.	Can you tell us about your experience and expertise?	Background Personal Information
4.	To what extent are you/is your department working and/or present in the Langkloof area?	Langkloof
5.	What do you think is the primary importance of the Langkloof area?	Langkloof.
6.	What is your main long-term goal in the Langkloof?	Langkloof
7.	What actions do you take to achieve that goal?	Actions in Langkloof
8.	If an organization, how many employees / representatives are present in the Langkloof?	Langkloof
9.	In what way have you or your department contributed to advancements in the Langkloof?	Actions in Langkloof
11.	Do you have any data on your activities in the Langkloof (or Eastern Cape), or any reports that document projects?	Actions in Langkloof
12.	What has been going well, and what could have gone better in regards to activities in the Langkloof?	Actions in Langkloof
13.	What is your experience with DFF in the Langkloof?	Stakeholder Interaction
14.	To what extent have you supported/worked with fruit farmers in the Langkloof?	Stakeholder Interaction
15.	What do you think is the relationship between the fruit farming industry and the citizens/government/municipality in the settlements?	Stakeholder Interaction
16.	What are the main issues that you or your organization is dealing with in the Langkloof area?	Concerns and Issues
17.	How are you dealing with these issues?	Concerns and Issues
18.	What are the main social issues that you are experiencing in the Langkloof, and how do you think these issues should be solved?	Concerns and Issues
19.	Are there any issues that are specific to only the Langkloof, which you are not experiencing elsewhere?	Concerns and Issues

20.	Are there any issues or conflicts of interest with the local municipalities or the fruit farmers?	Concerns and Issues
21.	If so, what issues and how can they be dealt with?	Concerns and Issues
22.	If you were to look 5 or 10 years into the future, how do you think the issues and the situation in the Langkloof area will develop?	Future
23.	Is the situation in the Langkloof getting better or worse, in your opinion, and why?	Future
24.	What do you think will be major obstacles in the future, and why?	Future
25.	What do you think needs to happen to solve the issues in the Langkloof area around water security, job security, agricultural production, environmental sustainability...?	Future
26.	Are you taking any actions to ensure that this happens? What actions?	Actions
27.	What is your opinion on climate change for the Langkloof?	
28.	What role does Climate Change play for you at present? Are you taking any actions to accommodate for Climate Change or to reduce the impact it might have in the future?	Climate Change
29.	Which governmental departments are you working closely with about issues concerning the Langkloof (or Eastern Cape) area?	Communication
30.	Which actors in the Langkloof are you regularly working/meeting with?	Communication
31.	How often do you communicate with those other stakeholders?	Communication
32.	How would you describe the communication between you or your organization and the other stakeholders? Do you communicate well or could things be better, and in what way?	Communication

Appendix V. Main characteristics of interviewed farmers in the Langkloof

This appendix summarizes the main characteristics of the interviewed farmers in terms of the area they manage, the settlements where they operate, the fruits they produce and complementary businesses they run in their farms. In addition to this general information, the code to refer to each deciduous fruit farmer in order to preserve their anonymity in this thesis is also presented in Table V-1 below.

Table V-1. Main characteristics of interviewed farmers in the Langkloof

Farmer	Area (ha) under fruit	Settlement	Pome fruit		Stone fruit				Other businesses in the farm				
			Apple	Pear	Apricot	Peach	Nectarine	Plum	Livestock	Honeybush	Nursery	Pack house	Others[2]
DFF 1	250	Joubertina	✓	✓	✓	✓		✓	○				
DFF 2	560	Louterwater	✓	✓								○	
DFF 3	200	Avontuur	✓	✓		✓			○				
DFF 4	214	Misgund	✓	✓						○			
DFF 5	72	Ongelegen	✓	✓			✓	✓	○				
DFF 6	945	Haarlem, Misgund, Louterwater, Joubertina and Twee Riviere	✓	✓				✓	○			○	
DFF 7	170	Louterwater	✓	✓				✓					
DFF 8	110	Haarlem	✓	✓		✓		✓	○				○
DFF 9	23	Louterwater	✓	✓									
DFF 10	270	Avontuur, Haarlem, Misgund, Joubertina and Twee Riviere	✓	✓									
DFF 11	80	Louterwater	✓	✓	✓	✓	✓	✓					
DFF 12	250	Twee Riviere	✓	✓							○		
DFF 13	250	Louterwater	✓	✓									

[1] DFF: Deciduous Fruit Farmer

[2] The others category includes pack houses, guesthouses and a bottling plant.

Key: ✓ fruit produced and ○ other business in the farm(s)

Source: interviews conducted between September and December 2014 in the Langkloof

Appendix VI. List of experts and stakeholders interviewed in South Africa

The experts and stakeholders (e.g. government actors or certain experts) interviewed in South Africa are presented in Table VI-1, specifying their expertise or role in their organization. In order to protect their anonymity, each interviewee is indicated with a code that is also used to refer to them in other sections in this thesis. These codes are the same as used by the other student conducting interviews in collaboration in the study area.

Table VI-1. Experts and stakeholders interviewed in South Africa

Expert or stakeholder	Expertise or role in the organization
EXP 1	Consultant for the Irrigation Board of Haarlem
EXP 2	Consultant and Senior Civil Engineer
EXP 3	Head of local NGO and specialized in social development
EXP 4	Retired technical advisor for the Department of Agriculture and Forestry for 40 years – now activist in the area
EXP 5	Project Manager for Gamtoos Irrigation Board of WfW
EXP 6	Chairperson of the Residence Association
Beekeeper 1	Beekeeper
Beekeeper 2	Beekeeper
GOV 1	Management of Water and Sanitation for the Koukamma Municipality
GOV 2	Head of the Joubertina Unit of the Koukamma Municipality
GOV 3	Station commander of the fire department of the Koukamma Municipality
GOV 4	Environmental Officer for Biodiversity - Department of Environmental Affairs
GOV 5	Environmental Officer - Department of Environmental Affairs
GOV 6	Senior Disaster Management Officer of the Sarah Baartman District Municipality
GOV 7	Co-ordinator of agricultural and rural development - Department of Rural Development and Agrarian Reform
GOV 8	Office manager - Department of Rural Development and Agrarian Reform

Appendix VII. Complementary information about compliance with global environmental standards in the Langkloof

The major role of exports in the farming business in the Langkloof has developed next to global quality standards that determine the farm management and practices. Among others, the global quality standards and regulations mentioned by farmers in the Langkloof include Global Good Agricultural Practices (GLOBALG.A.P.'s) standard, Tesco Nurture Scheme (formerly Tesco Nature's Choice), British Real Consortium (BRC) global standard, Fairtrade international standards and Field To Fork scheme.

All the interviewed farmers comply with the GLOBALG.A.P. requirements, which set the basic practices upon which other standards are added according to specific destination markets. GLOBALG.A.P standard is aimed at certifying producers in order to meet the accepted criteria of good agricultural practices to access European markets, namely: "food safety, sustainable production methods, worker and animal welfare, and responsible use of water, compound feed and plant propagation materials" (information provided at http://www.globalgap.org/). Besides a wide range of agricultural practices, particularly for fruit farming it establishes compliance criteria that are applicable to the soil management, substrates use, pre-harvest phase, harvesting phase and produce handling. Those criteria cover diverse specific issues such as the use of chemicals, application of organic fertilizers, water quality, hygiene procedures and infrastructural conditions, among others (GLOBALG.A.P., 2013).

Tesco Nurture Scheme is aimed at Tesco's producers and suppliers, for whom it establishes a code of practices that emphasizes the rational use of chemicals and organic products, pollution prevention, human health protection, efficient use of natural and other resources, recycling and re-using materials, and the formulation of a policy for "wildlife and landscape conservation and enhancement" (Tesco, 2006). The Nurture and Field to Fork assurance schemes are alike, being both originated by British multinational retailers and enforced by trade conditions (Soon and Baines, 2013). Field to Fork code of practice (by Marks & Spencer) addresses pesticide management, water quality, food safety, traceability, and genetically modified organisms (GMOs) in the food sector, including fresh fruit produce (Monaghan, 2006)

Fairtrade international standards focus on practices and terms of trade in order to achieve social, economic and environmental development for producers and workers in countries with disadvantaged economic and social conditions (available at http://www.fairtrade.net/standards.html/). For fruit producers the standards depend on specific products (e.g. pome and stone fruit) and establish social development, labour conditions, environmental development and trade requirements (Fairtrade International, 2011). Finally, the BRC global standards target retailers, and hence, in the case of the fruit-farming sector in the Langkloof, it concerns specifically those farms with pack houses (further information is available at: http://www.brcglobalstandards.com).

Appendix VIII. Drivers of change in water provision and flow regulation in the Langkloof

This appendix presents the supporting information for the analysis of the main drivers of changes in the regulation of water flows and water provision in the Langkloof. Each driver is individually described below.

a) Alien plants invasion

Alien plants in South Africa have usually higher water requirements than the vegetation they replace, and hence they have negative effects on streamflow (Enright, 2000; Görgens and van Wilgen, 2004; Blignaut *et al.*, 2007). Invasive alien plants are currently estimated to reduce around 1 billion m^3 of the mean annual surface water runoff in Fynbos in South Africa and they are expected to reduce another 1.7 billion m^3 under estimated infestation levels in the future (van Wilgen *et al.*, 2008). Similarly, about 4 million m^3 of the groundwater recharge are currently reduced and 36 million m^3 of reduction due to alien plant invasion is projected in the future (van Wilgen *et al.*, 2008). Reductions in streamflow caused by infestation with alien plants of about 6% and 16% have been calculated for the Eastern Cape and the Western Cape, respectively (Le Maitre *et al.*, 2000). In the Kouga catchment, a rate of spread of alien species is estimated at 15% per year (Hosking and du Preez, 2004). Experiments clearing alien species in different sites in the Western Cape have shown increases in the base flow of even 13% (Prinsloo and Scott, 1999). Nonetheless, van Wilgen (2009) estimates that, under favourable conditions, the infestations of important alien species in Fynbos would be cleared in a minimum of 35 to 85 years, and at current clearing rates the problem would not be tackled for more than a few species and areas. Furthermore, the lack of quantification of the current water gains (van Wilgen, 2009) and weaknesses in the clearing process (mentioned by 9 of the interviewed farmers) threaten the effectiveness of the WfW program in the study area. Based on this information, invasive alien plants in the study area can be still regarded as a future threat for water, which is likely to be negatively affected in its provision.

b) Fires

Fires can directly affect water provision and flow regulation due to changes in biomass or the loss of the vegetation cover (Hosking *et al.*, 2002). Indirectly, fires also provide conditions for invasive alien plants, such as pines and black wattles, to establish (van Wilgen, 2009). Fynbos vegetation types contain fire prone species for which an average fire return period between 12 and 15 years is estimated (GOV 3, pers. comm.; van Wilgen, 2009). The knowledge about these patterns in the dominant vegetation types in the study area currently allows implementing practices to maintain the natural frequency of fires (e.g. control burns) in coordinated actions between farmers and the municipality (GOV 3, pers. comm.). Nonetheless, the spread of alien plants after fires increases the unpredictability of these events in addition to the other impacts on water provision caused by such invasion (van Wilgen, 2009). Since fires are inevitable in the Fynbos in the study area, they are still expected to affect water provision and water flow regulation in a negative trend in the future, particularly in the interaction with alien plants infestation.

c) Land degradation

Particularly in terms of soil erosion, it represents a threat for the water provision and water flow regulation in the area (Jansen, 2008). Even though the interviewed deciduous fruit farmers (seven of them) take measures to prevent erosion, there are still cases in which deficient practices have caused severe erosion with consequent changes in surface runoff in the Langkloof (GOV 4, pers. comm.). Furthermore, coordinated actions at the scale of the catchment to stop the expansion of or to prevent soil erosion are not taken in the Kouga River in particular, neither by privates nor the government, in contrast with other areas such as the Kromme catchment (EXP 2, pers. comm.). In this context, soil erosion would likely affect the condition of both water provision and water flow regulation, unless coordinated measures are taken in the area.

d) Population growth

This is a driver of the demand for both, water provision and water flow regulation. In 2004, the DWAF estimated a small decline in future population in the catchment attributed to predicted lack of further economic growth and the impact of HIV/Aids. Nevertheless, fruit farming activities have positively developed since then and representatives from the Koukamma municipality have reported a different scenario, in which preliminary estimations would show an increase in the population in the area of around 2.5% (GOV 2, pers. comm.; GOV 1, pers. comm.). Furthermore, such increase in the population is accompanied by large water losses that are caused by deficient infrastructure maintenance and irresponsible water use (EXP 2, pers. comm.), which increases the demand even further. Since the Kouga dam supplies about 30% of the water demand of the Nelson Mandela Bay Metropolitan Municipality, population growth in that area projected even at 100% in 10 years (Jansen, 2008) will also put an additional pressure on water provision in the Kouga catchment. In this scenario, population growth is likely to influence a growing demand for water in the Kouga catchment.

e) Climate change

In general, in Southern African countries climate change is expressed in rising temperatures and exacerbated cold and warm extremes (Kusangaya *et al.*, 2014). Particularly in South Africa, expected higher temperatures are likely to be accompanied by lower rainfall levels (Calzadilla *et al.*, 2014). Indeed, the country was 2% hotter and 6% between 1997 and 2006 than in the 1970s (Blignaut *et al.*, 2009). The comparison for the Eastern Cape province shows that it became almost 3% hotter and 5% drier in recent years (Blignaut *et al.*, 2009). Such variations in temperature and precipitation also determine changes in surface runoff, thereby affecting water availability (Blignaut *et al.*, 2009; Calzadilla *et al.*, 2014; Kusangaya *et al.*, 2014). In spite of the lack of information in this regard, most studies in Southern Africa agree on decreasing streamflow caused by climate change (Kusangaya *et al.*, 2014). Although there is no specific data available for these factors in the study area, changes in groundwater recharge, and in timing, frequency and intensity of precipitations, can also be expected (Blignaut *et al.*, 2009). Based on this information, climate change in the study area is likely to influence decreasing trends in terms of water provision and water flow regulation.

f) Land use change

Land cover can determine changes in surface runoff and water flow regulation capacity of ecosystems, as well as the particular land uses put pressure on water resources in South Africa (Enright, 2000; Hosking *et al.*, 2002). The main water use in the Kouga catchment is for agriculture (Jansen, 2008). Nonetheless, the opportunities for agricultural expansion, especially in the Langkloof, are considered to be limited (DWAF, 2004), because of current limits on water storage capacity (EXP 4, pers. comm.). In addition to that, 30% of the Kouga catchment is currently formally protected. Formal protected areas contain a 28% of the Fynbos in the study area and 90% of the projected expansion of protected areas focuses on such vegetation types (see Section 2.2.3), which are relevant for water provision and water flow regulation (e.g. water retention). Based on the current and projected protection level of the ecosystems in the area and the limitations to agriculture expansion, land use change is unlikely to influence water provision and water flow regulation in the future.

Appendix IX. Supporting information about trends and drivers of change in extreme events moderation in the Langkloof

This appendix presents the supporting information for the analysis of the current condition of the moderation of extreme events in the Langkloof and the main drivers of change affecting this ecosystem service.

1. Complementary information about extreme events in the study area

Ecosystems in the Kouga catchment can potentially contribute to directly mitigate or minimize the damage of most extreme events identified in the study area (floods, fires and droughts), except for Hailstorm. While most of the Kouga catchment (91% of its area) and the Langkloof (61%) are classified as natural, no degraded areas are found in their surface according to the national land cover classification (SANBI, 2009). Most natural areas in the catchment are Fynbos vegetation types (Mucina and Rutherford, 2006). At least 28% of the catchment is currently protected (Government of South Africa, 2008). Large areas covered by natural vegetation and an important surface currently protected provide together favourable conditions in terms of water retention capacity and groundwater recharge, which can mitigate floods and minimize the damage of droughts. Nevertheless, soil erosion is not currently addressed at the scale of the catchment (EXP 2, pers. comm.) and orchards have historically replaced wetlands and riparian vegetation in the Langkloof (Haigh *et al.*, 2004). Even though neither the extent of such replacement nor current degree of erosion in the catchment are known, both processes hinder the capacity of ecosystems to moderate the impacts of extreme events such as floods and droughts.

In terms of fires, the Fynbos contain fire prone species, with an average fire return period between 12 and 15 years (van Wilgen, 2009). Invasive alien plants, however, provide additional biomass and in many cases create drier conditions, which increase the risk and unpredictability of fires (van Wilgen, 2009; GOV 3, pers. comm.).

Information about the **magnitude and frequency** of each extreme event is summarised below.

a) Floods

The erratic rainfall pattern described in the Kouga catchment determines a regular occurrence of floods in the Langkloof (Haigh *et al.*, 2004; Jansen, 2008). Even though no specific data is found to provide an estimation of the magnitude of such floods in the Kouga catchment, such information is analysed for the adjacent Kromme catchment by Kotze and Ellery (2009). Such analysis cannot be extrapolated to the study area in terms of precise estimates of floods magnitude, yet it still gives an indication of the major events in the last decades, since it is obtained from the gauging weir in the Churchill Dam (with measurements from 1955). Based on that data, Kotze and Ellery (2009) distinguish major events in 1981, 1983, 1996 and 2006, in which the average daily discharge was exceptionally high. Peak flows are also reported in the Kouga catchment at least in 1981, 1996 and 2006 (Jansen, 2008). From such events, the flood in 2006 had significantly higher flows than the others (Kotze and Ellery, 2009), increasing the volume in the Kouga dam in around 90 million m^3 in one day (water level raised 24.5 metres) (Jansen, 2008). This was the consequence of 250 mm to 500 mm of rain falling in only 5 days (1st to 5th of August) in the Langkloof (Kotze and Ellery, 2009).

The impacts in the area included infrastructure damage (e.g. dams and bridges) and agricultural losses (Sandbrink, 2008). From the 13 interviewed deciduous fruit farmers in the Langkloof, 11 of them were affected by at least one of these impacts of floods. The effects on deciduous fruit production included from a few trees to replace (DFF 7, pers. comm.) to even 12 million ZAR (total turnover for one farmer) due to the combined impact of floods and droughts (DFF 4, pers. comm.). Additionally, a substantial part of this damage in the farms was worsened after another flood in 2007 (Sandbrink, 2012). Despite being significantly smaller than the major events described in the area, the rehabilitation of infrastructure and the orchards was not complete in 2007, leaving the area particularly exposed to these extreme events (Kotze and Ellery, 2009).

Notwithstanding the ecosystems in the area cannot be expected to entirely mitigate major events, such as the flood in 2006, the return period of an event of this magnitude in the area is estimated at 50 years, whereas smaller events (e.g. flood in 2007) can be expected to occur every 5 years at least (Kotze and Ellery, 2009). Under such circumstances, the condition of the ecosystems can play a major role in the mitigation of the impacts of intense rain periods that frequently occur in the Kouga catchment.

b) Fires

A representative of the Fire Department of Koukamma Municipality indicates that 7 major fires have occurred in the Kouga catchment and adjacent mountainous areas in recent years. The biggest of these events happened in 2007, it affected the Heights, some orchards on the southern side of the Route N62 and the Tsitsikamma mountains. It was controlled after 3 weeks (GOV 3, pers. comm.). Other fires in the catchment occurred in 2008 and 2012 (Sandbrink, 2012), although there is no information available about their magnitude and extent. From the interviewed farmers, one of them suffered the impacts of a fire in 2010, but it was not a major event in the catchment and only damaged infrastructure. Although fires in the study area can originate differently (e.g. naturally or by human influence), their spread is highly influenced by the fire prone Fynbos vegetation types and alien plants invasion, because these factors lead to drier conditions and more biomass available (GOV 3, pers. comm.). After fires, alien plants can easily spread in the affected areas (van Wilgen, 2009)

c) Droughts

A drought period was experienced in the Langkloof from 2008 to 2011 (Veerkamp, 2013). These three years of insufficient rainfall significantly affected at least four of the interviewed farmers generating losses in terms of production and additional costs for them (e.g. planting new trees). By 2011, between 20 and 30% the farm dams were still damaged from the floods in 2006 and 2007 and communal dams were not completely repaired. Thus, the already reduced amount of water stored in the area could not meet the requirements of all users and restrictions on the use of water were implemented (Sandbrink, 2012). Even though local ecosystems are unlikely to prevent low rainfall periods as those experienced during the drought described above, the storage capacity of the vegetation and its influence in groundwater recharge are likely to mitigate the impacts of droughts on agricultural activities and domestic users.

d) Hailstorms

In contrast to the other extreme events described in this appendix, local ecosystems (regardless of their condition) are not expected to directly influence neither hailstorms frequency and magnitude nor the damage they cause in the study area. Thus, the information about hailstorms presented below aims only at covering the entire range of extreme events experienced in the area, although these specific events occur beyond the scope of this thesis.

In spite of not being influenced by local ecosystem conditions, hailstorms are perhaps the most common extreme event in the area, specially affecting deciduous fruit farms. From 13 interviewed farmers in the Langkloof, 10 of them have seen part of their production affected by hail damage and in many cases more than once. Production losses are unpredictable, given the localized effects of hailstorms. However, at least 2 farmers have seen their entire production affected in the past and other 2 more than half of it. Other damages in the area have included specific group of trees (e.g. young trees) or particular locations in their farms. As a climatic risk, hail damage is an insurable peril in the area (10 out of 13 interviewed farmers have partly or completely insured their farms in the Langkloof).

2. Main drivers of change in the moderation of extreme events

The information below describes the **main drivers of change** in the moderation of extreme events in the Kouga catchment and the Langkloof according to available literature and interviews conducted in the area.

a) Invasive alien plants

High water requirements of some invasive alien species (Enright, 2000; Hosking *et al.*, 2002; Görgens and van Wilgen, 2004; Blignaut *et al.*, 2007) can lead to drier condition in the areas where they establish (van Wilgen, 2009). Furthermore, alien plants provide additional biomass that increases the risks of fires (GOV 3, pers. comm.). Fires provide suitable conditions for certain invasive alien species in the area to establish instead of Fynbos vegetation (van Wilgen, 2009). Certain invasive alien species, such as *Acacia mearnsii*, grow in the riparian zone, but they are not well adapted to floods, thus leading to increased larger impacts of these events (Hosking *et al.*, 2002). A rate of spread of 15% per year has been estimated for alien species in the Kouga catchment (Hosking and du Preez, 2004). Nonetheless, rates of clearing are not considered to be enough for solving the problem. Van Wilgen (2009) estimates that between 35 and 85 years would be required to clear some of the most important infestations in Fynbos, although at current rates, the problem might not be solved except for few sites and particular species. Additionally, farmers in the area identified weaknesses of the WfW program (mentioned in nine out of 13 interviews) that hamper its ability to achieve its goals. Particularly in terms of fires, alien species can increase the unpredictability and magnitude of these events in the study area. In the case of flash floods, invasive alien plant species can increase the risk of these events and the vulnerability of riparian zones.

b) Land degradation

Vegetation cover losses and soil erosion can increase the exposure to the effects of floods. Specific farming practices in the Langkloof (implemented by at least 7 of the 13 interviewed farmers) can help minimize soil erosion and flood damage (e.g. bumps on farm roads and gabions). Nevertheless, isolated cases of deficient practices during the construction of roads, for instance, have degraded areas extending over more than one farm by changing surface runoff and causing erosion after heavy rain periods (GOV 4, pers. comm.). Soil erosion cases in which no control measures are taken are observed around the Kouga River (EXP 2, pers. comm.). In this context, despite some farmers' efforts to prevent soil erosion individually, the lack of coordinated actions at the catchment level can increase damage of extreme events in the future as a result of a decreased moderation capacity of the ecosystems in the area.

c) Climate change

In general, Southern African countries are expected to experience rising mean temperatures, and exacerbated cold and warm extremes as a result of climate change (Kusangaya *et al.*, 2014). In addition to changes in temperature, less rainfall in winter and more rainfall in summer could increase the vulnerability of the Kouga Catchment to extreme events (Jansen, 2008). A temperature and rainfall analysis from 1997 to 2006 shows that the Eastern Cape province became almost 3% hotter and 5% during that period than in the 1970s (Blignaut *et al.*, 2009), increasing risks of fires in the area. Foreseen changes in rainfall can lead to an increase in the frequency and magnitude of droughts and floods (Kusangaya *et al.*, 2014). Similarly, changes in both temperature and rainfall can also increase the risks of fires (GOV 3, pers. comm.).

d) Land use change

Changes in land use can affect the moderation of extreme events, such as floods and droughts, by replacing ecosystems with a high capacity to store water or regulate water flows. Furthermore, specific uses of land (e.g. irrigated lands) can change surface runoff and hence the vulnerability to and the risks of floods (Hosking *et al.*, 2002). In the study area, however, land use change can be considered a limited threat. Future agricultural expansion in the Langkloof is expected to be limited (DWAF, 2004) and mainly determined by limits to storage capacity (EXP 4, pers. comm.). Furthermore, 30% of the Kouga catchment is protected, and hence it is not susceptible to be replaced by other land uses (see Section 2.2.3).

Appendix X. Estimation of the pollination demand in the Langkloof

As an attempt to estimate the current deciduous fruit farming demand for managed pollinators in the Langkloof, two separate values can be obtained. The first estimates rely on the information provided by farmers about the number of beehives in their farms, while the second approximation is grounded on the information provided by beekeepers about average stocking rates (beehives per hectare) for different deciduous fruit.

1. Estimation based on interviews with deciduous fruit farmers in the Langkloof

From the 13 interviewed farmers, nine of them provided information about number of beehives in their farms. Nevertheless, given that the interview was open and not all of the interviewees had a precise estimation at that moment of the stocking rates, the answers were in some cases provided as a total number of beehives in the farm, whereas other farmers provided a range of the minimum and maximum number of beehives utilized depending on the productivity of different orchards.

In order to integrate different values provided in the interview answers, the average number of beehives per hectare was calculated. If information about total number of beehives (NB) was available, then the average number of beehives per hectare (Bh1) was calculated using the area under fruit in each respective farm (Af), which was also known from the interviews, through the simple formula: $Bh1 = NB/Af$. If only minimum (mBh) and maximum (MBh) were available, then the average stocking rate (Bh2) was estimated by a simple average: $Bh2 = (mBh + MBh)/2$.

All the values for Bh1 and Bh2 allow determining an indicative average of beehives per hectare in the Langkloof (Bh), which was then multiplied by the total area under fruit in the Langkloof from the Hortgro (2013) tree census (6,947 ha) to obtain the total number of beehives in the Langkloof.

According to the information provided by beekeepers in the study area (Beekeeper 1, pers. comm.), a single beehive contains between 30 and 50 thousand bees. Based on this figure, and only for communication and awareness rising purposes, the total number of bees required in the Langkloof for pollination of deciduous fruit can be calculated. Since the price of hiring a beehive is estimated at least as 450 ZAR (Beekeeper 1, pers. comm.), the minimum cost for deciduous fruit farming is estimated as expressed in the table above. The number of pollinations is also used as an indicator of the demand for pollination. In that regard, Melin *et al.* (2014) estimate a number of 1.7 pollinations provided by each beehive. This factor is used in the table for obtaining the number of pollinations required in the Langkloof in a year, which is a comparable value to the ones presented in other studies.

Table X-1 includes the information obtained from interviews with farmers in the Langkloof, as well as the estimates of beehives, pollinations, honeybees and direct costs of managed pollinators in a year in the Langkloof.

Table X-1. Estimates based on information about managed pollination provided by farmers

Farmers	**Average beehives/hectare**
DFF 1[1]	2.5 beehives/ha
DFF 3[1]	1.5 beehives/ha
DFF 5	0.3 beehives/ha
DFF 6	1.8 beehives/ha
DFF 8	0.5 beehives/ha
DFF 9	1.0 beehives/ha
DFF 10	1.1 beehives/ha
DFF 12	0.1 beehives/ha
DFF 13	0.8 beehives/ha
Average beehives /ha in the Langkloof (S)	**1.05 beehives/ha**
	Estimates[2]
Estimated total number of beehives needed in a year in the Langkloof	7,281
Estimated number of pollinations needed in a year	12,377
Estimated number of honeybees required in a year	218 to 364 million
Direct costs of managed pollinators for deciduous fruit farming in the Langkloof in a year	3,276,336 ZAR

[1] Only for DFF 1 and DFF 3 the average stocking rate was estimated by using S2.

[2] These estimations do not account for privately owned beehives by farmers.

Source: literature review and interviews with farmers.

2. Estimation based on interviews with beekeepers in the Langkloof

During the data collection phase, two beekeepers were interviewed in the Langkloof. Among other information, the approximate recommended stocking rates (beehives per hectare: S) for the pollination of the deciduous fruit in the Langkloof were indicated (Beekeeper 1, pers. comm.). The total surface of each deciduous fruit in the valley (AF) was known from the Hortgro (2013) tree census, and thus the total number of beehives in the area under each deciduous fruit was estimated using the following formula:

$$\sum_{x=1}^{x=n} AFx \times Sx$$

Where x represent each deciduous fruit, AF the area under that fruit and S the stocking rates for pollination of that fruit as presented in the Table X-2 below.

Table X-2. Inputs to estimate the demand for managed pollination

Deciduous fruit (x)	**Area (ha) under deciduous Fruit (AF) in the Langkloof[1]**	**Stocking rates (Sx)[2]**
1. Apple	4,493	1.5 to 4 beehives/ha
2. Pear	1,834	1.5 to 4 beehives/ha
3. Plums & prunes	235	5 to 7 beehives/ha
4. Peaches	155	5 to 7 beehives/ha
5. Nectarines	65	5 to 7 beehives/ha
6. Apricots	165	5 to 7 beehives/ha
Total	**6,947**	-

[1] Hortgro (2013)

[2] Beekeeper 1 (pers. comm.)

Source: interviews with beekeepers and Hortgro (2013) tree census.

After estimating the number of beehives for each deciduous fruit in the Langkloof, the following calculations of total number of beehives in the valley, number of bees, number of pollinations and cost for the deciduous fruit-farming sector, were calculated following the same steps as in the previous estimation based on information from deciduous fruit farmers, which is detailed above, in Section (1) of this appendix. The resulting estimates are presented in detail in the following table:

Table X-3. Pollination demand estimates based on stocking rates provided in beekeepers interviews

Deciduous fruit	Estimated number of beehives needed in a year in the Langkloof	Estimated pollinations needed in a year	Estimated number of honeybees required for pollination of deciduous fruit in a year	Direct costs of managed pollination for deciduous fruit farming in the Langkloof in a year
1. Apple	6,740 to 17,972	11,457 to 30,552	370,672,500 to 617,787,500	3,032,775 ZAR
2. Pear	2,751 to 5,502	4,677 to 9,353	123,795,000 to 206,325,000	1,237,950 ZAR
3. Plums & prunes	1,175 to 1,645	1,998 to 2,797	42,300,000 to 70,500,000	528,750 ZAR
4. Peaches	775 to 1,085	1,318 to 1,845	27,900,000 to 46,500,000	348,750 ZAR
5. Nectarines	325 to 455	553 to 774	11,700,000 to 19,500,000	146,250 ZAR
6. Apricots	825 to 1155	1,403 to 1,964	29,700,000 to 49,500,000	371,250 ZAR
Total	**12,591 to 27,814**	**21,404 to 47,284**	**606,067,500 to 1,010,112,500**	**5,665,725** ZAR

Source: interviews with beekeepers and Hortgro (2013) tree census.

Appendix XI. Drivers of change in pollination in the Langkloof

This appendix presents supporting information for the analysis of the main drivers of changes in pollination services provided in the ecosystems in the Langkloof.

a) Land use change

Land use change can lead to habitat loss and affect pollinators' diversity and abundance. Nevertheless, these changes can also create new habitats, particularly if foraging resources are provided or the existing patches of habitat are connected (Potts *et al.* 2010). Agricultural crops that are found in the Eastern Cape and Western Cape provinces, such as canola (Melin *et al.*, 2014) and to a lesser extent vegetables (e.g. onions and carrots) (Beekeeper 2, pers. comm.), are beneficial for wild pollinators and managed honeybees, since they provide forage source in different periods over the year (de Lange *et al.*, 2013). Furthermore, the Fynbos represent an important part of the habitat for both managed honeybees and wild pollinators in the study area (Melin *et al.*, 2014). In the Kouga catchment around 30% of the Fynbos are currently protected and around 90% of the projected expansion of protected areas focuses on Fynbos vegetation types. Furthermore, the results from interviewing deciduous fruit farmers show that their plans of expanding orchards are currently limited by water storage capacity, among other factors. Since no significant expansion of other land uses than agriculture is currently or potentially identified, land use change is not expected to lead to future changes in the supply for pollination in the study area.

b) Habitat degradation

The habitat for most pollinator species can be particularly degraded by the increased use of chemicals (Potts *et al.* 2010) associated to agricultural intensification (Klein *et al.*, 2007). Other factors that may cause habitat degradation generally include fires, grazing and urbanization, although these are not yet proven to cause significant disturbances on pollinators (Potts *et al.* 2010). Although there is uncertainty among beekeepers in the Langkloof about the actual effects of spraying orchards, they recognize the use of certain chemicals as dangerous for bees (Beekeeper 1, pers. comm.). It is known that using insecticides can directly reduce pollinator populations by intoxication, and affect their abundance and diversity (Potts *et al.*, 2010). Therefore, in spite of current efforts to reduce chemicals that can affect honeybee populations (Beekeeper 1, pers. comm.), habitat degradation for wild pollinators caused by these practices can be still considered a potential factor leading to declines or at least preventing the increase in the provision of pollination as an ecosystem service.

c) Invasive alien plant species (IAPs)

Invasive alien species can negatively contribute to habitat degradation, yet they can also provide new sources of nectar and pollen (Potts *et al.*, 2010). In the Western Cape province, certain alien plant species (e.g. *Eucalyptus camaldulensis*, *E. cladocalyx*, *E. conferruminata*, *E. sideroxylon*) are actually part of the main floral resources for managed honeybees (Melin *et al.*, 2010) and they also sustain wild pollinator species (de Lange *et al.*, 2013). From the different gum tree species (*Eucalyptus sp.*) that can be found in South Africa, most of them are cleared as part of the landowners' responsibilities established in the CARA (Conservation of Agricultural Resource Act No. 43 of 1983). These species must be cleared given the several impacts (e.g. on water provision) and degradation they cause on natural ecosystems. However, there are cases in which species that are not legally considered invasive (e.g. *Eucalyptus cladocalyx*) are still cleared in areas where is not required for mitigation purposes, despite the benefits these species provide to wild and managed pollinators. Such benefits are estimated, in terms of replacement cost for the Western Cape, between US$7.5 million (roughly 90 million ZAR) and US$20.5 million (around 250 million ZAR) (de Lange *et al.*, 2013). Regardless of all the economic and environmental implications of clearing or not the invasive alien species, it can still be considered a driver of future change in pollination. Given the current strategies in the area (e.g. WfW), this driver would most likely reduce foraging resources for pollinators in certain periods of the year, although the availability of other resources is still well established in the area.

d) Alien pollinators and disease and pests spreading

Alien pollinators can erode genetic diversity or increase the risk of pathogen spread, and hence affect local native populations (Potts *et al.*, 2010). Managed bees in the study area come from swarms trapped in the Langkloof or in other area mainly in the Western Cape (Beekeeper 2, pers. comm.). Although bee colonies are affected by the wax moth larvae in the Northern Cape, among other places, this pest is barely found in the Langkloof. This is attributed to the pest control systems implemented by farmers for deciduous fruit (Beekeeper 1, pers. comm.). Beekeepers in the area do not currently exchange bee species varieties from different regions, given that some specific traits can interfere with successful pollination (e.g. *Apis mellifera scutellata* found in the Northern Cape is particularly aggressive) (Beekeeper 1, pers. comm.). However, high colony losses in South Africa supported by beekeepers observations (Beekeeper 1, pers. comm.; Beekeeper 2, pers. comm.) have been attributed to moving colonies and the social parasitism by *A. mellifera capensis* (Melin *et al.*, 2014). Pest and diseases from North America and New Zealand have been imported to South Africa, affecting bee populations in the study area in the past, although beekeepers do not recognize them as a current threat (Beekeeper 2, pers. comm.). Given these conditions, alien pollinators and disease spreading represent potential risks, although they are likely to remain stable, at least in a short-term basis, in the area.

e) Climate change

It can potentially affect the distribution of certain pollinator species, trigger evolutionary changes, alter the temporal activity of pollinators and change the composition of pollinator communities, among others (Potts *et al.*, 2010). In the Langkloof, cold winters, frost and long periods of rain have been observed as climatic factors affecting honeybees. While recent cold winters have caused losses, frost hampers establishing new swarms (Beekeeper 1, pers. comm.). Moreover, after consecutive days of rain, in some cases bees leave their beehives (Beekeeper 2, pers. comm.). As described, these potential changes in climate in the area, can affect the supply of pollination service.