Wildflower farming on the Agulhas Plain – fynbos management and conservation

by

Martina Treurnicht

Thesis presented in partial fulfilment of the requirements for the degree Master of Science (Conservation Ecology)

at

Stellenbosch University

Supervisor: Prof. Karen J. Esler
Co-supervisor: Dr. Mirijam Gaertner
Faculty of AgriSciences
Department of Conservation Ecology and Entomology

December 2010

Declaration

By submitting this thesis/dissertation electronically, I declare that the entirety of the work contained therein is my own, original work, and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Martina Treurnicht

04/10/2010

Abstract

The Agulhas Plain is a constituent of the Cape Floristic Region, internationally known as a global biodiversity hotspot. The species-rich Agulhas Plain consists mainly of fire-prone fynbos shrublands of which sandstone fynbos covers a significant surface area. This lowland region is characterised by mostly infertile soils yet has unique floristic complexity and contains a high amount of threatened lowland species. Natural vegetation on the Agulhas Plain has been prone to large scale land transformation activities, mainly attributed to the extent of alien plant invasions, urbanisation and agricultural expansion. Fynbos wildflower farming, specifically from natural vegetation, is an important economic activity and contributes to the region's agricultural sector. Farmers harvest large quantities of commercial fynbos species and supply these to the market in an attempt to sustain a livelihood. Certain wildflower farming practices (burning, ploughing and broadcast sowing) are applied to natural vegetation in an attempt to increase the abundance of commercial species (i.e. augmentation). Numerous farming practices are used in the industry and the application of these methods can be dynamic and divergent. Furthermore, the implementation of farming practices manifest as anthropogenically induced disturbance events and are a concern for conservation. Previous investigations suggest that farming practices could establish monocultures of commercial wildflower species by reducing species richness and plant diversity of wildflower vegetation. Although the impact of natural disturbance regimes (e.g. fire) and flower harvesting activities have been researched, the impact of farming practices on fynbos structure and composition remains largely unknown.

This thesis reports on various aspects related to wildflower farming on the Agulhas Plain. Firstly, by administering a questionnaire, the extent and application of farming practices was investigated. Additionally, the opinion of wildflower farmers (referred to as landholders) about the impact of farming practices on wildflower populations was explored. Secondly, a vegetation survey aimed to assess the impact of farming practices on various structural (regeneration mode and growth form) and compositional attributes (plant family, dominant and rare species) of fynbos.

Results from the questionnaire indicate that the application of farming methods are seasonally restricted, often used in varying combinations and relatively small in spatial extent. Furthermore, results show that wildflower farmers have an ecologically acceptable knowledge base and awareness of fynbos management and conservation. Secondly results, obtained from the vegetation survey, imply that natural vegetation subjected to particular farming practices differ from pristine fynbos vegetation by having both altered structural and compositional attributes. However, the impact of farming practices on rare species was less apparent.

The conflict between commercial and conservation objectives are apparent from consultation with landholders. Nonetheless, landholders are optimistic about fynbos conservation and conservation can build upon these positive sentiments. Importantly, there is a need to communicate locally with landholders if a sustainable wildflower industry is a priority to stakeholders on the Agulhas Plain. Furthermore, fynbos ecosystems naturally entail complex ecological interactions. Wildflower farming practices reduce the ecological integrity (i.e. altered plant diversity, growth form and plant composition) of wildflower vegetation, at least at the local scale. These farming practices ultimately result both in distorted competitive interactions and disturbance regimes. Therefore, from a conservation perspective, the implementation of these farming practices (ploughing and broadcast sowing) should be cautioned against.

Opsomming

Die Agulhas-vlakte vorm deel van die Kaapse Blommeryk; ‘n gebied wat internasionale bekendheid verwerf het as ‘n biodiversiteits-brandpunt. Die spesieryke Agulhas-vlakte bestaan hoofsaaklik uit fynbosstruiklande wat geneig is tot veldbrande. Sandsteenfynbos beslaan ‘n beduidende oppervlak van die gebied (Agulhas-vlakte). Hierdie laagliggende area (Agulhas-vlakte) word meestal deur onvrugbare grondtipes gekenmerk maar beskik nogtans oor unieke fynbos kompleksiteit wat ‘n aantal bedreigde laagland spesies insluit. Natuurlike plantegroei op die Agulhas-vlakte is onderworpe aan grootskaalse grondgebruik transformasie; hoofsaaklik toe te skryf aan indringer plantegroei, verstedeliking en uitbreiding van landbou. Fynbos veldblomboerdery, spesifiek van natuurlike plantegroei, is ‘n belangrike ekonomiese aktiwiteit en lewer ‘n bydrae tot die Agulhas-vlakte se landbou sektor. Boere oes en lewer groot hoeveelhede kommersiële fynbos spesies aan die mark. Sekere veldblom-boerderypraktyke (brand, ploeg en saadstrooi) word ingespan op fynbosveld ten einde die opbrengs en afwisseling van kommersiële spesies te verhoog. ‘n Verskeidenheid boerderypraktyke word gevolg en die toepassing van hierdie boerderypraktyke is dinamies en uiteenlopend. Voorts manifesteer die implementering van hierdie boerderypraktyke as mensgemaakte versteurings wat kommerwekkend is vanuit ‘n bewaringsperspektief. Vorige ondersoeke dui moontlik daarop dat boerderypraktyke monokulture van kommersiële veldblomspesies kan vestig deur die veelheid van spesies en diversiteit van veldblomplantegroei te verminder. Ten spyte daarvan dat die impak van natuurlike versteuringsregimes (bv. vuur) en veldblompluk-aktiwiteite reeds nagevors is, bly die impak van veldblomboerderypraktyke op fynbosstruktuur en -samestelling grotendeels onbekend.

Hierdie tesis doen verslag oor verskeie aspekte van veldblomboerdery op die Agulhas-vlakte. Eerstens, deur middel van ‘n vraelys, is die omvang en aanwending van verskillende boerderypraktyke nagevors. Verder is die menings van veldblomboere (na wie verwys word as grondeienaars) ondersoek met die klem op die impak van boerderypraktyke op veldblombevolkings. Tweedens, is ‘n plantegroei-opname met die doelwit om die impak van landboupraktyke op verskeie strukturele- (regenerasiemodus en groeivorm) en samestellende eienskappe (plantfamilie, dominante- en seldsame spesies) van fynbos vas te stel gedoen.

Die resultate van die vraelys dui daarop dat die aanwending van boerderypraktyke seisoenaal beperk word, dikwels in wisselende kombinasies gebruik word en in ruimtelike omvang redelik klein is. Boonop toon die resultate dat veldblomboere oor ‘n ekologies-aanvaarbare kennisgrondslag en bewustheid van fynbosbestuur en –bewaring beskik. Tweedens, impliseer die resultate, vanuit die plantegroei-opname, dat fynbosveld wat onderwerp word aan sekere boerderypraktyke van natuurlike fynbosplantegroei verskil deurdat dit gewysigde strukturele- sowel as samestellende eienskappe toon. Die impak van die boerderypraktyke op seldsame spesies was egter minder waarneembaar.

Die botsing tussen kommersiële- en bewaringsoogmerke blyk duidelik uit konsultasie met grondeienaars. Nietemin is die grondeienaars optimisties oor fynbosbewaring en bewaring kan op hierdie positiewe sentimente staatmaak en voortbou. Dit is belangrik om daarop te let dat dit noodsaaklik is om plaaslik met grondeienaars oorleg te pleeg indien ‘n volhoubare veldblomindustrie ‘n prioriteit vir belanghebbendes op die Agulhas-vlakte is. Verder, aangesien fynbos ekosisteme natuurlik komplekse ekologiese wisselwerkings behels, verminder veldblom-boerderypraktyke die ekologiese integriteit (m.a.w. gewysigde plantdiversiteit, groeivorm en plantsamestelling) van fynbosveld, ten minste op kleinskaal (plaaslik). Hierdie landboupraktyke het uiteindelik beide verwronge kompeterende wisselwerkinge asook versteuringsregimes tot gevolg. Vanuit ‘n bewaringsperspektief moet daar dus teen hierdie boerderypraktyke gewaarsku word.

Dedication

To my two lovely Oumas,

Rita Leonhardt and Diedie Treurnicht.

This is always how it is
when I finish a poem.

A great silence overcomes me,
and I wonder why I ever thought to use language.

Mevlana Rumi (1207-1273)[1]

[1] With many thanks to Klara Mudge for sharing these words in a cabaret performance (Words, 2007)

Acknowledgements

I would like to thank the following people whose goodwill and expertise contributed significantly to the completion of this thesis:

Karen Esler and Mirijam Gaertner who have been continually patient, supportive and whose expert guidance is much appreciated.

The Gafney family (Nieuwepost) and the Van Dyk family (Nieuwedam) who were exceptionally kind to provide suitable study areas and, were both, friendly and welcoming throughout much of my field work.

Sean Privett, Wilhelm Rabe, Roger Bailey, Edwina Marinus and the Compton Herbarium,, Anne Horn, Lauren Urgenson, Heidi Prozesky, Theo Kleynhans, Grootbos Nature Reserve, Lize Joubert, Nashreen Williams, Fay Howa, Raphael Kongor, Ronelda Jacobs, Kenneth Oberlander and Monean Wenn whose contributions each proved invaluable.

Many thanks, specifically, to Dr Beatrice Conradie for approbation that allowed including questions into a land-use questionnaire. All landholders are gratefully acknowledged for sharing valuable information and for forfeiting their time to the interviews.

Suzaan Kritzinger-Klopper for invaluable assistance in the vegetation survey and identification of plant species.

Prof Martin Kidd at the Centre for Statistical Consultation (Stellenbosch University) for continual assistance with statistical analysis.

Miemie Taljaard for technical proof-reading and editing.

Flower Valley Conservation Trust and Centre for Invasion Biology (Stellenbosch University) who funded this project.

Last, but certainly not least, my family and friends for keeping me social and sane whilst completing this study.

Table of Contents

List of Figures

List of Plates

List of Tables

List of Appendices

CHAPTER 1:

Wildflower farming on the Agulhas Plain

1. Thesis outline and general introduction

The primary aim of this thesis was to investigate the impact of wildflower farming practices on the structure and diversity of sandstone fynbos on the Agulhas Plain, South Africa. This aim was addressed by conducting a vegetation survey, near the town of Baardskeerdersbos (Agulhas Plain), on natural fynbos vegetation previously subjected to fynbos management practices commonly used in wildflower farming. Additionally, there was an opportunity to personally consult with wildflower farmers (referred to as landholders) on the application of wildflower farming practices and landholder perception on certain ecological constructs. In light of the former, Dr. Beatrice Conradie (affiliated with the Flower Valley Conservation Trust) conducted a survey of land use practices on the Agulhas Plain by means of a structured questionnaire. As a result of this collaboration, this thesis reports on social and ecological aspects of wildflower farming on the Agulhas Plain.

This chapter (**Chapter 1**) introduces major themes, the study area, the rationale behind the investigation and particular research questions of the thesis. At the end of Chapter 1 certain terms and concepts appropriate in the context of wildflower farming are clarified by means of a literature review. All work in this chapter was by Ms. Martina Treurnicht. In addition, Prof. Karen J. Esler, Dr. Mirijam Gaertner and Ms. Miemie Taljaard provided comments to improve it. The results and outcome of ecological questions about farming practices in wildflower farming on the Agulhas Plain which was included in a land use questionnaire are presented in **Chapter 2**. All work in this chapter was by Ms. Martina Treurnicht; however, data (landholder consultation in the questionnaire) resulted from a land use questionnaire administered by Dr. Beatrice Conradie (affiliated with the Flower Valley Conservation Trust and also a senior lecturer at the University of Cape Town). This collaboration was initiated to minimise "stakeholder fatique" (*sensu* Hagan and Whitman, 2006) as several studies simultaneously needed information from land owners and managers on the Agulhas Plain. Collaboration facilitated the process of stakeholder engagement, necessary for the successful completion of this study. The broader questionnaire had a strong focus on agricultural activities and related economic issues on the Agulhas Plain. Additionally, ecological questions (see Appendix 1), formulated by M. Treurnicht, were included in the land use survey. In addition to supervisors input, Dr. Beatrice Conradie, made comments to improve this chapter.

Chapter 3 and **Chapter 4** report on a vegetation survey that aims to assess the impact of commonly used fynbos farming practices on structural and floristic attributes of the vegetation. All work in these chapters was by Ms. Martina Treurnicht. Assistance with statistical analysis was provided by Prof. Martin Kidd of the Centre for Statistical Consultation, Stellenbosch University. In **Chapter 5** conclusions drawn from this investigation are presented and validated. Additionally, conservation implications and recommendations for future research are discussed. All work in this thesis was reviewed by Prof. Karen J. Esler and Dr. Mirijam Gaertner.

This thesis is written in scientific paper format, each data chapter (Chapter 2, 3, 4) follows the format of an individual paper, with an introduction, materials and methods, results, discussion and conclusion section. For this reason, there will inevitably be some necessary overlap between chapters. Referencing in this thesis follow the format of the "South African Journal of Botany".

1.1 *People and fynbos*

Indigenous people, such as the *San* and the *Khoikhoi*[2] (*sensu* Deacon, 1984; Elphick, 1985) collectively referred to as Khoisan here (see Deacon and Deacon, 1999 for more), originally resided in the Cape area. These ethnic groups lived as pastoralists or hunter-gatherers (Lewis-Williams, 1981; Deacon, 1984; Smith, 1992) and their survival was greatly dependent on the natural surroundings, predominantly fynbos vegetation. Fynbos is characterised as a fine-leaved, evergreen shrubland and is a fire-prone vegetation type (Mucina and Rutherford, 2006). The Khoisan used fynbos for their daily survival needs (such as pasture, hunting and medicinal purposes) therefore there is a strong historical association between people and fynbos. However, as European settlers steadily arrived in the Cape and colonial settlement followed during the seventeenth century (Hall, 1993), fynbos was studied and explored by early European botanists with great scientific curiosity and fascination (Cowling and Richardson, 1995). This depicts two very different historical associations with fynbos vegetation (from here-on merely referred to as 'fynbos'). Exactly at the nexus of these two historical associations (survival and scientific) the wildflower industry has established itself.

Greyling and Davis (1989) highlight the multifaceted context of the wildflower industry by identifying commercial, research and conservation components. Acknowledging previous research contributions to the trans-disciplinary nature of the wildflower trade (Greyling and Davis, 1989; Davis, 1992; Heydenrych, 1999) much remains unknown about the fynbos ecosystem, i.e. the

[2] Literature uses a variety of terms such as "Bushman", "Hottentot", "San", "Khoikhoi" and "Khoisan" (see Schrire, 1980)

ecological component, which is currently supporting an established and growing industry (Laubscher and Ndakidemi, 2009). The impact of wildflower farming on the diversity and composition of fynbos remains *largely* unknown (Davis, 1990; Joubert et al., 2009). From a botanical and ecological perspective, fynbos is regarded as extremely rich and unique in diversity (Bond and Goldblatt, 1984; Raimondo et al., 2009). As such, fynbos is associated with a variety of endemic taxa, exclusive patterns of reproductive traits, unique patterns of diversity and a variety of environmental factors that act as selective regime (Cowling et al., 1992; Goldblatt and Manning, 2002; Linder, 2003). All of these facets emphasise the need for a scientific interest in understanding and ensuring a sustainable natural resource-based industry (Greyling and Davis, 1989; Laubscher and Ndakidemi, 2009). Moreover, conserving the rich biodiversity and threatened flora on the Agulhas Plain is of global significance and an issue in need of conservation attention in South Africa (UNDP, 2003).

2. Study area in context

In this section, the study area is placed in context by drawing on the fynbos biome and the diversity of the Cape Floristic Region (hereafter referred to as the CFR). Various abiotic and biotic (primarily vegetation) attributes related to the Agulhas Plain are briefly stipulated. Hereafter, special emphasis is placed on the western part of the Agulhas Plain as the individual sites studied in the vegetation survey are located in this area. Additionally, characteristics of Overberg Sandstone Fynbos and major features of the fynbos wildflower industry, specifically, on the Agulhas Plain are outlined.

The CFR is acknowledged as a biodiversity hotspot of endemism (Myers, 1990; Myers et al., 2000) where more than 9000 plant species can be found in a relatively small area (87 892 km^2) (Bond and Goldblatt, 1984; Goldblatt and Manning, 2000). Fynbos is exclusively diverse in patterns of plant species richness (Campbell and Van der Meulen, 1980) with high compositional turnover (beta diversity) and regional richness (gamma diversity); a result of various biotic and abiotic factors (see Cowling and Holmes (1992) and Cowling et al. (2009) for more). In the CFR 68-70% of plant species are endemic (Bond and Goldblatt, 1984). Furthermore, the Red List of South African Plants stresses the floral diversity of the fynbos biome and the huge amount of taxa that are so-called taxa of ‘conservation concern’ (3087) and faced with extinction (1736) in this region (Raimondo et al., 2009).

The Agulhas Plain (2160 km^2), a lowland region situated on the southern tip of Africa (Figure 1.1) (Cowling et al., 1988) comprises the coastal lowlands from Gansbaai/Danger Point in the west to the Gouritz River/Struisbaai in the east (Cole et al., 2000). The region (i.e. the Agulhas Plain) has typical Mediterranean climate (hot, dry summers and cold, wet winters) (see Kraaij et al., 2009 for more detail). The Agulhas Plain is an ancient weathered landscape, largely consisting of infertile soils (Cowling, 1990) and is characterised by low topographic diversity (Thwaites and Cowling, 1988). Despite this low environmental diversity the area is an incredibly species-rich constituent of the CFR, being floristically complex (Thwaites and Cowling, 1988; Raimondo et al., 2009) and uniquely heterogeneous in vegetation composition (Cowling et al., 1988; Cowling and Holmes, 1992; Raimondo et al., 2009). More specifically this region is recognised as a ‘centre of endemism’ as it supports more than 1750 vascular plant species of which 112 are known to be endemic (Cowling and Holmes, 1992). Fynbos and renosterveld (both fire-prone communities) are the dominant vegetation types on the Agulhas Plain (Mucina and Rutherford, 2006).

The western part of the Agulhas Plain is characterised by high habitat and floristic diversity (Cowling et al., 1988; Mergili and Privett, 2008). High compositional turnover (beta diversity) is a result of land system variation, change in soil type and shifting slope processes along toposequences (Cowling, 1990). Cowling et al. (1988) broadly recognised eight plant communities. These include; Forest and Thicket, Renosterveld shrubland, Mesotrophic Asteraceous Fynbos, Dune Asteraceous Fynbos, Dry Restioid Fynbos, Proteoid Fynbos, Mesic Ericaceous Fynbos and Azonal and vlei vegetation. These communities are still recognised today but have been refined in a more recent vegetation classification (see Mucina and Rutherford (2006) for more).

Overberg Sandstone Fynbos (also referred to as Acid Sand Fynbos (Heydenrych, 1999)) is the dominant vegetation unit (*sensu* Mucina and Rutherford, 2006) on the Agulhas Plain. Sandstone fynbos is not particularly threatened however only a small portion (6%) is formally conserved on the Agulhas Plain (Heydenrych, 1999; Hanks, 2007). Overberg Sandstone Fynbos is widely distributed throughout the Western Cape Province and can occur at a variety of altitudes ranging from 20 m to >1000 m (Mucina and Rutherford, 2006). For a further detailed description of this vegetation unit, see Mucina and Rutherford (2006). What is exceptionally important, in context of this thesis and the Agulhas Plain, is that sandstone fynbos is mostly utilised for wildflower farming (Heydenrych, 1999).

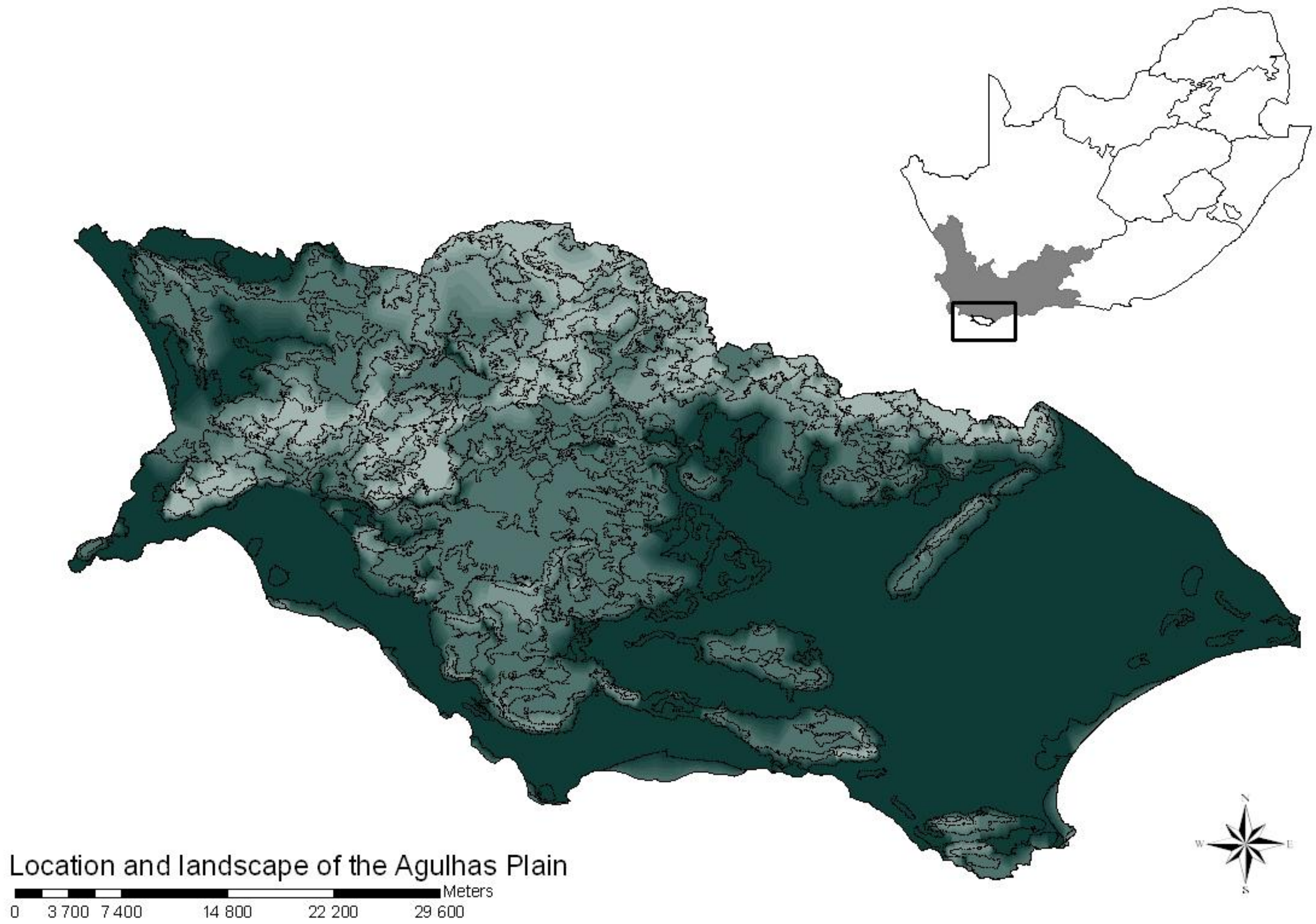


Figure 1.1: Location and elevational landscape of the study area, the Agulhas Plain, in context of the Western Cape of South Africa (Credit: Megan Nowell)

3. Broad rationale

Factors that threaten biodiversity are numerous and have recently received much attention in literature (Pimm et al., 1995; Myers et al., 2000; Sala et al., 2000; UNDP[3], 2003; Underwood et al., 2009). Habitat loss, predominantly through land-use practices, has been confirmed as one of the major threats to biodiversity (Wilcove et al., 1998; Sala et al., 2000; UNDP, 2003). Within the CFR, three major threats which are closely associated with anthropogenic activities have been identified, namely the exploitation of natural resources, the introduction and spread of invasive alien species as well as urban and agricultural land transformation (Lombard et al., 1997; Privett et al., 2002; Turpie et al., 2003). The Agulhas Plain is equally threatened by anthropogenic activities; agricultural conversion (Turpie et al., 2003), non-sustainable harvesting of wildflower populations and inappropriate fire regimes (Heydenrych, 1999; Cole et al., 2000; Laubscher et al., 2009). All of the above-mentioned threats fall within the activities of fynbos wildflower farming – the focus of this thesis.

Fynbos wildflower farming is a popular and lucrative agricultural activity in the CFR but this is especially true for the Agulhas Plain (Privett et al., 2002; Laubscher et al., 2009). It is thought that this region has higher flower harvesting levels and generates more income than any other fynbos area in the CFR. On the Agulhas Plain, fynbos flower farming (including wildflower and 'cultivated' fynbos) covers the second largest surface area (Heydenrych, 1999). In many cases fynbos wildflower farming is a major (and often the sole) income generator for farmers in the area (Privett et al., 2002).

The resource base of the fynbos wildflower industry can generally be classified into three major components (Greyling and Davis, 1989; Davis, 1990). Two can be viewed as complete opposites; the first being the intensive cultivation of fynbos stands that depend on horticultural and/or agricultural practices to deliver a high quality product while the second resource component is wildflower harvesting from entirely natural populations. The third component falls within the two mentioned extremes. This is the so-called marginal cultivation of fynbos material where relatively undisturbed vegetation is subjected to certain farming practices (like ploughing[4], broadcast sowing or burning) that would increase the amount of focal species in natural vegetation[5] (Davis, 1990; Heydenrych, 1999; Carinus et al., 2004).

[3] United Nations Development Programme (UNDP)
[4] Also termed 'tillage' by other (Davis, 1990)
[5] Also referred to as 'veld harvesting'

The fynbos wildflower industry utilises a variety of flowers that are harvested from both plantations ("cultivated" fynbos species[6]) and natural populations, i.e. natural vegetation (Carinus et al., 2004; Laubscher et al., 2009). Although market related factors have recently encouraged farmers on the Agulhas Plain to favour cultivated fynbos species (Privett et al., 2002) the industry will inevitably rely on harvesting from natural populations for certain products (Middelmann et al., 1989). When farming with natural wildflower vegetation, farmers need to provide focal flower species (i.e. those species demanded from the wildflower market). As such, fynbos wildflower farming remains an economic, market driven activity as farmers need to deliver these focal species to the market in order to maintain a profitable enterprise. Hence, fynbos wildflower farmers harvest considerable quantities of plant material from natural vegetation. Moreover, in order to be profitable (by supplying in the demand from the market), fynbos wildflower farmers implement various wildflower farming practices (Davis, 1990; Heydenrych, 1999; Joubert et al., 2009) described below.

Broadcast sowing is defined as a process of adding commercial fynbos species to natural vegetation thus allowing for a higher abundance of focal wildflower species than would naturally be present. Ploughing is generally defined as a process of loosening the soil to a certain depth with a toothed implement (Joubert et al., 2009). Joubert et al. (2009) distinguish between two types of ploughing; namely shallow and deep ploughing. Shallow ploughing loosens the topsoil layer (approximately up to a depth of ~ 7 cm) and is considered to be a 'low intensity' disturbance in comparison with deep ploughing. In contrast, deep ploughing is a method where the soil is loosened to a depth of >10 cm. Deep ploughing is thus not restricted to the topsoil layer and is therefore regarded as a 'high intensity' disturbance (Joubert et al., 2009). These farming practices are commonly used in wildflower farming in an attempt to overcome environmental factors like seasonality of flowers (Carinus et al., 2004) and to have higher quantities of focal flowers that can be harvested in a less labour intensive manner (Privett et al., 2002). Wildflower farmers need to supply healthy plants (i.e. pest free) and this can be achieved through implementing these particular farming practices that are seen to serve as a method of regeneration in natural vegetation (Van Wilgen et al., 1992).

These implemented farming practices attract certain concerns from the conservation sector. Cowling and Richardson (1995) and Manders (1989) highlight the harvesting of fynbos wildflowers (from natural vegetation) as a potential conflict for the conservation of such areas. Studies have so far mainly focused on the impact of harvesting on particular fynbos species, mainly Proteaceae, (Mustart and Cowling, 1992; Maze and Bond, 1996; Carinus et al., 2004; Mustart and Cowling,

[6] Meaning plant species intensively and artificially planted in rows; can also be associated with a natural or a horticultural/genetically improved variety

undated) which constitutes the prominent overstorey component of fynbos (Kruger, 1983; Bond et al., 1984; Bond, 1988; Le Maitre and Midgley, 1992). Proteas are commercially important species and generate high income for flower farmers (Carinus et al., 2004; Conradie and Knoesen, 2009). However, the implementation of farming practices in natural vegetation has been considered to facilitate the establishment of monocultures of focal (for example Proteaceae) flower species (Heydenrych, 1999). As such, these activities could potentially be detrimental for fynbos diversity (Van Wilgen et al., 1992) where processes significant for maintaining diversity and coexistence are disrupted (Bond et al., 1992; Thuiller et al., 2007). The concern of understorey shrub population persistence in the face of wildflower harvesting (Cowling, 1989; Esler et al., 1989) and farming (Davis, 1990; Joubert et al., 2009) has been raised but has not been investigated in detail. This thesis will attempt to contribute to current ecological understanding by investigating the impact of farming practices on fynbos community structure and plant composition.

As a final remark, landholders are acknowledged as role players in the conservation and effective management of fynbos as they will partly determine the sustainability of this natural resource enterprise on the Agulhas Plain. Currently, 4% of the Agulhas Plain is formally protected in reserves (Pence et al., 2003) and moreover, 95% of land on the Agulhas Plain is privately owned (Lombard et al., 1997). However, since the establishment of conservation initiatives and involvement of landholders in conservation agreements and stewardship programmes, a substantial 37% (102 000 ha) of the Agulhas Plain is currently protected (*sensu* Hanks, 2007). It is therefore evident that private landholders can contribute to the long term conservation of rare and threatened flora in the study area and play an important role in conservation in an agriculturally dominated landscape. Although conservation planning activities and the implementation of incentives are not a direct focus of this thesis, the results will provide guidelines for landholders to contribute to 'on-farm' conservation. It has been acknowledged that the success of any effort to conserve rare and threatened habitats is dependent on landholder involvement (Botha, 2001; Winter et al., 2007; Von Hase et al., 2010). Therefore, the outcome of this study will provide recommendations for landholders to consider implementing certain fynbos farming practices that can be *more* diversity friendly.

4. Aims and key questions

The primary aim of this study was to assess the impact that various farming practices[7] related to fynbos wildflower farming might have on the structural and floristic composition of sandstone fynbos, a predominant vegetation type (Mucina and Rutherford, 2006), on the Agulhas Plain. Additionally, this investigation aimed to determine the extent of such farming practices on the study area and reports on the opinion of landholders (i.e. landowners and land managers) about the perceived impact on fynbos community composition. Furthermore, the aim of the study was to provide guidelines for the wildflower industry that will facilitate sustainable fynbos farming for the Agulhas Plain.

The study was divided into two components, firstly a questionnaire and secondly, a vegetation survey. In the questionnaire (Chapter 2) the following questions were addressed;

a) What is the extent of disturbance activities in terms of fynbos farming on the Agulhas Plain, i.e. which fynbos farming practices are most widely implemented in wildflower farming? Additionally, it would be important to explore if the application of these farming practices can be traced to general management understanding (e.g. prescribed burning recommendations) of fynbos.
b) What, in the opinion of a landholder, is the impact of such disturbance activities on fynbos diversity?

In the vegetation survey (Chapter 3 and 4) the aim was to investigate how the structural and compositional attributes and ultimately diversity of sandstone fynbos is affected by fynbos wildflower farming. The following questions were addressed;

c) Are certain plant growth forms favoured by certain farming practices (i.e. compare structural characteristics between control and treatment sites)?
d) Are fynbos plants with different regeneration modes (e.g. reseeder or resprouter) affected by certain farming practices (i.e. compare structural characteristics between control and treatment sites)?
e) Do certain farming practices reduce or increase the species richness of sandstone fynbos on the Agulhas Plain (i.e. compare species richness and diversity between control (i.e. representing intact fynbos communities) and treatment sites)?

[7] The collective term used for any combination of augmentation, ploughing and burning that is implemented in fynbos wildflower farming

f) Are plant family composition, dominant and 'rare' species (as defined by the Red List of South African Plants (Raimondo et al., 2009)) affected by certain farming practices?

5. Literature review

5.1 *The fynbos wildflower industry: commercial overview and issues*

In an historical context, Cape fynbos harvesting activities were largely uncontrolled and unrestricted until 1938. Hereafter, the harvesting of species became restricted by a permit system and the publication of a list of protected wildflower species (Davis, 1990). Growing demand led to the establishment of a proper commerce that has for decades been recognised as a growing and competitive industry. In South Africa farmers started to commercially trade with fynbos flowers at an international level in the 1960's with the majority of this trade focused towards the European markets (Middelmann et al., 1989; Davis, 1990). Today the largest sector of the trade is still devoted to the export market and European countries (Heydenrych, 1999). In the past, the fynbos wildflower industry has been considered an important trade in South Africa primarily because of the significant income it has generated for the country (Middelmann et al., 1989).

By the end of the 1980's the wildflower trade (including cultivated and natural vegetation harvesting practices) had foreign and local sales amounting just below R30 million per annum. This contributed approximately 0.02% of the gross national product (GNP)[8] of South Africa at this time (Middelmann et al., 1989). Cowling (1989) estimates that (at this time) approximately 65% of the overall wildflower product was harvested from natural vegetation. According to 1997 prices (provided by SAPPEX[9]) the wildflower industry generated a gross income of R149.3 million per annum (Heydenrych, 1999) of which natural vegetation harvesting was responsible for R86 million (57.6%) (Heywood, 2003). In 2000 the exports (alone) of the whole industry generated a gross income of R173.1 million and in 2003 a figure of R209,7 million was reported (SAPPEX, 2006). It is however unclear how the natural vegetation harvested products contribute to these figures.

Wildflower harvesting from natural vegetation (also called 'veld picking' (Greyling and Davis, 1989) utilises a variety of fresh and dried fynbos products (Davis, 1992), including flowers/showy inflorescences and greens/foliage[10] (Greyling and Davis, 1989; Turpie et al., 2002). The industry

[8] Based on a 1985 GNP of R120 000 million (Middelmann et al., 1989)
[9] South African Protea Producers and Exporters Association
[10] Also termed 'filler' material (so called 'Cape greens' or 'loof') (Heydenrych, 1999; Davis, 1990)

utilises at least 100 different plant species (Cowling and Richardson, 1995) which depends greatly on fluctuating market demands (Davis, 1992). On the Agulhas Plain a total of 71 species have been recorded to be harvested from natural vegetation for the fresh and dried industries. For Acid Sand Fynbos in 1997 it was estimated that a total of 13 species of the family Proteaceae and 42 'other' species were utilised as a product for wildflower harvesting (Heydenrych, 1999). The nature of the wildflower industry is however extremely dynamic and severely influenced by the global market. Species that are utilised in wildflower harvesting vary from year to year (or even from season to season) depend on a number of factors (i.e. market demands, price tariffs and environmental availability) (Middelmann et al., 1989; Heydenrych, 1999).

Several estimates related to income and price trends can be extracted from literature for the fynbos wildflower industry. It is however difficult to compare the figures as some are based on exports alone, others include the overall (i.e. local and export figures) fynbos flower industry while some are based on wildflower harvesting from natural vegetation alone. According to Middelmann et al. (1989) and Davis (1992) there is a severe lack of statistics with regard to income and various other facets of the wildflower trade. Another problem is that in contrast to cultivated farming, the natural vegetation harvesting component does not have an organised infrastructure (Middelmann et al., 1989). As a consequence, materials travel a variety of channels to the less structured local market and other destinations (Greyling and Davis, 1989; Davis, 1990) which severely complicates price estimates. Nowadays the overall statistics situation has changed very little and information is still largely unobtainable (Bailey[11] pers. com.). However, it seems as if organisations are attempting to upgrade relevant databases (Rabe[12] pers. com.). Additionally, there seems to be some cohesion between various organisations (e.g. CapeNature, PPSA[13], SAPPEX, Flower Valley Conservation Trust and others) concerned with wildflower harvesting and conservation orientated activities.

Irrespective of specific price trends associated with the fynbos wildflower industry; the question arises as to how dependent the current fynbos wildflower industry is on produce derived from natural vegetation on the Agulhas Plain? A survey of wildflower farmers in this region reported that the ratio of income derived from natural-product compared to cultivated-product was 85:15 (Heydenrych, 1999). This indicates that (at least 10 years ago) the industry was dependent on natural vegetation for a considerable amount of product. In an environmental economics study of fynbos products it was estimated that products derived from natural vegetation are responsible for more than 50% of the overall fynbos industry's gross income (Turpie et al., 2002). Additionally

[11] Conservation Coordinator (based at the Flower Valley Farm in Gansbaai), Flower Valley Conservation Trust
[12] Executive Director, Tussenberge Boerdery (Pty) Ltd
[13] Protea Producers of South Africa

specifically in the Protea trade, which constitutes a significant component of the wildflower industry, a recent study (based on data for the year 2009) reported that 33% of focal flowers and 42% of filler material is harvested from natural vegetation (Conradie and Knoesen, 2009). These statistics clearly indicate the dependence of the fynbos wildflower industry on products harvested from natural vegetation and consequently there can be little doubt that this harvesting sector is an integral component of the wildflower industry (Cowling, 1989).

Moreover, the fynbos wildflower industry has been shaped by commercial demands, historical development and a number of biological and ecological constraints (Davis, 1990; Heydenrych, 1999). More research has been initiated due to increased global awareness and by devoting more efforts into environmental management strategies (Davis, 1990). Unfortunately, as fynbos wildflower farming has grown into a sizeable industry it has remained a poorly documented commerce from economic and conservation perspectives (Privett et al., 2002). The prosperity of the wildflower industry is highly dependent upon the resource (i.e. fynbos) and as such the sustainability of this natural resource is not only a conservation priority but also of economic importance (Heydenrych, 1999). Importantly, the so-called 'world problematique' (*sensu* Davis, 1989) has been recognised to be exceptionally relevant in context of the fynbos wildflower industry. Davis (1989) emphasises that greater cohesion is urgently needed from research, conservation and commercial sectors. As the wildflower industry in South Africa is fairly young, many lessons are continuously learnt (ecologically and commercially) from experience gained in this dynamic trade (Davis, 1989, 1990; Heydenrych, 1999).

5.2 *Fynbos wildflower farming: ecological considerations*

Disturbance is regarded to be a central concept for maintaining the ecological integrity of species-rich communities (Pickett and White, 1985; Cowling, 1987). However, a problem is to resolve issues related to the resilience and stability of ecological communities to disturbance (Holling, 1973) and this is particularly the case for plant community-response and recovery (Privett et al., 2001; Platt and Connell, 2003). The exact nature of the disturbance, defined by size (spatial extent), seasonality, frequency and intensity (collectively referred to as the 'disturbance regime' (*sensu* Sousa, 1984)) is essential in terms of community response and diversity (Pickett and White, 1985; Pickett and Parker, 1994).

Competition (and the degree of competitive interactions) between plant species and the particular disturbance regime involved have been highlighted as key factors that control and regulate species richness (Huston, 1979; Sousa, 1984). It is globally known that species composition and community recovery change over time after a disturbance (Connell and Slatyer, 1977; Kruger, 1983; Shmida and Ellner, 1984; Sousa, 1984). Importantly, ecological communities subjected to periodic disturbance are dominated by non-equilibrium conditions, as opposed to an equilibrium state (Pickett and White, 1985). In this context, competition has been acknowledged to play a less important role in determining community structure especially in nutrient poor environments (Grime, 1977; Cowling, 1987; Richards et al., 1997). There is hence no upper limit to the number of species that can coexist in non-equilibrium environments (Caswell, 1982; Cowling et al., 2010). Therefore, the widely established 'competitive exclusion principle' is less applicable in this situation (Grubb, 1977; Cowling, 1987). It is suggested that this principle is replaced through a 'weighted lottery' process explained by temporal variability of the disturbance and overlapping generations of species (Chesson and Warner, 1981; Lavorel, 1999). More recently however, competition has once again been considered a key concept in structuring environments (Chesson and Huntly, 1997). Hitherto few studies have satisfactorily explained and quantified the role of competition in the fynbos environment (Bond et al., 1992). Ignoring the controversy in the ecological debate, the number of species that persist within a community may well be limited by competition but, more importantly for this investigation, the disturbance regime may mediate the competitive interactions amongst species that survive in any given community (Connell, 1978; Huston, 1979; Vlok, 1996).

Predictions related to community recovery and responses, in the post-disturbance environment are extremely challenging due to the interconnected ecological components expressed in the theory of ecological succession (Sousa, 1984; Pickett and White, 1985). This is particularly the case for fynbos vegetation (Kruger, 1983; Cowling, 1987; Midgley, 1989; Bond et al., 1992; Vlok, 1996; Privett et al., 2001). Arguably the disturbance the regime influences competitive interactions (Huston, 1979; Huston, 1999), which produce enormous variation in vegetation structure and diversity as well as characteristic life history traits and unique species properties (Grubb, 1977; Yeaton and Bond, 1991) (see Figure 1.2).

In the following paragraphs, the ecological connotations between fynbos and, specifically, fire as a periodic disturbance are discussed. The two concepts are vital (as a backdrop) for an understanding of this thesis. Additionally, brief reference is made to some ecological studies investigating the variety of responses that have been documented for post-fire fynbos environments.

5.2.1 *Fire as a natural disturbance in fynbos*

Fynbos ecosystems, like other mediterranean-type shrublands (Kruger, 1983; Cowling, 1987), are characterised by natural fire events as periodic disturbances (Cowling, 1987; Midgley, 1989; Bond and Van Wilgen, 1996). In these ecosystems fire plays an important role in maintaining ecosystem structure, diversity and stability (Kruger, 1983; Bond et al., 1984; Cowling, 1987; Bond and Keeley, 2005). However, with the floral and structural diversity prevalent in fynbos (Kruger, 1983; Cowling and Holmes, 1992; Raimondo et al., 2009) the impacts of fire on the recovery of the plant community are extremely dynamic and can produce varying results (Cowling, 1987; Van Wilgen et al., 1994; Bond and Van Wilgen, 1996).

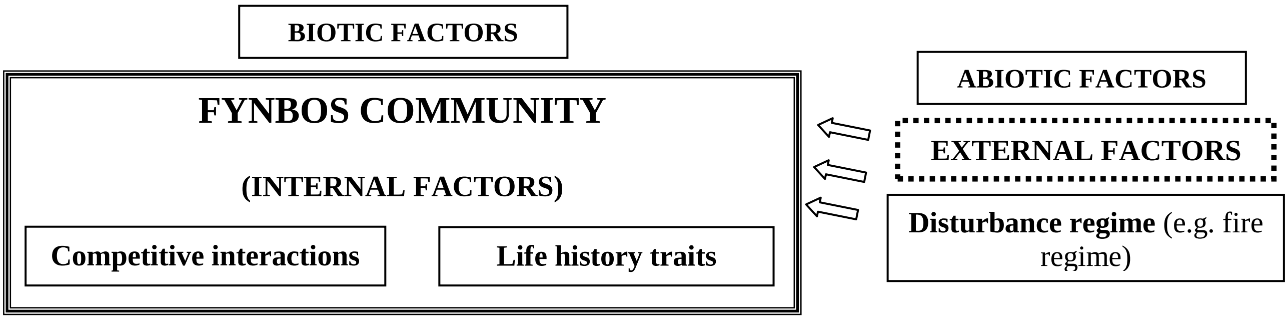


Figure 1.2: How a particular community is shaped after a disturbance is determined by external factors (the disturbance regime) and factors internal to the fynbos community (competitive interactions and life history traits).

Fynbos plant recruitment is initiated immediately after a fire with a sudden pulse of species, most prominent in 'young' fynbos (i.e. less than 10 years old) (Kruger, 1983; Privett et al., 2001). Hereafter, species are gradually 'lost' from the community during the course of succession as short-lived species are substituted with longer-lived species (Kruger, 1983; Kruger, 1987; Cowling and Gxaba, 1990; Privett et al., 2001). For the fynbos environment, various factors related to the nature of a fire (season, intensity and frequency) are considered to influence post-fire recruitment and recovery (Kruger, 1983; Bond et al., 1984; Cowling, 1987). Successional phases prominent in the fynbos post-fire community include changes in structure, diversity and species richness (Kruger, 1983). Additionally, the post-fire environment is characterised by unique conditions that initiate successional patterns that allow a variety of species to coexist (Cowling, 1987; Cowling and Pierce, 1988; Yeaton and Bond, 1991; Bond et al., 1992). As a concluding remark, it is necessary to state that successional patterns on a community level are governed by an assortment of processes. Community recovery can hence only be interpreted in context of the specific geographical area and the prevalent fire regime. Therefore, field observations and explanations, even specifically for fynbos, vary from one community to another (Cowling, 1987; Van Wilgen et al., 1994).

Varying results have been reported for community recovery in fynbos and some studies have elicited an understanding of how community composition changes in the post-fire environment. For example, on Table Mountain it has been reported that where an original 92 species were present prior to a fire, only 76 species reappeared six years after the fire (Adamson, 1935). Further results for fynbos post-fire recovery from Van Wilgen and Kruger (1981) reported that the floristic composition of certain plots changed by more than 50% even though species richness and total flora did not indicate significant change. Similarly dramatic changes in plant composition were reported for the Cape of Good Hope Nature Reserve where species turnover averaged at approximately 40% over a 30 year interval (Privett et al., 2001). However, the issue of scale becomes important when interpreting fynbos community stability. A recent study by Thuiller et al. (2007) showed that the temporal turnover of species is high at the local scale however turnover seems stable at the meta-community scale. This was mainly attributed to the stochastic nature of the fire regime and weather conditions in the post-fire environment (Thuiller et al., 2007).

The evolution of various reproductive traits in fynbos is considered to be a result of fire regime (amongst other factors) (Kruger, 1983; Le Maitre and Midgley, 1992). Resprouting (vegetative growth) and reseeding (production of seeds) are two dominant regeneration traits of plants in fire-prone communities (Cowling, 1992; Bellingham and Sparrow, 2000). The dominance of one over the other is however greatly determined by the fire frequency and intensity prevalent in the particular community (Le Maitre and Midgley, 1992). Changes in reproductive responses and regeneration success after fire have been investigated (Mustart and Cowling, 1991; Le Maitre and Midgley, 1992; Bond et al., 1995; Thuiller et al., 2007). However, much remains unknown and unexplained but an understanding of how these reproductive traits function is important as the mentioned qualities will ultimately determine community recovery and the structural and floristic characteristics of the community (Cowling, 1987; Le Maitre and Midgley, 1992; Thuiller et al., 2007).

For reseeding species it is important to distinguish between two subcategories, i.e. serotiny (canopy storage of seeds in the canopy of a plant (Cowling, 1987; Lamont et al., 1991)) and myrmecochory[14] (soil-stored seed ‘planted’ by ants (Bond and Slingsby, 1983)). These reseeding fynbos species vary widely in terms of degree of serotiny or myrmecochory, post-fire regeneration

[14] Serotinous and myrmecochorous species are collectively referred to as reseeders (‘seed producing’ species (Yeaton and Bond, 1991)

capability and size of viable seed banks (Cowling, 1987; Lamont et al., 1991). Serotinous species (mostly *Proteaceae*) are known to dominate the fynbos overstorey (Kruger, 1983; Le Maitre and Midgley, 1992) and their responses to fire have been intensively studied (Bond et al., 1984; Bond, 1988; Mustart and Cowling, 1991; Cowling, 1992 and references therein). Research has shown that both serotinous and myrmecochorous species are affected by fire dynamics (Bond, 1988; Cowling, 1992; Privett et al., 2001). Serotinous species release their seeds after fire which are consequently exposed to seed predation and/or heat (potentially resulting in seed loss). Such species rely heavily on conditions in the post-fire environment for successful germination (Bond et al., 1984; Cowling, 1987).

For serotinous species, seed germination is seasonally restricted and thus season of burn is extremely important for population recovery (Bond et al., 1984; Van Wilgen and Viviers, 1985; Le Maitre, 1988). If the regeneration of reseeders (i.e. non-sprouting species) is considered, winter and spring burns are discouraged in practice as such burns produce poorer regeneration than summer or autumn burns (Bond et al., 1984; Van Wilgen and Viviers, 1985; Van Wilgen et al., 2010). However, Van Wilgen and Viviers (1985) also warn against summer burns as such fire events result in highly variable seedling recruitment and survival for serotinous species. For most fynbos environments the "late-summer/early autumn period" (*sensu* Van Wilgen and Viviers, 1985) is most favourable for seedling recruitment and survival. Recently, however Heelemann et al. (2008) noted that recruitment patterns differ within the fynbos biome. The former studies (Bond et al., 1984; Van Wilgen and Viviers, 1985; Le Maitre, 1988) focused on recruitment patterns in the western part of the biome. Recruitment patterns may be very different in eastern parts of the fynbos biome where fire occurrence should coincide with rainfall peaks, i.e. spring and autumn burns (Heelemann et al., 2008). In the specific context of the Agulhas Plain wildflower industry, Maze and Bond (1996) and Mustart and Cowling (undated) highlight that out-of-season burns (like spring burns) combined with flower harvesting can potentially cause population crashes for certain serotinous Proteaceae species.

Moreover, short fire intervals (of approximately six years) reduce the occurrence of reseeding species and over time recurrent fires of this nature will gradually cause population extinction (Van Wilgen and Kruger, 1981; Vlok and Yeaton 2000a; Privett et al., 2001). In light of this, it has been reported that two successive fires replaced a tall Protea overstorey with an understorey consisting of low shrubs dominated by resprouters and short-lived reseeders (Van Wilgen and Kruger, 1981). Evidently, serotinous species (for example Proteaceae) in fynbos ecosystems are particularly susceptible to population crashes when exposed to inappropriate fire regimes as they are slow maturing and require a good number of years before being reproductive (i.e. producing seeds) (Bond et al., 1984; Vlok, 1996). On the other hand, long fire-free intervals (more than 40 years) are associated with species diversity declines and a decline in reseeding species (Bond, 1980; Kruger, 1983; Bond et al., 1984).

Resprouters conversely are capable of vegetative growth immediately after fire. As such, these species rely less on successful germination and seedling survival over time and are expected to be more prominent in the immediate post-fire environment (Kruger, 1983; Bond and Midgley, 2001). Despite ongoing debates related to competitive advantages between reseeders and resprouters, it is generally expected that resprouters have a competitive advantage over reseeding species in the immediate post-fire environment as resprouters can immediately re-establish from storage organs (Vlok, 1996; Bond and Midgley, 2001). Fire, and more importantly disturbance frequency and intensity (Bellingham and Sparrow, 2000), is known to have an effect on resprouters and varying results have been reported for such species in the post-fire environment (Midgley, 1996).

Several, short fire intervals are considered to favour resprouting species as these species will increase in density and may even become dominant (Kruger, 1983; Vlok and Yeaton, 2000a). At the same time, however, resprouters have been reported to be negatively affected by short fire intervals. This happens under intense fire conditions where such species are literally scorched off and unable to re-establish (Privett et al., 2001). On the other hand, long fire-free intervals are associated with low reproductive potential (Bond, 1980) and species diversity declines (Kruger, 1983; Cowling, 1992; Privett et al., 2001). Additionally, Privett et al. (2001) specifically note a decline in resprouting species in the absence of fire. Overall (for resprouting and reseeding species) the absence of fire has been associated with causing senescence of fynbos species that will ultimately lead to local extinctions (Bond, 1980; Cowling, 1992; Privett et al., 2001).

After all, considering the relationship between understorey and overstorey species in a fynbos community a spatial and temporal patchiness in density can be generated in a Protea overstorey as a result of different fire cycles (Vlok and Yeaton, 1999). Vlok and Yeaton (1999) suggest that this can counteract the effect of competitive exclusion processes amongst subdominants. As such the Protea overstorey, that manifests as clumping with several gaps, is considered to be essential for maintaining species richness in the understorey (Vlok and Yeaton, 1999). On the contrary; competitive interactions amongst species may also affect the patchiness of the fynbos community (Yeaton and Bond, 1991). Vlok and Yeaton (2000b) emphasise that intricate interactions between overstorey and understorey species are essential in maintaining structure and function of fynbos communities. Again one can clearly interpret that any fynbos community is shaped from the inside (endogenous) and from the outside (exogenous) (refer to Figure 1.2) and community response is extremely dynamic (Bond et al., 1995; Thuiller et al., 2007).

Understanding the effect of a particular fire regime on fynbos is problematic as illustrated above. Fynbos ecosystems are exceptionally complex and the understanding ecologists have developed through studying such systems remains severely limited for two major reasons. Firstly, studies have mainly focused on Proteaceae in an attempt to explain the effects of fire regime on community structure and stability but very few studies have investigated the response of species in relation to fire for the fynbos understorey (Cowling, 1987; Vlok and Yeaton, 2000b). Secondly, to analyse cause and effect of fire regime (or any other disturbance regime for that matter) on community composition, recovery and individual species response is a complex task (Bond and Van Wilgen, 1996; Bellingham and Sparrow, 2000; Thuiller et al., 2007). To uncouple fire regime effects when interpreting factors associated with species diversity and composition would be pointless. Several authors (Cowling, 1987; Le Maitre and Midgley, 1992; Bond et al., 1995; Vlok and Yeaton, 1999; Thuiller et al., 2007) emphasise the stochastic nature of fire in the context of fynbos and emphasises an understanding hereof.

5.2.2 *Anthropogenic disturbances*

As discussed earlier wildflower farmers use a variety of methods in an attempt to deliver focal flower species to the market. These so-called methods include burning, ploughing and augmenting natural vegetation (i.e. veld) (Heydenrych, 1999; Joubert et al., 2009). According to Davis (1990) the usual method of wildflower vegetation preparation entails burning the veld and loosening the top-soil by tilling. This removes all aboveground biomass whereafter veld is ready to be sown-in with seeds of commercial fynbos species (Davis, 1990; Heydenrych, 1999). In light of the above it is important to note that fynbos ecosystems are not only subjected to a single disturbance event but rather to a sequence of events. Again, one starts to speculate about the resilience to disturbance within such ecosystems (Lavorel, 1999).

Ploughing (or ‘tillage’ (*sensu* Davis, 1990)) of pristine vegetation as an agricultural practice has previously been criticised in literature (Chan, 2001; Kladivko, 2001). From an ecological perspective, ploughing is considered to be a process that causes ecosystem degradation. Davis (1990) has compared this agricultural practice to the very destructive ‘slash and burn’ technique implemented in tropical forests. Ploughing ultimately involves the physical disturbance of an ecosystem that affects both abiotic and biotic factors (Prose et al., 1987; Davis, 1990; Joubert et al., 2009).

Abiotic factors include water and energy flow regimes, soil nutrient aspects (Davis, 1990) and gaseous emissions into the atmosphere (Yamulki and Jarvis, 2002). A study by Davis (1990) could not prove experimentally that ploughing was immediately damaging to abiotic components of mountain fynbos systems. Very few studies have examined the effects of ploughing on plant diversity and structural changes in fynbos. In mediterranean ecosystems various ploughing intensities have different effects on plant composition and seed bank dynamics, although these insights are mainly from pasture management (Levassor et al., 1990). However, significantly low species richness and diversity observations were apparent in ploughed study sites used for the marginal cultivation of fynbos wildflowers (Davis, 1990). A more recent study by Joubert et al. (2009) investigated the effects of two types of ploughing (shallow and deep) on fynbos diversity. Shallow ploughed (regarded as an 'intermediate-intensity disturbance' (*sensu* Joubert et al., 2009)) areas had the highest total species richness and highest richness in all growth forms (except large shrubs). Thus the study concluded that this practice has no significant negative effect on plant diversity. Joubert et al. (2009) did however emphasise that deep ploughing (regarded as a 'high-intensity disturbance') must be avoided as this farming method could be detrimental to fynbos diversity. Wildflower farming practices furthermore include augmentation of natural vegetation which results in a higher abundance of commercial species (e.g. Proteaceae) (Carinus et al., 2004; Joubert et al., 2009). However, so far there are no studies on a potential shift in competitive interactions between overstorey and understorey species (Vlok and Yeaton, 2000b) due to farming practices (i.e. altered disturbance regime).

6. Fynbos wildflower farming: connecting people and conservation

Since the 1980's the conservation status of the Agulhas Plain has changed considerably as a result of both political issues and scientific advancement (Privett et al., 2002; Lombard et al., 1997). Despite the failure of a previous attempt to develop a conservation strategy for the region (MLH, 1994; Cowling and Mustart, 1994) the situation is currently improving (Lombard et al., 1997; Privett et al., 2002; Rouget, 2003; Hanks, 2007). However, sustaining costs related to implementing strategic conservation plans (such as C.A.P.E. [15]) in biodiversity hotspots like the Cape Floristic Region are questionable as financial resources are severely limited (Balmford, 2003). Therefore,

[15] Cape Action for People and the Environment

there is a call to also consider investing scarce conservation resources to other sectors (e.g. social) and to not devote finances exclusively to costly spatial prioritization activities (Colwing et al., 2010). This is especially important as people (including landowners and local communities) on the Agulhas Plain are increasingly aware of the inherent value of natural and remnant fynbos and possibly interested in developing a market for this ‘green product’ (i.e. fynbos) (Hanks, 2007; Conradie, 2009).

The fynbos wildflower industry provides livelihoods to more than 10 000 people in the Cape region (Middelmann et al., 1989). Although employment in the wildflower sector is often seasonal and characterised by low profit margins, making the industry an insecure source of livelihood and employment (Sekhran and Richardson, 2008), the fynbos industry currently remains an important provider of jobs to locals and is by far the largest industry on the Agulhas Plain (Privett et al, 2002; FVCT, 2008). Sekhran and Richardson (2008) also refer to the lack of social responsibility that has previously been apparent in the context of the South African wildflower trade. Nowadays community empowerment is considered key to ensure biodiversity conservation and the sustainable utilisation of fynbos (Privett et al., 2002; Hanks, 2007; FVCT, 2008). Consequently, conservation organisations such as C.A.P.E and the Flower Valley Conservation Trust currently invest a great deal in human capital and are increasingly devoted to this (FVCT, 2008; Balmford, 2003). In addition, landowner involvement and stewardship are considered vital for conservation success on the (largely) privately owned Agulhas Plain (Lochner et al., 2003; Hanks, 2007; Conradie, 2009). Successful partnerships with the private sector have been established and strengthened, as well as attracting government and non-governmental organisations (Privett et al., 2002). Acknowledging the former positive sentiments, however, conservation on the Agulhas Plain remains challenging. Robinson (2006) provides a solution to the compound task at hand;

“As we look to the next 20 years, we need to become more relevant and important to the societies in which we live. To do so, the discipline of conservation biology must generate answers even when full scientific knowledge is lacking, structure scientific research around polices and debates that influence what we value as conservationists, go beyond the certitude of the biological sciences into the more contextual debates of the social sciences, engage scientifically with human-dominated landscapes, and address the question of how conservation can contribute to the improvement of human livelihoods and the quality of human life.”

7. Concluding remarks

The key issues that emerged from this literature review are highlighted as follows:

1) Fynbos ecosystems are complex, dynamic entities for which varying results have been recorded for community recovery in the post-disturbance environments, specifically in response to fire regime. Each fire regime (or disturbance event) is unique and interacts as such with the fynbos community.

2) The South African fynbos wildflower industry relies undoubtedly on products derived from natural vegetation.

3) The application of certain farming practices (e.g. burning, ploughing and broadcast-sowing) in wildflower farming attracts conservation concern regarding the resilience and stability of fynbos communities. Currently an ecological understanding on the impact of wildflower farming practices is severely lacking.

4) Local conservation organisations acknowledge social empowerment and integration of stakeholders as essential for biodiversity conservation and for ensuring a sustainable wildflower industry which is important for people’s livelihoods on the Agulhas Plain.

Plate 1: Fynbos wildflower farming on the Agulhas Plain (South Africa); (a) Implement used in fynbos wildflower farming, Agulhas Plain (Photo: M. Treurnicht), (b) Fynbos vegetation used in wildflower farming immediately after burning and ploughing (foreground) and older vegetation (background) (Photo: M. Treurnicht), (c) Workers packing fynbos wildflower material in a local packshed (Photo: Flower Valley Conservation Trust), (d) Workers packing fynbos wildflower material in a local packshed (Photo: M. Treurnicht).

8. Literature cited

Adamson, R.S., 1935. The plant communities of Table Mountain, III. A six years study of regeneration after burning. Journal of Ecology 23, 52-55.

Bailey, R., 2009. Personal communication. Flower Valley Conservation Trust.

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

Bellingham, P.J., Sparrow, A.D., 2000. Resprouting as a life history strategy in woody plant communities. Oikos 89, 409-416.

Bond, W.J., 1980. Fire and senescent fynbos in the Swartberg, southern Cape. South African Forestry Journal 114, 68-71.

Bond, W.J., 1988. Proteas as 'tumbleseeds': Wind dispersal through the air and over soil. South African Journal of Botany 54, 455-460.

Bond, W.J., Cowling, R.M., Richards, M.B., 1992. Competition and coexistence. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 206-225.

Bond, P., Goldblatt, P., 1984. Plants of the Cape flora: a descriptive catalogue. Journal of South African Botany 13, 1-13.

Bond, W.J., Keeley, J.E., 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. Trends in Ecology and Evolution 20, 387-394.

Bond, W.J., Maze, K., Desmet, P., 1995. Fire life-histories and the seeds of chaos. Ecoscience 2, 252-260.

Bond, W.J., Midgley, J.J., 2001. Ecology of sprouting in woody plants: the persistence niche. Trends in Ecology and Evolution 16, 45-51.

Bond, W.J., Slingsby, P., 1983. Seed dispersal by ants in shrublands of the Cape Province and its evolutionary implications. South African Journal of Science 19, 231-233.

Bond, W.J., Van Wilgen, B.W., 1996. Fire and Plants. Chapman and Hall, London.

Bond, W.J., Vlok, J., Viviers, M., 1984. Variation in seedling recruitment of Cape Proteaceae after fire. Journal of Ecology 72, 209-221.

Botha, M., 2001. Conservation options for farmers and private landholders. Summary report. Cape Conservation Unit, Botanical Society of South Africa. Report No. 01/2001.

Campbell, B.M., Van der Meulen, F., 1980. Patterns of plant-species diversity in fynbos vegetation, South Africa. Vegetatio 43, 43-47.

Carinus, T., Blomerus, L., de Ponte Machado, M., Gerber, F., Holmes, P., Kabot, L., Marais, C., Martens, C., Middelman, M., Privett, S., Palmer, G., Saunders, R., Scott, A., Scott, M.,

2004. Guidelines for Sustainable Harvesting of Selected Indigenous Plant Species in the Cape Floristic Region. In SAPPEX, Cape Flora, Cape Town.

Caswell, H., 1982. Life-history theory and the equilibrium status of populations. American Naturalist 120, 317-339.

Chan, K.Y., 2001. An overview of some tillage impacts on earthworm population abundance and diversity - implications for functioning in soils. Soil and Tillage Research 57, 179-191.

Chesson, P.L., Huntly, N., 1997. The roles of harsh and fluctuating conditions in the dynamics of ecological communities. American Naturalist 150, 519-553.

Chesson, P.L., Warner, R.R., 1981. Environmental variability promotes coexistence in lottery competitive-systems. American Naturalist 117, 923-943.

Cole, N.S., Lombard, A.T., Cowling, R.M., Euston-Brown, D., Richardson, D.M., Heijnis, C.E. (Eds.), 2000. Framework for a conservation plan for the Agulhas Plain, Cape Floristic Region, South Africa. IPC Report 00/01. Institute for Plant Conservation, University of Cape Town.

Connell, J.H., 1978. Diversity in tropical rain forests and coral reefs - high diversity of trees and corals is maintained only in a non-equilibrium state. Science 199, 1302-1310.

Connell, J.H., Slatyer, R.O., 1977. Mechanisms of succession in natural communities and their role in community stability and organization. American Naturalist 111, 1119-1144.

Conradie, B., 2009. Boerdery en bewaring in die Strandveld. Available at: www.flowervalley.org.za Accessed on: 09/02/2010.

Conradie, B., Knoesen, H., 2009. A survey of the cultivation and wild harvesting of fynbos flowers in South Africa. Available at: http://www.flowervalley.org.za Accessed on: 17/05/2010.

Cowling, R.M., 1987. Fire and its role in coexistence and speciation in Gondwanan shrublands. South African Journal of Science 83, 106-111.

Cowling, R.M., 1989. The Research Perspective: Veld Resources. In: Greyling, T., Davis, G.W. (Eds.), The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes: Occasional Report No. 40. Foundation for Research Development, CSIR, PO Box 395, Pretoria. pp. 14-16.

Cowling, R.M., 1990. Diversity components in a species-rich area of the Cape Floristic Region. Journal of Vegetation Science 1, 699-710.

Cowling, R.M., 1992. The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town.

Cowling, R.M., Campbell, B.M., Mustart, P.J., McDonald, D.J., Jarman, M.L., Moll, E.J., 1988. Vegetation classification in a floristically complex area: the Agulhas Plain. South African Journal of Botany 54, 290-300.

Cowling, R.M., Gxaba, T., 1990. Effects of a fynbos overstorey shrub on understorey community structure: implications for the maintenance of community wide species richness. South African Journal of Ecology 1, 1-7.

Cowling, R.M., Holmes, P.M., 1992. Endemism and speciation in a lowland flora from the Cape Floristic Region. Biological Journal of the Linnean Society 47, 367-383.

Cowling, R.M., Holmes, P.M., Rebelo, A.G., 1992. Plant diversity and endemism. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 62-112.

Cowling, R.M., Knight, A.T., Privett, S.D.J., Sharma, G., 2010. Invest in opportunity, not inventory of hotspots. Conservation Biology 24**,** 633-635.

Cowling, R.M., Mustart, P.J., 1994. Vegetation and conservation. Volume 2. Appendix 5. Southern Overberg sub-regional structure plan. MLH Architects and Planners, Cape Town.

Cowling, R.M., Pierce, S.M., 1988. Secondary succession in coastal dune fynbos: variation due to site and disturbance. Vegetatio 76, 131-139.

Cowling, R.M., Proches, S., Partridge, T.C., 2009. Explaining the uniqueness of the Cape flora: incorporating geomorphic evolution as a factor for explaining its diversification. Molecular Phylogenetics and Evolution 51, 64-74.

Cowling, R.M., Richardson, D.M., 1995. Fynbos: South Africa's unique floral kingdom. Fernwood Press, Cape Town.

Davis, G.W., 1989. Introduction. In: Greyling, T., Davis, G.W. (Eds.), The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes: Occasional Report No. 40. Foundation for Research Development, CSIR, PO Box 395, Pretoria. pp. 1-9.

Davis, G.W., 1990. Commercial wildflower production in the fynbos biome and its role in the management of land-use. PhD Thesis, Department of Botany, University of Cape Town.

Davis, G.W., 1992. Commercial exploitation of natural vegetation: an exploratory model for management of the wildflower industry in the fynbos biome of the Cape, South Africa. Journal of Environmental Management 35, 13-29.

Deacon, J., 1984. Later Stone Age people and their descendants in southern Africa. In: Klein, R. (Ed.), Southern African Prehistory and Paleaoenvironments. pp. 231-238.

Deacon, H.J., Deacon, J., 1999. Human beginnings in South Africa: uncovering the secrets of the Stone Age. David Philip Publishers, Cape Town.

Elphick, R., 1985. Khoikhoi and the founding of white South Africa. Ravan Press, Johannesburg.

Esler, K.J., Cowling, R.M., Witkowski, E.T.F., Mustart, P.J., 1989. Reproductive traits and accumulation of nitrogen and phosphorus during the development of fruits of *Protea compacta* (Calcifuge) and *Protea obtusifolia* (Calcicole). New Phytologist 112, 109-115.

FVCT., 2008. Flower Valley Conservation Trust. Annual Report 2008/2009. Available at: www.flowervalley.co.za Accessed on: 16/07/2010.

Goldblatt, P., Manning, J., 2000. Cape Plants: A Conspectus of the Cape Flora of South Africa. Strelitzia 9. National Botanical Institute, Cape Town. (Missouri Botanical Garden).

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

Greyling, T., Davis, G.W. (Eds.), 1989. The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes. Occasional Report No. 40. Foundation for Research Development, CSIR, PO Box 395, Pretoria.

Grime, J.P., 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. American Naturalist 111, 1169-1194.

Grubb, P.J., 1977. Maintenance of species-richness in plant communities - importance of regeneration niche. Biological Reviews of the Cambridge Philosophical Society 52, 107-145.

Hagan, J.M., Whitman, A.A., 2006. Biodiversity indicators for sustainable forestry: simplifying complexity. Journal of Forestry 104, 203-210.

Hall, M., 1993. The archaeology of colonial settlement in southern Africa. Annual Review of Anthropology 22, 177-200.

Hanks, J., 2007. Talking of nature. Africa Geographic, February Issue. Available at: www.africageographic.com Accessed on: 17/05/2010.

Heelemann, S., Proches, S., Rebelo, A.G., Van Wilgen, B.W., Porembski, S., Cowling, R.M., 2008. Fire season effects on the recruitment of non-sprouting serotinous Proteaceae in the eastern (bimodal rainfall) fynbos biome, South Africa. Austral Ecology 33**,** 119-127.

Heydenrych, B.J., 1999. An investigation of land-use practices on the Agulhas Plain (South Africa), with emphasis on socio-economic and conservation issues. MSc Thesis, Institute for Plant Conservation, University of Cape Town.

Heywood, V., 2003. Conservation and sustainable use of wild species as sources of new ornamentals. Acta Horticulturae 598, 43-53.

Holling, C.S., 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4, 1-23.

Huston, M. A., 1979. A general hypothesis of species diversity. American Naturalist 113, 81-101.

Huston, M.A., 1999. Local processes and regional patterns: appropriate scales for understanding variation in the diversity of plants and animals. Oikos 86, 393-401.

Joubert, L., Esler, K.J., Privett, S.D.J., 2009. The effect of ploughing and augmenting natural vegetation with commercial fynbos species on the biodiversity of Overberg Sandstone fynbos on the Agulhas Plain, South Africa. South African Journal of Botany 75, 526-531.

Kladivko, E.J., 2001. Tillage systems and soil ecology. Soil and Tillage Research 61, 61-76.

Kraaij, T., Hanekom, N., Russell, I.A., Randall, R.M., 2009. Agulhas National Park – State of Knowledge. South African National Parks.

Kruger, F.J., 1983. Plant community diversity and dynamics in relation to fire. In: Kruger, F.J., Mitchell, D.T., Jarvis, J.U.M. (Eds.), Mediterranean-type ecosystems: the role of nutrients. Springer-Verlag, Berlin, Germany. pp. 446-472.

Kruger, F.J., 1987. Succession after fire in selected fynbos communities of the southwestern Cape. PhD Thesis, University of the Witwatersrand.

Lamont, B.B., Le Maitre, D.C., Cowling, R.M., Enright, N.J., 1991. Canopy seed storage in woody-plants. Botanical Review 57, 277-317.

Laubscher, C.P., Ndakidemi, B.A., 2009. A survey of farm-level practices on endangered Leucadendron species and the future influence of ecotourism development on the Agulhas Plain. African Journal of Agricultural Research 4, 1455-1463.

Laubscher, C.P., Ndakidemi, P.A., Bayat, M.S., Slabbert, A., 2009. Conservation and propagation of endangered Proteaceae on the Agulhas Plain for sustainable ecotourism development. Scientific Research and Essay 4, 374-380.

Lavorel, S., 1999. Ecological diversity and resilience of Mediterranean vegetation to disturbance. Diversity and Distributions 5, 3-13.

Le Maitre, D.C., 1988. Effects of season of burn on the regeneration of two Proteaceae with soil-stored seed. South African Journal of Botany 54, 575-580.

Le Maitre, D.C., Midgley, J.J., 1992. Plant reproductive ecology. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 135-174.

Levassor, C., Ortega, M., Peco, B., 1990. Seed bank dynamics of Mediterranean pastures subjected to mechanical disturbance. Journal of Vegetation Science 1, 339-344.

Linder, H.P., 2003. The radiation of the Cape flora, southern Africa. Biological Reviews 78, 597-638.

Lombard, A.T., Cowling, R.M., Pressey, R.L., Mustart, P.J., 1997. Reserve selection in a species-rich and fragmented landscape on the Agulhas Plain, South Africa. Conservation Biology 11, 1101-1116.

Manders, P.T., 1989. Chapter 4: The Conservation Perspective. In: Greyling, T., Davis, G.W. (Eds.), The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes Occasional Report No. 40. Foundation for Research Development, CSIR, PO Box 395, Pretoria. pp. 20-24.

Maze, K.E., Bond, W.J., 1996. Are Protea populations seed limited? Implications for wildflower harvesting in Cape fynbos. Australian Journal of Ecology 21, 96-105.

Mergili, M., Privett, S.D.J., 2008. Vegetation and vegetation-environment relationships at Grootbos Nature Reserve, Western Cape, South Africa. Bothalia 38, 89-102.

Middelmann, W.J., Gibson, G., Bell, I., 1989. Chapter 2: The Commercial Perspective. In: Greyling, T., Davis, G.W. (Eds.), The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes Occasional Report No. 40. Foundation for Research Development, CSIR, PO Box 395, Pretoria. pp. 10-13.

Midgley, J.J., 1989. Season of burn of serotinous Proteaceae: a critical review and further data. South African Journal of Botany 55, 165-170.

Midgley, J.J., 1996. Why the world's vegetation is not totally dominated by resprouting plants; because resprouters are shorter than reseeders. Ecography 19, 92-95.

MLH Architects and Planners, 1994. Southern Overberg Sub-Regional Structure Plan, MLH, Contract No., CR991114, MLH, Cape Town.

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

Mustart, P.J., Cowling, R.M., undated. Fynbos ecology for wildflower harvesters. Unpublished document. Department of Botany, University of Cape Town.

Mustart, P.J., Cowling, R.M., 1991. Seed-germination of four serotinous Agulhas Plain Proteaceae. South African Journal of Botany 57, 310-313.

Mustart, P.J., Cowling, R.M., 1992. Impact of flower and cone harvesting on seed banks and seed set of serotinous Agulhas-Proteaceae. South African Journal of Botany 58, 337-342.

Myers, N., 1990. The biodiversity challenge: expanded hot-spots analysis. Environmentalist 10, 243-256.

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

Pence, G.Q.K., Botha, M.A., Turpie, J.K., 2003. Evaluating combinations of on- and off-reserve conservation strategies for the Agulhas Plain, South Africa: a financial perspective. Biological Conservation 112, 253-272.

Pickett, S.T.A., Parker, K.R., 1994. Avoiding the old pitfalls: opportunities in a new discipline. Restoration Ecology 2, 75-79.

Pickett, S.T.A., White, P.S., 1985. The ecology of natural disturbance and patch dynamics. Academic Press, London.

Pimm, S.L., Russell, G.J., Gittleman, J.L., Brooks, T.L., 1995. The future of biodiversity. Science 269, 347-350.

Platt, W.J., Connell, J.H., 2003. Natural disturbances and directional replacement of species. Ecological Monographs 73, 507-522.

Privett, S.D.J., Cowling, R.M., Taylor, H.C., 2001. Thirty years of change in the fynbos vegetation of the Cape of Good Hope Nature Reserve, South Africa. Bothalia 31, 99-115.

Privett, S.D.J., Heydenrych, B.J., Cowling, R.M., 2002. Putting Biodiversity to Business on the Agulhas Plain. In: Pierce, S.M., Cowling, R.M., Sandwith, K., MacKinnon, K. (Eds.), Mainstreaming Biodiversity in Development. The World Bank Environment Department. pp. 101-111.

Prose, D.V., Metzger, S.K., Wilshire, H.G., 1987. Effects of substrate disturbance on secondary plant succession; Mojave Desert, California. Journal of Applied Ecology 24, 305-313.

Rabe, W., 2009. Personal communication. Flower Valley Conservation Trust.

Raimondo, D., von Staden, L., Foden, W., Victor, J.E., Helme, N.E., Turner, R.C., Kamundi, D.A., Manyama, P.A., 2009. Red List of South African Plants 2009. Strelitzia 25, South African National Biodiversity Institute, Pretoria.

Richards, M.B., Cowling, R.M., Stock, W.D., 1997. Soil factors and competition as determinants of the distribution of six fynbos Proteaceae species. Oikos 79, 394-406.

Robinson, J.G., 2006. Conservation biology and real-world conservation. Conservation Biology 20, 658-669.

Rouget, M., 2003. Measuring conservation value at fine and broad scales: implications for a diverse and fragmented region, Agulhas Plain. Biological Conservation 112, 217-232.

Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., Wall, D.H., 2000. Biodiversity - global biodiversity scenarios for the year 2100. Science 287, 1770-1774.

SAPPEX. 2006. South African Protea Producers and Exporters Association. An overview of the South African fynbos and Protea industry. Unpublished document.

Shmida, A., Ellner, S., 1984. Coexistence of plant species with similar niches. Vegetatio 58, 29-55.

Sousa, W.P., 1984. The role of disturbance in natural communities. Annual Review of Ecology and Systematics 15, 353-391.

Thuiller, W., Slingsby, J.A., Privett, S.D.J., Cowling, R.M., 2007. Stochastic species turnover and stable coexistence in a species-rich, fire-prone plant community. Public Library of Science One 2, e938. doi:10.1371.

Thwaites, R.N., Cowling, R.M., 1988. Soil-vegetation relationships on the Agulhas Plain, South Africa. Catena 15, 333-345.

Turpie, J., Heydenrych, B.J., Hassan, R., 2002. Fynbos: a preliminary assessment of its status and economic value. In: Hassan, R. (Ed.), Accounting for stock and flow values of woody land resources. Centre for Environmental Economics and Policy in Africa, University of Pretoria. pp. 73-115.

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, 233-251.

Underwood, E.C., Viers, J.H., Klausmeyer, K.R., Cox, R.L., Shaw, M.R., 2009. Threats and biodiversity in the mediterranean biome. Diversity and Distributions 15, 188-197.

UNDP., 2003. United Nations Development Programme. Agulhas Biodiversity Initiative. Global Environmental Facility Project document: Cape Action Plan for the Environment.

Van Wilgen, B.W., Bond, W.J., Richardson, D.M., 1992. Ecosystem management. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 345-371.

Van Wilgen, B.W., Forsyth, G.G., de Klerk, H., Das, S., Khuluse, S., Schmitz, P., 2010. Fire management in Mediterranean-climate shrublands: a case study from the Cape fynbos, South Africa. Journal of Applied Ecology 47, 631-638.

Van Wilgen, B.W., Kruger, F.J., 1981. Observations on the effects of fire in mountain fynbos at Zachariashoek, Paarl. Journal of South African Botany 47, 195-212.

Van Wilgen, B.W., Richardson, D.M., Seydack, A.H.W., 1994. Managing fynbos for biodiversity: constraints and options in a fire-prone environment. South African Journal of Science 90, 322-329.

Van Wilgen, B.W., Viviers, M., 1985. The effects of season of fire on serotinous Proteaceae in the Western Cape and the implications for fynbos management. South African Forestry Journal 133, 49-53.

Vlok, J.H.J., 1996. The role of overstorey proteoid shrubs in maintaining species richness in a southern Cape mountain fynbos community, MSc Thesis, Department of Botany, University of Natal.

Vlok, J.H.J., Yeaton, R.I., 1999. The effect of overstorey proteas on plant species richness in South African mountain fynbos. Diversity and Distributions 5, 213-222.

Vlok, J.H.J., Yeaton, R.I., 2000a. The effect of short fire cycles on the cover and density of understorey sprouting species in South African Mountain Fynbos. Diversity and Distributions 6, 233-242.

Vlok, J.H.J., Yeaton, R.I., 2000b. Competitive interactions between overstorey proteas and sprouting understorey species in South African mountain fynbos. Diversity and Distributions 6, 273-281.

Von Hase, A., Rouget, M., Cowling, R.M., 2010. Evaluating private land conservation in the Cape lowlands, South Africa. Conservation Biology 24, 1182-1189.

Wilcove, D.S., Rothstein, D., Dubow, J., Phillips, A., Losos, E., 1998. Quantifying threats to imperiled species in the United States. Bioscience 48, 607-615.

Winter, S.J., Prozesky, H., Esler, K.J., 2007. A case study of landholder attitudes and behaviour toward the conservation of renosterveld, a critically endangered vegetation type in Cape Floral Kingdom, South Africa. Environmental Management 40, 46-61.

Yamulki, S., Jarvis, S.C., 2002. Short-term effects of tillage and compaction on nitrous oxide, nitric oxide, nitrogen dioxide, methane and carbon dioxide fluxes from grassland. Biology and Fertility of Soils 36, 224-231.

Yeaton, R.I., Bond, W.J., 1991. Competition between two shrub species: dispersal differences and fire promote coexistence. The American Naturalist 138, 328-341.

CHAPTER 2:

Determining extent of wildflower farming practices and landholder opinion about farming practices (Agulhas Plain, South Africa)

Abstract

The Agulhas Plain is an area of exceptional biodiversity and is currently threatened by a number of (mostly) anthropogenic activities. Fynbos wildflower farming is widely practiced, as a land use, and covers a large surface area on the Agulhas Plain. Wildflower farming is seen as potential threat to fynbos conservation but is simultaneously regarded as an opportunity for biodiversity conservation. This contradiction can partly be solved by the role private landholders play in conserving pristine fynbos managed as intact wildflower populations. Using results of a questionnaire, this chapter reports on farming practices used in wildflower farming from natural vegetation and probes landholders' opinion about the impact of such practices on fynbos diversity. Results reveal that farming practices are diversified and dynamic. Farming practices are applied to certain management areas, in specific seasons and are mostly small in spatial scale. Twenty different wildflower farming practices were identified including those commonly recognised. Most landholders believe that farming practices increase wildflower production and responses reflected knowledge of fynbos supported by current ecological understanding. Landholders acknowledge that fynbos diversity is integral for wildflower farming and landholders perceive themselves to be custodians of fynbos in the study area. Overall, landholders' perceptions seem fairly positive in terms of fynbos conservation, but results of the survey point towards the conflicting objectives of commerce and conservation in the wildflower industry.

Keywords: fynbos management, private land conservation, plant diversity, disturbance

1. Introduction

Mediterranean regions across the globe are severely threatened by pressures caused by human activities (Myers et al., 2000; Underwood et al., 2009). The Agulhas Plain (2160 km^2), a significant constituent of the Cape Floristic Region (a biodiversity hotspot (Myers, 1990; Myers et al., 2000)), is in a similar situation (Myers, 1990; Lombard et al., 1997; Cole et al., 2000). Fynbos wildflower farming as a land use covers the second largest surface area (after cereal/cropping) in a survey conducted on the Agulhas Plain (Heydenrych, 1999) and has already caused transformation of diverse habitats (Lombard et al., 1997). Wildflower farmers on the Agulhas Plain widely utilise fynbos products derived from natural vegetation on private property (Heydenrych, 1999; Privett et al., 2002). In this component of wildflower farming, i.e. excluding farming from cultivated plantations, landholders implement farming practices in an attempt to increase the abundance of focal flower species (i.e. those demanded from the market) (Carinus et al., 2004; Heydenrych, 1999). Certain wildflower farming practices have shown to negatively impact on fynbos diversity (Joubert et al., 2009; Davis, 1990) and as such wildflower farming has been acknowledged to pose a threat to the conservation of the region's floral diversity (Manders, 1989; Cowling and Richardson, 1995). At the same time, however, wildflower farming is described as a land-use practice that can be conservation compatible (Sekhran and Richardson, 2008).

The flora of the Agulhas Plain has long been associated with exceptional species richness and diversity (Cowling et al., 1988; Thwaites and Cowling, 1988; Cowling and Holmes, 1992; Privett et al., 2002; Raimondo et al., 2009); and is recognised as a 'centre of endemism' (Cowling and Holmes, 1992). Despite this botanical significance, approximately 40% of natural vegetation on the Agulhas Plain has been transformed; mainly due to agricultural practices and alien plant invasions (Lombard et al., 1997; Cole et al., 2000; Privett et al., 2002). Alarmingly, only a small percentage (4%) of the Agulhas Plain is protected in "reserve status" (Pence et al., 2003). However, since the establishment of conservation initiatives and involvement of landholders in conservation agreements and stewardship programmes, a substantial 37% (102 000 ha) of the Agulhas Plain is currently protected (Hanks, 2007). It has been acknowledged that the success of any effort to conserve rare and threatened habitats is dependent on landholder involvement (Botha, 2001). Since 95% of land on the Agulhas Plain is privately owned (Lombard et al., 1997) this investigation argues that private landholders can contribute significantly to the long term conservation of biota in the study area by sustainably managing intact wildflower populations. Internationally (Margules and Pressey, 2000; Norton, 2000; Millar, 2001) and locally (Botha, 2001; Privett et al., 2002;

Winter et al., 2007) the contribution private land can make towards conservation has been addressed, acknowledged and investigated (Bean and Wilcove, 1997).

In context of the Agulhas Plain, the Flower Valley Conservation Trust (FVCT) has emerged as a recognised stakeholder working in collaboration with reputable conservation partners like the Agulhas Biodiversity Initiative (an umbrella project coordinated by Cape Action for People and the Environment (CAPE)). FVCT is concerned with the conservation of natural resources, social empowerment and environmental education activities (FVCT, 2008) and is affiliated with this investigation. The existence of conservation initiatives (also acknowledging others) on the Agulhas Plain, in the simplest sense, agrees with Margules and Pressey (2000) that conservation goals can no longer be achieved by focusing on reserves alone (Bean and Wilcove, 1997; Botha, 2001; Hilty and Merenlender, 2003). Furthermore, the need to extend conservation research into other disciplines for example the social sciences has been emphasised as urgent (Ehrenfeld, 1987; Mascia et al., 2003; Robinson, 2006; Saunders et al., 2006). Beedell and Rehman (1999) point out that the survival of what remains as semi-natural remnants in fragmented, lowland agricultural areas (like the Agulhas Plain) inherently depend on individual farmer characteristics. Importantly, conservation goals must be guided by questions that investigate the relationships between humans and nature, as biodiversity data alone will not be sufficient to resolve environmental issues (Knight et al., 2006; Saunders et al., 2006; Cowling et al., 2010).

Wildflower farming, a natural resource based enterprise, is a sector where cohesion amongst conservation, research and commerce has been stressed and is critical in ensuring a sustainable trade (Davis, 1989). Acknowledging a previous survey of wildflower farmers and cultivators by Heydenrych (1999), the “farming” division of the wildflower industry remains poorly researched. Recently, however, more research has focused specifically on the economics of this component of the wildflower industry on the Agulhas Plain (Conradie and Knoesen, 2009; Conradie et al., 2010). However, little is known about fynbos management practices used in wildflower farming (Davis, 1990; Heydenrych, 1999; Joubert et al., 2009). The general understanding is that landholders apply burning, ploughing and broadcast sowing on wildflower management units. However, in many cases only one or two of these practices are applied and it is possible that other unknown farming practices can also be implemented (Privett pers. com.). Finally, no study associated with wildflower farming has involved any consultation from private landholders to aid in understanding and reasoning behind preferred fynbos management practices.

Acknowledging the above, this chapter tackles two fundamental research questions in an attempt to elucidate aspects related to fynbos wildflower farming on the Agulhas Plain. Firstly, which fynbos farming practices are most widely implemented in wildflower farming? This question is restricted to the use of natural populations alone. Additionally, it would be important to explore if the application of these farming practices can be traced to general management understanding (e.g. prescribed burning recommendations) of fynbos. Secondly, the opinion of landholders with respect to the impact of implemented farming practices on the diversity of fynbos was investigated and landholders were asked about their knowledge and opinion of fynbos management and conservation.

2. Methods

2.1 *Study area*

The study area is situated on the Agulhas Plain in the Western Cape Province (South Africa); covering agricultural areas east of Gansbaai and west of Bredasdorp and including smaller towns (Baardskeerdersbos, Elim and Napier). The Agulhas Plain is a lowland region, consisting of a mosaic of vegetation types, with Overberg Sandstone Fynbos being the predominant vegetation unit (*sensu* Mucina and Rutherford, 2006). This vegetation type is most widely used for wildflower farming (Heydenrych, 1999). Results are however not confined to this vegetation type as it was impossible to restrict the sample selection to this criterion.

2.2 *Sample selection and approach*

The study sample was drawn from membership lists of commercial farmer associations, tenant lists and other additional sources in the region (supplied by Flower Valley Conservation Trust). These sources provided names and contact details of both landowners and landholders in the study area, of which 75 participated in the survey. Importantly, (both) landowners and landholders were selected to partake in the survey. The reasoning for this is that often a landowner was unreachable, as he/she is resident elsewhere, and it was decided that a landholder (i.e. farm manager or property lessee) would be appropriate to interview (see Conradie et al., 2010 for full sampling protocol and data collection). Collectively, landowners and landholders are merely referred to as ‘landholders’ throughout this chapter.

This study was part of a broader land-use survey and, as such, it is beyond the scope of this paper to present the complete survey results (see Conradie, 2009 and Conradie et al., 2010 for more). A subsection of the results from an ecological component of the survey relevant to objectives of this study; i.e. fynbos wildflower farming (N = 44 fynbos wildflower farmers), is presented here[16]. A 'landholder' and a 'fynbos wildflower farmer' are considered synonymous in this study based on the selection criteria used to identify the fynbos wildflower farmers from the larger sample. A criterion used to identify a fynbos wildflower farmer was "percentage (%) income received from wildflower harvesting and farming"; ranging between 1 – 100%. Additionally, a landholder was asked if any area of land on his/her farm serves in the purpose of wildflower farming from, specifically, natural vegetation. Therefore this investigation focused exclusively on wildflower landholders deriving any percentage of income from natural vegetation; i.e. excluding the farmer using cultivated fynbos plantations.

2.3 *Research and questionnaire design*

The questionnaire (Appendix 1) consisted of a combination of open-ended and closed (structured) questions (*sensu* Babbie and Mouton, 2001). In some cases open-ended questions were provided after a closed question to elucidate details on a certain issue. Pilot surveys were conducted to ensure that the questionnaire was structured appropriately and would yield relevant information. The information from pilot surveys was included in the results section to increase sample size, as this section remained unchanged after the pilot study. Additionally, the content of the questionnaire was subject to review by experts in academic organisations. Prior to the interview all interviewees were briefly informed about the aims and objectives of the questionnaire and that a component of the results will be used for a Masters thesis at Stellenbosch University. The participants were assured that all responses would be treated with discretion and that their privacy would be respected in all reports and publications.

The questionnaire consisted of three sets of items that aimed to establish the following information from each participant;

- The farming practices applied in wildflower farming (also termed 'disturbance history' in this chapter) on the property;
- A landholder's knowledge of ecologically important fynbos traits;

[16] Content of questions from the 'ecological subsection' were structured and designed by M. Treurnicht in April 2009 to be included into the broader land use questionnaire (courtesy Dr. B. Conradie)

- The opinion of landholders on the impacts of farming practices on fynbos and conservation in the context of wildflower farming.

The aim of the first section of the questionnaire was to determine management methods applied to wildflower vegetation on private property. Landholders were asked which farming practices (controlled burning, ploughing and/or broadcast sowing) are applied to wildflower vegetation before enquiring about detailed aspects related to such practices. For practical reasons the questionnaire limited the number of farming events for each type of implemented farming practice to the three most recent events. It was important to distinguish between shallow- and deep ploughing, i.e. non-inversion and conventional ploughing, (*sensu* Joubert et al., 2009) which was accommodated by the questionnaire. Detailed information such as year, season and size (ha) of a particular farming practice was recorded. If a landholder was planning to implement a certain farming practice in the year after the survey (2010) this was also recorded. This was done because related farming practices (used in combination) frequently do not happen in the same year but rather over a period of two or three years. These responses allowed for generalisation of farming practices (for example season of application, size of disturbance) and identification of particular combinations of farming practices used on the same area. If two (or more) particular types of disturbances were reported for the same year and for the same spatial extent (ha) it was assumed they were applied in sequence, thus qualifying as a 'combination' wildflower farming practice.

The second part of the questionnaire focused on the landholders' perceptions of changes in wildflower vegetation associated with wildflower management. Landholders were asked about appropriate burning intervals for fynbos, and if they were aware of rare/threatened fynbos species on the property. This was included to provide an overview of farmers' knowledge about fynbos ecology. The final section consisted entirely of Likert statements. The five-point Likert scale is useful as, "A systematic scaling technique to transform attitudinal responses to survey questions into quantitative measures" (Falconer, 2000). Although this study is not concerned with quantifying landholder attitude, Likert statements remain a useful tool to investigate landholders' opinion for the purposes of this research. The first ten statements aimed to investigate farmers' perceptions of the potential impact of individual methods on aspects of fynbos diversity. The content of the statements was based on information extracted from Heydenrych (1999) and Davis (1990) who investigated different aspects of wildflower farming. The last four statements enquired about general fynbos conservation in the specific context of wildflower farming.

2.4 *Data analysis*

Microsoft Excel (2007) was used to analyse data. Descriptive analysis was conducted with data (quantitative and qualitative) collected during the interviews.

3. Results

3.1 *Farming practices applied in wildflower farming – "disturbance history"*

From the survey sample (N = 44) a total of 40 landholders acknowledged to 'actively manage' the wildflower vegetation on their property. Four landholders "do nothing" to their wildflower vegetation, apart from harvesting activities. 'Active management' was defined as any method a farmer intentionally implements in an attempt to increase wildflower production. This meant that only natural burning is considered to be 'non-active management'. Results refer specifically to this (N = 40) group of landholders i.e. the "active wildflower farmers".

3.1.1 *Controlled burning*

Controlled burning was applied by 65% of the landholders (26 landholders) (Table 2.1). A total of 41 controlled burning events were reported amongst the 26 landholders (Table 2.2). Controlled burns were mostly performed in autumn (56%), 27% were performed in winter and 7% in summer. Some of the landholders (10%) were unable to report on the season of burn (i.e. "don't know"). Regarding the size of controlled burning activities, most burns (46%) were categorised as being <10 ha while an equal amount (46%) was dispersed in larger (>10 ha) spatial extent categories (Table 2.3).

3.1.2 *Ploughing*

Fifty eight percent of the survey (23 landholders) reported to have used ploughing in wildflower farming (Table 2.1). A total of 39 ploughing events were reported amongst the 23 landholders. Shallow ploughing constituted 28 (72%) of the ploughing events recorded, whereas deep ploughing only accounted for six of the events (15%). In five cases landholders were unable to specify the type of ploughing (shallow or deep) implemented, i.e. 'don't know' (12%).

In terms of ploughing seasonality, shallow ploughing was mostly implemented in autumn (54%), with 32% of the events applied in winter and 7% in summer (Table 2.2). Concerning size of the ploughing events, most (61%) of the events were categorised as < 10 ha and the remaining events (39%) corresponded with larger (> 10 ha) spatial extent categories (Table 2.3). The method of deep ploughing was implemented in both autumn (3 events) and winter (3 events). The size of deep ploughing events ranged from 1 ha to 30 ha in size. One landholder was unable to specify the size of a deep ploughing event. Deep ploughing events are not included in Table 2.2 or 2.3 as observations were too few to allow for generalisations.

3.1.3 *Broadcast sowing*

Broadcast sowing was the most widely used method in wildflower farming with 83% of landholders (33 landholders) acknowledging to have implemented this method. A total of 49 broadcast sowing events were recorded throughout the survey. This farming practice is mostly (43%) implemented in autumn, with a slightly lower occurrence (39%) in winter. A small number of the events (2%) are implemented in summer (Table 2.2). Size categories of the broadcast sown events mostly corresponded with the < 10 ha category (69%) while the remaining 18% are larger (> 10 ha) in spatial extent (Table 2.3).

Table 2.1: Percentage (%) of landholders (N = 40) who applied a certain farming practice in wildflower farming on the Agulhas Plain (South Africa).

Farming practice	Yes (%)	No (%)
Controlled burning	65	35
Ploughing	58	43
Broadcast sowing	83	18

Table 2.2: Preferred season of applying three farming practices (controlled burning, ploughing and broadcast sowing) reported by landholders (N = 40) used in wildflower farming on the Agulhas Plain. Values for each seasonal category are expressed as percentage (%) of events recorded for each farming practice in the survey.

		Treatment		
		Controlled burning	Ploughing	Broadcast sowing
Season	Autumn	56	54	43
	Winter	27	32	39
	Summer	7	7	2
	Spring	0	0	0
	Don't know	10	7	16

* Ploughing refers to shallow ploughing events only.

Table 2.3: Preferred size categories (spatial extent, hectares) of applying three farming practices (controlled burning, ploughing and broadcast sowing) reported by landholders (N = 40) used in wildflower farming on the Agulhas Plain (South Africa). Values for each size category are expressed as percentage (%) of events recorded for each farming practice in the survey.

		Treatment		
		Controlled burning	Ploughing	Broadcast sowing
Size	<10 ha	46	61	69
	10-20 ha	7	4	4
	20-50 ha	22	11	4
	50-100 ha	10	14	4
	>100 ha	7	11	6
	Don't know	7	0	12

* Ploughing refers to shallow ploughing events only.

Landholders identified 11 fynbos species widely used in an attempt to increase wildflower production by broadcast sowing (Table 2.4). Landholders reported that their own farms are mostly (36%) the 'source' of seed collection. Other sources included in the responses were; 'neighbouring farm' (9%), 'local and regional' (12%), 'regional only' (21%), 'other' (6%). In some cases (15%) landholders were unable to provide a specific 'source of origin' for seeds used in broadcast sowing (i.e. "don't know" responses).

Table 2.4: Fynbos species identified from interviews (N = 40) that are widely used in broadcast sowing as a wildflower farming practice on the Agulhas Plain (South Africa). Frequency refers to the times mentioned in the survey (open-ended question).

	Scientific name	RED LIST STATUS (Raimondo et al., 2009)	Frequency
1	*Protea compacta* R. Br.	NEAR THREATENED	22
2	*Leucadendron platyspermum* R. Br.	VULNERABLE	19
3	*Leucadendron xanthoconus* (Kuntze) K. Schum.	LEAST CONCERN	7
4	*Brunia laevis* Thunb.	LEAST CONCERN	5
5	*Protea repens* (L.) L.	LEAST CONCERN	4
6	*Leucadendron coniferum* L. (Meisn.)	VULNERABLE	4
7	*Leucadendron salicifolium* (Salisb.) I. Williams	LEAST CONCERN	4
8	*Phaenocoma prolifera* (L.) D. Don	LEAST CONCERN	2
9	*Protea cordata* Thunb.	LEAST CONCERN	1
10	Ericaceae (various)		1
11	*Staavia radiata* (L.) Dahl	LEAST CONCERN	1
12	*Aulax umbellata* (Thunb.) R. Br	NEAR THREATENED	1
13	Proteaceae (various)		1

3.1.4 Combinations of farming practices

A total of 20 different farming practices (used as combinations) were reported for wildflower farming (Table 2.5). Controlled burning (22%), controlled burning followed by broadcast sowing (14%), controlled burning followed by shallow ploughing and broadcast sowing (13%) and, shallow ploughing followed by broadcast sowing (11%) were the four most widely applied methods amongst wildflower landholders.

Table 2.5: Landholder responses pertaining to wildflower farming practices used on the Agulhas Plain (South Africa) as combination (N = 40). Frequency and percentage (%) values are expressed as 'times recorded' in the survey (open-ended question).

Management method (used as combination)	Frequency	%
1) Controlled burning	18	22
2) Controlled burning and broadcast sowing	12	14
3) Controlled burning and shallow ploughing and broadcast sowing	11	13
4) Shallow ploughing and broadcast sowing	9	11
5) Natural burning and broadcast sowing**	5	6
6) Broadcast sowing	5	6
7) Controlled burning and deep ploughing and broadcast sowing	3	4
8) Controlled burning and 'sleepyster'*	3	4
9) Deep ploughing and broadcast sowing	3	4
10) Shallow ploughing	2	2
11) Controlled burning and shallow ploughing	2	2
12) Natural burning and shallow ploughing and broadcast sowing**	2	2
13) Brushcutting and broadcast sowing	1	1
14) Brushcutting	1	1
15) Natural burning and shallow ploughing	1	1
16) Brushcutting and shallow ploughing	1	1
17) Natural burning and 'sleepyster'* and broadcast sowing	1	1
18) Controlled burning and deep ploughing	1	1
19) Brushcutting and broadcast sowing and controlled burning	1	1
20) Controlled burning and 'tyres'*	1	1

* 'Sleepyster' is an implement used in wildflower farming in an attempt to clear vegetation after burning. 'Tyres' (towed behind a tractor) are used for similar purposes in wildflower farming

** Should be interpreted as a landholder's management response to a natural fire event

3.2 *Landholder's knowledge of fynbos*

The majority of landholders (40%) reported that a 'good' fynbos burning interval varies between 12 and 15 years. Furthermore, 15% responded with a less detailed answer of "more than 10 years" but did not specify the exact frequency. The remaining respondents (36%) responded with "less than 10 years" and the further remaining landholders (10%) did not provide an answer, i.e. "no response". Landholders strongly perceived that the method(s) applied to wildflower vegetation increased wildflower production as 63% responded in the affirmative to this question. Almost half of the landholders (19 landholders; 48%) are of the opinion that so-called 'rare/threatened' plant species could be found on the properties. A very small number of landholders (4 landholders; 10%) stated that 'rare/threatened' plant species did not exist on their properties and a large proportion of the landholders (16 landholders; 40%) indicated a "don't know" response (Table 2.6).

Table 2.6: Landholder responses (N = 40) from three questions relating to (1) fynbos burning intervals, (2) subsequent changes in wildflower vegetation and (3) the occurrence of 'rare' species on the property, Agulhas Plain (South Africa).

Question	Response categories				
(1) *In your opinion, how often must fynbos burn (in years)*?	*12-15*	*> 10*	*8-10*	*< 8*	*No response*
(%)	40	15	13	23	10
(2) *Do you think applied methods increased wildflower production?*	*Yes*		*No*	*Don't know*	*No response*
(%)	63		18	8	13
(3) *Do you know if there are 'rare/threatened' species on the property?*	*Yes*		*No ('none')*	*Don't know*	*No response*
(%)	48		10	40	3

3.3 *Landholder opinion: impact of farming practices and fynbos conservation*

The 14 Likert statements included in the questionnaire yielded interesting results (summarised in Table 2.7). Three of the so-called ‘active wildflower landholders’ did not complete this section (N = 37). In two of the statements (statement nr. 4 and nr. 13) some landholders did not respond (N = 36).

Regarding fire, the largest proportion (49%) of landholders disagreed that “fire has no influence on fynbos diversity”.

More than half of the landholders (54%) disagreed that fynbos vegetation aged approximately 4-5 years old must burn. Sixty two percent of the survey perceived that consecutive burns (i.e. in consecutive years) promote weedy species.

Seventy five percent of landholders were of the opinion that the method of ploughing has an influence on fynbos diversity. Ploughing is not considered to “stimulate new growth” in wildflower vegetation as 57% of landholders disagreed with the statement: “Ploughing regenerates vegetation (as it stimulates new growth)”. Eighty six percent of landholders perceived that some species will ‘disappear’ if ploughing is used consecutively (i.e. in consecutive years). Furthermore, 62% of the landholders agreed that the method of ploughing stimulates growth of weedy species and can affect so-called ‘rare’ fynbos species (49%).

Broadcast sowing is seen as a mechanism that ‘helps nature to perform’ as 65% of landholders agreed with this particular statement. Additionally, broadcast sowing is considered to be less damaging to fynbos as 73% of landholders disagreed that ‘rare’ species will be affected.

Seventy percent of landholders are of the opinion that wildflower material not useful for the industry has little value to him/her. A large number (68%) of the landholders agreed that fynbos diversity is important in wildflower farming. Most landholders (81%) disagreed that fynbos conservation is not compatible with wildflower farming. Almost all landholders (89%) consider themselves to be role players in fynbos conservation.

Table 2.7: Landholder responses (N = 37) pertaining to the impact of implemented farming practices on fynbos vegetation in the context of wildflower farming on the Agulhas Plain (South Africa).

Nr	Statement	Agree (%)	Neutral (%)	Disagree (%)
	FIRE			
1	Fire has no influence on fynbos diversity	38	14	49
2	Fynbos vegetation of 4-5 years old is ‘old veld’ and must be burnt	32	14	54
3	I observe more weedy species after consecutive burns	62	16	22
	PLOUGHING			
4	Ploughing has no influence on fynbos diversity	14	11	75
5	Ploughing regenerates vegetation (as it stimulates new growth)	27	16	57
6	Some species will ‘disappear’ after ploughing in two consecutive years	86	3	11
7	Ploughing vegetation stimulates the growth of weedy species	62	14	24
8	‘Rare’ fynbos species are even ‘more rare’ after ploughing vegetation	49	11	41
	BROADCAST SOWING			
9	By sowing in seed I am ‘helping nature to perform’	65	14	22
10	‘Rare’ fynbos species are even ‘more rare’ after broadcast sowing	22	5	73

* Three landholders did not complete this section; therefore N = 37; statement nr. 4 included one ‘no response’; therefore N = 36.

Table 2.7 (cont.): Landholder responses (N = 37) related to diversity and conservation of fynbos vegetation in the context of wildflower farming on the Agulhas Plain (South Africa).

Nr	Statement	Agree (%)	Neutral (%)	Disagree (%)
	DIVERSITY AND CONSERVATION IN WILDFLOWER FARMING			
11	Fynbos spp. that cannot be used in the flower industry has no value to me	70	8	22
12	Fynbos diversity is important for the success of my business/farm	68	14	19
13	Fynbos conservation is contradictory with my flower farming	11	8	81
14	I am a role player in the conservation of fynbos	89	5	5

* Three landholders did not complete this section; therefore N = 37

4. Discussion

This investigation focused explicitly on wildflower farming from natural vegetation on the Agulhas Plain. Forty four wildflower farmers were identified as opposed to 35 wildflower farmers by a previous investigation (Heydenrych, 1999). Of note, the current survey had 73% coverage (Conradie et al., 2010) compared to 57% coverage from Heydenrych's (1999) survey. Consequently it is likely that overlap exists with Heydenrych's land-use survey of the Agulhas Plain but this investigation identified some additional wildflower farmers. Considering that this investigation is representative of the region, the most apparent observation is that wildflower farming practices on the Agulhas Plain are numerous and dynamic. Landholders apply a variety of farming practices, varying in season and spatial extent. Landholder opinion generally corresponds with ecological knowledge and understanding of fynbos management. Most landholders perceive farming practices to impact on diversity and that repeated application will increase unwanted species and/or negatively impact on fynbos. Groupings in the data are apparent but arguably not convincing enough (as there is variation amongst responses) to allow generalisations. Overall, wildflower farmers on the Agulhas Plain seem to be a diverse group; not only in terms of the farming practices applied but also in their opinions about the impact of farming practices on fynbos.

With more specific reference to the 'disturbance history' the general trend is to apply farming practices that would, firstly, remove aboveground biomass and, secondly, increase the abundance of certain species (Carinus et al., 2004). This should be seen as a process rather than separate entities as, overall, this allows for 'rearrangement' in wildflower vegetation by manipulating successional stages in the vegetation (Van Wilgen et al., 1992). Additionally, to further increase abundance of a focal flower species (i.e. those demanded from the market) broadcast sowing is often applied (Carinus et al., 2004; Joubert et al., 2009). Broadcast sowing and controlled burning are the most commonly applied methods, with ploughing playing a slightly less important role. Farming practices can be implemented as single events but are more often used in combination with one another as also reported by Davis (1990) and Joubert et al. (2009). Not only is varying combinations of popular farming practices like broadcast sowing, burning and ploughing used in wildflower farming but other unfamiliar farming practices are also occasionally applied (see Table 2.4). These results correspond with what has previously been stated to be applied in wildflower farming (Davis, 1990; Heydenrych, 1999; Joubert et al., 2009) although there are apparent additions.

Ploughing is the least common farming practice used amongst landholders in wildflower farming. Of note, this investigation recorded only six deep ploughing events (section 3.1.2). The distinction between deep ploughing and shallow ploughing is important as previous research (Joubert et al., 2009) has shown that deep ploughing can be detrimental for fynbos diversity. This can suggest that the use of deep ploughing as a farming practice is less prevalent. Additionally, landholders on several occasions reported that deep ploughing is often used specifically and only used for purposes of clearing alien vegetation (personal observation). Deep ploughing is a time consuming and expensive exercise (Marais et al., 2004; Van Wilgen, 2009) and, thus due to financial expenses involved, could serve as an explanation for the low occurrence of deep ploughing events in this investigation.

The application of farming practices, more specifically controlled burning, that occur in autumn and summer corresponds with general management understanding (Van Wilgen et al., 1992; Van Wilgen, 2009). From the ‘evolution of fire management’ (*sensu* Van Wilgen, 2009) it is possible to extrapolate an understanding of the (potential) impact of, specifically, controlled burning on fynbos in the context of wildflower farming. Several studies recognize that burning in summer and autumn result in favourable recruitment of reseeding (serotinous) Proteaceae species (Bond, 1980; Bond et al., 1984; Van Wilgen and Viviers, 1985). Protea species serve as an ‘umbrella’ for fynbos plant recovery in the post-fire environment and as such has been thoroughly researched (Van Wilgen et al., 1992). Additionally, other species also show good recruitment after fires implemented during these seasons (Le Maitre, 1984) but landholders also prefer to implement farming practices in winter. Repeated burning outside the prescribed burning interval (i.e. late summer-early autumn) could result in local extinction of species (Bond et al., 1984) and hence should be avoided (Van Wilgen et al., 1992). Recently Van Wilgen (2009) emphasised that; “Current understanding of the role of fire in fynbos is relatively robust”. However, little research has investigated impact of other farming practices like ploughing and broadcast sowing. One can only assume that fire and ploughing could, in the simplest sense, be somewhat similar by removing aboveground biomass, acknowledging that the impact of ploughing extends far greater than that of fire or burning (Davis, 1990; Joubert et al., 2009).

Regarding spatial extent of farming practices, broadcast sowing and ploughing as augmentation methods are mostly applied to smaller areas (<10 ha). This can be explained by considering that these particular practices are more costly (in terms of equipment and fuel costs) than controlled burning. Broadcast sowing involves obtaining fynbos seeds that are not readily available as a commodity, and if available, are highly expensive. Alternatively, seeds can be obtained by intense harvesting from a landholder’s own property (Rabe pers. com.). These statements are supported from data as most landholders acknowledge harvesting seeds from their own property instead of purchasing it. Proteaceae and Ericaceae are plant families most popular in wildflower harvesting activities (Greyling and Davis, 1989; Heydenrych, 1999), thus explaining common use in purposes of augmenting wildflower vegetation by means of broadcast sowing. All eleven species have been recorded as harvestable wildflower products (Heydenrych, 1999), which confirms landholders' reasoning for augmenting vegetation with such species. Additionally, four of the species used in broadcast sowing (*P. compacta, L. platyspermum, L. coniferum, A. umbellata*) have a 'rarity status' (other than 'least concern') according to the Red List of South African Plants (Raimondo et al., 2009) and are therefore considered to be species of conservation priority.

Overall, landholders reflect opinions about fynbos ecology supported by general management understanding. Most landholders are of the opinion that a 'good' burning interval for fynbos is every 12 – 15 years. Such burning intervals (as minimum intervals) are seen as ecologically acceptable (Van Wilgen et al., 1992; Van Wilgen, 2009). On the other hand, fynbos burning intervals of less than six years are considered detrimental for serotinous plant species (Mustart and Cowling, undated; Kruger, 1983). Short interval burns (i.e. less than 10 years (see Van Wilgen et al., 1992 for a review)) have shown to increase the amount of resprouting species and reduce economically important Protea species for wildflower farmers (Mustart and Cowling, undated). With 35% of landholders responding with fynbos burning intervals of "less than 10 years" could indicate a potential concern, not only for conservation, but also specifically for the widlfower industry. For wildflower farming purposes a period of 15 – 20 years is recommended (Mustart and Cowling, undated). Landholders strongly perceive that farming practices increase wildflower production in the post-augmented environment. With so many landholders agreeing with this statement future application of farming practices will probably persist. Almost half of the landholders surveyed (48%) responded that so-called 'rare' plant species occur on the property and surrounding vegetation. Landholders also readily provided names in some cases, although most responses related to; "*Yes, there's lots – ask the experts!".* This suggests that landholders carry some awareness of the unique plant diversity known to occur on the Agulhas Plain (Cowling et al., 1988; Thwaites and Cowling, 1988; Cowling and Holmes, 1992; Privett et al., 2002; Raimondo et al., 2009).

From the opinion data, landholders perceive ploughing as being a more disruptive (for plant species) farming practice than fire (i.e. burning) or broadcast sowing. The majority of landholders are of the opinion that fire and ploughing certainly have an influence on fynbos diversity. To enquire about further details regarding these statements (asking "what type of influence?" or "what do you consider as components of diversity?") would have been interesting and would be worthwhile to explore in the future. As clarification, one needs to consider that a farmer's view of (bio) diversity can often be limited and may exclude important species. Therefore such questions are possibly interpreted on knowledge of wildlife alone and do not include all aspects of ecosystem diversity (Herzon and Mikk, 2007). Perceptions regarding biodiversity are often varied and influenced by a number of factors (Soini and Aakkula, 2006) and, in this case, should not be excluded for interpretation or perceptions related to plant diversity. As such, this issue requires clarification and should be explained to farmers in the future.

The second overarching premise apparent from the opinion data is the so-called 'dilemma of the wildflower industry' (i.e. the conflicting worlds of commerce and conservation (*sensu* Greyling and Davis, 1989)), previously acknowledged (Davis, 1989; Privett et al., 2002). A valid explanation for this inconsistency can be extracted from literature where Potter and Gasson (1988) and Camboni and Napier (1993) emphasise the importance to conservation of demographic and financial characteristics. Local studies also support these findings (Winter et al., 2007) and specifically for Agulhas Plain farmers (Conradie et al., 2010). As such, conservation is said to "begin after breakfast" (*sensu* Conradie et al., 2010) which is pertinent in the context of wildflower farming. This so-called 'dilemma' is particularly well illustrated by referring to the contrasting results from particular Likert statements; here some landholders attach monetary value explicitly to a species that has market value, however, at the same time landholders acknowledge fynbos diversity as an imperative factor for a successful wildflower enterprise. Winter et al. (2007) comment on poor relationships between conservationists and farmers (here referred to as landholders) and landholders are often prejudiced by conservationists as being uncooperative. The results from this investigation reporting on landholder opinion and conservation do not show support for this. The fact that landholders acknowledge themselves to be important in fynbos conservation and that landholders perceive this not to be at odds with flower farming is encouraging for conservation and, as such, conservationists should build on these relationships (Winter et al., 2007).

5. Conclusion

Landholder consultation from this questionnaire showed interesting observations for wildflower farming. This investigation provides evidence that wildflower farmers are heterogenous, both in application of farming practices and this is also reflected in their opinion about the impact of farming and fynbos conservation. As such, generalisations about landholder's application of farming practices and opinion about the impact of farming are possible, yet challenging. Results presented suggest that landholders reveal ecological knowledge of fynbos plant diversity and optimistic opinions about fynbos conservation. However, these entities require an in-depth investigation with a strong social component. The conflicting worlds of commerce and conservation in the wildflower industry are clearly illustrated from the two data themes (i.e. disturbance history and opinion data). Evidently, wildflower vegetation is managed with a commercial goal in mind. Maintaining a profitable wildflower business is priority for the landholder and therefore conservation in context of wildflower farming is severely complicated by real-life issues.

Currently the greatest shortcoming, in context of wildflower farming, is that fynbos ecologists understand very little of the impact of wildflower farming practices on fynbos. This knowledge gap needs more focus from fynbos ecologists in an attempt to understand the impact of farming practices on plant structure and composition (Chapters 3 and 4). Subsequently, ecology can then provide management recommendations for wildflower farmers that will facilitate sustainable wildflower farming on the Agulhas Plain (Chapter 5). When these questions are addressed and appropriately communicated to wildflower farmers, they can possibly consider implementing ecologically-sound wildflower farming practices. These recommended practices must transpire without compromising wildflower production. In due course wildflower farmers can strive to manage wildflower vegetation as intact natural populations; contributing informally, yet importantly, to private land conservation.

6. Literature cited

Babbie, E.R., Mouton, J., 2001. The practice of social research. Oxford University Press, Oxford.

Bean, M.J., Wilcove, D.S., 1997. The private-land problem. Conservation Biology 11, 1-2.

Beedell, J.D.C., Rehman, T., 1999. Explaining farmers' conservation behaviour: Why do farmers behave the way they do? Journal of Environmental Management 57, 165-176.

Bond, W.J., 1980. Fire and senescent fynbos in the Swartberg, southern Cape. South African Forestry Journal 114, 68-71.

Bond, W.J., Vlok, J., Viviers, M., 1984. Variation in seedling recruitment of Cape Proteaceae after fire. Journal of Ecology 72, 209-221.

Botha, M., 2001. Conservation options for farmers and private landholders. Summary report. Cape Conservation Unit, Botanical Society of South Africa. Report No. 01/2001.

Camboni, S.M., Napier, T.L., 1993. Factors affecting use of conservation farming practices in east central Ohio. Agriculture, Ecosystems and Environment 45, 79-94.

Carinus, T., Blomerus, L., de Ponte Machado, M., Gerber, F., Holmes, P., Kabot, L., Marais, C., Martens, C., Middelman, M., Privett, S., Palmer, G., Saunders, R., Scott, A., Scott, M., 2004. Guidelines for Sustainable Harvesting of Selected Indigenous Plant Species in the Cape Floristic Region. In SAPPEX, Cape Flora, Cape Town.

Cole, N.S., Lombard, A.T., Cowling, R.M., Euston-Brown, D., Richardson, D.M., Heijnis, C.E. (Eds.), 2000. Framework for a conservation plan for the Agulhas Plain, Cape Floristic Region, South Africa. IPC Report 00/01. Institute for Plant Conservation, University of Cape Town.

Conradie, B., 2009. Boerdery en bewaring in die Strandveld. Available at: www.flowervalley.org.za Accessed on: 09/02/2010.

Conradie, B., Knoesen, H., 2009. A survey of the cultivation and wild harvesting of fynbos flowers in South Africa. Available at: http://www.flowervalley.org.za Accessed on: 17/05/2010.

Conradie, B., Treurnicht, M., Esler, K.J., Gaertner, M., 2010. Conservation begins after breakfast: A logit model of conservation involvement on the Agulhas Plain, CFR. Presented at the 49th annual conference of the Agricultural Economics Association of South Africa, September 2010, Cape Town, South Africa.

Cowling, R.M., Campbell, B.M., Mustart, P.J., McDonald, D.J., Jarman, M.L., Moll, E.J., 1988. Vegetation classification in a floristically complex area: the Agulhas Plain. South African Journal of Botany 54, 290-300.

Cowling, R.M., Holmes, P.M.. 1992. Flora and vegetation. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 23-61.

Cowling, R.M., Knight, A.T., Privett, S.D.J., Sharma, G., 2010. Invest in opportunity, not inventory of hotspots. Conservation Biology 24, 633-635.

Cowling, R.M., Richardson, D.M., 1995. Fynbos: South Africa's unique floral kingdom. Fernwood Press, Cape Town.

Davis, G.W., 1989. Introduction. In: Greyling, T., Davis, G.W. (Eds.), The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes: Occasional Report No. 40. Foundation for Research Development, CSIR, PO Box 395, Pretoria. pp. 1-9.

Davis, G.W., 1990. Commercial wildflower production in the fynbos biome and its role in the management of land-use. PhD Thesis, Department of Botany, University of Cape Town.

Ehrenfeld, D., 1987. Editorial. Conservation Biology 1, 6-7.

Falconer, K., 2000. Farm-level constraints on agri-environmental scheme participation: a transactional perspective. Journal of Rural Studies 16, 379-394.

FVCT., 2008. Flower Valley Conservation Trust. Annual Report 2008/2009. Available at: www.flowervalley.co.za Accessed on: 16/07/2010.

Greyling, T., Davis, G.W. (Eds.), 1989. The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes. Occasional Report No. 40. Foundation for Research Development, CSIR, PO Box 395, Pretoria.

Hanks, J., 2007. Talking of nature. Africa Geographic, February Issue p.83. Available at: www.africageographic.com Accessed on: 17/05/2010.

Herzon, I., Mikk, M., 2007. Farmers' perceptions of biodiversity and their willingness to enhance it through agri-environment schemes: A comparative study from Estonia and Finland. Journal for Nature Conservation 15, 10-25.

Heydenrych, B.J., 1999. An investigation of land-use practices on the Agulhas Plain (South Africa), with emphasis on socio-economic and conservation issues. MSc Thesis, Institute for Plant Conservation, University of Cape Town.

Hilty, J., Merenlender, A.M., 2003. Studying biodiversity on private lands. Conservation Biology 17, 132-137.

Joubert, L., Esler, K.J., Privett, S.D.J., 2009. The effect of ploughing and augmenting natural vegetation with commercial fynbos species on the biodiversity of Overberg Sandstone fynbos on the Agulhas Plain, South Africa. South African Journal of Botany 75, 526-531.

Knight, A.T., Cowling, R.M., Campbell, B.M., 2006. An operational model for implementing conservation action. Conservation Biology 20, 408-419.

Kruger, F.J., 1983. Plant community diversity and dynamics in relation to fire. In: Kruger, F.J., Mitchell, D.T., Jarvis, J.U.M. (Eds.), Mediterranean-type ecosystems: the role of nutrients. Springer-Verlag, Berlin, Germany. pp. 446-472.

Le Maitre, D.C., 1984. A short note on seed predation in *Watsonia pyramidata* (Andr.) Stapf in relation to season of burn. Journal of South African Botany 50, 407-415.

Lombard, A.T., Cowling, R.M., Pressey, R.L., Mustart, P.J., 1997. Reserve selection in a species-rich and fragmented landscape on the Agulhas Plain, South Africa. Conservation Biology 11, 1101-1116.

Manders, P.T., 1989. The conservation perspective. In: Greyling, T., Davis, G.W. (Eds.), The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes. Occasional Report No. 40. Foundation for Research Development, CSIR, PO Box 395, Pretoria. pp. 20-24.

Marais, C., Van Wilgen, B.J., Stevens, D., 2004. The clearing of invasive alien plants in South Africa: a preliminary assessment of costs and progress. South African Journal of Science 100, 97-103.

Margules, C. R., Pressey, R.L., 2000. Systematic conservation planning. Nature 405, 243-253.

Mascia, M.B., Brosius, J.P., Dobson, T.A., Forbes, B.C., Horowitz, L., McKean, M.A., Turner, N.A., 2003. Conservation and the social sciences. Conservation Biology 17, 349-350.

Millar, J., 2001. Listening to landholders: approaches to community nature conservation in Queensland. National Forum-Taking Care of the Bush, Perth, Australia. Available at: http://www.unu.edu/env/plec/cbd/Montreal/papers/Millar.pdf. Accessed on: 21/04/2010.

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

Mustart, P.J., Cowling, R.M., undated. Fynbos ecology for wildflower harvesters. Unpublished document. Department of Botany, University of Cape Town.

Myers, N., 1990. The biodiversity challenge: expanded hot-spots analysis. Environmentalist 10, 243-256.

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

Norton, D.A., 2000. Conservation biology and private land: shifting the focus. Conservation Biology 14, 1221-1223.

Pence, G.Q.K., Botha, M.A., Turpie, J.K., 2003. Evaluating combinations of on- and off-reserve conservation strategies for the Agulhas Plain, South Africa: a financial perspective. Biological Conservation 112, 253-272.

Potter, C., Gasson, R., 1988. Farmer participation in voluntary land diversion schemes: some predictions from a survey. Journal of Rural Studies 4, 365-375.

Privett, S.D.J. 2009. Personal communication.

Privett, S.D.J., Heydenrych, B.J., Cowling, R.M., 2002. Putting Biodiversity to Business on the Agulhas Plain. In: Pierce, S.M., Cowling, R.M., Sandwith, K., MacKinnon, K. (Eds.), Mainstreaming Biodiversity in Development. The World Bank Environment Department. pp. 101-111.

Rabe, W., 2010. Personal communication. Flower Valley Conservation Trust.

Raimondo, D., von Staden, L., Foden, W., Victor, J.E., Helme, N.E., Turner, R.C., Kamundi, D.A., Manyama, P.A., 2009. Red List of South African plants 2009. Strelitzia 25, South African National Biodiversity Institute, Pretoria.

Robinson, J.G., 2006. Conservation biology and real-world conservation. Conservation Biology 20, 658-669.

Saunders, C.D., Brook, A.T., Myers, O.E., 2006. Using psychology to save biodiversity and human well-being. Conservation Biology 20, 702-705.

Sekhran, N., Richardson, L., 2008. Biodiversity and business: harvesting wild flowers to safeguard biodiversity - a case study from South Africa. Available at: www.flowervalley.org.za. Accessed on: 17/05/2010.

Soini, K., Aakkula, J., 2007. Framing the biodiversity of agricultural landscape: the essence of local conceptions and constructions. Land Use Policy 24, 311-321.

Thwaites, R.N., Cowling, R.M., 1988. Soil-vegetation relationships on the Agulhas Plain, South Africa. Catena 15, 333-345.

Underwood, E.C., Viers, J.H., Klausmeyer, K.R., Cox, R.L., Shaw, M.R., 2009. Threats and biodiversity in the mediterranean biome. Diversity and Distributions 15, 188-197.

Van Wilgen, B.W., 2009. The evolution of fire and invasive alien plant management practices in fynbos. South African Journal of Science 105, 335-342.

Van Wilgen, B.W., Bond, W.J., Richardson, D.M., 1992. Ecosystem management. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 345-371.

Van Wilgen, B.W., Viviers, M., 1985. The effects of season of fire on serotinous Proteaceae in the Western Cape and the implications for fynbos management. South African Forestry Journal 133, 49-53.

Winter, S.J., Prozesky, H., Esler, K.J., 2007. A case study of landholder attitudes and behaviour toward the conservation of renosterveld, a critically endangered vegetation type in Cape Floral Kingdom, South Africa. Environmental Management 40, 46-61.

CHAPTER 3:

Impact of wildflower farming practices on fynbos structure and diversity (Agulhas Plain, South Africa)

Abstract

The Agulhas Plain is an area of exceptional plant diversity and is currently threatened by a number of (mostly) anthropogenic activities. Fynbos wildflower farming is a widely practiced land-use, covering the second largest surface area (after cereal/cropping), on the Agulhas Plain. Fynbos wildflower farming is perceived to be a potential threat to fynbos conservation but at the same time seen as an opportunity for biodiversity conservation. This contradiction can be partly explained by the role fynbos farmers can play in conserving pristine fynbos areas, managed as intact wildflower populations on private property. Although fire (or burning) and flower harvesting, have been thoroughly researched in fynbos ecology, augmentation practices unique to wildflower farming have not received similar attention. Consequently, current ecological understanding as to how such farming practices impact on fynbos structure and diversity is severely limited. By performing a vegetation survey, the impact of augmentation practices on the structural and floristic attributes of wildflower vegetation was evaluated. Plant diversity seems to be severely compromised by implementing farming practices previously thought to be 'diversity-friendly'. Furthermore, results suggest that natural and augmented fynbos differ in terms of regeneration mode and growth form composition. Additionally, strong correlations are apparent between certain environmental attributes and specific growth forms. This investigation emphasises the complex interplay of ecological components prevalent in the fynbos plant community when anthropogenic disturbances are implemented. The insights gained from this study will aim to establish consensus whether or not fynbos farming practices can indeed be diversity-friendly for the flora of the Agulhas Plain.

Keywords: fynbos management, conservation, disturbance, growth form, reseeder, resprouter

1. Introduction

The Cape Floristic Region (87 892 km^2) (CFR, Bond and Goldblatt, 1984) is recognised as a biodiversity hotspot (Myers, 1990; Myers et al., 2000) with more than 9000 plant species and remarkable endemism (Goldblatt and Manning, 2000). The unique levels of speciation and endemism in this mediterranean plant assemblage (Cowling et al., 1996) are globally recognised and weigh strongly against other speciose areas (Linder, 2003). The Agulhas Plain (2160 km^2), situated on the southern tip of Africa, is a significantly species-rich constituent of the CFR with more than 1750 vascular plant species, 112 endemics and many edaphic specialists (i.e. restricted to localised populations on specific soil types) (Cowling and Holmes, 1992). Moreover the Agulhas Plain is especially complex in vegetation composition (see Chapter 1 for review) (Thwaites and Cowling, 1988) and is renowned for being an area of conservation priority (Privett, 2002; UNDP[17], 2003; Raimondo et al., 2009). Habitat transformation and alien plant invasions are, however, increasingly threatening the ecological integrity of this lowland region (Lombard et al., 1997; Cole et al., 2000; Privett, 2002). Besides the spread of alien plant invasions and expanding agriculture and urbanization, the non-sustainable harvesting of wildflowers and inappropriate fire regimes have been highlighted as threats to biodiversity (Lombard et al., 1997; Rebelo, 1992). Consequently, natural vegetation persists as remnants in, what is largely, an agricultural and invaded landscape (Lombard et al., 1997; Cole et al., 2000).

The unique vegetation of the study area and the poor agricultural potential of land is reason for an established wildflower industry (Heydenrych, 1999; Privett, 2002; Conradie and Knoesen, 2009). This agricultural land use covers the second largest surface area, after traditional cereal/cropping agriculture, in the region (Heydenrych, 1999) and is a vital source of income to farmers and workers in the region (Privett, 2002). Approximately 4 million kg of fynbos wildflower material is exported annually (PPSA[18], 2009) (thus excluding product sold to the local market) and a significant component of this supply chain is focused on the Agulhas Plain (Middelmann, 1989). Large amounts (between 50 – 60% (Middelmann, 1989)) of wildflower material (Proteaceae and 'greens' (SAPPEX[19], 2006)) are products derived from natural vegetation and will continually be harvested from this resource (Cowling, 1989; Davis, 1992; Conradie and Knoesen, 2009).

In an attempt to supply higher quantities of focal wildflower material (i.e. species demanded from the market) farmers implement particular farming practices, i.e. veld management (Cowling, 1989;

[17] United Nations Development Programme (UNDP)
[18] Protea Producers of South Africa (PPSA)
[19] South African Protea Producers and Exporters Association (SAPPEX)

Van Wilgen et al., 1992; Carinus et al., 2004). These farming practices (also called ‘augmentation techniques’ (Joubert et al., 2009)) involve combinations of burning, ploughing and broadcast sowing applied to wildflower vegetation (Chapter 2). Ploughing and burning is often used prior to broadcast sowing. Fire is most widely used in wildflower farming and is probably the single most important tool available to wildflower farmers (Davis, 1990). Ploughing, however, is also commonly implemented and plays an important role in fynbos management. Shallow (non-inversion) and deep (conventional) (*sensu* Joubert et al., 2009) ploughing can be distinguished in wildflower farming. Deep ploughing involves using a disc plough to loosen soil to a large depth whereas shallow ploughing is seen as a minimal disturbance technique and only loosens the topsoil layer (Joubert et al., 2009). Broadcast sowing augments natural vegetation with higher densities of a chosen species, usually of the family Proteaceae, which has commercial value (Joubert et al., 2009; Carinus et al., 2004). Overall, farming practices serve as a process of rearrangement in wildflower vegetation (i.e. the manipulation of succession (*sensu* Van Wilgen et al., 1992)) that will increase the abundance and density of market related species (Carinus et al., 2004). Additionally, Van Wilgen et al. (1992) emphasise maintenance of healthy plants (i.e. pest free) and adequate seed reserves to regenerate wildflower populations (despite flower removal) and pest control to increase flower quality as justification for implementing wildflower farming practices.

Overexploitation in terms of wildflower harvesting is considered a potential threat to conserving biodiversity in wildflower vegetation (Cowling, 1989; Mustart and Cowling, 1992; Maze and Bond, 1996). Subsequently, responses of serotinous species of the family Proteaceae to harvesting practices have been extensively studied. The impact of wildflower farming practices on fynbos vegetation communities (as a whole) has also been addressed (Cowling, 1989) but received less attention in the scientific literature (Davis, 1990; Joubert et al., 2009). From an ecological perspective these farming practices manifest as periodic ‘disturbances’ in the fynbos community. Much research has been devoted to the impact and role of disturbance in plant communities (Chesson and Warner, 1981; Sousa, 1984; White and Pickett, 1985). For fynbos, fire (as a periodic disturbance) is considered integral for species persistence and has been a focus for research in these ecosystems (Kruger, 1983; Cowling, 1987; Van Wilgen et al., 1992; Van Wilgen et al., 2010).

An anthropogenically induced disturbance event like ploughing is known as a “destructive, rapid and intense unnatural disturbance event resulting in the complete removal of above- and below-ground biomass” (Walton, 2006). Therefore one would expect succesional pathways and community composition of vegetation to be affected by such a disturbance. Furthermore, plant competition is considered to play an important role in structuring fire-prone fynbos communities

(Bond et al., 1984; Yeaton and Bond, 1991; Bond et al., 1992). As such, and in the context of wildflower farming, the process of broadcast sowing (combined with e.g. ploughing or burning the vegetation) could possibly compromise the diversity of non-target species through altering competitive interactions (Heydenrych, 1999) but also the particular disturbance regime (Davis, 1990). Two earlier studies (Davis, 1990; Joubert et al., 2009) have explicitly focused on the impact of wildflower farming practices on fynbos composition and structure. Although these investigations revealed valuable insights, the impact of these anthropogenically induced disturbances on fynbos composition and structure remain largely unknown and will be investigated in more detail here.

Wildflower farming vegetation ultimately remains as islands of fynbos in a transformed landscape (the Agulhas Plain) that is extensively threatened by human and biotic encroachments (Lombard et al., 1997; Cole et al., 2000). Therefore, natural vegetation entities require careful management (Van Wilgen et al., 1994; Davis, 1990) to ensure the persistence of intact wildflower populations. Davis (1990) and Mustart and Cowling (undated) emphasise that fynbos management requires a full understanding of ecosystem response to disturbance to secure a sustainable commercial resource for the wildflower industry. Not only is sound management important for these particular reasons but also to contribute to plant conservation and 'managing for biodiversity' in a region of conservation concern (Van Wilgen et al., 1992; Pence et al., 2003; UNDP, 2003; Raimondo et al., 2009).

Focusing specifically on wildflower farming from natural vegetation, Joubert et al. (2009) reported that 'high impact' farming practices (like deep ploughing, recurring ploughing and burning) should be avoided as these activities may lead to a reduction in plant diversity. Joubert et al. (2009) observed increased richness in growth forms and, resprouters and reseeders in shallow ploughed treatments. Furthermore, observations from a broadcast sowing treatment (*L. platyspermum*) did not exert stress on naturally occurring fynbos species via competitive exclusion. Subsequently, Joubert et al. (2009) mainly explained the results based on the intermediate disturbance hypothesis; i.e. intermediate levels of disturbance will maintain plant diversity by preventing competitive exclusion of sub dominants (Connell, 1979; Huston, 1979). Vegetation age was considered a major limiting factor in Joubert et al.'s (2009) study which focused on early successional stages, and therefore this investigation extends the temporal scale. Consequently, the impact of farming practices widely used in wildflower farming on fynbos structural attributes are investigated by focusing on older vegetation stands. The research objectives were to; (1) compare structural characteristics (regeneration mode, growth forms and environmental variables) between control and treatment sites and, (2) compare species richness and diversity between control (i.e. representing intact fynbos communities) and treatment sites (i.e. subjected to wildflower farming practices).

2. Methods

2.1 *Location*

Study sites (Plate 1) were located on two neighbouring farms (referred to as Farm "Post" (34°37'06.5"S/19°36'18.8"E) and Farm "Dam" (34°36'59.3"S/19°37'27.7"E) on the Agulhas Plain (2160 m^2). Both farms are situated within the Elim land system (Bezuidenhout, 2003; in ANP Management Plan 2006) and within 15 km from the Atlantic Ocean. The Agulhas Plain region is characterised by low topographic diversity where geological processes produce (mostly) infertile soils (Thwaites and Cowling, 1988). The vegetation type on both study sites was Overberg Sandstone Fynbos (Mucina and Rutherford, 2006). Farm "Post" is mainly a commercial cattle farm but also relies on wildflower harvesting for an additional income. Cattle do not graze in any of the wildflower vegetation. Farm "Dam" is co-owned and one of the owners relies entirely on wildflower harvesting as a source of income. Both farms supply fynbos wildflowers to pack-sheds in the area.

2.2 *Treatments*

Control and treatment sites were chosen to represent different post-fire ages with post-disturbance vegetation age ranging from 8 years to 20 years as this is known to have a major influence on community composition via succession (Kruger, 1983; Cowling and Pierce, 1988; Cowling and Gxaba, 1990; Privett et al., 2001). The study approach assumed that treatments can be compared with adjoining undisturbed vegetation (i.e. fence-line contrasts) (Herath et al., 2009; Joubert et al., 2009). In doing so, it was ensured that vegetation type and environmental circumstances were the same. It is important to state, for reliability-related reasons, that management information for all study sites was obtained from the current owner of the property. In the subsequent sections, study areas are described in more detail.

Plate 2: Study sites located on sandstone fynbos that are either completely natural vegetation or subjected to wildflower farming practices on the Agulhas Plain (South Africa).

Farm "Post"

Reference study site of approximately fourteen year old vegetation. Site abbreviation: C1[14].

Fynbos study site of approximately fourteen year old vegetation subjected to shallow ploughing and broadcast sowing (*L. platyspermum*). Site abbreviation: SP1[14].

Fynbos study site of approximately fourteen year old vegetation subjected (only) to broadcast sowing (*P. compacta*). Site abbreviation: BCS[10].

Farm "Dam"

Reference study site of approximately twenty year old vegetation. Site abbreviation: C2[20].

Fynbos study site of approximately twenty year old vegetation subjected to shallow ploughing and broadcast sowing (*L. platyspermum*). Site abbreviation: SP2[20].

Fynbos study site of approximately eight year old vegetation subjected to shallow ploughing and broadcast sowing (*L. platyspermum*). Site abbreviation: SP3[8].

On both farms, a control area was compared with two treatment areas. On the first study site (Farm "Post") the control area was burnt fourteen years ago (i.e. post-fire age) (C1[14]). The two treatment sites differ from each other in terms of treatment and post-fire age. The first treatment site was burnt 14 years ago, subjected to the method of shallow ploughing and broadcast sown with *Leucadendron platyspermum* (SP1[14]). The second treatment site was burnt ten years ago and broadcast sown with *Protea compacta* (BCS[10]). This specific treatment site was not ploughed. The vegetation age in all three mentioned sub-sites is similar (i.e. between 10 – 14 years) and thus allows for comparison in terms of vegetation composition (Privett pers. com.). On the second study site (Farm "Dam") the control area was burnt 20 years ago (C2[20]). Both treatment sites were subjected to similar augmentation techniques that involved burning, shallow ploughing and broadcast sown with *L. platyspermum*. The only difference between the two treatment sites was the post-fire age; where the one site was burnt twenty years ago (SP2[20]) and the other eight years ago (SP3[8]).

From here on, the wildflower farming practice of combining shallow ploughing and broadcast sowing is merely referred to as 'shallow ploughing' and the practice of using broadcast sowing alone is referred to as 'broadcast sowing'. Collectively these sites are referred to as treatment sites.

2.3 *Experimental design*

The experimental design on both study sites is similar. On the one study site, Farm "Post", the fence-line contrast was conducted between a control site (C1[14]) and two treatment sites, SP1[14] and BCS[10]. On the other study site, Farm "Dam", a fence-line contrast was conducted between a control site (C2[20]) and two treatment sites, SP2[20] and SP3[8]. Slope, aspect and elevation were similar for all study sites (both control and for all treatment sites) therefore control and treatment sites could be compared with each other.

On Farm "Post", fifteen replicates of 5 × 5 m plots (Vlok and Yeaton, 1999; Joubert et al., 2009) were allocated within control and treatment sites. On Farm "Dam", fourteen replicates of 5 x 5 m plots were allocated in control and treatment sites. In all cases plots were spaced a minimum of 12 m from each other. Edge-effects were avoided by spacing plots not less than 15 m from a road. Photographs of study sites are provided in Plate 2.

2.4 *Vegetation sampling and species identification*

Vegetation sampling was done in mid-September 2009 until the end of November 2009. Every 5 × 5 m plot was divided into four smaller quadrats to increase accuracy of cover estimates when performing vegetation sampling. The floristic data sheet used for recording environmental and vegetation attributes is provided in Appendix 2. A similar sampling approach (with the exception of sampling season) to Joubert et al. (2009) was followed to allow for comparison of results.

Firstly, GPS coordinates and environmental variables were recorded for each plot. Environmental variables included; total projected foliage cover (%), open soil (%), litter (%), plot maximum height (cm), plot average height (cm). Secondly, percentage (%) cover was recorded for different growth forms. Plant species were categorized into one of six growth form categories: (1) graminoids – includes restios, sedges and grasses (Campbell and Van der Meulen, 1980), (2) geophytes – includes plant species with bulbs or underground stems (rhizomes), (3) herbs, (4) small shrubs (<50 cm), (5) medium-sized shrubs (50 – 100 cm) and (6) large shrubs (>100 cm) (Joubert et al., 2009). Additionally, for each of the small, medium and large shrub categories plants were categorised as being 'ericoid' (Ericaceae), 'proteoid' (Proteaceae) or 'other' species. Thirdly, percentage (%) cover was recorded for individual species in a plot and assigned a scientific name. Throughout the sampling procedure if an individual plant had more than 50% cover outside the plot it was considered to be off the plot. If a species could not be identified in the field a specimen was collected, pressed, given a field-name and identified at a later stage. Species that could not be identified at Stellenbosch University were taken to one of two herbariums (Grootbos Nature Reserve Herbarium or Compton Herbarium, Kirstenbosch Botanical Gardens). When a species was assigned a scientific name; each plant was categorized according to regeneration mode (resprouter or non-sprouter/reseeder) by examining if a lignotuber was present or from existing literature sources and expert opinion. Resprouters recover from fire vegetatively and/or from seeds; non-sprouters (from here on referred to as reseeders) are killed by fire and regenerate from seeds only (as described by Herath et al., 2009). Finally, each plant species was assigned a so-called 'rarity' status according to the Red List of South African Plants (Raimondo et al., 2009).

As a final note, much confusion is noticeable in literature about the concepts of species richness and diversity, therefore this investigation follows guidelines from Spellenberg and Fedor (2003) to avoid confusion of such concepts. As such, species richness refers specifically to the number of species in a study site (i.e. "direct species count" (*sensu* Peet, 1974)) and species diversity and evenness is expressed by using an index. Three widely accepted indexes (Stirling and Wilsey, 2001) were used as estimates of species diversity (also termed 'heterogeneity indices' by Peet (1974)), namely the Shannon (H') diversity index (Shannon and Weaver, 1949), the Simpson (D') index of diversity (Simpson, 1949) and Pielou's (J') evenness index (Pielou, 1966). Species richness, diversity and evenness remain equally important in estimating diversity of a given locality despite criticism to the concept of diversity (see Hurlbert, 1971 for more). Therefore this investigation focuses explicitly on these measures as indicators of species diversity. Equations to indices are provided in Appendix 3.

2.5 *Data analysis*

General trends in the data were obtained by summing the cover of environmental variables and growth form categories in each treatment. Species diversity, growth form categories and environmental variables were analysed using one-way analysis of variance (ANOVA with *post-hoc* analysis by using Fischer's (LSD)) in STATISTICA 9 (Statsoft, inc., 2010) after determining that assumptions for parametric statistics were not violated. This determined if any species richness and diversity patterns, growth form categories and environmental variables were consistently and significantly different across all study sites. For regeneration mode individual species were categorised (either as a resprouter or reseeder) and cover of individuals was summed to form a new dataset. One-way analysis of variance (ANOVA with *post-hoc* analysis by using Fischer's (LSD)) was used in STATISTICA 9 (Statsoft, inc., 2010) to illustrate consistently and significantly different patterns in the data across all study sites.

Correspondence analysis (CA) was selected as an ordination technique in STATISTICA 9 (Statsoft, inc., 2010) to show the relationship between study sites (control and treatment sites) and regeneration mode cover (resprouters and reseeders) and, between study sites (control and treatment sites) and growth form cover. Canonical correspondence analysis (CCA) (R programming language in STATISTICA 9 (Statsoft, inc., 2010)) was used to show the relationship between study sites (control and treatment sites) and environmental variables and, between growth forms and environmental variables. Additionally, the relationship between different growth forms and environmental variables was investigated in more detail by using regression analysis (Spearman rank coefficient) in STATISTICA 9 (Statsoft, inc., 2010).

3. Results

3.1 *Species richness, diversity and evenness*

In all, 177 species were recorded in the study (Appendix 4 for species information). Species richness (Table 3.1) was highest in the control site, C1[14], and the lowest species richness was recorded in the shallow ploughed site, SP3[8]. Species richness in all other study sites (C2[20], SP1[14], SP2[20], BCS[10]) was lower than C1[14] but higher than SP3[8] and did not differ significantly. Control sites (C1[14], C2[20]) showed higher diversity (Shannon (H') and Simpson (D')) and evenness (Pielou's (J')) than treatment sites (broadcast sown, BCS[10], and shallow ploughed, SP1[14], SP2[20], SP3[8]) (Table 3.1). Shannon (H') and Simpson (D') diversity indexes were significantly higher for both control sites compared to treatment sites (broadcast sown and shallow ploughed). Shannon diversity (H') was lowest in a shallow ploughed site (SP3[08]). Three other treatment sites (SP1[14], SP2[20] and BCS[10]) did not differ significantly for the measure of Shannon diversity (H'). Simpson (D') diversity showed slightly different trends for treatment sites (broadcast sown and shallow ploughed) than Shannon (H') diversity did. Lowest Simpson diversity (D') was observed in a shallow ploughed site (SP2[20]). Three other treatment sites (SP1[14], SP3[8] and BCS[10]) did not differ significantly in terms of Simpson diversity (D'). Pielou's (J') evenness showed similar trends than Shannon (H') and Simpson (D') diversity and was significantly higher in both control sites and lower in all treatment sites (broadcast sown and shallow ploughed). Additional graphs showing significant differences in species richness, diversity and evenness are provided in Appendix 5.

3.2 *Regeneration mode*

The lowest percentage cover of reseeders was observed in the control site, C2[20] (Figure 3.1). Cover of reseeding species was significantly higher in the shallow ploughed site, SP2[20]. Other treatment sites (SP1[14], SP3[8], BCS[10]) and another control site (C1[14]) did not show significant differences in reseeder cover. Resprouter percentage cover showed more variation between study sites and, particularly, in treatment sites (broadcast sown and shallow ploughed). Highest cover of resprouters was observed in both control sites and the shallow ploughed site, SP2[20]. Significantly lower resprouter cover was observed in the shallow ploughed site, SP1[14]. Two treatment sites, SP3[8] and BCS[10], had higher cover of resprouters than SP1[14] but did not differ significantly from each other. The correspondence analysis (CA) with percentage (%) cover data, confirmed that resprouter species associated with both control sites while reseeders showed

Table 3.1: Statistical comparison of mean species richness, diversity, evenness (±standard deviation) of species, regeneration mode (% cover) and environmental variables across study sites in wildflower farming on the Agulhas Plain (South Africa). Study sites include; control sites (C1[14], C2[20]), broadcast sown site (BCS[10]) and shallow ploughed sites (SP1[14], SP2[20], SP3[8]). Environmental variables include; total vegetation cover (%) (T.COVER), open soil cover (%) (O.SOIL), litter cover (%) (LIT), average vegetation height (cm) (AVE.H), maximum vegetation height (cm) (MAX.H). Study sites vary in post-fire age indicated in brackets [ ].

	C1[14]	C2[20]	BCS[10]	SP1[14]	SP2[20]	SP3[8]	$F_{5, 82}$	P-value
Species richness	40.87 ± 8.90^{c}	34.21 ± 4.89^{ab}	31.13 ± 4.31^{a}	33.07 ± 3.08^{ab}	36.07 ± 6.79^{b}	31.14 ± 2.71^{a}	7.15	P<0.01
Shannon (H')	3.25 ± 0.22^{a}	3.09 ± 0.23^{a}	2.81 ± 0.25^{bc}	2.86 ± 0.17^{b}	2.81 ± 0.39^{bc}	2.66 ± 0.19^{c}	10.87	P<0.01
Simpson (D')	0.94 ± 0.01^{a}	0.93 ± 0.03^{a}	0.90 ± 0.05^{b}	0.89 ± 0.04^{bc}	0.87 ± 0.07^{c}	0.88 ± 0.03^{bc}	7.92	P<0.01
Pielou (J’)	0.88 ± 0.03^{a}	0.88 ± 0.04^{a}	0.82 ± 0.06^{b}	0.82 ± 0.05^{b}	0.79 ± 0.09^{b}	0.78 ± 0.04^{b}	9.06	P<0.01
Reseeders	48.5 ± 8.40^{a}	33.9 ± 8.50^{b}	49.7 ± 10.97^{a}	50.5 ± 8.03^{ac}	56.8 ± 14.28^{c}	46.1 ± 9.64^{a}	16.86	P<0.01
Resprouters	33.5 ± 6.30^{b}	37.6 ± 5.20^{b}	25.8 ± 9.00^{d}	14.4 ± 5.10^{e}	33.2 ± 6.92^{b}	23.6 ± 7.70^{d}		
T.COVER	74.07 ± 4.10^{ab}	68.07 ± 8.17^{bc}	74.73 ± 4.91^{a}	58.87 ± 11.53^{d}	81.64 ± 11.44^{e}	67.21 ± 7.82^{c}	12.46	P<0.01
AVE.H	62.33 ± 15.10^{a}	59.29 ± 8.74^{a}	89.00 ± 13.78^{b}	72.00 ± 24.91^{a}	109.29 ± 29.86^{c}	89.64 ± 12.93^{b}	14.47	P<0.01
MAX.H	184.33 ± 27.70^{a}	203.21 ± 29.97^{c}	167.20 ± 20.47^{ab}	173.67 ± 23.71^{a}	222.14 ± 26.36^{d}	149.64 ± 20.14^{b}	15.35	P<0.01
O.SOIL	2.80 ± 1.78^{a}	3.36 ± 2.10^{a}	5.53 ± 2.47^{a}	13.07 ± 7.16^{b}	3.14 ± 4.52^{a}	14.21 ± 7.31^{b}	17.13	P<0.01
LIT	11.67 ± 3.48^{b}	20.91 ± 5.61^{a}	22.33 ± 9.10^{a}	20.73 ± 6.22^{a}	22.36 ± 5.46^{a}	19.64 ± 5.44^{a}	6.41	P<0.01

* Letters in superscript show where significant differences exist between treatments (ANOVA with *post-hoc* analysis by using Fischer’s (LSD); P < 0.01)

affinity for the treatment sites (broadcast sown and shallow ploughed) (results shown in Appendix 6).

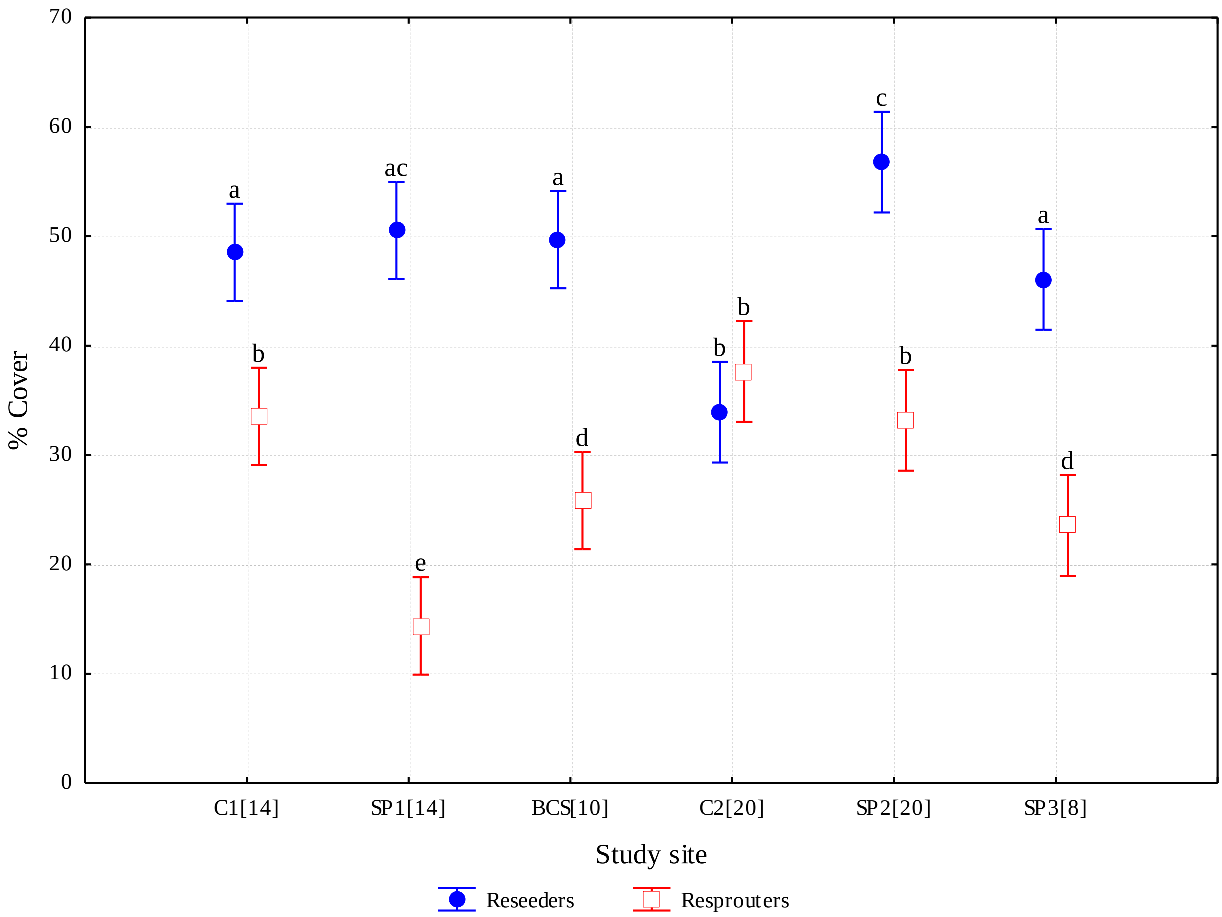


Figure 3.1: Graphic representation of percentage (%) cover of reseeding and resprouting species in wildflower farming study sites on the Agulhas Plain (South Africa) (also see Table 3.1). Study sites include; control sites (C1[14], C2[20]), broadcast sown site (BCS[10]) and shallow ploughed sites (SP1[14], SP2[20], SP3[8]). Study sites vary in post-fire age indicated in brackets [ ]. (ANOVA with *post-hoc* analysis by using Fischer's (LSD)).

3.3 *Environmental variables*

The canonical correspondence analysis (CCA) ordination diagram indicates variation in the relationship between study sites and environmental variables (Figure 3.2). The first two axes of the CCA explained 92.25% of the data (Axis 1, Eigenvalue 0.0865, total variance 70.06%; Axis 2, Eigenvalue 0.0274, total variance 22.20%) (similar to Figure 3.2). (also see Figure 3.4). Groupings can be observed between certain study sites and environmental variables. The group indicated by "A" corresponds with both control sites (C1[14]; C2[20]) which associated with one another. The control sites also associated with total vegetation cover (T.COVER) and maximum vegetation height (MAX.H.). Control sites did not associate with open soil cover (O.SOIL), litter cover (LITTER) and average vegetation height (AVE.H.). Two shallow ploughed sites, SP1[14] and SP3[8], grouped differently from other study sites (indicated by "B") and associated with open soil cover (O.SOIL). The third shallow ploughed site, SP2[20], grouped from other study sites (indicated by "C") and associated closely with total vegetation cover (T.COVER) and maximum height (MAX.H.). The broadcast sowing site (BCS[10]) did not show a strong association with any of the environmental variables but this site showed some overlap with the control sites.

Environmental variables are summarized in Table 3.1. Total vegetation cover differed amongst study sites. Highest vegetation cover was observed in the shallow ploughed site, SP2[20]. Lowest cover was observed in another shallow ploughed site, SP1[14]. The two control sites had similar cover, however, one of the control sites (C1[14]) had similar cover to the broadcast sown site (BCS[10]) and, in turn, control site C2[20] had similar cover to the shallow ploughed site, SP3[8]. Vegetation height differed amongst study sites. Average vegetation height (cm) was significantly higher in the shallow ploughed site, SP2[20]. Lower average height was recorded in two treatment sites (BCS[10] and SP3[8]) and lowest average height was observed in both control sites and the shallow ploughed site, SP1[14]. Maximum height (cm) was highest in the shallow ploughed site, SP2[20], and second highest in the control site, C2[20]. Two treatment sites (BCS[10] and SP3[8]) did not differ in terms of maximum height. Lowest maximum height was recorded in the shallow ploughed site, SP3[8]. Open soil cover (%) was highest in two treatment sites (SP1[14] and SP3[8]). Other study sites (C1[14], C2[20], SP2[20], BCS[10]) did not differ in vegetation height. Litter cover was similar in most study sites except for the control site, C1[14], which indicated significantly lower litter cover than other study sites.

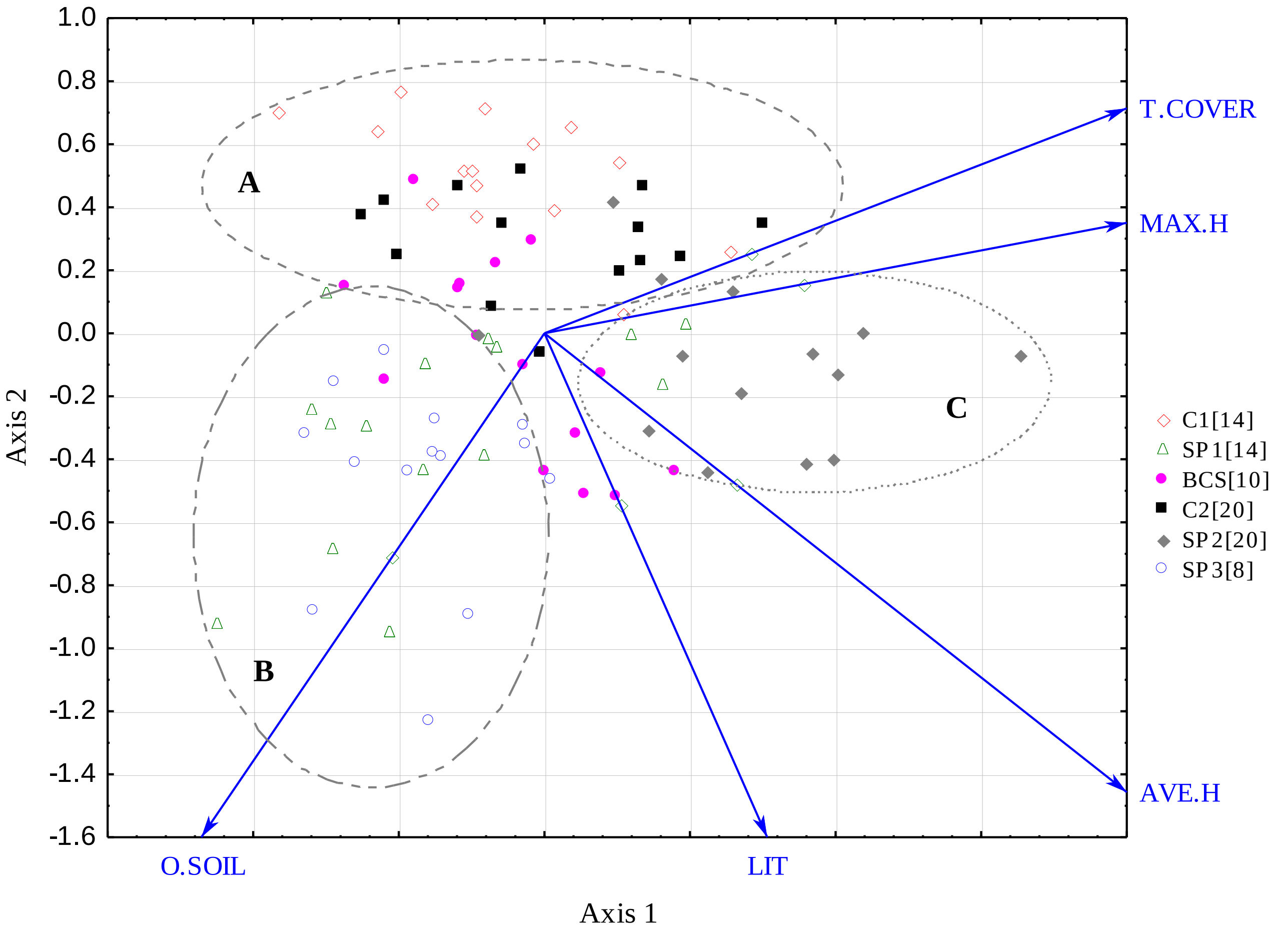


Figure 3.2: Canonical correspondence analysis (CCA) ordination diagram showing the relationship between study sites (5 × 5 m plots depicted) and environmental variables in wildflower farming on the Agulhas Plain (South Africa). The first two axes of the CCA explained 92.25% of the data (Axis 1, Eigenvalue 0.0865, total variance 70.06%; Axis 2, Eigenvalue 0.0274, total variance 22.20%) (similar to Figure 3.4). Associations between study sites are indicated by circles (“A”, “B”, “C”). Study sites include; control sites (C1[14], C2[20]), the broadcast sown site (BCS[10]) and shallow ploughed sites (SP1[14], SP2[20], SP3[8]). Environmental variables include; total vegetation cover (%) (T.COVER), open soil cover (%) (O.SOIL), litter cover (%) (LIT), average vegetation height (cm) (AVE.H), maximum vegetation height (cm) (MAX.H). Study sites vary in post-fire age indicated in brackets [ ].

3.4 *Growth forms*

A correspondence analysis (CA) showed that growth form categories associated differently with control (C1[14], C2[20]) and treatment sites (broadcast sown and shallow ploughed) (Figure 3.3). The first two axes explained 75.67% of the data (Dimension 1, Eigenvalue 0.08948, total variance 52.42%; Dimension 2, Eigenvalue 0.03969, total variance 23.25%). Both control sites are similar in growth form composition. The broadcast sown site, BCS[10] also corresponded strongly with the control sites in terms of growth form composition. Shallow ploughed sites (SP1[14], SP2[20] and SP3[8]) differed from control and the broadcast sown site and also uniquely from one another.

Cover of growth form categories is summarised in Table 3.2. Graminoid cover (GRAM) was highest in the control site, C2[20], and the shallow ploughed site, SP3[8]. Second highest graminoid cover was observed in the control site, C1[14], and the broadcast sown site, BCS[10]. Lowest graminoid cover was recorded in two shallow ploughed sites, SP1[14] and SP2[20]. Highest geophyte cover (GEO) was observed in the shallow ploughed site, SP2[20]. Both control sites (C1[14]; C2[20]) had lower geophyte cover than the shallow ploughed site, SP2[20]. Lowest geophyte cover was observed in other treatment sites, SP1[14], SP3[8], BCS[10]. Cover of herbaceous species (HERB) was significantly higher in the shallow ploughed site, SP2[20], and second highest in the control site, C1[14]. Low herbaceous cover was observed in two treatment sites, SP1[14] and BCS[10], and control site, C2[20]. Herbaceous cover was significantly low in the shallow ploughed site, SP3[8]. Small shrub 'ericoid' cover (SS.E.) was highest in the shallow ploughed site, SP3[8]. Both control sites (C1[14] and C2[20]) had lower cover of small shrub 'ericoid'. Lowest small shrub ericoid cover was observed in the shallow ploughed site, SP1[14] but this did not differ significantly from two other treatment sites, BCS[10] and SP[20]. No significant differences were observed for other small shrub categories (SS.P. and SS.O.).

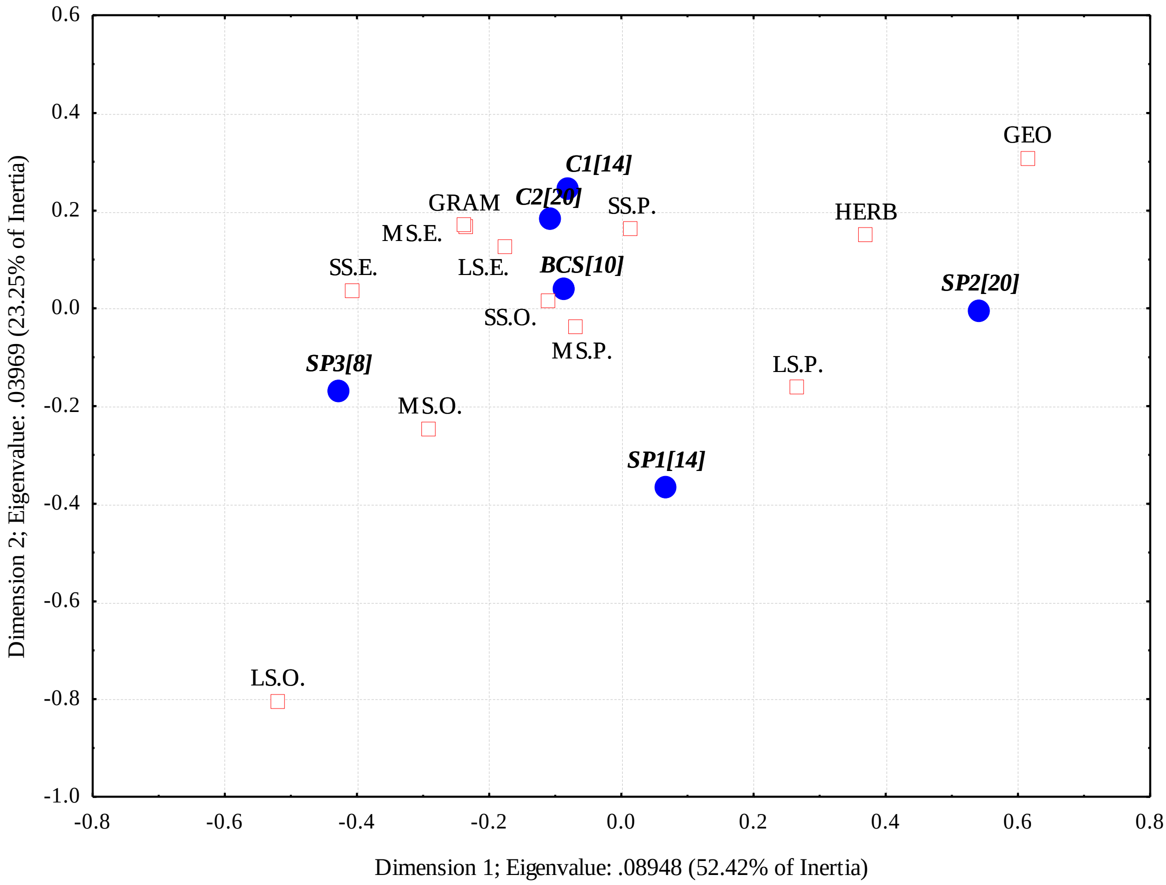


Figure 3.3: Correspondence analysis (CA) ordination diagram showing the relationship between study sites and the cover of different growth form categories in wildflower farming on the Agulhas Plain (South Africa). The first two dimensions of the CA accounted for 75.67% of the data (Dimension 1, Eigenvalue 0.08948, total variance 52.42%; Dimension 2, Eigenvalue 0.03969, total variance 23.25%). Study sites abbreviated as follow; control sites (C1[14], C2[20]), the broadcast sown site (BCS[10]) and shallow ploughed sites (SP1[14], SP2[20], SP3[8]). Study sites vary in post-fire age indicated in brackets [ ]. Growth form categories include; graminoids (GRAM), geophytes (GEO), herbs (HERB), small shrubs (SS), medium shrubs (MS), large shrubs (LS), proteoid species (P), ericoid species (E) and other species (O).

Table 3.2: Statistical comparison of mean cover (±standard deviation) of growth form categories across study sites in wildflower farming on the Agulhas Plain (South Africa). Study sites include; control sites (C1[14], C2[20]), broadcast sown site (BCS[10]) and shallow ploughed sites (SP1[14], SP2[20], SP3[8]). Study sites vary in post-fire age indicated in brackets [ ].

	C1[14]	C2[20]	BCS[10]	SP1[14]	SP2[20]	SP3[8]	$F_{5, 82}$	P-value
Graminoids	16.27 ± 6.46[a]	20.93 ± 5.36[c]	16.20 ± 8.75[a]	7.20 ± 2.81[b]	10.07 ± 4.40[b]	16.93 ± 6.57[ac]	10.01	P<0.01
Geophytes	5.67 ± 3.87[a]	5.14 ± 4.05[a]	2.00 ± 1.13[b]	1.77 ± 0.90[b]	11.64 ± 6.38[c]	0.46 ± 0.31[b]	19.34	P<0.01
Herbs	3.80 ± 1.52[b]	2.50 ± 0.94[a]	2.07 ± 1.10[a]	2.4 ± 1.50[a]	4.86 ± 1.83[c]	0.43 ± 0.58[d]	18.83	P<0.01
Small S. Ericoids	8.07 ± 2.76[a]	6.79 ± 1.52[ac]	5.33 ± 2.87[bc]	3.53 ± 1.68[b]	3.07 ± 1.64[b]	11.14 ± 7.18[d]	9.72	P<0.01
Small S. Proteoids	3.00 ± 2.20[a]	2.14 ± 1.17[ab]	3.27 ± 2.34[a]	1.20 ± 1.37[b]	3.00 ± 1.47[a]	2.00 ± 1.36[ab]	3.12	NS
Small S. Other	3.07 ± 1.75[a]	3.93 ± 1.64[a]	3.13 ± 2.50[a]	2.60 ± 0.99[a]	2.86 ± 0.99[a]	3.29 ± 2.64[a]	0.73	NS
Medium S. Ericoids	9.00 ± 4.21[d]	3.14 ± 2.32[bc]	5.20 ± 2.81[a]	3.87 ± 1.60[ab]	1.79 ± 1.25[c]	3.86 ± 1.56[ab]	14.19	P<0.01
Medium S. Proteoids	7.33 ± 5.16[ab]	3.43 ± 1.95[c]	8.73 ± 3.90[b]	4.60 ± 2.50[ac]	7.50 ± 3.50[ab]	8.07 ± 5.61[b]	4.00	P<0.01
Medium S. Other	2.00 ± 1.25[a]	2.50 ± 3.13[ab]	2.40 ± 3.36[ab]	3.00 ± 1.60[ab]	1.43 ± 1.45[a]	4.00 ± 2.99[b]	1.83	NS
Large S. Ericoids	1.27 ± 0.96[a]	0.79 ± 1.05[a]	3.33 ± 2.64[b]	0.93 ± 1.10[a]	0.36 ± 0.50[a]	0.36 ± 0.93[a]	9.52	P<0.01
Large S. Proteoids	16.13 ± 4.85[a]	15.71 ± 5.17[a]	21.80 ± 8.21[ab]	24.47 ± 12.16[b]	38.14 ± 16.92[c]	15.36 ± 6.85[a]	10.96	P<0.01
Large S. Other	0.47 ± 0.83[a]	1.07 ± 1.86[a]	0.70 ± 0.88[a]	3.20 ± 2.31[b]	0.14 ± 0.36[a]	3.70 ± 2.09[b]	13.52	P<0.01

* Letters in superscript show where significant differences exist between treatments (ANOVA with *post-hoc* analysis by using Fischer's (LSD); P < 0.01); NS = not significant.

** Abbreviation "S" = shrub

Overstorey components, medium and large shrub cover, showed variation amongst study sites (Table 3.2). Medium shrub ‘ericoid’ cover was highest in the control site, C1[14]. Second highest cover was observed in the broadcast sown site, BCS[10], and the shallow ploughed sites, SP1[14], SP3[8]. The control site, C2[20], and the shallow ploughed site, SP3[8], had lower medium shrub ‘ericoid’ cover compared to other study sites. Lowest cover for this growth form category was recorded in SP2[20]. Medium shrub ‘proteoid’ cover was highest in the broadcast sown site and did not differ significantly from the shallow ploughed sites, SP2[20], SP3[8] and the control site, C1[14]. The other control site, C2[20], and the shallow ploughed site, SP1[14], had lowest cover of medium shrub ‘proteoids’. The growth form category medium shrub ‘other’ did not show significant variation amongst any of the study sites. Large shrub ‘ericoid’ cover was highest in the broadcast sown site, BCS[10]. Other study sites did not show significant differences in this growth from category. Large shrub ‘proteoid’ cover was highest in the shallow ploughed site, SP2[20], and second highest in two treatment sites, SP1[14] and BCS[10]. Lowest large shrub ‘proteoid’ cover was observed in both control sites and the shallow ploughed site, SP3[8]. Cover of large shrub ‘other’ was similar in most study sites, except for two shallow ploughed sites, SP1[14] and SP3[8] which had significantly higher cover of this growth form.

Growth form categories correlated in the following ways (Table 3.3). Positive correlations include; graminoid cover with small shrub ‘ericoid’ cover (Spearman $r=0.35$; $P<0.01$), geophyte cover with herbaceous cover (Spearman $r=0.76$; $P<0.01$) and also with large shrub ‘proteoid’ cover (Spearman $r=0.30$; $P<0.01$), medium shrub ‘ericoid’ cover with small shrub ‘ericoid’ cover (Spearman $r=0.41$; $P<0.01$) and large shrub ericoid (Spearman $r=0.30$; $P<0.01$), medium shrub proteoid cover with small shrub proteoid cover (Spearman $r=0.42$; $P<0.01$), large shrub ‘other’ cover with medium shrub ‘other’ cover (Spearman $r=0.50$; $P<0.01$). Negative correlations were observed between the following growth forms; graminoid with large shrub ‘proteoid’ cover (Spearman $r=-0.45$; $P<0.01$), geophyte cover with large shrub ‘other’ cover (Spearman $r=-0.56$; $P<0.01$), herbaceous cover with large shrub ‘other’ cover (Spearman $r=-0.42$; $P<0.01$), small shrub ‘proteoid’ cover with large shrub ‘other’ cover (Spearman $r=-0.36$; $P<0.01$), small shrub ericoid with large shrub ‘proteoid’ cover (Spearman $r=-0.49$; $P<0.01$), medium shrub ‘proteoid’ cover with medium shrub ‘other’ cover (Spearman $r=-0.28$; $P<0.01$).

Table 3.3: Summary of Spearman (*r*) rank correlations between various growth forms encountered in wildflower farming study sites on the Agulhas Plain (South Africa).

Growth form/Growth form		Spearman (*r*)	P-value
Graminoids	Small S. Ericoids	0.35	P<0.01
Geophytes	Herbs	0.76	P<0.01
	Large S. Proteoids	0.30	P<0.01
Medium S. Ericoids	Small S. Ericoids	0.41	P<0.01
	Large S. Ericoids	0.30	P<0.01
Medium S. Proteoids	Small S. Proteoids	0.42	P<0.01
Large S. Other	Medium S. Other	0.50	P<0.01
Graminoids	Large S. Proteoids	-0.45	P<0.01
Geophytes	Large S. Other	-0.56	P<0.01
Herbs	Large S. Other	-0.42	P<0.01
Small S. Proteoids	Large S. Other	-0.36	P<0.01
Small S. Ericoids	Large S. Proteoids	-0.49	P<0.01
Medium S. Proteoids	Medium S. Other	-0.28	P<0.01

* Only significant differences (P<0.01) are shown. View jointly with Figure 3.3

** Abbreviation "S" = shrub

3.5 *Growth forms and environmental variables*

A canonical correspondence analysis (CCA) ordination diagram shows the relationship between different growth form cover and environmental variables (Figure 3.4). The first two axes of the CCA explained 92.25% of the data (Axis 1, Eigenvalue 0.0865, total variance 70.06%; Axis 2, Eigenvalue 0.0274, total variance 22.20%) (similar to Figure 3.2).

Correlations of growth from categories with environmental variables are summarised in Table 3.4. Total cover (T.COVER) correlated positively with geophyte cover (Spearman r=0.46; P<0.01), herbaceous cover (Spearman r=0.42; P<0.01), large shrub ‘proteoid’ (Spearman r=0.46; P<0.01), medium shrub ‘proteoid’ (Spearman r=0.30; P<0.01) and small shrub ‘proteoid’ (Spearman r=0.44; P<0.01). Total cover correlated negatively with large shrub ‘other’ (Spearman r=-0.42; P<0.01). Maximum height (MAX.H.) showed positive correlations with geophyte cover (Spearman r=0.65; P<0.01), herbaceous cover (Spearman r=0.46; P<0.01) and large shrub ‘proteoid’ cover (Spearman r=0.50; P<0.01) but negative correlations with large shrub ‘other’ cover (Spearman r=-0.40; P<0.01), medium shrub ‘ericoid’ cover (Spearman r=-0.32; P<0.01) and small shrub ‘ericoid’ cover (Spearman r=-0.31; P<0.01). Average height (AVE.H.) showed a positive correlation with large shrub ‘proteoid’ cover (Spearman r=0.58; P<0.01) and medium shrub ‘proteoid’ cover (Spearman r=0.43; P<0.01) but a negative correlation with small shrub ‘ericoid’ cover (Spearman r=-0.28; P<0.01). Open soil cover (O.SOIL) showed positive correlations with large shrub ‘other’ (Spearman r=0.51; P<0.01) but negative correlations with geophyte cover (Spearman r=-0.64; P<0.01), herbaceous cover (Spearman r=-0.54; P<0.01) and small shrub ‘proteoid’ (Spearman r=-0.35; P<0.01). Litter cover (LIT.) did not show any positive correlations with any growth form category but did associate negatively with small shrub ‘ericoids’ (Spearman r=-0.29; P<0.01).

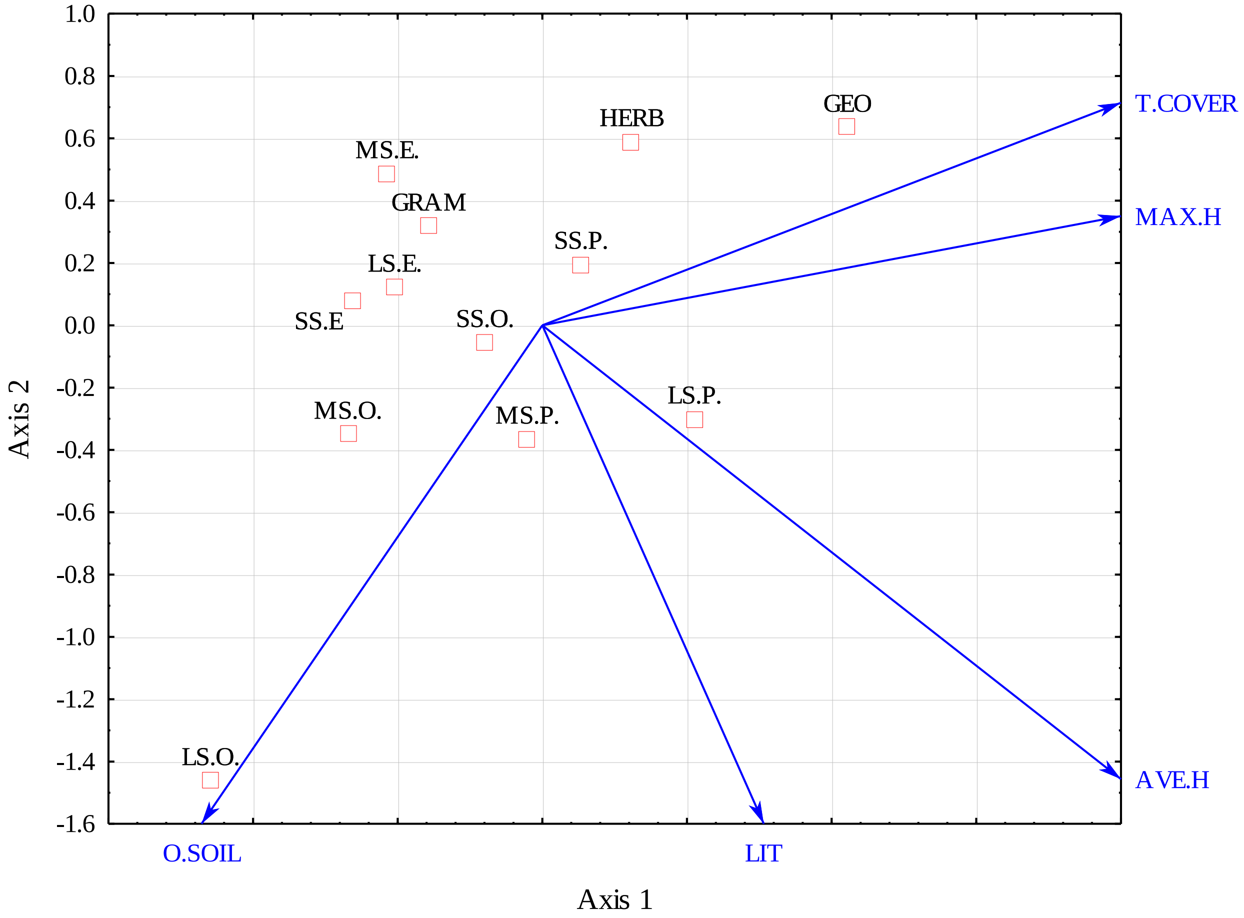


Figure 3.4: Canonical correspondence analysis (CCA) ordination diagram showing the relationship between growth form categories and environmental variables in wildflower farming on the Agulhas Plain (South Africa). The first two axes of the CCA explained 92.25% of the data (Axis 1, Eigenvalue 0.0865, total variance 70.06%; Axis 2, Eigenvalue 0.0274, total variance 22.20%) (similar to Figure 3.2). Growth form categories include; graminoids (GRAM), geophytes (GEO), herbs (HERB), small shrubs (SS), medium shrubs (MS), large shrubs (LS), proteoid species (P), ericoid species (E) and other species (O). Environmental variables include; total vegetation cover (%) (T.COVER), open soil cover (%) (O.SOIL), litter cover (%) (LIT), average vegetation height (cm) (AVE.H), maximum vegetation height (cm) (MAX.H). Study sites vary in post-fire age indicated in brackets [ ].

Table 3.4: Summary of Spearman (*r*) rank correlations between various growth forms encountered in wildflower farming study sites on the Agulhas Plain (South Africa).

Environmental variable/Growth form		Spearman	P-value
Total cover	Geophytes	0.46	P<0.01
	Herbs	0.42	P<0.01
	Large S. Proteoids	0.46	P<0.01
	Medium S. Proteoids	0.30	P<0.01
	Small S. Proteoids	0.44	P<0.01
Average height	Large S. Proteoids	0.58	P<0.01
	Medium S. Proteoids	0.43	P<0.01
Maximum height	Geophytes	0.65	P<0.01
	Herbs	0.46	P<0.01
	Large S. Proteoids	0.50	P<0.01
Open soil	Large S. Other	0.51	P<0.01
Total cover	Large S. Other	-0.42	P<0.01
Average height	Small S. Ericoids	-0.28	P<0.01
Maximum height	Large S. Other	-0.40	P<0.01
	Medium S. Ericoids	-0.32	P<0.01
	Small S. Ericoids	-0.31	P<0.01
Open soil	Geophytes	-0.64	P<0.01
	Herbs	-0.54	P<0.01
Open soil	Small S. Proteoids	-0.35	P<0.01
Litter	Small S. Ericoids	-0.29	P<0.01

* Only significant differences (P<0.01) are shown. View jointly with Figure 3.4
** Abbreviation “S” = shrub

4. Discussion

This investigation showed that wildflower farming practices (broadcast sowing and shallow ploughing) impact significantly on structure (growth form composition and regeneration mode) and diversity of fynbos vegetation. Neither shallow ploughing nor broadcast sowing are 'diversity friendly' and, as such, these practices are not compatable with plant diversity conservation. Study areas subjected to wildflower farming practices showed low resprouter cover that, in turn, reflected low richness, diversity and evenness of fynbos species (Vlok and Yeaton, 2000). Furthermore, the balance between reseeder and resprouter cover (regeneration mode composition) was disrupted by wildflower farming practices that ultimately manifests as altered disturbance regimes. No marked differences existed in regeneration mode composition between broadcast sowing and shallow ploughing. Broadcast sowing had a lower structural impact on fynbos growth form composition than shallow ploughing. However this phenomenon did not support high plant diversity (i.e. species richness, diversity and evenness).

In contrast to results presented here, Joubert et al. (2009) found higher species richness and growth form composition in treatment sites (broadcast sown and shallow ploughed), and resprouters were significantly more abundant (by percentage cover) in treatment sites. Joubert et al. (2009) explained this phenomenon by referring to the intermediate disturbance hypothesis, i.e. diversity will be highest at an intermediate level of disturbance by preventing competitive exclusion (Connell, 1978; Huston, 1979). The observations from this study, despite overlap in research design, are considerably different from Joubert et al. (2009) and can rather be explained by referring to Petraitis et al. (1989) who state that; "species can resist competitors or resist disturbance, but they cannot excel at both". If this trade-off does not occur, maximum species diversity will not transpire at intermediate levels of disturbance (Petraitis et al., 1989).

The following factors can explain observed differences between this investigation and Joubert et al. (2009). Firstly, this study deliberately selected study sites older in post-disturbance age as vegetation age is known to impact on community composition (Kruger, 1983; Privett et al., 2001). Grime (1977) stated that resource demand is probably low in early successional stages and therefore competition for resources would be lower during this 'early establishment' phase. Thus, in an attempt to compensate for this, this investigation selected study sites older in vegetation age. Secondly, vegetation sampling was performed in spring whilst Joubert et al. (2009) sampled during winter. Fynbos plants are known for swift vegetative growth and high allocation to aboveground biomass during spring and summer on an annual basis (Stock et al., 1987) and fynbos species show a typical peak for flowering in spring that extends well into summer (Johnson, 1992). It is obvious that these factors could influence species inventory in a fynbos vegetation survey and are likely to attribute to different observations.

Plant competition (Connell, 1983; Vila and Sardans, 1999) in relation to the particular disturbance regime has been highlighted (Lavorel, 1999; Pickett and White, 1985; Sousa, 1984) and these two entities should be viewed in parallel in context of this discussion. The implementation of wildflower farming practices ultimately manifests as periodic disturbances in fynbos and therefore frequency and intensity of disturbance (*sensu* White and Pickett, 1985) also becomes fundamental for interpreting results from this study. Reseeding proteas are known to form a dominant overstorey in fynbos (Le Maitre and Midgley, 1992). This overstorey plays an important role in maintaining the species richness of fynbos communities (Vlok, 1996; Vlok and Yeaton, 1999). It is therefore not unusual to observe high total cover in this component of fynbos vegetation. Ultimately, the management goal of wildflower farming is to increase the abundance of reseeding, overstorey species that have higher commercial value such as *P. compacta* and *L. platyspermum* (Heydenrych, 1999; Carinus et al., 2004; Joubert et al., 2009; Mustart and Cowling, undated). Here, both species used in broadcast sowing created a dense overstorey which dominated the treatment sites resulting in lower resprouter cover. This artificial overtopping effect can exert strain on understorey species which decrease dominance of the resprouter component (Campbell and Van der Meulen, 1980; Vlok and Yeaton, 2000) and, in turn, lead to declines in plant diversity (Campbell and Van der Meulen, 1980; Specht and Specht, 1989; Cowling and Gxaba, 1990; Esler and Cowling, 1990). Similarly low species richness and diversity have also been observed by Davis (1990) who investigated the impact of marginal cultivation practices used in wildflower farming on fynbos. Low resprouter cover in treatment sites can be explained by physical soil disturbance (ploughing) resulting in altered abiotic conditions and competitive interactions that favour reseeding species (Davis, 1990).

Furthermore, suppression of understorey species (Vlok and Yeaton, 2000) in treatment sites is prominent from the negative relationships between smaller growth forms (graminoids and small shrub ericoid) and large shrub proteoid cover. The CA analysis indicates a close association between graminoids, small shrub ericoids, small shrub proteoids and control sites which is not observed in shallow ploughed sites. Also, from the CA analysis the recovery of shallow ploughed sites seems to differ with vegetation age. Younger vegetation tended to support smaller growth forms whereas older vegetation is dominated by medium- and large growth forms. In context of wildflower farming, it is evident that where competitive interactions are altered by deliberately implementing a disturbance regime that will favour a particular guild (e.g. reseeders), that particular guild will become dominant in the community. This can be paralleled with forestry management principles where artificial disturbance regimes are implemented in an attempt to select for maximum harvesting of a particular species composition in the growth phase following disturbance (Runkle, 1985).

The particular disturbance regime (frequency and intensity) (*sensu* White and Pickett, 1985) is of utmost importance to maintain safe recruitment sites for plants (Grubb, 1977; Cowling, 1987; Lavorel et al., 1994). In context of wildflower farming the frequency and intensity of the disturbance regime are altered. Wildflower farmers implement management practices arguably low in frequency (i.e. every 10 – 15 years) which can largely be observed from the vegetation age structure of study sites and from Chapter 2 (see results). These intervals are commonly recommended by ecological researchers in an attempt to allow for seed maturation in serotinous Proteaceae (Mustart and Cowling, undated; Van Wilgen et al., 1992). Van Wilgen et al. (1994) however highlights that, in the context of natural disturbance regimes, best management principles for Proteaceae species are not necessarily best for all other fynbos species. The low disturbance frequency, could therefore explain violation of the intermediate disturbance hypothesis (Connell, 1978; Huston, 1979) resulting in notably low observations of plant diversity across treatment sites. More importantly however, disturbance intensity should be considered. Joubert et al. (2009) circuitously defines shallow ploughing and broadcast sowing as wildflower farming practices that are ‘low intensity’ disturbances. Acknowledging that this definition made sense in context of the particular study (see Joubert et al., 2009) this investigation does not support a similar view for these farming practices. The impact of disturbance, even naturally occurring fires, on the plant community is governed by both exogenous (Cowling, 1987; Bond and Van Wilgen, 1996) and endogenous factors (Bond et al., 1984; White and Pickett, 1985; Bond, 1995; Thuiller et al., 2007). Therefore, at the plant population scale, recurring disturbances can instigate a stochastic influence on plant composition, structure and life history strategy (Sousa, 1984; White and Pickett, 1985). Given this complex interplay of ecological factors it is suggested that wildflower farming practices, ultimately anthropogenically induced disturbances (Davis, 1990), should not be treated as ‘low intensity’ disturbance types. This has also been addressed in other vegetation types (like renosterveld) where any form of ploughing is regarded as destructive for plant diversity (Walton, 2006).

It is worth mentioning some peculiar observations from the results. Firstly, the marked differences in reseeder cover for the two control sites can possibly be explained by very different fire histories at the sites in preceding years. Van Wilgen et al. (2010) emphasise that community response to fire and subsequent community composition does not only depend on the most recent fire but on all previous fire events. Secondly, observations for species richness and diversity are not higher in 'younger fynbos' (*sensu* Kruger, 1983; Privett et al., 2001) sites as commonly observed by others (Kruger, 1987; Cowling and Pierce, 1988; Cowling and Gxaba, 1990). A possible explanation for these low plant diversity observations, besides altered competitive interactions and disturbance regime, could be intensity and frequency of wildflower harvesting activities, causing open soil cover to increase due to excessive trampling of sensitive understorey vegetation, i.e. geophytes, herbs and small shrub species. This is supported by the negative correlation between these particular growth form categories and open soil cover. Furthermore, one shallow ploughed site (SP2[20]) had a very different arrangement of environmental variables and growth form cover compared to other shallow ploughed sites (SP1[14] and SP3[8]). Total vegetation cover and maximum height was significantly higher for SP2[20]. Additionally, this treatment site (SP2[20]) showed similar cover of the resprouting component than control sites. This treatment site was much older (20 years) in post-disturbance vegetation age, therefore senescence of overstorey reseeding shrubs (Campbell and Van der Meulen, 1980; Picket and White, 1985; Cowling and Gxaba, 1990; Esler and Cowling, 1990) in mature vegetation (i.e. between 12 - 20 years old), that eventually diminish reproductive output (Bond, 1980), could be the reason for increased resprouter cover as resprouter species have the ability to outlive woody shrubs (Campbell and Van der Meulen, 1980). Additionally, the senescence of the overstorey can also explain observed increase in herbaceous cover (Peet, 1978; Campbell, 1980) for this particular site as herbaceous species can persist under a dense overstorey by having different nutrient resource requirements based on unique root depth (Van Der Heyden and Lewis, 1989).

5. Conclusion

Both shallow ploughing and broadcast sowing, as wildflower farming practices, reduce species richness, diversity and evenness at the local scale as these measures of plant diversity were significantly lower in all treatment sites when compared to control sites. Overall, results suggest that both regeneration mode (resprouters and reseeders) and growth form composition are highly altered in fynbos communities subjected to these particular wildflower farming practices. Wildflower farming practices increase the cover of overstorey reseeding shrubs, by broadcast sowing large proteoid shrub species such as *L. platyspermum* and *P. compacta*, that exert stress on understorey sprouting species and general composition. Collectively, altered competitive interactions and disturbance regime brought about by implementing these farming practices play a role in explaining results from this investigation. In the particular context of wildflower farming, the intermediate disturbance hypothesis does not explain results from this survey as suggested by others.

6. Literature cited

Agulhas National Park Management Plan, 2006. Available at: http://www.sanparks.org/parks/agulhas/tourism/plan.php. Accessed on: 21/01/2009.

Bezuidenhout, H., 2003. Major soil types of Cape Agulhas National Park. Internal document, South African National Parks, pp.2.

Bond, W.J., 1980. Fire and senescent fynbos in the Swartberg, southern Cape. South African Forestry Journal 114, 68-71.

Bond, P., Goldblatt, P., 1984. Plants of the Cape flora: a descriptive catalogue. Journal of South African Botany 13, 1-13.

Bond, W.J., Vlok, J., Viviers, M., 1984. Variation in seedling recruitment of Cape Proteaceae after fire. Journal of Ecology 72, 209-221.

Bond, W.J., Cowling, R.M., Richards, M.B., 1992 Competition and coexistence. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 206-225.

Bond, W.J., Maze, K., Desmet, P., 1995. Fire life-histories and the seeds of chaos. Ecoscience 2, 252-260.

Bond, W.J., Van Wilgen, B.W., 1996. Fire and Plants. Chapman and Hall, London.

Campbell, B.M., 1980. Some mixed hardwood forest communities of the coastal ranges of southern California. Phytocoenologia 8, 297-320.

Campbell, B.M., Van der Meulen, F., 1980. Patterns of plant-species diversity in fynbos vegetation, South Africa. Vegetatio 43, 43-47.

Carinus, T., Blomerus, L., de Ponte Machado, M., Gerber, F., Holmes, P., Kabot, L., Marais, C., Martens, C., Middelman, M., Privett, S., Palmer, G., Saunders, R., Scott, A., Scott, M., 2004. Guidelines for Sustainable Harvesting of Selected Indigenous Plant Species in the Cape Floristic Region. In SAPPEX, Cape Flora, Cape Town.

Chesson, P.L., Warner, R.R., 1981. Environmental variability promotes coexistence in lottery competitive-systems. American Naturalist 117, 923-943.

Cole, N.S., Lombard, A.T., Cowling, R.M., Euston-Brown, D., Richardson, D.M., Heijnis, C.E. (Eds.), 2000. Framework for a conservation plan for the Agulhas Plain, Cape Floristic Region, South Africa. IPC Report 00/01. Institute for Plant Conservation, University of Cape Town.

Connell, J.H., 1978. Diversity in tropical rain forests and coral reefs - high diversity of trees and corals is maintained only in a non-equilibrium state. Science 199, 1302-1310.

Connell, J.H., 1983. On the prevalence and relative importance of interspecific competition: evidence from field experiments. The American Naturalist 122, 661-696.

Conradie, B., Knoesen, H., 2009. A survey of the cultivation and wild harvesting of fynbos flowers in South Africa. Available at: http://www.flowervalley.org.za Accessed on: 17/05/2010.

Cowling, R.M., 1987. Fire and its role in coexistence and speciation in Gondwanan shrublands. South African Journal of Science 83, 106-111.

Cowling, R.M., 1989. The Research Perspective: Veld Resources. In: Greyling, T., Davis, G.W. (Eds.), The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes: Occasional Report No. 40. Foundation for Research Development, CSIR, Pretoria, South Africa. pp. 14-16.

Cowling, R.M., Rundel, P.W., Lamont, B.B., Arroyo, M.K., Arianoutsou, M., 1996. Plant diversity in mediterranean-climate regions. Trends in Ecology and Evolution 11, 362-366.

Cowling, R.M., Gxaba, T., 1990. Effects of a fynbos overstorey shrub on understorey community structure: implications for the maintenance of community wide species richness. South African Journal of Ecology 1, 1-7.

Cowling, R.M., Holmes, P.M., 1992. Flora and vegetation. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 23-61.

Cowling, R.M., Pierce, S.M., 1988. Secondary succession in coastal dune fynbos: variation due to site and disturbance. Vegetatio 76, 131-139.

Davis, G.W., 1990. Commercial wildflower production in the fynbos biome and its role in the management of land-use. PhD Thesis, Department of Botany, University of Cape Town.

Davis, G.W., 1992. Commercial exploitation of natural vegetation: an exploratory model for management of the wildflower industry in the fynbos biome of the Cape, South Africa. Journal of Environmental Management 35, 13 - 29.

Esler, K.J., Cowling, R.M., 1990. Effects of density on the reproductive output of *Protea lepidocarpodendron*. South African Journal of Botany 56, 29-33.

Goldblatt, P., Manning, J., 2000. Cape Plants: A Conspectus of the Cape Flora of South Africa. Strelitzia 9. National Botanical Institute, Cape Town. (Missouri Botanical Garden).

Grime, J.P., 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. American Naturalist 111, 1169-1194.

Grubb, P.J., 1977. Maintenance of species-richness in plant communities - importance of regeneration niche. Biological Reviews of the Cambridge Philosophical Society 52, 107-145.

Herath, D.N., Lamont, B.B., Enright, N.J., Miller, B.P., 2009. Comparison of post-mine rehabilitated and natural shrubland communities in southwestern Australia. Restoration Ecology 17, 577-585.

Heydenrych, B.J., 1999. An investigation of land-use practices on the Agulhas Plain (South Africa), with emphasis on socio-economic and conservation issues. MSc Thesis, Institute for Plant Conservation, University of Cape Town.

Hurlbert, S.H., 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52, 577-586.

Huston, M.A., 1979. A general hypothesis of species diversity. American Naturalist 113, 81-101.

Joubert, L., Esler, K.J., Privett, S.D.J., 2009. The effect of ploughing and augmenting natural vegetation with commercial fynbos species on the biodiversity of Overberg Sandstone fynbos on the Agulhas Plain, South Africa. South African Journal of Botany 75, 526-531.

Johnson, S.D., 1992. Climatic and phylogenetic determinants of flowering seasonality in the Cape flora. Journal of Ecology 81, 567-572.

Kruger, F.J., 1983. Plant community diversity and dynamics in relation to fire. In: Kruger, F.J., Mitchell, D.T., Jarvis, J.U.M. (Eds.), Mediterranean-type ecosystems: the role of nutrients. Springer-Verlag, Berlin, Germany. pp. 446-472.

Kruger, F.J., 1987. Succession after fire in selected fynbos communities of the southwestern Cape. PhD Thesis, University of the Witwatersrand.

Lavorel, S., Lepart, J., Debussche, M., Lebreton, J.D., Beffy, J.L., 1994. Small scale disturbances and the maintenance of species diversity in mediterranean old fields. Oikos 70, 455-473.

Lavorel, S., 1999. Ecological diversity and resilience of mediterranean vegetation to disturbance. Diversity and Distributions 5, 3-13.

Le Maitre, D.C., Midgley, J.J., 1992. Plant reproductive ecology. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 135–174.

Linder, H.P. 2003. The radiation of the Cape flora, southern Africa. Biological Reviews 78, 597-638.

Lombard, A.T., Cowling, R.M., Pressey, R.L., Mustart, P.J., 1997. Reserve selection in a species-rich and fragmented landscape on the Agulhas Plain, South Africa. Conservation Biology 11, 1101-1116.

Maze, K.E., Bond, W.J., 1996. Are Protea populations seed limited? Implications for wildflower harvesting in Cape fynbos. Australian Journal of Ecology 21, 96-105.

Middelmann, W.J., Gibson, G., Bell, I., 1989. Chapter 2: The Commercial Perspective. In: Greyling, T., Davis, G.W. (Eds.), The Wildflower Resource: Commerce, Conservation and

Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes Occasional Report No.40. Foundation for Research Development, CSIR, Pretoria, South Africa. pp. 10-13.

Mucina, L., Rutherford, M.C., 2006. The Vegetation of South Africa, Lesotho and Swaziland. South African National Biodiversity Institute, Pretoria.

Mustart, P.J., Cowling, R.M., undated. Fynbos ecology for wildflower harvesters. Unpublished document. Department of Botany, University of Cape Town.

Mustart, P.J., Cowling, R.M., 1992. Impact of flower and cone harvesting on seed banks and seed set of serotinous Agulhas-Proteaceae. South African Journal of Botany 58, 337-342.

Myers, N., 1990. The biodiversity challenge: expanded hot-spots analysis. Environmentalist 10, 243-256.

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

Peet, R.K., 1974. The measurement of species diversity. Annual Review of Ecology and Systematics 5, 285-307.

Peet, R.K., 1978. Latitudinal variation in southern Rocky Mountain forest. Journal of Biogeography 5, 275-289.

Pence, G.Q.K., Botha, M.A., Turpie, J.K., 2003. Evaluating combinations of on- and off-reserve conservation strategies for the Agulhas Plain, South Africa: a financial perspective. Biological Conservation 112, 253-272.

Petraitis, P.S., Latham, R.E., Niesenbaum, R.A., 1989. The maintenance of species diversity by disturbance. The Quarterly Review of Biology 64, 393-418.

Pickett, S.T.A., White, P.S., 1985. The ecology of natural disturbance and patch dynamics. Academic Press, London.

Pielou, E.C., 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13, 131-144.

PPSA., 2009. (Protea Producers of South Africa). A survey of the cultivation and wild harvesting of fynbos flowers in South Africa. Newsletter/July 2009. Available at: http://www.givengain.com/cause_data/images/1866/Nuusbrief_5_-_July_2009.pdf. Accessed on: 09/06/2010.

Privett, S.D.J., Cowling, R.M., Taylor, H.C., 2001. Thirty years of change in the fynbos vegetation of the Cape of Good Hope Nature Reserve, South Africa. Bothalia 31, 99-115.

Privett, S.D.J., 2002. Agulhas Biodiversity Initiative: Sustainable Harvesting Component. Agulhas Biodiversity Initiative.

Privett, S.D.J., 2009. Personal communication. Flower Valley Conservation Trust.

Raimondo, D., von Staden, L., Foden, W., Victor, J.E., Helme, N.E., Turner, R.C., Kamundi, D.A., Manyama, P.A., 2009. Red List of South African Plants 2009. Strelitzia 25, South African National Biodiversity Institute, Pretoria.

Rebelo, A.G., 1992. Red data book species in the Cape Floristic Region - threats, priorities and target species. Transactions of the Royal Society of South Africa 48, 55-86.

Runkle, J.R., 1985. Disturbance regimes in temperate forests. In: Pickett, S.T.A., White, P.S. (Eds.), The ecology of natural disturbance and patch dynamics. Academic Press, London. pp.17-33.

Shannon, C.E., Weaver, W., 1949. The mathematical theory of communication. University of Illinois Press, Urbana.

Simpson, E.H., 1949. Measurement of diversity. Nature 163, 688.

Sousa, W.P., 1984. The role of disturbance in natural communities. Annual Review of Ecology and Systematics 15, 353-391.

SAPPEX., 2006. South African Protea Producers and Exporters Association. An overview of the South African fynbos and Protea industry. Unpublished document.

Specht, R.L., Specht, A., 1989. Species richness of sclerophyll (heathy) plant communities in Australia - the influence of overstory cover. Australian Journal of Botany 37, 337-350.

Spellerberg, I.F., Fedor, P.J., 2003. A tribute to Claude Shannon (1916–2001) and a plea for more rigourous use of species richness, species diversity and the 'Shannon-Wiener' index. Global Ecology and Biogeography 12, 177-179.

Statsoft, Inc. 2010. STATISTICA (data analysis software system). Version 9.0. www.statsoft.com

Stirling, G., Wilsey, B., 2001. Empirical relationships between species richness, evenness and proportional diversity. The American Naturalist 158, 286-299.

Stock, W.D., Sommerville, J.E.M., Lewis, O.A.M., 1987. Seasonal allocation of dry mass and nitrogen in a fynbos endemic Restionaceae species *Thamnochortus punctatus* Pill. Oecologia 72, 315-320

Thuiller, W., Slingsby, J.A. Privett, S.D.J. Cowling, R.M., 2007. Stochastic species turnover and stable coexistence in a species-rich, fire-prone plant community. Public Library of Science One 2, e938. doi:10.1371.

Thwaites, R.N., Cowling, R.M., 1988. Soil-vegetation relationships on the Agulhas Plain, South Africa. Catena 15, 333-345.

Van der Heyden, F., Lewis, O.A.M., 1989. Seasonal variation in photosynthetic capacity with respect to plant water status of five species of the Mediterranean climate region of South Africa. South African Journal of Botany 55, 509-515.

Van Wilgen, B.W., Bond, W.J., Richardson, D.M., 1992. Ecosystem management. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 345-371.

Van Wilgen, B.W., Richardson, D.M., Seydack, A.H.W., 1994. Managing fynbos for biodiversity: constraints and options in a fire-prone environment. South African Journal of Science 90, 322-329.

Van Wilgen, B.W., Forsyth, G.G., de Klerk, H., Das, S., Khuluse, S., Schmitz, P., 2010. Fire management in Mediterranean-climate shrublands: a case study from the Cape fynbos, South Africa. Journal of Applied Ecology 47, 631-638.

Vila, M., Sardans, J., 1999. Plant competition in mediterranean-type vegetation. Journal of Vegetation Science 10, 281-294.

Vlok, J.H.J. 1996. The role of overstorey proteoid shrubs in maintaining species richness in a southern Cape mountain fynbos community. MSc Thesis, Department of Botany, University of Natal.

Vlok, J.H.J., Yeaton, R.I., 1999. The effect of overstorey Proteas on plant species richness in South African mountain fynbos. Diversity and Distributions 5, 213-222.

Vlok, J.H.J., Yeaton, R.I., 2000. Competitive interactions between overstorey proteas and sprouting understorey species in South African mountain fynbos. Diversity and Distributions 6, 273-281.

Walton, B.A., 2006. Vegetation patterns and dynamics of Renosterveld at Agter-Groeneberg Conservancy, Western Cape, South Africa. MSc, Stellenbosch University.

White, P.S., Pickett, S.T.A., 1985. Natural disturbance and patch dynamics: an introduction. In Pickett, S.T.A., White, P.S. (Eds.), The ecology of natural disturbance and patch dynamics. Academic Press, London. pp. 3-13

UNDP., 2003. United Nations Development Programme. Agulhas Biodiversity Initiative. Global Environmental Facility Project document: Cape Action Plan for the Environment.

Yeaton, R.I., Bond, W.J., 1991. Competition between two shrub species: dispersal differences and fire promote coexistence. The American Naturalist 138, 328-341.

CHAPTER 4:

Impact of wildflower farming practices on fynbos composition and rare species (Agulhas Plain, South Africa)

Abstract

Natural disturbance regimes are known to impact on vegetation composition, and have been well studied in the context of fynbos ecology. However, the impact of anthropogenically induced disturbance regimes, such as wildflower farming practices, on fynbos species composition and 'rarity' are completely unknown. The mediterranean Cape Floristic Region is known as a global biodiversity hotspot of which the Agulhas Plain is a significant species-rich constituent. On the Agulhas Plain fynbos wildflower farming is widely practiced and farming practices are used as augmentation in an attempt to supply focal (i.e. commercial) species to the market. From a conservation perspective, farming practices manifest as anthropogenically induced disturbances in the landscape and are seen as a potential threat to the conservation of the region's botanical diversity. Studies have shown that wildflower farming practices significantly alter fynbos structure (growth form and regeneration mode) and plant diversity. Therefore, farming practices could possibly impact on fynbos composition by firstly, changing abundance of dominant species and, secondly, altering abundance of so-called 'rare' species which are known to be more sensitive to anthropogenically induced disturbances. This chapter reports on fynbos compositional change (plant family and dominant species) and, the abundance and presence of 'rare' species between control (representing intact wildflower vegetation) and treatment sites (subjected to wildflower farming practices). Additionally, in an attempt to justify application of wildflower farming practices, reference is made to the abundance of certain commercial species between control and treatment sites. Fynbos composition, plant family and dominant species, compared across study sites showed marked variation. Contrary to expectations, control sites did not support a higher number or abundance of 'rare' species. Furthermore, there is no clear evidence that farming practices explicitly favour certain commercial species by increasing the abundance of these species. The major constraint that limits generalisation is the local (alpha) scale of this investigation as fynbos species are known to be naturally patchily distributed

Keywords: fynbos conservation, disturbance, fynbos composition, plant diversity, plant family, commercial species

1. Introduction

Loss of biodiversity is a pressing issue as global biodiversity is increasingly threatened by the current rapid growth of the human population which relates directly to various forms of environmental degradation (Ehrlich and Holdren, 1971; Pimm et al., 1995; Harte, 2007; Vié et al., 2008). Mediterranean biomes boast exceptional plant species richness and endemism (Cowling et al., 1996; Underwood et al., 2009) however at the same time these areas are facing greatest biodiversity change (Sala et al., 2000; Underwood et al., 2009). The Cape Floristic Region (87 892 km^2) (CFR, Bond and Goldblatt, 1984) is known as a global biodiversity hotspot (Mittermeier et al., 1998; Myers et al., 2000) and has subsequently been a focus for conservation (Gelderblom et al., 2003; Pressey et al., 2003; Raimondo et al., 2009). The Agulhas Plain (2160 km^2), a major species-rich constituent of the CFR, is unique in plant diversity and endemism (Thwaites and Cowling, 1988; Cowling and Holmes, 1992; Raimondo et al., 2009) and is known as a priority area for conservation with a high concentration of threatened lowland species (UNDP[20], 2003).

Natural disturbance events are known to impact on vegetation composition. Consequently, species abundance and composition change over time due to varying responses to the particular disturbance regime (Pickett and White, 1985). The impact of natural disturbance events on species composition is a central issue in vegetation ecology (Sousa, 1984; Picket and White, 1985) and specifically in fynbos communities (Van Wilgen and Kruger, 1981; Kruger, 1983; Bond et al., 1984; Privett, 1998). Considering the current biodiversity crisis (*sensu* Pimm et al., 1995) anthropogenically induced disturbances receive increased attention from the scientific community as these disturbances are known to cause severe degradation of natural systems (Vitousek, 1994; Pimm et al., 1995; Sala et al., 2000; Leadley et al., 2010). Wildflower farming, strictly from natural vegetation, covers a large surface area on the Agulhas Plain (Heydenrych, 1999; Privett et al., 2002; Conradie and Knoesen, 2009). This land use is highlighted as a potential concern to plant diversity conservation of the region as farming practices (used in wildflower farming) impact significantly on abiotic and biotic components of fynbos (Cowling, 1989; Davis, 1990; Joubert et al., 2009; also see Chapter 3).

Wildflower farmers rely on supplying focal (i.e. commercial) wildflower species to the market (Heydenrych, 1999) which includes a range of focal flower material such as flowers/showy inflorescences (e.g. Proteaceae) and filler material (Ericaceae, Bruniaceae, Asteraceae, Thymelaeaceae)

[20] United Nations Development Programme (UNDP)

derived from fynbos vegetation (Conradie, 2009). In an attempt to increase the abundance of commercial species and to maintain healthy plants (i.e. pest free and reproductive) certain farming practices are implemented (Cowling, 1989; Van Wilgen et al., 1992; Carinus et al., 2004). Ploughing, burning and broadcast sowing are used in varying combinations in wildflower farming (Joubert et al., 2009; also see Chapter 2). In terms of ploughing, the use of shallow and deep ploughing can be distinguished. Shallow ploughing is a topsoil disturbance whilst deep ploughing is a soil disturbance extending to depths > 10 cm (Joubert et al., 2009). So-called "high intensity" farming practices (e.g. deep ploughing) are known to be detrimental to fynbos diversity (Joubert et al., 2009) but also "low intensity" farming practices (e.g. shallow ploughing and broadcast sowing) exert stress on fynbos structure and diversity (see Chapter 3).

Changes in the natural environment that result in altered community composition are poorly understood. Nonetheless structural alterations, such as changes in growth form composition, are closely associated with modified species abundance that can potentially promote extinction (Westman, 1990; Privett, 1998; Larsen et al., 2005). Westman (1990) emphasised that active ecosystem management, i.e. promoting the abundance of desired species, often changes abundance of coexisting species and especially impact on so-called 'endangered' species. Such species are regarded as more susceptible to extinction by both natural and human disturbances (Gaston, 1994; Levin et al., 1996; Privett, 1998; Davies et al., 2004). In context of wildflower farming, Cowling (1989) highlights that any species extinction due to, specifically, overharvesting is unacceptable. However, equally undesirable are extinctions brought about by any other form of wildflower management. Therefore, a key point in the application of fynbos farming practices (management) should be to minimise impact on or alterations in fynbos composition that can potentially be detrimental for plant diversity (Cowling, 1989; Van Wilgen et al., 1992).

Plant diversity represents an exceptional constituent of global biodiversity and is the foundation of most foodwebs (Huston, 1994; Groombridge and Jenkins, 2002). Currently, plant diversity declines are escalating and it is speculated that such loss will have greatest impact on society as plants are considered important for human welfare and economic development (Kier et al., 2005; Schatz, 2009). Species of conservation importance/attention (*sensu* Vié et al., 2008; Underwood et al. 2009) are an important constituent of biological diversity (Prendergast et al., 1993; Gaston, 1994; Vié et al., 2008) and these species are often termed 'rare', 'endangered' or 'threatened' species based on specific criteria

(Vié et al., 2008). The IUCN[21] Red List is a process where certain taxa are assessed in order to reveal information about the conservation status and related threats of a particular species (extinction risk) (Collar, 1996; Butchart et al., 2005; Rodrigues et al., 2006), i.e. identifying species of conservation concern (Raimondo et al., 2009). The diverse flora of South Africa has recently been comprehensively assessed by the publication of the Red List of South African Plants (Raimondo et al., 2009). Species that have a 'rarity status' other than 'least concern' according to the Red List of South African Plants (Raimondo et al., 2009) are considered to be species of conservation priority. In this chapter these species are collectively termed 'rare' species. Threatened species lists have been prone to criticism (Possingham et al., 2002) and recognised as not being absolute (Rodrigues et al., 2006). However the IUCN Red List assessment process has developed considerably over past years and is seen as an influential tool that can aid in conservation related issues (Rodrigues et al., 2006; Butchart et al., 2007).

The impact of wildflower farming practices on fynbos composition (i.e. plant family, dominant and rare species) has not been investigated. This study aims to investigate the impact of farming practices on fynbos composition, by looking specifically at plant family, dominant and rare species. This study suggests that wildflower farming practices possibly change fynbos composition, a result of altered growth form composition (see Chapter 3). Two specific aims are addressed in this chapter. Firstly, to compare plant composition, by investigating plant family and dominant species between control sites (i.e. representing intact fynbos communities) and treatment sites (i.e. subjected to wildflower farming practices). Secondly, to investigate abundance and presence of rare species, as defined by using rarity criteria from the Red List of South African Plants 2009 (Raimondo et al., 2009), between control and treatment sites. Finally, the abundance of selected commercial species are compared between control and treatment sites in an attempt to justify application of wildflower farming practices.

2. Methods

Vegetation sampling and experimental design followed a similar approach outlined in Chapter 3 (section 2.1 – 2.4). After plant species identification, each species was defined a 'rarity' status according to the Red List of South African Plants (Raimondo et al., 2009). Any species having a 'rarity status' other than 'least concern' (LC) was defined as 'rare' and is presented in Table 4.2.

[21] International Union for Conservation of Nature and Natural Resources

2.1 *Data analysis*

Correspondence analysis (CA) was selected as the ordination technique to show the relationship, firstly, between study sites (control and treatment sites) and plant family cover and, secondly, between study sites (control and treatment sites) and dominant species cover. A dominant species was defined as a species having more than 50% cover summed across all study sites (summed cover presented in Appendix 7). Mean cover of 'rare' species in all study sites is only presented qualitatively (summarised in Table 4.2) as nature of the data did not allow for any formal statistical analysis (Kidd pers.com.). All statistical analysis were performed in STATISTICA 9 (Statsoft, inc., 2010).

3. Results

One hundred and seventy seven (177) plant species were recorded in all study sites of which a hundred and seventy four (174) could be identified up to genera and species level. The 174 plant species constituted 41 plant families and 102 plant genera. Four species remained unidentified after extensively consulting all available resources and were excluded from results presented here. Species that were identified up to genus level (16 species) were included in data analysis and results. All species information (plant family, genus, scientific name, regeneration mode, "Red List status" (*sensu* Raimondo et al., 2009) and mean cover) are provided in Appendix 4.

3.1 *Plant family composition*

The correspondence analysis (CA) (Figure 4.1) shows the relationship between plant family composition and study sites. The first two dimensions of the CA[22] accounted for 67.98% of the variance (Dimension 1, Eigenvalue 0.10238, total variance 38.60%; Dimension 2, Eigenvalue 0.07793, total variance 29.38%). The broadcast sowing site (BCS[10]) had similar plant family composition to control sites (C1[14]; C2[20]) whereas plant family composition between shallow ploughed sites (SP1[14], SP2[20] and SP3[8]) and control sites (C1[14]; C2[20]) differed significantly. Acknowledging the former, the shallow ploughed site (SP3[8]) showed more correspondence with control sites (C1[14]; C2[20]) than the other two shallow ploughed sites (SP1[14], SP2[20]). Shallow

[22] Column totals of the CA analysis (Figure 4.1, variable: plant family) are provided in Appendix 8

ploughed sites (SP1[14], SP2[20]) had markedly different family composition when compared to each other. Mean cover of plant families across study sites are provided as additional results in Appendix 9.

Plant families restricted to reference sites included; Convallariaceae, Geraniaceae, Santalaceae and Schizaeaceae. In turn, plant families exclusive to shallow ploughed sites include; Apiaceae, Crassulaceae and Plumbaginaceae. Poaceae species were restricted to both treatments, i.e. shallow ploughed and broadcast sown and did not occur in control sites. No plant family occured exclusively at the broadcast sown site (results not shown, see Appendix 9).

The five most speciose (i.e. highest number of species recorded) plant families in the vegetation survey were Asteraceae, Restionaceae, Iridaceae, Proteaceae and Ericaceae. These plant families accounted for 90 (51.7%) of the 174 plant species recorded in the survey. Furthermore these plant families were also the five most dominant families (by percentage cover) across all study sites. Asteraceae cover was fairly similar in most study sites except for a marked increase in one shallow ploughed site, SP1[14]. Restionaceae species showed exceptionally low cover in two shallow ploughed sites, SP1[14] and SP2[20]. Iridaceae cover was either exceptionally low in certain treatment sites (BCS[10], SP1[14], SP3[8]) or exceptionally high in one shallow ploughed site (SP2[20]). Proteaceae showed marked increased cover in a shallow ploughed site (SP2[20]) and the broadcast sown site (BCS[10]). Ericaceae cover was noticeably lower in two shallow ploughed sites, SP1[14] and SP2[20] (Table 4.1).

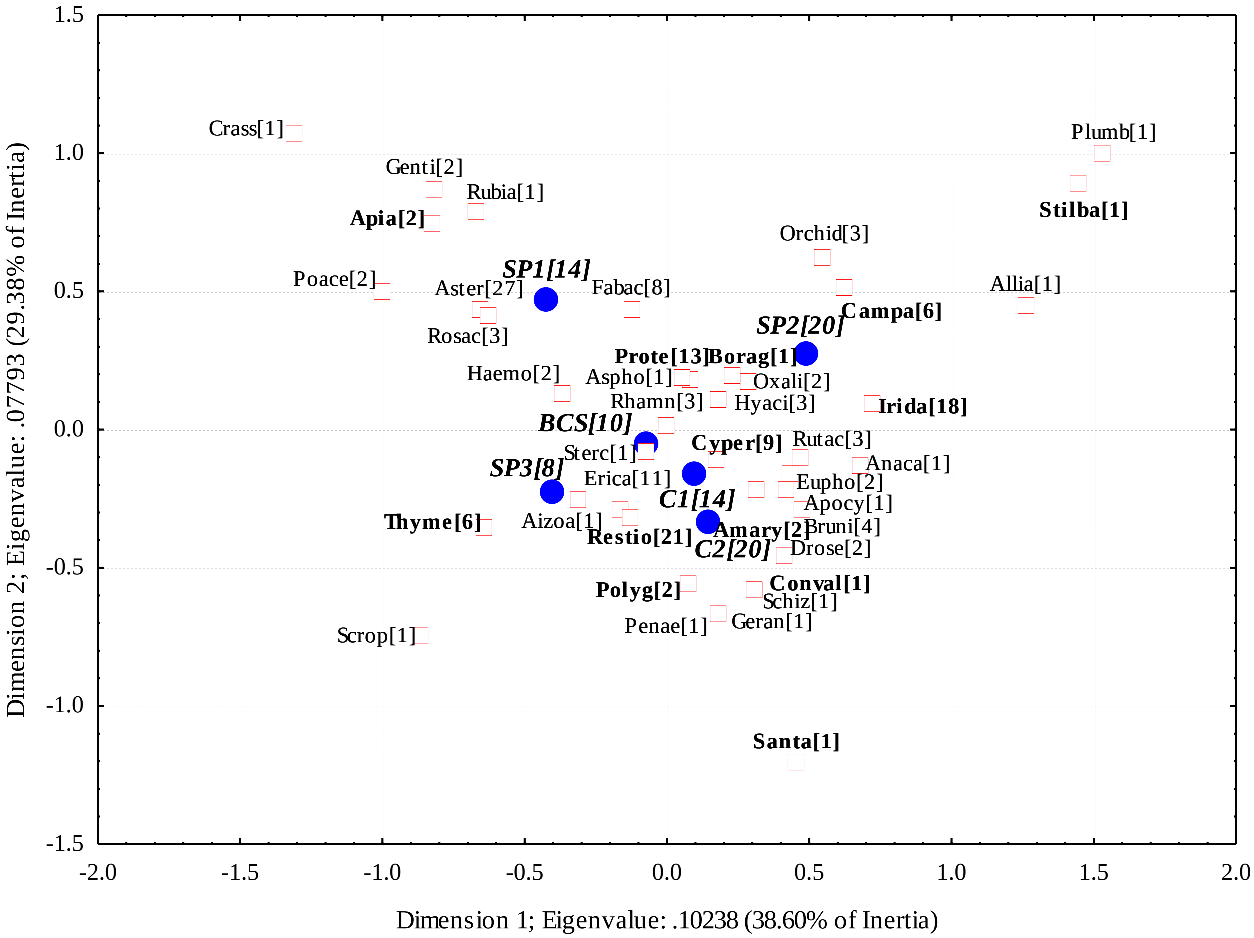


Figure 4.1: Correspondence analysis (CA) showing the relationship between plant family cover and study sites on the Agulhas Plain (South Africa). The first two dimensions of the CA accounted for 67.98% of the variance (Dimension 1, Eigenvalue 0.10238, total variance 38.60%; Dimension 2, Eigenvalue 0.07793, total variance 29.38%). Study sites abbreviated as follow; control sites (C1[14], C2[20]), broadcast sown site (BCS[10]) and shallow ploughed sites (SP1[14], SP2[20], SP3[8]). Study sites vary in post-fire age, indicated in brackets []. Plant families are abbreviated by first five letters (full names provided in Appendix 9); number of species recorded per family indicated in brackets []. Plant families with any number of 'rare' species (Raimondo et al., 2009) (also see Table 4.2) printed in bold.

Table 4.1: Five most dominant plant families (by mean cover and number of species) with constituent dominant species (by 50% cover; depicted in Figure 4.2) occurring in study sites on the Agulhas Plain (South Africa). Study sites are abbreviated as follow; control sites (C1[14], C2[20]), broadcast sown site (BCS[10]) and shallow ploughed sites and (SP1[14], SP2[20], SP3[8]). Study sites vary in post-fire age, indicated in brackets [].

			Natural		*Treatments*			
Family	# of species	Dominant species across study sites (depicted in Figure 4.2)	C1[14]	C2[20]	BCS[10]	SP1[14]	SP2[20]	SP3[8]
Asteraceae	**27**		**3.37**	**2.43**	**1.60**	**10.17**	**1.46**	**4.86**
		*Metalasia densa**	0	0.1	0	4.3	0	0.3
Iridaceae	**18**		**5.33**	**5.25**	**1.47**	**1.00**	**11.11**	**0.82**
		Lanaria lanata	2.3	2.8	0.3	0.5	7.4	0
		Aristea bakeri	1.5	1.3	0	0	2.7	0
Restionaceae	**21**		**10.10**	**13.18**	**13.60**	**4.97**	**6.61**	**14.00**
		Calopsis hyalina	2.8	0.5	2.5	0.4	0.4	4.8
		Mastersiella digitata	2.3	4.1	2.3	1.0	0.8	0.3
		Ischyrolepis capensis	0.5	1.8	3.2	0.8	1.4	3.4
		Thamnochortus fraternus	0.1	0.3	0.9	1.0	0.3	1.2
		Elegia stipularis	1.4	3.2	1.9	0	0.3	0.2
		Restio filiformis	0.4	1.2	0.9	0.2	1.2	0.5
Proteaceae	**13**		**24.83**	**16.64**	**31.37**	**25.13**	**45.07**	**21.89**
		*Protea compacta**	4.4	8.9	13.1	0.6	4.6	1.0
		*Leucadendron xanthoconus**	4.3	5.2	9.1	10.6	2.4	1.6
		*Leucadendron platyspermum**	0	0	0	9.7	28.1	17.4
		Aulax umbellata	8.1	0	0.1	2.3	5.8	0.5
		Serruria elongata	1.5	0.9	1.1	1.0	1.2	1.0
		Serruria fasciflora	1.6	0.8	6.1	0.4	0	0
		Mimetes cucullatus	1.3	0.9	0.8	0	0.8	0.3
		Protea longifolia	3.5	0	0.4	0.1	2.0	0
Ericaceae	**11**		**16.97**	**11.68**	**11.60**	**6.93**	**5.50**	**14.57**
		Erica plukenetti	5.1	1.8	3.7	1.8	1.5	0
		Erica bruniades	3.6	4.5	3.1	0.1	1.6	8.9
		*Erica imbricata**	4.9	1.9	1.4	4.1	1.6	2.6
		*Erica coriifolia**	2.4	3.4	3.1	0.8	0.6	2.6
TOTAL	**90 (51.7%)**							

* Indicates a species used commercially in the wildflower industry (Conradie, 2009)

3.2 *Dominant species*

The correspondence analysis (CA) indicates variation amongst the 31 dominant species and study sites (Figure 4.2). The first two dimensions of the CA[23] accounted for 61.16% of the variance (Dimension 1, Eigenvalue 0.228891, total variance 37.80%; Dimension 2, Eigenvalue 0.17858, total variance 23.36%). Certain dominant species show affinity for particular study sites. Control sites (C1[14] and C2[20]) were mostly dominated by Proteaceae, Ericaceae and Restionaceae species. However, three species (encircled by "A" (*Mimetes cucullatus* (Proteaceae), *Penaea mucronata* (Peneaceae), *Elegia stipularis* (Restionaceae)) corresponded strongly with control sites (C1[14] and C2[20]). In shallow ploughed sites, *Metalasia densa* (Asteraceae) and *Cliffortia stricta* (Rosaceae) was exceptionally dominant in SP1[14]. Similarly, *Passerina corymbosa* (Thymelaeaceae), *Calopsis hyalina* (Restionaceae) and *Ischyrolepis capensis* (Restionaceae) showed higher cover at one shallow ploughed site, SP3[8], than at any oher study site. The oldest shallow ploughed site, SP2[20], had significant dominance of two geophytic species, *Lanaria lanata* (Iridaceae) and *Aristea bakeri* (Iridaceae). In turn, *Serruria fasciflora* (Proteaceae) showed strong affinity for the broadcast sowing site (BCS[10]). The group indicated by "B" (in Figure 4.2) constitutes various Restionaceae, Ericaceae and Cyperaceae species. These dominant species are markedly 'shared' between control and treatment sites (BCS[10], SP1[14], SP2[20] and SP3[8]). Other dominant species (*Drimia media* (Hyacinthaceae), *Oxalis stellata* (Oxalidaceae) and *Phylica ericoides* (Rhamnaceae)) occurred across both control and treatment sites (shallow ploughed and broadcast sown).

Mean cover of all the dominant species across study sites are provided as additional results in Appendix 11.

[23] Column totals of the CA analysis (Figure 4.2, variable: dominant species) are provided in Appendix 10

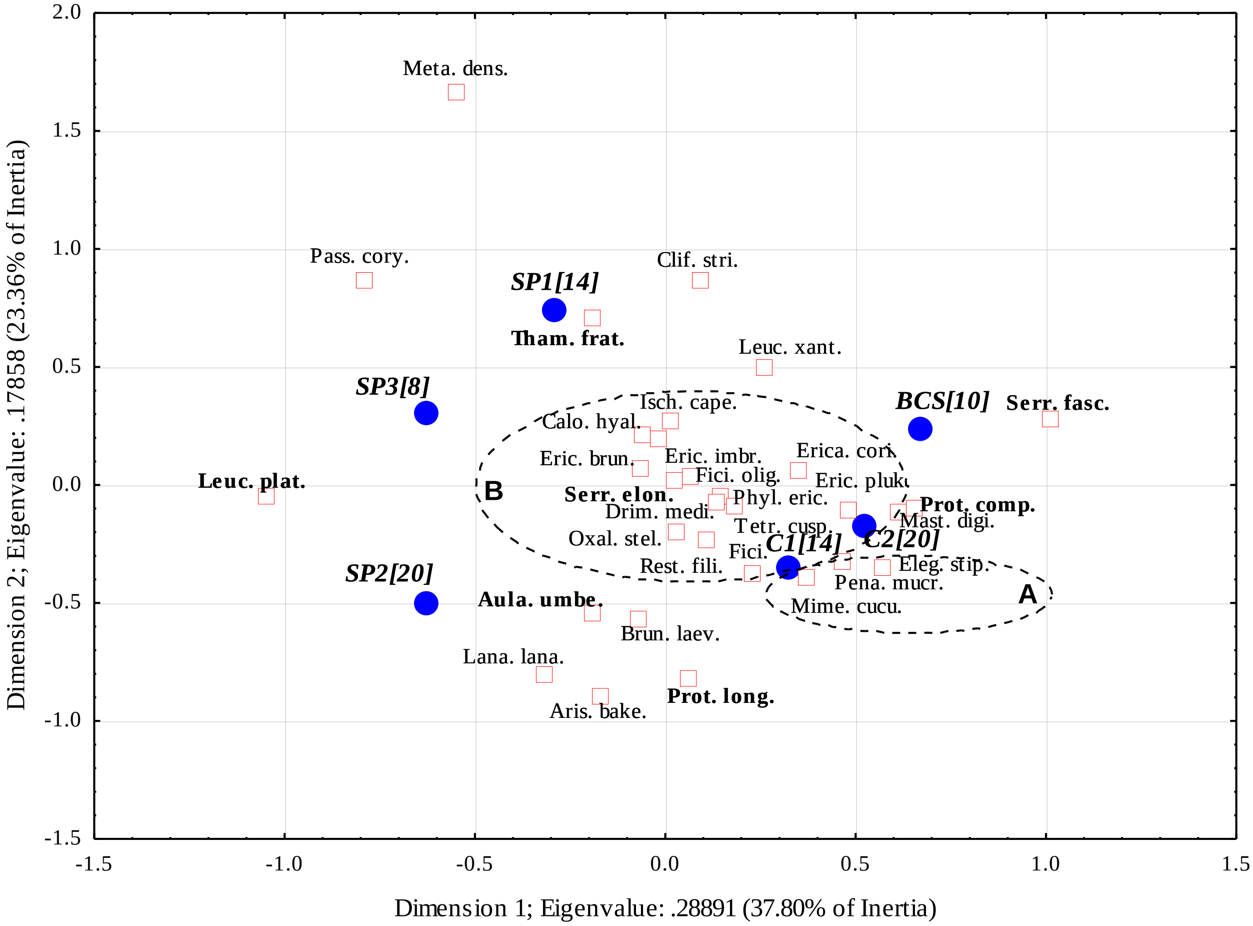


Figure 4.2: Correspondence analysis (CA) showing the relationship between 31 dominant species (by percentage cover) and study sites on the Agulhas Plain (South Africa). The first two dimensions of the CA accounted for 61.16% of the variance (Dimension 1, Eigenvalue 0.228891, total variance 37.80%; Dimension 2, Eigenvalue 0.17858, total variance 23.36%). Study sites abbreviated as follow; control sites (C1[14], C2[20]), broadcast sown site (BCS[10]) and shallow ploughed sites (SP1[14], SP2[20], SP3[8]). Study sites vary in post-fire age, indicated in brackets []. 'Rare' species (*sensu* Raimondo et al., 2009) are printed in bold (also see Table 4.2). The group indicated by "A" are species that showed marked affinity for control sites and the group indicated by "B" constitutes mostly Restionaceae, Ericaceae and Cyperaceae species. Full species names provided in Table 4.1 and Appendix 11.

3.3 *Rarity*

The 25 species classified according to 'rarity' status (Raimondo et al., 2009) varied across study sites (Table 4.2). The highest number of 'rare' species (16) was recorded in a control site (C1[14]) whilst the lowest number (10) of 'rare' species was recorded in the other control site (C2[2]) and a shallow ploughed site (SP3[8]).

Six species classified as 'rare' also constituted dominant species (by percentage cover) in study sites. All six species belong to the family Proteaceae and include; *Aulax umbellata*, *Leucadendron platyspermum*, *Protea compacta*, *Protea longifolia*, *Serruria elongata* and *Serruria fasciflora*. Of note, *Leucadendron platyspermum* and *Protea compacta* were the species used in, respectively, shallow ploughing (SP1[14], SP2[20] and SP3[8]) and broadcast sowing (BCS[10]) and are therefore strongly associated with these particular sites. *Protea compacta* however also occurs naturally in the study area and therefore shows affinity for control sites (C1[14] and C2[20]).

3.4 *Commercial species*

Eight of the 31 dominant species corresponded with fifteen commercial species identified from a recent commercial assessment by Conradie (2009). An additional seven species that are not dominant in study sites are also used commercially (Conradie, 2009) (Table 4.3). Price per stem was stipulated to indicate price trends of (currently) popular wildflower species, i.e. used commercially by the wildflower industry (Conradie, 2009).

One commercial species used in shallow ploughed sites as augmentation, *L. platyspermum* (Proteaceae), showed major increased cover in the three shallow ploughed sites (SP1[14], SP2[20] and SP3[8]) but was completely absent from both control sites (C1[14] and C2[20]) and the broadcast sown sites (BCS[10]). Similarly, the species used in the broadcast sown site (BCS[10]) as augmentation, *P. compacta* (Proteaceae), showed increased cover at this particular site but this species also occurred in control sites (C1[14] and C2[20]).

Table 4.2: Mean cover of 'rare' species (*sensu* Raimondo et al., 2009) occurring in study sites on the Agulhas Plain (South Africa). Study sites are abbreviated as follow; control sites (C1[14], C2[20]), broadcast sown site (BCS[10]) and shallow ploughed sites (SP1[14], SP2[20], SP3[8]). Study sites vary in post-fire age indicated in brackets [ ].

Scientific name	Family	RED LIST STATUS (Raimondo et al., 2009)	*Natural*		*Treatments*			
			C1[14]	C2[20]	BCS[10]	SP1[14]	SP2[20]	SP3[08]
Cyrtanthus carneus	Amaryllidaceae	VULNERABLE	0.1	0	0.2	0	0.1	0
Centella tridentata	Apiaceae	ENDANGERED	0	0	0	0.1	0	0.1
Echiostachys incanus	Boraginaceae	VULNERABLE	0.1	0	0	0.1	0.1	0
Merceira leptoloba	Campanulaceae	NEAR THREATENED	0.1	0.1	0.1	0	0	0.1
Eriospermum capense subsp. stoloniferum	Convallariaceae	VULNERABLE	0.1	0	0	0	0	0
Tetraria brachyphylla	Cyperaceae	NEAR THREATENED	0.1	0.1	0	0	0.2	0
Bobartia longicyma	Iridaceae	VULNERABLE	0.1	0.1	0.1	0.1	0	0.2
Watsonia rogersii	Iridaceae	NEAR THREATENED	0.1	0	0	0.1	0	0
Tritoniopsis bicolor	Iridaceae	VULNERABLE	0.1	0	0	0	0.1	0.1
Freesia caryophyllacea	Iridaceae	DECLINING	0.1	0	0	0	0	0
Muraltia stokoei	Polygalaceae	RARE	0	0.1	0	0	0.1	0
Protea compacta	Proteaceae	NEAR THREATENED	4.4	8.8	13.1	0.6	4.6	1.0
Protea longifolia	Proteaceae	VULNERABLE	3.5	0	0.4	0.1	2.0	0
Aulax umbellata	Proteaceae	NEAR THREATENED	8.1	0	0.1	2.3	5.8	0.5
Serruria elongata	Proteaceae	NEAR THREATENED	1.5	0.9	1.0	1.0	1.2	1.0
Serruria fasciflora	Proteaceae	NEAR THREATENED	1.6	0.8	6.0	0.4	0	0.1
Leucadendron platyspermum	Proteaceae	VULNERABLE	0	0	0	9.7	28.1	17.4
Leucospermum truncatulum	Proteaceae	NEAR THREATENED	0	0	0.5	0.4	0.1	0
Spatalla squamata	Proteaceae	NEAR THREATENED	0	0	0.1	0	0	0
Spatalla curvifolia	Proteaceae	NEAR THREATENED	0	0	0.1	0	0	0
Leucospermum cordifolium	Proteaceae	NEAR THREATENED	0	0	0	0	0.1	0
Thamnochortus fraternus	Restionaceae	NEAR THREATENED	0.1	0.3	0.9	1.0	0.3	1.2
Osyris speciosa	Santalaceae	VULNERABLE	0	0.1	0	0	0	0
Kogelbergia verticillata	Stilbaceae	RARE	0.1	0	0	0	1.0	0
Lachnaea grandiflora	Thymelaeaceae	VULNERABLE	0	0.1	0.1	0	0	0
Total number of Red Data species per site			16	10	13	12	14	10

Cover of the remaining twelve commercial species varied between different treatments (broadcast sown and shallow ploughed). Higher percentage of cover was observed for the following species in treatment sites compared to control sites; *Phaenocoma prolifera* (Asteraceae) in a shallow ploughed site (SP3[8]), *Metalasia muricata* (Asteraceae) in three shallow ploughed sites (SP1[14], SP2[20] and SP3[8]), *Metalasia densa* (Asteraceae) in two shallow ploughed sites (SP1[14] and SP3[8]), *Staavia radiata* (Bruniaceae) in two treatment sites (BCS[10] and SP2[20]). *Leucadendron cordifolium* (Proteaceae) showed a slight increase in cover in a shallow ploughed site, SP2[20].

Lower percentage of cover was observed for the following species in treatment sites compared to control sites; *Berzelia lanuginosa* (Bruniaceae), *Berzelia abrotanoides* (Bruniaceae). Furthermore, cover of *Protea compacta* (Proteaceae) was low in two shallow ploughed sites (SP1[14] and SP3[8]) compared to both control sites (C1[14] and C2[20]).

Leucadendron xanthoconus (Proteaceae) showed both high cover in certain treatment sites (BCS[10] and SP1[14]) but low cover in two other treatment sites (SP2[20] and SP3[8]) when compared to control sites (C1[14] and C2[20]). Species that showed similar cover between control and treatment sites (broadcast sown and shallow ploughed) include the following species; *Brunia laevis* (Bruniacaeae), *Erica imbricata* (Ericaceae), *Erica coriifolia* (Ericaceae), *Phylica ericoides* (Rhamnaceae), *Anthospermum aethiopicum* (Rubiaceae).

Table 4.3: Mean cover of 15 species occurring in study sites and used commercially in the wildflower industry (from Conradie, 2009) on the Agulhas Plain (South Africa). Study sites are abbreviated as follow; control (C1[14], C2[20]), broadcast sown site (BCS[10]) and shallow ploughed sites (SP1[14], SP2[20], SP3[8]). Study sites vary in post-fire age indicated in brackets [].

			Natural		Treatments				Price/stem[24]
Family	Species	Trade name	C1[14]	C2[20]	BCS[10]	SP1[14]	SP2[20]	SP3[8]	
Asteraceae	*Phaenocoma prolifera*	Rooisewejaartjie	0.57	0	0.10	0.60	0.04	1.79	0.24 (f)
	Metalasia muricata	Blombos	0	0	0	0.23	0.04	0.39	0.22 (f)
	Metalasia densa	Blombos	0	0.1	0	4.3	0	0.3	0.23 (f)
Bruniaceae	*Brunia laevis*	Silver Brunia	1.27	0.07	0.97	0	1.86	0.29	0.86 (f); 0.35 (d)
	Staavia radiata	Glass eyes	0	0.04	1.13	0	0.39	0	0.22 (f)
	Berzelia lanuginosa	Kol-kol	0.13	0.61	0	0	0	0	0.29 (f)
	Berzelia abrotanoides	Bloed kol-kol	0	2.11	0	0	0	0	0.25 (f)
Ericaceae	*Erica imbricata*	Salt and Pepper	4.93	1.86	1.43	4.13	1.57	2.57	0.20 (f)
	Erica coriifolia		2.43	3.36	3.07	0.77	0.64	2.64	0.21 (f)
Proteaceae	*Protea compacta*	Compacta	4.40	8.86	13.13	0.60	4.57	1.00	0.35 (d); 1.69 (f)
	Leucadendron xanthoconus	Salignum	4.33	5.21	9.13	10.60	2.43	1.64	0.31 (f)
	Leucadendron platyspermum	Platystar	0	0	0	9.73	28.07	17.43	0.37 (d)
	Leucospermum cordifolium		0	0	0	0	0.14	0	0.75 (f)
Rhamnaceae	*Phylica ericoides*	White phylica	0.93	1.39	1.70	0.70	1.54	0.82	0.20 (f)
Rubiaceae	*Anthospermum aethiopicum*		0.07	0	0	0.10	0	0	0.20 (f)

[24] Mean price trend per stem (R/c) for years 2006-2008, derived from Conradie (2009)
Abbreviations: f = fresh material; d = dry material
*Note: Heydenrych (1999) also provides a list of species used in the wildflower industry but these were not included as harvesting and price trends changed significantly in the past decade for wildflower species

4. Discussion

Results from this investigation suggest that wildflower farming practices are causing some degree of compositional change in fynbos. Plant composition, family and dominant species, were most comparable between control sites and the broadcast sown site which reflects the ‘structural similarity’ between these sites mentioned in Chapter 3. All shallow ploughed sites differed markedly from both control sites and the broadcast sown site. Type of disturbance is commonly associated with unique post-disturbance communities as community composition is highly altered with the particular intensity of disturbance (Pickett and White, 1985; Peltzer et al., 2000). Of note, all shallow ploughed sites showed peculiar deviations not only from control sites and the broadcast sown site but shallow ploughed sites also differed uniquely from each other. Besides disturbance intensity (i.e. mechanical disturbance from shallow ploughing) the observed deviations in the shallow ploughed sites can be explained by different vegetation age of sites (ranging from 8-20 years since the last disturbance). Kruger (1983) described the successional change in fynbos and its profound effects on community composition when comparing fynbos stands of varying age. Therefore, this should be kept in mind when interpreting results presented for the shallow ploughed sites.

The five most speciose plant families were also dominant by percentage cover in study sites and showed marked variation between control and the shallow ploughed sites. Shallow ploughed sites showed increased cover of certain speciose and dominant (by percentage cover) plant families such as Asteraceae, Iridaceae and Ericaceae. This can be explained by referring to increased cover of a single dominant species in a particular shallow ploughed site. Asteraceae dominance was prominent in a shallow ploughed site, SP1[14], which corresponds with the high cover (4.3%) of a dominant species, *Metalasia densa* (Asteraceae). Similarly, Iridaceae dominance was pronounced in one shallow ploughed site, SP2[20], which corresponds with high cover (respectively, 7.4% and 2.7%) of two dominant species, *Lanaria lanata* (Iridaceae) and *Aristea bakeri* (Iridaceae). Furthermore, Ericaceae strongly associated with a shallow ploughed site, SP3[8], and this can be attributed to high cover (8.9%) of a dominant species, *Erica bruniades* (Ericaceae).

On the other hand, Restionaceae cover was low in two shallow ploughed sites, SP1[14] and SP2[20], and Ericaceae species showed a similar trend for these particular sites. The reduced cover of Restionaceae and Ericaceae in SP1[14] and SP2[20] seems to be affected by a subset of species as there is no obvious increase in cover for a single dominant species as was observed for Asteraceae and

Iridaceae in shallow ploughed sites, and Ericaceae in SP3[8]. Restionaceae species were also exclusively resprouting species and subsequently reflects the negative impact of wildflower farming practices on resprouters (Chapter 3).

Furthermore, other speciose plant families (Cyperaceae and Bruniaceae) also associated with control sites rather than with treatment sites (broadcast sown and shallow ploughed) and for these plant families, the association with control sites can also not be attributed to a single dominant species (by percentage cover). Therefore, speciose plant families (e.g. Asteraceae, Iridaceae, Ericaceae) may well associate with shallow ploughed sites but this tends to be due to a single dominant species, instead of multiple species subsets which are apparently observed for control sites. This ultimately manifests in the significantly higher diversity indices (Shannon, Simpson indices and Pielou's evenness index) that were recorded for control sites reported in Chapter 3 (Table 3.1). Diversity indices are after all most affected by changes in species which are less observed (non-dominant species, i.e. having low cover abundance) in a vegetation survey (Peet, 1974; Van Wilgen and Kruger, 1981).

Similarly, the association of other plant families with treatment sites (broadcast sown and shallow ploughed) can be explained in a similar manner by referring to particular dominant species (results not shown; see Appendix 11). Rosaceae corresponded strongly with the broadcast sown site and a shallow ploughed site (SP1[14]) which can be traced to high cover abundance of a dominant species, *Cliffortia stricta* (Rosaceae). Likewise, Thymelaeaceae showed a marked affinity for a shallow ploughed site (SP3[8]) which can be explained by increased cover of a single dominant species, *Passerina corymbosa* (Thymelaeaceae). *P. corymbosa* also had higher cover in the broadcast sown site and another shallow ploughed site (SP1[14]) than in control sites. Both species (*C. stricta* and *P. corymbosa*) are widely distributed throughout the Western and Eastern Cape (South Africa) (Goldblatt and Manning, 2000) and not listed as 'rare' (Raimondo et al., 2009). Of further note, *P. corymbosa* (Thymelaeaceae) is described in local botanical literature as a species associated with "…disturbed flats and slopes" (Goldblatt and Manning, 2000), "…such as roadsides…" (Manning, 2007). Therefore, this species can be regarded as 'disturbance orientated' and can serve as indicators of poor vegetation condition in natural fynbos. These species (*C. stricta* and *P. corymbosa*) did not show marked affinity for the control sites.

Conversely, certain dominant species (*Mimetes cucullatus* (Proteaceae), *Penaea mucronata* (Penaeaceae) and *Elegia stipularis* (Restionaceae) showed marked affinity for control sites. This could suggest that these species are more sensitive to wildflower farming practices by occuring in very low cover abundance in treatment sites (broadcast sown and shallow ploughed). Of note, all three species are strongly resprouting (see Appendix 4) which supports the findings from Chapter 3; i.e. wildflower farming practices exert unusual stress on the resprouting component of fynbos. Moreover, Raimondo et al. (2009) also consider the family Peneaeceae and the genera *Mimetes* as ‘range restricted’. Therefore, from a plant conservation perspective, reducing cover abundance, and possibly eliminating these species from the system, should be a concern if plant diversity is a priority to wildflower farmers (see Chapter 2).

Apart from attributing comparable structural (i.e. growth form composition; see Chapter 3) and plant family composition between the control sites and the broadcast sown site to the limited disturbance intensity involved (i.e. broadcast sowing excludes mechanical disturbance), compositional similarity can be accredited to the particular species involved used in augmentation via broadcast sowing. In the broadcast sown site *Protea compacta* (Proteaceae) was used whereas in the shallow ploughed site *Leucadendron platyspermum* (Proteaceae) was used. *P. compacta* occurs naturally in control sites, whereas *L. platyspermum* is absent from both control sites and the broadcast sown site. Note that, although Proteaceae cover is much higher (31.37%) in the broadcast sown site than in control sites, Asteracae, Iridaceae, Restionaceae and Ericaceae showed less pronounced changes in cover than in shallow ploughed sites, i.e. augmented with *L. platyspermum*. Acknowledging that disturbance intensity plays a role in treatment sites, one cannot exclude the possibility that *L. platyspermum* could have a different (i.e. significantly reducing cover of other plant families) impact on fynbos than in the case of using *P. compacta* in broadcast sowing. *L. platyspermum* is known to have a higher proportion embryo-filled seed than *P. compacta* and could possibly, in this sense, be a more reproductive species than *P. compacta* (Mustart pers. com.). However, both species are known to co-occur on the Agulhas Plain and form dense stands (Rebelo, 2001). Joubert et al. (2009) mentions that different species could have different impacts on fynbos, however this has not been researched for these particular species, *P. compacta* and *L. platyspermum*. Finally, *P. compacta* has a higher price/stem (Table 4.3; Conradie, 2009) which can potentially be an attractive option if it is indeed a ‘low impact’ species in wildflower farming.

From a commercial perspective, the wildflower industry (and farmer) relies on a constant supply of a diversity of species derived from natural vegetation (Conradie, 2009). This includes both focal/showy inflorescences and filler material (Greyling and Davis, 1989; Turpie et al., 2002; Conradie, 2009).

From the fifteen commercial species, only two species (*P. compacta* (Proteaceae) and *L. platyspermum* (Proteaceae)) showed marked increased cover abundance in treatment sites (broadcast sown and shallow ploughed). This is perceptible due to augmentation in the method of broadcast sowing that ultimately aims to increase the abundance of such ‘primary commercial species’ (i.e. focal species) (Davis, 1990; Carinus et al., 2004; Joubert et al., 2009). Furthermore, slight increased cover was noticeable for the following ‘secondary commercial species’ in treatment sites (broadcast sown and shallow ploughed); *Metalasia muricata* (Asteraceae), *Metalasia densa* (Asteraceae) and *Staavia radiata* (Bruniaceae). However, this increased cover was very marginal. On the contrary, other ‘secondary commercial species’ such as *Berzelia lanuginosa* (Bruniaceae) and *Berzelia abrotanoides* (Bruniaceae) were completely absent from treatment sites (broadcast sown and shallow ploughed). Given the variety of vegetation ages in treatment sites, this phenomenon cannot be attributed to succesional change over time (Kruger, 1983). Therefore, it is possible that farming practices (broadcast sown and shallow ploughed) only marginally favour ‘primary commercial species’ but this is at the cost of other species (‘secondary commercial species’) that have both conservation and commercial significance.

Heydenrych (1999) suggests that wildflower farming (from natural vegetation) could over time establish monocultures of focal (commercial) species. There is evidence from this investigation that farming practices could well, in the long term, be promoting monocultures of commercial Proteaceae species (*P. compacta* and *L. platyspermum*). This ought to raise concern from wildflower farmers, especially since they state that “diversity is important for the success of my business/farm” (Chapter 2). Lawton (1994) stresses the important associations between ecosystem processes and population biology that can be summarised in the simplest sense; “Without species there would be no ecosystems” (Lawton, 1994). All species, common and rare, have inherent roles to play in ecosystem functioning and interactions are so far poorly understood (Gaston, 2010). This connection should be an important consideration in wildflower farming which manifests as an industry exceptionally dependent on the integrity of natural vegetation and ecosystems. The necessity to implement wildflower farming practices is questionable given the finding of this study, and given that fynbos is known to change in composition via successional pathways over time (Van Wilgen and Kruger, 1981; Kruger, 1983) (which would naturally supply a diversity of products to the wildflower farmer in the long term).

Finally, results from this investigation could not indicate whether (or not) farming practices are detrimental for ‘rare’ species. ‘Rare’ species, with the exception of certain broadcast sown Proteaceae species, were present in exceptionally low abundance (mean cover <1%) in all study sites and these species were not necessarily more represented in control versus treatment sites (broadcast sown and shallow ploughed). The major limitation to interpretation and generalisation of the ‘rarity’ results presented in this investigation can be attributed to two factors. Firstly, the particular local (alpha diversity) scale of the investigation requires clarification. Alpha diversity is strongly influence by habitat (Thuiller et al., 2007) and, in turn, habitat is influenced by the particular disturbance event (Pickett and White, 1985; Cowling, 1992). This creates a complex interplay of ecological components that affects vegetation composition and change. Many fynbos species are locally restricted or occur in low densities across vast areas (Moll and Gubb, 1981; de Lange and Boucher, 1993; Simmons, 1996; Privett, 1998) and this is especially true for the flora of the Agulhas Plain (Cowling and Holmes, 1992). Furthermore, Thuiller et al. (2007) emphasise that species presence and abundance is highly variable at the local scale and that rare species are not more likely to face local extinction than common species. Local extinction of species (common and rare), under natural disturbance regimes, is a common phenomenon (Thuiller et al., 2007). However, how such species are affected under anthropogenically induced disturbances (like wildflower farming practices) remains questionable. Generalisation on the impact of wildflower farming on rare and range-restricted species (Privett, 1998) necessitates an investigation at a larger spatial scale that would capture the spatial variation in fynbos plant assemblages (Vlok, 1996). Secondly, the Red List of South African Plants (as a classification on plant ‘rarity’) is a national plant assessment (Raimondo et al., 2009) and therefore this publication will not necessarily convey rarity information accurately in the context of wildflower farming at the local scale. As a final note, this investigation has identified a major paradox, i.e. that particular species (*P. compacta* and *L. platyspermum*) are categorised as ‘rare’ (Raimondo et al., 2009) but simultaneously these species are artificially favoured in wildflower farming at the cost of various non-target species. This issue necessitates urgent attention and future research. Simultaneously, one might also question whether it is appropriate to commercially exploit species of endangered status.

5. Conclusion

Wildflower farming practices result in compositional alterations in fynbos plant families and dominant species. Shallow ploughed sites had markedly different fynbos composition than the broadcast sown site. In particular cases, the dominance of a speciose plant family in a specific treatment site can be explained by referring to increased cover of a single dominant species. Furthermore, it is possible that different species used in broadcast sowing have unique impacts on plant composition; an issue that needs to be explored in future studies. There is evidence from this investigation that wildflower farming can establish monocultures of focal flower species. Apart from the single commercial species used in broadcast sowing, an arrangement of commercial species did not necessarily show marked increased cover in any treatment site. Consequently, the usefulness of wildflower farming practices such as shallow ploughing for increased flower production is brought into question, but this would need a more detailed investigation. Finally, there is no apparent trend from this investigation to suggest that rare species would occur in higher richness or abundance in control sites compared to treatment sites. Answering such research questions in a diverse and patchy vegetation type, like fynbos, would require a larger spatial scale for investigation to allow for more accurate results.

6. Literature cited

Bond, P., Goldblatt, P., 1984. Plants of the Cape flora: a descriptive catalogue. Journal of South African Botany 13, 1-13.

Bond, W.J., Vlok, J., Viviers, M., 1984. Variation in seedling recruitment of Cape Proteaceae after fire. Journal of Ecology 72, 209-221.

Butchart, S. H. M., Stattersfield, A.J., Baillie, J., Bennun, L.A., Stuart, S.N., Akcakaya, H.R., Hilton-Taylor, C., Mace, G.M., 2005. Using Red List Indices to measure progress towards the 2010 target and beyond. Philosophical Transactions of the Royal Society Biological Sciences 360, 255-268.

Butchart, S. H. M., Akcakaya, H.R., Chanson, J., Baillie, J.E.M., Collen, B., Quader, S., Turner, W.R., Amin, R., Stuart, S.N., Hilton-Taylor, C., 2007. Improvements to the Red List Index. Public Library of Science One 2,e140. doi:110.1371.

Carinus, T., Blomerus, L., de Ponte Machado, M., Gerber, F., Holmes, P., Kabot, L., Marais, C., Martens, C., Middelman, M., Privett, S., Palmer, G., Saunders, R., Scott, A., Scott, M., 2004. Guidelines for Sustainable Harvesting of Selected Indigenous Plant Species in the Cape Floristic Region. In SAPPEX, Cape Flora, Cape Town.

Collar, N.J., 1996. The reasons for Red Data Books. Oryx 30, 121–130

Conradie, B., 2009. Pryse volumes en produksiekoste van veldblomme. Available at: www.flowervalley.org Accessed on: 17/08/2010.

Conradie, B., Knoesen, H., 2009. A survey of the cultivation and wild harvesting of fynbos flowers in South Africa. Available at: http://www.flowervalley.org.za Accessed on: 17/05/2010.

Cowling, R.M., 1989. The Research Perspective: Veld Resources. In: Greyling, T., Davis, G.W. (Eds.), The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes: Occasional Report No. 40. Foundation for Research Development, CSIR, Pretoria, South Africa. pp. 14-16.

Cowling, R.M., 1992. The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town.

Cowling, R.M., Holmes, P.M., 1992. Endemism and speciation in a lowland flora from the Cape Floristic Region. Biological Journal of the Linnean Society 47, 367-383.

Cowling, R.M., Rundel, P.W., Lamont, B.B., Arroyo, M.K., Arianoutsou, M., 1996. Plant diversity in Mediterranean-climate regions. Trends in Ecology and Evolution 11, 362-366.

Davies, K.F., Margules, C., Lawrence, J.F., 2004. A Synergistic effect puts rare, specialized species at greater risk of extinction. Ecology 85, 265-271.

Davis, G.W., 1990. Commercial wildflower production in the fynbos biome and its role in the management of land-use. PhD Thesis. Department of Botany, University of Cape Town.

de Lange, J.H., Boucher, C., 1993. Autecological studies on *Audouinia capitata* (Bruniaceae). Role of fire in regeneration. South African Journal of Botany 59, 188-202.

Ehrlich, P., Holdren, J., 1971. The impact of population growth. Science 171, 1212–1217.

Gaston, K.J., 1994. Rarity. Chapman and Hall.

Gaston, K.J., 2010. Valuing common species. Science 327, 154-155.

Gelderblom, C.M., Van Wilgen, B.W., Nel, J.L., Sandwith, T., Botha, M., Hauck, M., 2003. Turning strategy into action: implementing a conservation action plan in the Cape Floristic Region. Biological Conservation 112, 291-297.

Goldblatt, P., Manning, J., 2000. Cape Plants: A Conspectus of the Cape Flora of South Africa. Strelitzia 9. National Botanical Institute, Cape Town. (Missouri Botanical Garden).

Greyling, T., Davis, G.W. (Eds.), 1989. The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes. Occasional Report No. 40. Foundation for Research Development, CSIR, PO Box 395, Pretoria.

Groombridge, B., Jenkins, M.D., 2002. World atlas of biodiversity. University of California Press, Berkeley.

Harte, J., 2007. Human population as a dynamic factor in environmental degradation. Population and Environment 28, 223-236.

Heydenrych, B.J., 1999. An investigation of land-use practices on the Agulhas Plain (South Africa), with emphasis on socio-economic and conservation issues. MSc Thesis, Institute for Plant Conservation, University of Cape Town.

Huston, M.A., 1994. Biological diversity. Cambridge University Press, Cambridge.

Joubert, L., Esler, K.J., Privett, S.D.J., 2009. The effect of ploughing and augmenting natural vegetation with commercial fynbos species on the biodiversity of Overberg Sandstone fynbos on the Agulhas Plain, South Africa. South African Journal of Botany 75, 526-531.

Kidd, M. (Prof). 2010. Personal communication. Centre for Statistical Consultation, Departmentt of Statistics and Actuarial Sciences, Stellenbosch University.

Kier, G., Mutke, J., Dinerstein, M., Rickett, T.H., Kuper, W., Kreft, H., Barthlott, W., 2005. Global patterns of plant diversity and floristic knowledge. Journal of Biogeography 32, 1107-1116.

Kruger, F.J., 1983. Plant community diversity and dynamics in relation to fire. In: Kruger, F.J., Mitchell, D.T., Jarvis, J.U.M. (Eds.), Mediterranean-type ecosystems: the role of nutrients. Springer-Verlag, Berlin, Germany. pp. 446-472.

Larsen, T.H., Williams, N.M., Kremen, C., 2005. Extinction order and altered community structure rapidly disrupt ecosystem functioning. Ecology Letters 8, 538-547.

Lawton, J.H., 1994. What do species do in ecosystems? Oikos 71, 367-374.

Leadley, P., Pereira, H.M., Alkemade, R., Fernandez-Manjarres, J.F., Proenca, V., Scharlemann, J.P.W., Walpole, M.J. 2010. Biodiversity Scenarios: Projections of 21st century change in biodiversity and associated ecosystem services. Secretariat of the Convention on Biological Diversity, Montreal. Technical Series no. 50, 132 pages.

Levin, D.A., Francisco Ortega, J., Jansen, R.K., 1996. Hybridization and the extinction of rare plant species. Conservation Biology 10, 10-16.

Manning, J., 2007. Field guide to fynbos. Struik Publishers, Cape Town.

Mittermeier, R.A., Myers, N., Thomsen, J.B., da Fonseca, G.A.B., Olivieri, S., 1998. Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. Conservation Biology 12, 516-520.

Moll, E.J., Gubb, A.A., 1981. Aspects of the ecology of Staavia dodii in the South Western Cape of South Africa. In Synge, H. (Ed.), The Biological Aspects of Rare Plant Conservation, John Wiley and Sons Ltd. pp. 331-342.

Mustart, P. J., 2010. Personal commuinication. Fynbos ecologist.

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

Peet, R.K., 1974. The measurement of species diversity. Annual Review of Ecology and Systematics 5, 285-307.

Peltzer, D.A., Bast, M.L., Wilson, S.D., Gerry, A.K., 2000. Plant diversity and tree response following contrasting disturbances in boreal forest. Forest Ecology and Management 127, 191-203.

Pickett, S.T.A., White, P.S., 1985. The ecology of natural disturbance and patch dynamics. Academic, New York, NY, USA.

Pimm, S.L., Russell, G.J., Gittleman, J.L., Brooks, T.M., 1995. The future of biodiversity. Science 269, 347-350.

Possingham, H.P., Andelman, S.J., Burgman, M.A., Medellín, R.A., Master, L.L., Keith, D.A., 2002. Limits to the use of threatened species lists. Trends in Ecology and Evolution 17, 503-507.

Prendergast J.R., Quinn R.M., Lawton J.H., Eversham B.C., Gibbons D.W., 1993. Rare species, the coincidence of diversity hotspots and conservation strategies. Nature 365, 335-337.

Pressey, R.L., Cowling, R.M., Rouget, M., 2003. Formulating conservation targets for biodiversity pattern and process in the Cape Floristic Region, South Africa. Biological Conservation 112, 99-127.

Privett, S.D.J., 1998. Determinants of pattern in fynbos vegetation. Physical site factors, disturbance regime, species attributes and temporal change. MSc Thesis. University of Cape Town.

Privett, S.D.J., Heydenrych, B.J., Cowling, R.M., 2002. Putting Biodiversity to Business on the Agulhas Plain. In: Pierce, S.M., Cowling, R.M., Sandwith, K., MacKinnon, K. (Eds.), Mainstreaming Biodiversity in Development. The World Bank Environment Department. pp. 101-111.

Raimondo, D., Von Staden, L., Foden, W., Victor, J.E., Helme, N.A., Turner, R.C., Kamundi, D.A., Manyama, P.A., 2009. Red list of South African Plants 2009. Strelitzia 25. South African National Biodiversity Institute, Pretoria.

Rebelo, A.G., 2001. Proteas. A field guide to the Proteas of Southern Africa. Fernwood Press, Cape Town, South Africa.

Rodrigues, A.S.L., Pilgrim, J.D., Lamoreux, J.F., Hoffmann, M., Brooks, T.M., 2006. The value of the IUCN Red List for conservation. Trends in Ecology and Evolution 21, 71-76.

Sala, O.E., Chapin, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., Wall, D.H., 2000. Biodiversity - global biodiversity scenarios for the year 2100. Science 287, 1770-1774.

Schatz, G.E., 2009. Plants on the IUCN Red List: setting priorities to inform conservation. Trends in Plant Science 14, 638-642.

Simmons, M.T., 1996. Vegetation, diversity and rarity the Cape Peninsula, South Africa. MSc Thesis, University of Cape Town.

Sousa, W.P., 1984. The role of disturbance in natural communities. Annual Review of Ecology and Systematics 15, 353-391.

Statsoft, Inc., 2010. STATISTICA (data analysis software system). Version 9.0. www.statsoft.com

Thuiller, W., Slingsby, J.A. Privett, S.D.J. Cowling, R.M., 2007. Stochastic species turnover and stable coexistence in a species-rich, fire-prone plant community. Public Library of Science One 2, e938. doi:10.1371.

Thwaites, R.N., Cowling, R.M., 1988. Soil-vegetation relationships on the Agulhas Plain, South Africa. Catena 15, 333-345.

Turpie, J., Heydenrych, B.J., Hassan, R., 2002. Fynbos: a preliminary assessment of its status and economic value. In: Hassan, R. (Ed), Accounting for stock and flow values of woody land resources. Centre for Environmental Economics and Policy in Africa, University of Pretoria. pp. 73-115

Underwood, E.C., Viers, J.H., Klausmeyer, K.R., Cox, R.L., Shaw, M.R., 2009. Threats and biodiversity in the mediterranean biome. Diversity and Distributions 15, 188-197.

UNDP., 2003. United Nations Development Programme. Agulhas Biodiversity Initiative. Global Environmental Facility Project document: Cape Action Plan for the Environment.

Van Wilgen, B.W., Bond, W.J., Richardson, D.M., 1992. Ecosystem management. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 345-371.

Van Wilgen, B.W., Kruger, F.J., 1981. Observations on the effects of fire in mountain fynbos at Zachariashoek, Paarl. Journal of South African Botany 47, 195-212.

Vié, J.C., Hilton-Taylor, C., Pollock, C., Ragle, J., Smart, J., Stuart, S.N., Tong, R., 2008. The IUCN Red List: a key conservation tool. In: J.-C. Vié, C. Hilton-Taylor and S.N. Stuart, editors. The 2008 Review of The IUCN Red List of Threatened Species. IUCN Gland, Switzerland.

Vitousek, P. M., 1994. Beyond global warming - ecology and global change. Ecology 75, 1861-1876.

Vlok, J.H.J., 1996. The role of overstorey proteoid shrubs in maintaining species richness in a southern Cape mountain fynbos community, MSc Thesis, Department of Botany, University of Natal.

Westman, W. E., 1990. Managing for biodiversity. Bioscience 40, 26-33.

CHAPTER 5:

Synthesis and recommendations

1. Key messages

This thesis has elucidated on the following aspects related to fynbos wildflower farming on the Agulhas Plain:

a) Overall, wildflower farmers on the Agulhas Plain are a diverse group; not only in terms of the wildflower farming practices applied to vegetation but also in opinions about the impact of specific farming practices on fynbos (Chapter 2).

b) Wildflower farmers have both an understanding of fynbos management and an awareness of local plant diversity. Farmers seem optimistic in opinions related to fynbos conservation and therefore local conservation authorities should invest in these positive sentiments (Chapter 2).

c) The conflicting worlds of commerce and conservation in wildflower farming were highlighted from the questionnaire. On the one hand, landholders have a strong commercial objective in mind in wildflower farming and explicitly value commercial species. However, landholders also acknowledge that fynbos diversity is important for a successful wildflower enterprise. Ecological researchers should provide sound management recommendations that do not conflict with wildflower production.

d) Shallow ploughing and broadcast sowing, implemented as wildflower farming practices, cause significant alterations in fynbos structure, i.e. growth form and regeneration mode composition. The alterations in vegetation structure are closely associated with significantly lower species richness and fynbos diversity for sandstone fynbos (Chapter 3).

e) Broadcast sowing has a limited impact on fynbos structure but this phenomenon does not necessarily support higher species richness or plant diversity (Chapter 3).

f) Fynbos composition, plant family and dominant species, varied between control and treatment sites (broadcast sown and shallow ploughed). The method of broadcast sowing seems to have a restricted impact on fynbos composition, as plant composition was more comparable between the control sites and the broadcast sown site than between the control sites and all the shallow ploughed sites (Chapter 4).

g) Commercial species used in broadcast sowing (*P. compacta* and *L. platyspermum*) are favoured, i.e. occur in higher abundance, in treatment sites (broadcast sown site and shallow ploughed). However, other (subsets) commercial species are not. In some cases, other commercial species (especially Bruniaceae) occur in lower abundance in treatment sites versus control sites. The necessity to implement wildflower farming practices therefore becomes questionable (Chapter 4).

h) Twenty-five plant species categorised in different categories of 'rarity' (Raimondo et al., 2009) were identified in the vegetation survey. The control sites did not necessarily support higher number or cover abundance of 'rare' species than the broadcast sown or any of the shallow ploughed sites (Chapter 4).

Minimising physical disturbance of natural fynbos used for wildflower farming is a key issue that emerged from this thesis. Some plants, especially resprouting understorey species, show reduced abundance in sites subjected to broadcast sowing and shallow ploughing. Fynbos must be viewed as a delicate, complex ecosystem shaped by the interaction of various abiotic and biotic processes. To disrupt such interactions is erroneous for many, conservation-related and ethical, reasons. In short, the world is currently facing a biodiversity crisis (Pimm et al., 1995; Singh, 2002) and sustainable resource management is a pressing issue. Results from this investigation suggest that fynbos diversity and composition is altered, at least, in the next generation after wildflower farming practices (disturbance) have been applied (Chapter 3 and 4). How these changes manifest and impact over time is however unknown and should be investigated in the future.

This thesis is not absolute as an assessment of the impact of wildflower farming practices on fynbos, nonetheless it did provide important insights. Main observations from the vegetation survey can be used to formulate guidelines for plant diversity conservation in context of wildflower farming. Implications for wildflower farming, conservation recommendations, management recommendations, research limitations and future recommendations are discussed below.

2. Implications for wildflower farming: non-target species, commercial species and lowland fynbos conservation

Change in relative abundance and species composition is probable, and indeed likely, for fynbos communities in the post disturbance environment (Kruger, 1983; Privett, 1998; Thuiller et al., 2007). Most studies, however, investigate the impacts of disturbance on fynbos assemblages in relation to natural disturbance events such as fire, whereas wildflower farming practices manifest as anthropogenic disturbances that are less commonly studied. How likely then is change, in fynbos composition and species persistence, in this unique post-disturbance environment? This thesis cannot ascertain a complete answer to this question but can remark considerably on the topic.

High cover of overstorey shrubs can potentially increase alpha diversity of the understorey (Vlok and Yeaton, 2000). Also, species composition prior to a disturbance event will ultimately determine post-disturbance species composition (Hanes, 1971). However, altered structural composition in fynbos and associated lower species richness and diversity observations in treatment sites (broadcast sown and shallow ploughed) (Chapter 3) do not suggest a considerable increase in plant diversity in the near future. This is supported by Davis (1990) who reported that ploughing reduced species richness and plant diversity in mountain fynbos. Whether or not this phenomenon extends over a longer temporal scale has not been investigated and must be explored in the future (see section 5 this chapter). Therefore, one could (at least in the short term) argue that mechanical disturbance methods used in wildflower farming (like shallow ploughing) will compromise plant diversity conservation. Heydenrych (1999) also suggested that wildflower farming practices could establish monocultures of commercial species and results presented in this study strongly correspond with the former research findings (Davis, 1990) and supposition (Heydenrych, 1999). Some results from a previous study by Joubert et al. (2009) are in direct contradiction to the latter statement and Chapter 3 outlines possible reasons for deviation.

Wildflower farmers, farming with natural vegetation, rely directly on fynbos diversity to sustain a livelihood (Conradie, 2009a). Therefore it is important to maintain some degree of plant diversity within wildflower vegetation. Heydenrych (1999) recorded a total of 71 fynbos species used by the entire wildflower market (includes naturally occurring and cultivated species) on the Agulhas Plain. Fifteen species recorded in the vegetation survey (Chapter 4) are currently popular and commercially harvested products (Conradie, 2009a). Some species are commercially more important (*Protea* *compacta* and *Leucadendron platyspermum*) than others and can be intensively cultivated (i.e. orchard-like cultivation). However, fynbos bouquets hardly consist of a single commercial species (Plate 3) and many species, especially filler material (used to assemble fynbos bouquets), cannot be cultivated (due to resistance to growing in a controlled environment, pests, parasites etc.). As a result, 'filler' species will continuously be harvested from natural vegetation (Cowling, 1989; Davis, 1992; Conradie and Knoesen, 2009). Moreover, the establishment of cultivated plantations is expensive and labour intensive which often favours sustained harvesting from natural vegetation (Greyling and Davis, 1989). The vegetation survey suggests that, although some commercial species increase in cover (*Protea compacta* and *Leucadendron platyspermum*), a result of broadcast sowing and/or shallow ploughing, other commercially important species (*Berzelia lanuginosa* and *Berzelia abrotanoides*) are simultaneously affected by showing reduced cover in treatment sites. This reduces the profusion of wildflower products available to the farmer and must surely rouse concern. Overshadowing this effect, however, is the fact that most commercial species seem unaffected (see Chapter 4). Moreover, this investigation showed that it is not only commercial species that are favoured by wildflower farming practices but also other fynbos species (e.g. *Passerina corymbosa*, *Cliffortia strica*) that have no commercial value to the wildflower farmer (Conradie, 2009a).

Four species that have been used in broadcast sowing (*P. compacta, L. platyspermum, L. coniferum, A. umbellata*) (Table 2.4) have a so-called 'rarity status' (other than 'least concern') according to the Red List of South African Plants (Raimondo et al., 2009) and are therefore species of conservation priority. Furthermore, three of the four species (excluding *A. umbellata*) are known to be widely cultivated (marginally and intensively) on the Agulhas Plain (Heydenrych, 1999). From this an interesting issue arises, i.e. that these species are artificially favoured, in terms of increased cover, in wildflower farming practices (see Chapter 4). The conflict in this is; that a species of 'conservation concern' is benefitting from wildflower farming but the fynbos community is suffering (in terms of structure, species richness, plant diversity, plant family and dominant species composition). Genetic contamination is also a conservation issue in need of research attention (Littlejohn, 2002; Whelan et al., 2006; also see section 5). As a final note with no perceptible answer, one also has to ask the question; "Why are species with a particular 'rarity' status (Near Threatened (NT) and Vulnerable (VU) (*sensu* Raimondo et al., 2009)) harvested from natural vegetation"?

Plate 3: Fynbos bouquets (assembled from vegetation on the Agulhas Plain) which are sold locally and internationally (Photos: courtesy Frieda Lloyd)

Heydenrych (1999) reported that a total area of 89 767 ha indigenous vegetation is used exclusively for fynbos wildflowers of which Acid Sand Proteoid Fynbos[25] is the dominant vegetation type. As a consequence approximately 3000 ha on the Agulhas Plain has been mechanically disturbed (scarified (i.e. worked lightly with a toothed implement) and ploughed) for purposes of fynbos wildflower farming. This figure includes both 'marginally cultivated' and 'intensively cultivated' fynbos (see Chapter 1 for definitions) where 'marginally cultivated' areas include; broadcast sowing (1962 ha) and strip ploughing (913 ha). 'Intensively cultivated' fynbos constituted 93 ha (Heydenrych, 1999). Although a distinction is made in wildflower farming between cultivation intensities (marginal versus intensive) much remains in a 'grey area' regarding types of farming practices and exact application. The 'broadcast sowing' in the above figure also includes other farming practices (such as burning and shallow ploughing) that contributes to the disturbance event but it is not always clear how individuals (researchers and farmers) define particular events. This can significantly diminish the accuracy of survey/management information. Furthermore, it is significant to note that although sandstone fynbos is not currently a vegetation type of conservation priority (a result of large expanse on the Agulhas Plain and few threatened plant species restricted to this vegetation (Mucina and Rutherford, 2006)), plant diversity conservation in context of wildflower farming is an emerging issue, especially considering that 55 of the 71 species harvested on the Agulhas Plain are derived from sandstone fynbos vegetation (Heydenrych, 1999).

3. Recommendations for fynbos conservation in the face of wildflower farming

This thesis has attempted to emphasise what has previously been acknowledged essential for ensuring a sustainable wildflower industry on the Agulhas Plain, i.e. greater cohesion between the various components of the wildflower trade, namely; research, commerce and conservation (Greyling and Davis, 1989). This is a multifaceted predicament hampered by increasingly scarce financial resources to facilitate such collaboration. Regrettably, due to the enormous spatial extent and unique plant diversity of the study area, the flora of the Agulhas Plain will not be meticulously assessed, in the light of this 'limited funding' crisis. Therefore it is unlikely in the near future that research and funding will focus intensively and exclusively on wildflower farming from natural vegetation (personal observation), especially in an isolated area (situated on the southern tip of Africa) such as the Agulhas Plain.

[25] Vegetation terminology used by Heydenrych (1999)

However, increased research of biological aspects is not necessarily the only solution to the problem (Cowling et al., 2009) and therefore this chapter argues, like many others (see Cowling et al., 2010 and references therein), to not devote resources only to this. There has been an increased focus on the role private land can play to contribute to areas under conservation (Bean and Wilcove, 1997; Margules and Pressey, 2000) and this is also a growing consensus for conservation on the Agulhas Plain (Privett et al., 2002; Hanks, 2007). Private landholders (exclusively as wildflower farmers) are pivotal for conservation planning activities (Privett et al., 2002) and therefore these individuals require more time and devotion from conservation organisations. Areas in the CFR are becoming increasingly threatened by habitat loss and therefore conservation action is regarded equally important as the inventory of species (Cowling et al., 2010). In light of this, there are some case studies to draw upon which could prove promising for conservation in context of wildflower farming. The Renosterveld stewardship project[26] can serve as a good starting point for a wildflower farming conservation approach in an agricultural landscape. Brief points are outlined below (ideas from Milton, 2007; Curtis, 2009);

- Stewardship efforts (with private landholders) are absolutely necessary for conservation success and also for establishing a land tenant database and a plant species database, admittedly this will require time and financial investment.
- Partnerships with landholders and management plans (for burning and related wildflower farming activities, species conservation) are imperative to conservation.
- Although fynbos ecology under natural disturbance events is well understood, responses to disturbance intensity and frequency are highly context specific and might not hold true in the specific framework of wildflower farming: this must be communicated to wildflower farmers.
- Various types of lowland fynbos are utilised for wildflower farming (Heydenrych, 1999) and harvesting and specific recommendations must be developed for each (as far as possible).
- Management guidelines must provide for biodiversity conservation in an agricultural landscape (context specific).

Building relationships, an essential component of conservation success, and trust takes time. Simultaneously, while acknowledging that stewardship alone cannot guarantee conservation success (Von Hase et al., 2010); it is nonetheless a good foundation for developing a detailed plan on community-based conservation (Hulme and Murphree, 2001), especially in an agricultural landscape

[26] http://www.capeaction.org.za

where land is mostly privately owned (Curtis pers. com.). Closing the gap between science and management (Milton, 2007) is compulsory if conservation is to reap rewards for the common goal: sustainable biodiversity utilisation and management. This is especially relevant in context of the Agulhas Plain where farmers widely acknowledge the poor relationship between themselves and local conservation organisations (Conradie, 2009b; Conradie pers. com.).

As a final note, (any natural resource based) commerce has an exceptionally important role to play in fynbos conservation. This is becoming increasingly important to ensure sustainable utilisation of natural resources such as wildflower vegetation. Currently there are a number of organisations involved in the commercial trade of fynbos floral material (FVCT[27], SAPPEX[28], FYNSA[29], PPSA[30] and others (see Flower Valley Conservation Trust website[31])). In recent years, successful partnerships have been established between some organisations that have greatly benefitted local employment and fynbos operators (Privett, 2002; FVCT, 2008). However, simultaneously, there seems to be minor issues relating to such meaningful cooperation that primarily concerns the private landholder. The private individual is often neglected in terms of communicating objectives and strategy of joint organisational cooperation (Gafney pers. com.). As such, these individuals are uninformed and feel isolated from such initiatives in their area. It is therefore imperative to communicate conservation and business policies at the local level for the individual's understanding and peace of mind (Conradie pers.com.; M. Treurnicht personal observation).

4. An understanding of fynbos ecology

Wildflower vegetation situated on the lowlands of the Agulhas Plain manifest as islands of fynbos which require careful management. The probability of a stochastic event is naturally high in fynbos populations (Bond et al., 1995; Van Wilgen et al., 1994; Thuiller et al., 2007) and could easily be magnified in the face of anthropogenically induced disturbance events. Knowledge of natural fynbos ecology is essential for wildflower management purposes (Mustart and Cowling, undated) and this includes numerous features unique to fynbos, i.e. structure of growth forms (understorey and overstorey interactions (Vlok, 1996)), species diversity and rare species (supposedly acknowledged to

[27] Flower Valley Conservation Trust
[28] http://www.sappex.org.za
[29] Fynsa (Pty) Ltd
[30] ***Protea*** Producers of South Africa
[31] www.flowervalley.org

be sensitive to disturbance (Gaston, 1994), species response to disturbance events and unique reproductive traits (reseeders and resprouters). The ecology of fynbos in its natural existence is, after extensive research (see Kruger, 1983; Cowling, 1992; Thuiller et al., 2007; Cowling et al., 2009), not fully understood and therefore management recommendations provided here for wildflower farming should be interpreted as mere guidelines and not robust rules.

Scientific evidence related to developing fynbos fire management policies (see Van Wilgen, 2009), adopted over the past decades, is arguably the best example to draw upon in an attempt to change conventional fynbos management habits. Fixed adherence to disturbance regimes of long frequency (e.g. 15 years) is known to increase the density of overstorey Proteaceae shrubs in natural fynbos at the expense of understorey species (Campbell and Van der Meulen, 1980; Cowling and Gxaba, 1990). Van Wilgen et al. (1994) recommend to alternate fire frequency in an attempt to manage fynbos for biodiversity and discourage the use of a single, fixed fire interval on a continuous basis for reserve management. Although this has not been explored in the specific context of wildflower farming, this approach seems to establish promising management results for pristine fynbos areas (in reserves (see Van Wilgen et al., 2010)). Additionally, since natural fires (i.e. wild fires) are increasing in frequency across the Cape and Agulhas Plain (Fatoki, 2007; Van Wilgen et al., 2010) to minimise prescribed burning should also benefit wildflower farmers, in terms of safety regulations on private property.

5. Management recommendations: wildflower farming

Any farmer would naturally benefit from the occurrence of natural vegetation on many levels (Walton, 2006) and this is especially true for the wildflower farmer, harvesting fynbos from natural vegetation. Shallow ploughing resulted in more apparent changes in fynbos structure and composition. Therefore, from a conservation perspective, an immediate primary recommendation would be to reduce (or possibly completely exclude) mechanical disturbance of fynbos, induced via shallow ploughing, since this causes marked changes in plant diversity and vegetation composition (Chapter 3 and 4). The limited ‘structural impact’ of broadcast sowing similarly reflected a limited change in plant composition. However, this limited structural and compositional impact did not necessarily reflect higher species richness or plant diversity for the broadcast sown site, which complicates definite recommendations. Furthermore, the particular species used in broadcast sowing requires particular consideration as different species could have different impacts on fynbos (Chapter 4). However, this is mere speculation as there is currently no knowledge available on this issue.

The use of Proteaceae species as ‘indicator species’ is emphasised in context of wildflower farming (Mustart and Cowling, undated) but, evidently from this investigation, what is best for Proteaceae species is not best for all species (Van Wilgen et al., 1992). Ultimately, the aim of applying wildflower farming practices is to promote abundance of high value commercial species (mostly Proteaceae), therefore having an abundance of these species would be satisfying to the wildflower farmer (commercial goal). Acknowledging this, landholders must nonetheless be aware of an integrated ecosystem focus, instead of implementing farming practices focused on individual species. This will ensure the persistence of intact wildflower vegetation for future use (direct and indirect).

Local (site) conditions (e.g. open soil) and presence of species (e.g. *Passerina corymbosa* (Thymealeaeceae)) in wildflower vegetation can be used to visually assess patch quality. For example, when vegetation cover seems low and open soil cover appears high, whether it may be from excessive harvesting and trampling or even more complex ecological interactions; it is important to allow for such a particular management unit to rest and recover. Of upmost importance, landholders must be encouraged to keep a detailed record of applied wildflower farming practices. This will not only aid in questionnaires/surveys similar to this investigation (Chapter 2) but also be useful for personal reference purposes. Wildflower farming practices are mostly implemented at 10-15 year intervals. Therefore recalling what practices were applied (at 10 year intervals) to particular vegetation can subsequently be difficult.

As a final note, few detailed suggestions can be highlighted for fynbos wildflower management recognising that research has been limited, collectively with the fact that the fynbos ecosystem is complex itself. Fynbos management has two extreme and much separated endpoints, presence of disturbance and at the other end, absence of disturbance. Somewhere between these two entities lies the answer to appropriate management for biodiversity – widely debated yet unanswered, clogged with nature’s uncertainties. Additionally the particular management goal in mind also complicates the situation.

6. Research challenges, limitations and interpretation

This thesis investigated ecological and social components. Research limitations related to each research component, i.e. questionnaire and vegetation survey are discussed below.

In social surveys (questionnaires) sources of error can arise from factors relevant to the researcher and/or the participant (Mouton, 1996; Winter, 2003). Winter (2003) suggests that landholder surveys should be brief but at the same time ensure accurate data collection. The researcher is confident that the survey complied with this suggestion as the average time spent per interview was 47 minutes (Conradie, 2009b). Additionally, all interviews were kept anonymous and therefore should not have made respondents uncomfortable with sharing personal or management related information. With specific reference to the ecology section of the questionnaire (Chapter 2), which was part of a broader land-use survey, questions were also kept short and the overall ecology section took no longer than 15 minutes (Conradie pers. com.). Furthermore, this section of the questionnaire was only relevant to landholders involved in wildflower farming from natural vegetation. Mouton (1996) stresses that topics of interest and relevance to the participant are more likely to be answered with motivation and accuracy, therefore it is believed that responses conveyed accurate information.

Most interviews were conducted in a helpful, forthcoming spirit although certain landholders initially seemed irritated by yet another "green survey". Reasoning for this supposed attitude from some landholders is not clear and possibly needs further investigation (Conradie pers. com.). Interviews were performed by an Afrikaans speaking senior lecturer at the University of Cape Town with extensive experience. Therefore, it is believed that distance between the researcher and participant should be negligible and the affiliation of the researcher should also not be seen as a possible source of error as it is a reputable university. Social desirability bias is the most likely factor that could have affected conservation-related responses. Some questions (open-ended and Likert statements) investigated a respondent's self-reported knowledge of fynbos and certain statements could have made a respondent appear anti-conservation (Winter, 2003). Arguably, the fact that the questionnaire was not performed by the student herself provides possible limitations to interpreting results but on the other hand the student was also able to handle the data purely as given. Commenting on the sample size of the questionnaire; 44 wildflower farmers (explicitly farming with natural vegetation) were identified in the study area as opposed to a previous survey (Heydenrych, 1999) that identified 35 wildflower farmers (includes wildflower farmers of cultivated and natural vegetation). Arguably the sample size is small but with the high coverage achieved in the 2009 survey (73%) it is believed that the only a minority of wildflower farmers were possibly excluded. Therefore the survey can be regarded as representative of wildflower farmers on the Agulhas Plain.

Of note, conservation-related responses associated with wildflower farming are especially dependent on farm size (spatial scale). For example, where a landholder has a larger area under management a question like "are there any rare or threatened species on your property?" is more likely to be answered in the affirmative than on a smaller farm (with less habitat diversity). This is especially relevant as farm size in the land-use questionnaire ranged from 11 ha – 11 000 ha (Conradie et al., 2010). Another important constraint is that the questionnaire relies on a respondent's ability to provide detailed management data about farming practices that happened several years ago. Whilst some landholders keep a comprehensive record of wildflower management activities (year and season of disturbance implemented, species used in broadcast sowing etc.) others do not (personal observation). It is obvious that this would influence accuracy of responses. Milton (2007) stipulates that "Only with good records of landuse history, will our understanding of factors causing species losses… be improved". These factors must be kept in mind when interpreting results from the questionnaire and the vegetation assessment.

Ecological processes in relation to disturbance function at various spatial and temporal scales and result in unique patterns (Pickett and White, 1985; Pickett et al., 1989; Wiens, 1989). The two mentioned entities, i.e. scale and pattern, are interconnected and widely debated in ecology (see Levin (1992) and references therein). The hierarchical levels of ecology (individuals, ecosystems and landscapes) are also distinctively affected by disturbance (Pickett et al., 1989) which limits an ecologist's interpretation of the natural system. Fynbos is known for high alpha- (local richness), beta- (regional richness) and gamma diversity (landscape richness) (Campbell and Van der Meulen, 1980; Cowling et al., 2009). The major ecological constraint to this investigation becomes apparent when acknowledging the patchiness component of fynbos (*sensu* Vlok, 1996) as fynbos diversity measurements are highly influence by the scale of the investigation (Vlok and Yeaton, 1999). At the same time, the Agulhas Plain is an area exceptionally complex in vegetation composition, geology and other abiotic components (Thwaites and Cowling, 1988; Cowling, 1990; Cowling and Holmes, 1992; Raimondo et al., 2009). This has produced an evolutionary compound and species-rich area (Linder, 2005). Therefore, the area is exceptionally complex to study and any investigation is but a snapshot in time simultaneously limited by the particular scale of the investigation.

Vlok and Yeaton (1999) emphasise that spatial scale is very important when estimating alpha diversity in fynbos. Suppression of understorey vegetation is most likely to be observed at small spatial scales ($5m^2$). Consequently, at larger spatial scales such observations should not hold true (Vlok and Yeaton, 1999). Despite using a fairly large spatial scale ($25m^2$) in this investigation plant diversity was significantly lower in all treatment sites (broadcast sown and shallow ploughed). Arguably it should not be the size of individual plots that did not provide corresponding results with Vlok and Yeaton (1999), but the unique environment brought about by wildflower farming practices. This includes; firstly, the altered disturbance regime where vegetative organs of resprouting species are possibly damaged by the disturbance intensity (shallow ploughing). Secondly, a shift in competitive interactions where reseeding species are favoured by both disturbance intensity (shallow ploughing) and applying the method of broadcast sowing. Constructive generalisations about the impact of wildflower farming practices on individual species are severely complicated by the scale of the research. Sampling a wider range of treatments and/or sampling more replicates of the same treatments should allow more precise generalizations about the impact of wildflower farming practices on the fynbos community. Although, the impact of particular wildflower farming practices on individual species, especially uncommon, species will inevitably be difficult to explore due to the botanical complexity of fynbos. Alpha diversity studies will forever be challenged by this and therefore Vlok (1996) cautions against extrapolating small scale studies to wider spatial scales.

Species identification proved challenging throughout this investigation. Vegetation sampling was performed during spring and early summer when most species were flowering. This eased identification procedures as good photographs and flowering specimens could be collected from all study sites. However, many fynbos species' flowering is restricted to other seasons (e.g. autumn, winter and late summer) (Manning, 2007). Therefore, flowering samples that would allow accurate identification had to be collected during additional field visits during appropriate seasons. After consulting various sources, four species remained unidentified and sixteen were only accurately identified up to genera level. While misidentifying or incomplete identification of species and even overlooking certain species in the field is common in fynbos studies (Van Wilgen and Kruger, 1981), every effort was made to avoid this, and experts were consulted where necessary.

7. Future research topics

Fynbos wildflower farms on the Agulhas Plain provide an ideal natural setting for research that involves comparing biotic entities, conditions and interactions between completely pristine, natural locations (reference sites) with semi-modified systems under different wildflower farming practices (broadcast sowing and shallow ploughing). In terms of ecology, the following components can be worthy of future research;

(i) Undertake to compare species recovery and vegetation composition to a more detailed vegetation assessment (than presented in Chapter 4): extensive replication of similar age and farming practices in study sites.

(ii) Compare vegetation recovery between environments that were previously subjected to wildflower farming practices and currently recovering from a natural fire (i.e. post-disturbance environment). This will provide valuable insights to investigate if changes in vegetation composition (growth form, regeneration mode) extend over larger temporal scales (i.e. not restricted to the first generation after wildflower farming practices).

(iii) Origin of plant genetic material has been highlighted in this investigation and previously as a threat to fynbos diversity (Heydenrych, 1999; Littlejohn, 2002). This is a topic of growing concern (Levin et al., 1996) worthy of future research as no research has focused on this component of wildflower farming.

(iv) Investigate the possibility of using certain plant species (e.g. *Passerina corymbosa*) and abiotic conditions (open soil) in developing a simple, reliable vegetation assessment protocol for wildflower vegetation (patches). This would identify fynbos patches in need of conservation attention, i.e. wildflower vegetation that is either severely degraded (for example repeatedly subjected to disturbance) which requires urgent management intervention. A similar approach developed for Renosterveld vegetation is outlined by Milton (2007) and a similar approach, in the context of wildflower farming, can possibly provide valuable insights.

On the other hand, wildflower farming remains market driven, like any other agricultural activity. Therefore, establishing a convincing economic argument for conservation (Conradie, 2009a; 2009b) in context of wildflower farming (and vice versa) is indispensable. Currently, although farming practices impact negatively on fynbos structure and diversity as shown in this thesis, this is insufficient to convince landholders to alter wildflower farming practices if we (i.e. ecologists and other scientists) cannot prove that the yields/profit margin from such activities remain the same or (even better) are increased. A sound economic argument is therefore essential, i.e. comparing volumes harvested (yield) from completely natural (reference sites) vs. managed vegetation (treatment sites) in an attempt to link the "economics versus the ecologics" (*sensu* Du Toit, 2010) of wildflower farming. This is specifically relevant for the Agulhas Plain, where financial considerations are becoming increasingly important in conservation decisions (Conradie et al., 2010).

8. Summary of issues: local trends and global context

The year 2010 was declared (by the United Nations General Assembly) as the "International Year of Biodiversity" (IYB[32]). This year and event was linked to a target to limit global biodiversity loss by nations who are parties of the Convention on Biological Diversity (CBD[33]). However, 2010 was also a gloomy year due to large scale environmental disasters, and the recognition that these targets have not been met (Butchart et al., 2010). Subsequently, there are few achievements compared to the ideals outlined by conservation and environmental efforts, e.g. CBD (Mooney and Mace, 2009; Butchart et al., 2010). Wildflower farming activities on the Agulhas Plain, although localised, fall under the umbrella of global biodiversity loss which is a pressing issue. These include; utilisation of natural resources and resource sustainability issues, plant diversity conservation and, last but not least, the urgency for facilitating cohesion amongst stakeholders in the process of conservation development.

The Agulhas Plain farming industry (as a whole) has been suffering in the last decade and more specifically, the fynbos export market has not experienced growth and prosperity in recent years (Conradie pers. com.). Diversifying farming activities is considered key to survival (Heydenrych, 1999; Conradie, 2009b). Heydenrych (1999) identified deciduous fruit and grape production, intensive cultivation of wildflowers and wine production as potential crops for future cultivation on the Agulhas

[32] International Year of Biodiversity official website: http://www.cbd.int/2010/welcome/
[33] Convention on Biological Diversity official website: http://www.cbd.int/

Plain. Subsequently, irrigated agriculture was seen as a major threat to biodiversity conservation in the area but this was not supported by a recent land use survey (Conradie, 2009b) which identified tourism, wildflower harvesting, conservation and international interest in fynbos as opportunities in the area. If these opportunities are to be realised, focus must be placed on sustainable enterprises that favour the biological diversity of the region.

Wilcove (1989) emphasises that biological diversity will not successfully be conserved by establishing nature reserves alone. In the past, protected areas were often established in an informal manner, i.e. not truthfully representing all hierarchies (genes, species, populations, ecosystems) of biodiversity (Cowling et al., 1999; Margules and Pressey, 2000). Therefore, there is a need to apply ecological principles at the landscape level to ensure sustainable environments and biodiversity conservation in the future (Harris, 1984; Hansen et al., 1991; Opdam et al., 2006; Chazdon et al., 2009). At the same time, however, it is necessary to keep in mind that wildflower farming is not a typical 'agricultural activity'. While the wildflower farmer may potentially cause alterations in fynbos composition and diversity, this activity is still the single economic sector contributing informally but significantly to biodiversity conservation in the fragile and threatened Cape lowlands. Therefore, from a conservation perspective, organisations and individuals must be especially cautious and sensitive in their approach to cooperate with this sector of agriculture. 'Losing' these areas to other types of more destructive land use practices would forever condemn fynbos conservation in the lowlands of the Agulhas Plain.

9. Literature cited

Bean, M.J., Wilcove, D.S., 1997. The private-land problem. Conservation Biology 11, 1-2.

Bond, W.J., Maze, K., Desmet, P., 1995. Fire life-histories and the seeds of chaos. Ecoscience 2, 252-260.

Butchart, S.H.M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J.P.W., Almond, R.E.A., Baillie, J.E.M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K.E., Carr, G.M., Chanson, J., Chenery, A.M., Csirke, J., Davidson, N.C., Dentener, F., Foster, M., Galli, A., Galloway, J.N., Genovesi, P., Gregory, R.D., Hockings, M., Kapos, V., Lamarque, J.F., Leverington, F., Loh, J., McGeoch, M.A., McRae, L., Minasyan, A., Morcillo, M.H., Oldfield, T.E.E., Pauly, D., Quader, S., Revenga, C., Sauer, J.R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S.N., Symes, A., Tierney, M., Tyrrell, T.D., Vie, J.C., Watson, R., 2010. Global biodiversity: indicators of recent declines. Science 328**,** 1164-1168.

Campbell, B.M., Van Der Meulen, F., 1980. Patterns of plant species diversity in fynbos vegetation, South Africa. Vegetatio 43, 43-47.

Chazdon, R.L., Harvey, C.A., Komar, O., Griffith, D.M., Ferguson, B.G., Martines-Ramos, M., Morales, H., Nigh, R., Soto-Pinto, L., van Breugel., M., Philpott, S.M., 2009. Beyond reserves: A research agenda for conserving biodiversity in human-modified tropical landscapes. Biotropica 41, 142-153.

Conradie, B., 2009a. Is sustainable fynbos harvesting a viable biodiversity business on the Agulhas Plain, South Africa? Unpublished document. School of Economics, University of Cape Town.

Conradie, B., 2009b. Boerdery en bewaring in die Strandveld. Available at: www.flowervalley.org.za Accessed on: 09/02/2010.

Conradie, B., Knoesen, H., 2009. A survey of the cultivation and wild harvesting of fynbos flowers in South Africa. Available at: http://www.flowervalley.org.za Accessed on: 17/05/2010.

Conradie, B. (Dr.), 2010. Personal communication. Flower Valley Conservation Trust and School of Economics, University of Cape Town.

Conradie, B., Treurnicht, M., Esler, K.J., Gaertner, M., 2010. Conservation begins after breakfast: A logit model of conservation involvement on the Agulhas Plain, CFR. Presented at the 49th annual conference of the Agricultural Economics Association of South Africa, September 2010, Cape Town, South Africa.

Cowling, R.M., 1989. The Research Perspective: Veld Resources. In: Greyling, T., Davis, G.W. (Eds.), The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial

Ecosystems Section Ecosystem Programmes: Occasional Report No. 40. Foundation for Research Development, CSIR, Pretoria, South Africa. pp. 14-16.

Cowling, R.M., 1990. Diversity components in a species-rich area of the Cape Floristic Region. Journal of Vegetation Science 1, 699-710.

Cowling, R.M., 1992. The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town.

Cowling, R.M., Gxaba, T., 1990. Effects of a fynbos overstorey shrub on understorey community structure: implications for the maintenance of community-wide species richness. South African Journal of Ecology 1, 1-7.

Cowling, R.M., Holmes, P.M., 1992. Flora and vegetation. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 23-61.

Cowling, R.M., Pressey, R.L., Lombard, A.T., Desmet, P.G., Ellis, A.G., 1999. From representation to persistence: requirement for a sustainable reserve system in the species rich mediterranean-climate deserts of southern Africa. Diversity and Distributions 5, 51-71.

Cowling, R.M., Proches, S., Partridge, T.C., 2009. Explaining the uniqueness of the Cape flora: incorporating geomorphic evolution as a factor for explaining its diversification. Molecular Phylogenetics and Evolution 51, 64-74.

Cowling, R.M., Knight, A.T., Privett, S.D.J., Sharma, G., 2010. Invest in opportunity, not inventory of hotspots. Conservation Biology 24, 633-635.

Curtis, O. 2009. Personal communication. CAPE Renosterveld Project Coordinator.

Curtis, O. 2009. Renosterveld under scrutiny. Bringing science, management and stewardship together. Veld and Flora 95, 150-152.

Davis, G.W., 1990. Commercial wildflower production in the fynbos biome and its role in the management of land-use. PhD Thesis, Department of Botany, University of Cape Town.

Davis, G.W., 1992. Commercial exploitation of natural vegetation: an exploratory model for management of the wildflower industry in the fynbos biome of the Cape, South Africa. Journal of Environmental Management 35, 13-29.

Du Toit, S., 2010. Economics verses ecologics-two languages with little in common? Newsletter of the Wildlife and Environment Society of South Africa 3, pp.3.

Fatoki, O.B., 2007. Monitoring the regrowth rate of alien vegetation after fire on Agulhas Plain, South Africa. MSc Thesis. Stellenbosch University.

FVCT., 2008. Flower Valley Conservation Trust. Annual Report 2008/2009. Available at: www.flowervalley.co.za Accessed on: 16/07/2010.

Greyling, T., Davis, G.W. (Eds.), 1989. The Wildflower Resource: Commerce, Conservation and Research - A Report of the Terrestrial Ecosystems Section Ecosystem Programmes. Occasional Report No. 40. Foundation for Research Development, CSIR, PO Box 395, Pretoria.

Gafney, M., 2010. Personal communication. Wildflower Farmer (Agulhas Plain).

Gaston, K.J., 1994. Rarity. Chapman and Hall.

Hanes, T.L., 1971. Succession after fire in the Chaparral of Southern California. Ecological Monographs 41, 27-52.

Hanks, J., 2007. Talking of nature. Africa Geographic, February Issue, p.83. Available at: www.africageographic.com Accessed on: 17/05/2010.

Hansen, A.J., Spies, T.A., Swanson, F.J., Ohmann, J.L., 1991. Conserving biodiversity in managed forests. Bioscience 41, 382-392.

Harris, L.D., 1984. The Fragmented Forest. University of Chicago Press, Chicago.

Heydenrych, B.J., 1999. An investigation of land-use practices on the Agulhas Plain (South Africa), with emphasis on socio-economic and conservation issues. MSc Thesis, Institute for Plant Conservation, University of Cape Town.

Hulme, D., Murphree, M., 2001. African wildlife and livelihoods. David Philip, Cape Town.

Joubert, L., Esler, K.J., Privett, S.D.J., 2009. The effect of ploughing and augmenting natural vegetation with commercial fynbos species on the biodiversity of Overberg Sandstone fynbos on the Agulhas Plain, South Africa. South African Journal of Botany 75, 526-531.

Kruger, F.J., 1983. Plant community diversity and dynamics in relation to fire. In: Kruger, F.J., Mitchell, D.T, Jarvis, J. U. M. (Eds.), Mediterranean-type ecosystems: the role of nutrients. Springer-Verlag, Berlin, Germany. pp. 446-472.

Levin, S.A., 1992. The problem of pattern and scale in ecology. Ecology 73, 1943-1967.

Levin, D.A., Francisco-Ortega, J., Jansen, R.K., 1996. Hybridization and the extinction of rare plant species. Conservation Biology 10, 10-16.

Linder, H.P., 2005. Evolution of diversity: the Cape flora. Trends in Plant Science 10, 536-541.

Littlejohn, G., 2002. Legal issues, Planning and Planting. Cultivating fynbos for quality cut flower production. Unpublished ARC training course manual. Agricultural Research Council, Elsenburg, South Africa. pp.82-90.

Manning, J., 2007. Field Guide to Fynbos. Struik Publishers, Cape Town.

Margules, C.R., Pressey, R.L., 2000. Systematic conservation planning. Nature 405, 243-253.

Milton, S.J., 2007. Rapid assessment method for Renosterveld. Discussions from the Renosterveld Assessment Workshop. Available at: www.elsenburg.com Accessed on: 02/03/2009.

Mooney, H., Mace, G., 2009. Biodiversity policy challenges. Science 325, 1471.

Mouton, J., 1996. Understanding Social Research. Van Schaik, Pretoria.

Mustart, P.J., Cowling, R.M., undated. Fynbos ecology for wildflower harvesters. Unpublished document. Department of Botany, University of Cape Town.

Mucina, L., Rutherford, M.C., 2006. The Vegetation of South Africa, Lesotho and Swaziland. South African National Biodiversity Institute, Pretoria.

Opdam, P., Steingröver, E., Rooij, S.V., 2006. Ecological networks: A spatial concept for multi-actor planning of sustainable landscapes. Landscape and Urban Planning 75, 322-332.

Pickett, S.T.A., White, P.S., 1985. The Ecology of Natural Disturbance and Patch Dynamics. Academic Press, New York.

Pickett, S.T.A., Kolasa, J., Armesto, J.J., Collins, S.L., 1989. The ecological concept of disturbance and its expression at various hierarchical levels. Oikos 54, 129-136.

Pimm, S.L., Russell, G.J., Gittleman, J.L., Brooks, T.L., 1995. The future of biodiversity. Science 269, 347-350.

Privett, S.D.J., 1998. Determinants of pattern in fynbos vegetation. Physical site factors, disturbance regime, species attributes and temporal change. MSc Thesis, University of Cape Town.

Privett, S.D.J., Heydenrych, B.J., Cowling, R.M., 2002. Putting Biodiversity to Business on the Agulhas Plain. In: Pierce, S.M., Cowling, R.M., Sandwith, K., MacKinnon, K. (Eds.), Mainstreaming Biodiversity in Development. The World Bank Environment Department. pp. 101-111.

Raimondo, D., von Staden, L., Foden, W., Victor, J.E., Helme, N.E., Turner, R.C., Kamundi, D.A., Manyama, P.A., 2009. Red List of South African plants 2009. Strelitzia 25, South African National Biodiversity Institute, Pretoria.

Singh, J.S., 2002. The biodiversity crisis: A multifaceted review. Current Science 82, 638-647.

Thuiller, W., Slingsby, J.A. Privett, S.D.J. Cowling, R.M., 2007. Stochastic species turnover and stable coexistence in a species-rich, fire-prone plant community. Public Library of Science One 2, e938. doi:10.1371.

Thwaites, R.N., Cowling, R.M., 1988. Soil-vegetation relationships on the Agulhas Plain, South Africa. Catena 15, 333-345.

Van Wilgen, B.W., 2009. The evolution of fire and invasive alien plant management practices in fynbos. South African Journal of Science 105, 335-342.

Van Wilgen, B.W., Bond, W.J., Richardson, D.M., 1992. Ecosystem management. In: Cowling, R.M. (Ed.), The Ecology of Fynbos. Nutrients, Fire and Diversity. Oxford University Press, Cape Town. pp. 345-371.

Van Wilgen, B.W., Forsyth, G.G., de Klerk, H., Das, S., Khuluse, S., Schmitz, P., 2010. Fire management in Mediterranean-climate shrublands: a case study from the Cape fynbos, South Africa. Journal of Applied Ecology 47, 631-638.

Van Wilgen, B.W., Kruger, F.J., 1981. Observations on the effects of fire in Mountain Fynbos at Zachariashoek, Paarl. Journal of South African Botany 47, 195-212.

Van Wilgen, B.W., Richardson, D.M., Seydack, A.H.W., 1994. Managing fynbos for biodiversity: constraints and options in a fire-prone environment. South African Journal of Science 90, 322-329.

Vlok, J.H.J., 1996. The role of overstorey proteoid shrubs in maintaining species richness in a southern cape mountain fynbos community. MSc Thesis, Department of Botany. University of Natal.

Vlok, J.H.J., Yeaton, R.I., 1999. The effect of overstorey Proteas on plant species richness in South African Mountain Fynbos. Diversity and Distributions 5, 213-222.

Vlok, J.H.J., Yeaton, R.I., 2000. Competitive interactions between overstorey proteas and sprouting understorey species in South African mountain fynbos. Diversity and Distributions 6, 273-281.

Von Hase, A., Rouget, M., Cowling, R.M., 2010. Evaluating private land conservation in the Cape lowlands, South Africa. Conservation Biology 24, 1182-1189.

Walton, B.A., 2006. Vegetation patterns and dynamics of Renosterveld at Agter-Groeneberg Conservancy, Western Cape, South Africa. MSc Thesis. Stellenbosch University.

Whelan, R.J., Roberts, D.G., England, P.R., Ayre, D.J., 2006. The potential for genetic contamination vs. augmentation by native plants in urban gardens. Biological Conservation 128, 493-500.

Wiens, J.A., 1989. Spatial scaling in ecology. Functional Ecology 3, 385-397.

Wilcove, D.S., 1989. Protecting biodiversity in multiple-use lands: lessons from the US Forest Service. Trends in Ecology and Evolution 4, 385-388.

Winter, S.J., 2003. Attitudes and behaviour of landholders towards the conservation of Overberg Coastal Renosterveld, a threatened vegetation type in the Cape Floral Kingdom. MSc Thesis, Stellenbosch University.

APPENDIX 1:

Land use questionnaire: **Ecology section** (English version; translated by M. Treurnicht)

VEGETATION MANAGEMENT (i.e. "ecology section")

☼ HOW DO YOU USE NATURAL VEGETATION (i.e. veld) ON YOUR PROPERTY?

☼ DO YOU TREAT ALL YOUR FLOWER VELD THE SAME?

YES	NO	APPROX.

☼ IN YOUR OPINION, HOW MUST FLOWER VELD BE MANAGED FOR 'BEST' FLOWER YIELDS?

☼ PLEASE PROVIDE INFORMATION ON THE THREE MOST RECENT FIRES ON YOUR PROPERTY...

1	TYPE (N/W)		YEAR		SEASON	S	A	W	SP	SIZE	
2	TYPE (N/W)		YEAR		SEASON	S	A	W	SP	SIZE	
3	TYPE (N/W)		YEAR		SEASON	S	A	W	SP	SIZE	

☼ HAVE YOU EVER IMPLEMENTED PLOUGHING ON YOUR VELD?

NOT SURE	YES	NO

☼ IF YES, PLEASE DESCRIBE THE THREE MOST RECENT EVENTS...

1	YEAR		SEASON	S	A	W	SP	SIZE		DEPTH		METHOD	
2	YEAR		SEASON	S	A	W	SP	SIZE		DEPTH		METHOD	
3	YEAR		SEASON	S	A	W	SP	SIZE		DEPTH		METHOD	

☼ HAVE YOU EVER USED THE METHOD OF BROADCAST SOWING ON YOUR PROPERTY?

NOT SURE	YES	NO

☼ IF YES, PLEASE DESCRIBE THE THREE MOST RECENT EVENTS...

1	YEAR		SEASON	S	A	W	SP	SIZE		ORIGIN	FARM	<10km	AP	OTHER
2	YEAR		SEASON	S	A	W	SP	SIZE		ORIGIN	FARM	<10km	AP	OTHER
3	YEAR		SEASON	S	A	W	SP	SIZE		ORIGIN	FARM	<10km	AP	OTHER

☼ CAN YOU NAME THE SPECIES YOU USED IN BROADCAST SOWING? PLEASE PROVIDE NAMES IF POSSIBLE...

☼ DO YOU USE ANY OTHER METHODS SUCH AS BUSHCUT OR 'IRON TOWING'? (IF YES, PLEASE PROVIDE DETAIL BELOW...

1	YEAR		SEASON	S	A	W	SP	SIZE		TYPE	
2	YEAR		SEASON	S	A	W	SP	SIZE		TYPE	
3	YEAR		SEASON	S	A	W	SP	SIZE		TYPE	

☼ HAVE YOU EVER USED ANY OF THE FOLLOWING COMBINATION PRACTICES?

CONTROLLED BURN AND SHALLOW PLOUGH		CONTROLLED BURN AND DEEP PLOUGH	
CONTROLLED BURN AND BROADCAST SOWN		SHALLOW PLOUGH AND BROADCAST SOWN	
DEEP PLOUGH AND BROADCAST SOWN		BUSHCUT AND BROADCAST SOWN	
IRON TOWING AND BROADCAST SOWN		OTHER…(please specify)	

☼ DID THE APPLICATION OF FARMING PRACTICES INCREASE YOUR FLOWER PRODUCTION?	YES	NO	DON'T KNOW
☼ DID THE COMPOSITION OF VELD CHANGE NOTICABLY?	YES	NO	DON'T KNOW

☼ IF YES, CAN YOU DESCRIBE THE CHANGE?

☼ IN YOUR OPINION HOW OFTEN MUST FYNBOS BURN (YEARS)?			
☼ DO 'RARE/THREATENED' SPECIES OCCUR ON YOUR PROPERTY?	YES	NO	DON'T KNOW

☼ IF YES, CAN YOU NAME THEM?

☼ HOW WOULD YOU DESCRIBE FLOWER VELD THAT IS IN 'GOOD CONDITION'?

☼ TO WHAT EXTENT DO YOU AGREE WITH THE FOLLOWING STATEMENTS?

	FULLY AGREE	AGREE	NEUTRAL	DISAGREE	FULLY DISAGREE
PLOUGHING REGENERATES (STIMULATES GROWTH) FLOWER VELD	5	4	3	2	1
SOME SPECIES WILL DISAPPEAR IF PLOUGHED IN TWO CONSECUTIVE YEARS	5	4	3	2	1
BURNING HAS NO INFLUENCE ON FYNBOS PLANT DIVERSITY	5	4	3	2	1
PLOUGHING HAS NO INFLUENCE ON FYNBOS PLANT DIVERSITY	5	4	3	2	1
PLOUGHING STIMULATES THE GROWTH OF WEEDY (UNWANTED) SPECIES	5	4	3	2	1
I NOTICE MORE WEEDY (UNWANTED) SPECIES AFTER CONSECUTIVE BURNS	5	4	3	2	1
RARE FYNBOS SPECIES ARE 'MORE RARE' AFTER PLOUGHING	5	4	3	2	1
RARE FYNBOS SPECIES ARE 'MORE RARE' AFTER BROADCAST SOWING	5	4	3	2	1
VEGETATION OF 4-5 YEARS OLD ARE 'OLD' AND MUST BURN	5	4	3	2	1
IF I CAN NOT SELL A FYNBOS SPECIES IT IS OF NO VALUE TO ME	5	4	3	2	1
FYNBOS PLANT DIVERSITY IS IMPORTANT FOR MY FLOWER BUSINESS	5	4	3	2	1
BROADCAST SOWING SIMPLY 'HELPS NATURE TO PERFORM'	5	4	3	2	1
FYNBOS CONSERVATION IS CONTRADICTORY WITH MY FLOWER BUSINESS	5	4	3	2	1
I AM A ROLE PLAYER IN THE CONSERVATION OF FYNBOS	5	4	3	2	1

APPENDIX 1 (cont.):

Land use questionnaire (Full Afrikaans version; courtesy Dr B. Conradie)

Universiteit van Kaapstad

Ref	
Datum	
Begin tyd	

Grondgebruik in die Bredasdorp Strandveld

Dr. Beatrice Conradie

ABI besef dat hulle sonder die boere nie veel gaan bereik nie. Dis my job om uit te vind hoe die boerdery werk en hoe boere hulle grond gebruik

Let wel:

1. Alle inligting word vertroulik hanteer
2. Dit staan u vry om op enige stadium ‘n vraag oor te slaan of uit te laat

AGTERGROND

☼ Hoeveel grond besit u?	
☼ Van wanneer af besig u dit al?	
☼ Hoe lank is die grond al in die familie?	

☼ Samestelling van inkomste in persentasie

1. Nie landbou inkomste / Inkomste van buite die plaas	
2. Skape	
3. Beeste	
4. Melkery	
5. Graan / gewasse	
6. Groente	
7. Wingerd	
8. Blomme	
9. Bye	
10. Dekriet	
11. Brandhout	
12. Toerisme	
13. Verhuring	
14. Ander ______________________________	

☼ Respondent se besonderhede

1. Ouderdom			
2. Geslag			
3. Taal			
4. Kwalifikasie			
5. Posisie			
6. Is u aktief by die boerdery betrokke	Ja	Nee	Soortvan

GEVARE & GELEENTHEDE

☼ Beskou u die volgende as ‘n geleentheid of ‘n bedreiging / gevaar vir u boerdery / besigheid?

Stygende brandstof pryse	Gevaar	Geleentheid	Neutraal	NVT
Stygende minimum lone	Gevaar	Geleentheid	Neutraal	NVT
Grondhervorming	Gevaar	Geleentheid	Neutraal	NVT
Verblyfreg (ESTA)	Gevaar	Geleentheid	Neutraal	NVT
Armoede en werkloosheid wat tot misdaad lei	Gevaar	Geleentheid	Neutraal	NVT
HIV/ VIGS	Gevaar	Geleentheid	Neutraal	NVT
Handelsregulasies	Gevaar	Geleentheid	Neutraal	NVT
Dumping	Gevaar	Geleentheid	Neutraal	NVT
Produkpryse wat nie byhou met insetkoste nie	Gevaar	Geleentheid	Neutraal	NVT
Inkommers wat hoë pryse vir grond betaal (Life style)	Gevaar	Geleentheid	Neutraal	NVT
LAgulhas Nasionale Park	Gevaar	Geleentheid	Neutraal	NVT
Uitbreiding van die LAgulhas Nasional Park	Gevaar	Geleentheid	Neutraal	NVT
Die regering	Gevaar	Geleentheid	Neutraal	NVT
Wingerd	Gevaar	Geleentheid	Neutraal	NVT
Blomme	Gevaar	Geleentheid	Neutraal	NVT
Wildboerdery	Gevaar	Geleentheid	Neutraal	NVT
Houtskool uit indringer plante	Gevaar	Geleentheid	Neutraal	NVT
Koolstof krediete / carbon trading	Gevaar	Geleentheid	Neutraal	NVT
Toerisme	Gevaar	Geleentheid	Neutraal	NVT
Na aan Kaapstad geleë	Gevaar	Geleentheid	Neutraal	NVT
Bantamsklip se kernkragsentrale	Gevaar	Geleentheid	Neutraal	NVT
ABI	Gevaar	Geleentheid	Neutraal	NVT
Flower Valley	Gevaar	Geleentheid	Neutraal	NVT
Internasionale belangstelling in fynbos	Gevaar	Geleentheid	Neutraal	NVT

BETROKKENHEID

☼ Behoort u aan die boerevereeniging?		Ja	Nee
☼ Behoort u aan 'n studiegroep?		Ja	Nee
☼ Is u 'n lid van PPSA (Protea Produsente van Suid-Afrika)?		Ja	Nee
☼ Is u 'n lid van 'n brandvereeniging?		Ja	Nee
☼ Is u by enige van ABI se bedrywighede betrokke?		Ja	Nee
☼ Is die plaas deel van 'n CapeNature conservancy?		Ja	Nee
☼ Is die plaas deel van 'n CapeNature stewardship program?		Ja	Nee
☼ Grens u grond aan die Park?		Ja	Nee
☼ Word daar beplan om die Park op u grond uit te brei?	Ja	Nee	Weet nie
☼ Is u tans deel van die Nuwejaars SMA?		Ja	Nee
☼ Stel u belang daar in om aan 'n SMA te behoort?		Ja	Nee

☼ Kry u goeie diens van of het u goeie samewerking met enige van die volgende partye?

Departement Landbou se Land Care program	Ja	Nee	Neutraal
Werk vir Water	Ja	Nee	Neutraal
Die plaaslike park	Ja	Nee	Neutraal
Nasionale Parke in die algemeen	Ja	Nee	Neutraal
Cape Nature	Ja	Nee	Neutraal
Flower Valley	Ja	Nee	Neutraal

☼ Wie is ABI en hoe sien u die rol van ABI?

GRONDGEBRUIK

☼ Hoeveel grond besit u?	
☼ Hoeveel daarvan is	
1. Lande (wat nie besproei word nie)	
2. Grond wat tans besproei word	
3. Vleie / rivier	
4. Veld waarop blomme ingesaai/ geplant is	
5. Ander veld wat gepluk word	
6. Ander veld wat gewei word	
7. Ander veld wat nog nooit gepluk of gewei is nie	
☼ Hoeveel geregistreerde besproeiingswater het die plaas?	
☼ Watter gewasse word besproei?	

☼ Het u in die afgelope seisoen enige wingerd aangeplant?		Ja	Nee
☼ Beplan u om wingerd te plant?	Ja	Nee	Weet nie
Min of meer hoe groot gaan die ontwikkeling wees?			
Wat gaan dit kos?			

☼ Oor watter van die volgende toerisme fassiliteite beskik u?

Akkommodasie		4x4 roetes	
Konferensie geriewe		Stap roetes	
Restaurant		Kloofing of rotsklim	
Kamp terrein		Wildkyk	
Voëlskyk			

☼ Beplan u om u toerisme besigheid uit te brei?	Ja	Nee	Weet nie
☼ Het u sedert 1999 enige grond verkoop?		Ja	Nee
☼ Beplan u om binnekort nog grond te verkoop?	Ja	Nee	Weet nie
☼ Het u sedert 1999 enige grond verkoop?		Ja	Nee
☼ Beplan u om enige grond aan te koop?	Ja	Nee	Weet nie

BESTUUR VAN U VELD

☼ Hoe word u veld in die boerdery opset gebruik?

☼ Word al u blomveld op dieselfde manier behandel?	Ja	Nee	Min of meer

☼ Hoe moet veld bestuur word vir die beste blom opbrengs?

☼ Vertel my van die laaste drie brande op u grond

1	Tipe (B/O)		Jaar		Seisoen	S	H	W	L	Grootte		
2	Tipe (B/O)		Jaar		Seisoen	S	H	W	L	Grootte		
3	Tipe (B/O)		Jaar		Seisoen	S	H	W	L	Grootte		

☼ Het u die kamp al ooit voorheen geploeg?	Weet nie	Ja	Nee

☼ Indien wel, beskryf die laaste drie bewerkings

1	Jaar		Seisoen	S	H	W	L	Grootte		Diepte		Metode		
2	Jaar		Seisoen	S	H	W	L	Grootte		Diepte		Metode		
3	Jaar		Seisoen	S	H	W	L	Grootte		Diepte		Metode		

☼ Het u al enige saad in die stuk grond ingesaai?	Weet nie	Ja	Nee

☼ Indien wel, beskryf die laaste drie kere wat saad gesaai is

1	Jaar		Seisoen	S	H	W	L	Grootte		Oorsprong	plaas	<10km	SV	elders
2	Jaar		Seisoen	S	H	W	L	Grootte		Oorsprong	plaas	<10km	SV	elders
3	Jaar		Seisoen	S	H	W	L	Grootte		Oorsprong	plaas	<10km	SV	elders

☼ Kan u enige van die spesies noem wat gesaai is?

☼ Gebruik u enige ander skoonmaak metodes in u veld, byvoorbeeld bossieslaners of sleepysters?

1	Jaar		Seisoen	S	H	W	L	Grootte		Tipe	
2	Jaar		Seisoen	S	H	W	L	Grootte		Tipe	
3	Jaar		Seisoen	S	H	W	L	Grootte		Tipe	

☼ Het u al enige van die volgende kombinasies van bewerking probeer?

Beheerde brand + vlak ploeg		Beheerde brand + diep ploeg	
Beheerde brand + saad in saai		Saad insaai + vlak ploeg	
Saad in saai + diep ploeg		Bossieslaner + saad insaai	
Sleepyster + saad in saai		Ander	

☼ Het hierdie strategie u blomproduksie verhoog?	Ja	Nee	Weet nie
☼ Het die veld se voorkoms/ samestelling verander?	Ja	Nee	Weet nie

☼ Indien wel, beskryf die verandering

☼ Volgens u, hoe gereeld moet fynbos brand?			
☼ Kom daar Skaars of bedreigde spesies op u grond voor?	Ja	Nee	Weet nie

Kan u enige van die spesies noem?

☼ Hoe weet 'n mens of veld in 'n goeie toestand is of nie?

☼ Tot watter mate stem u met die volgende stellings saam?

	Stem volkome saam	Stem saam	Neutraal	Stem nie saam nie	Stem glad nie saam nie
Ploeg vernuwe die veld omdat dit groei stimuleer	5	4	3	2	1
Sekere s sal verdwyn as daar 2 jaar na mekaar geploeg word	5	4	3	2	1
Brand het geen invloed op die biodiversiteit van fynbos nie	5	4	3	2	1
Ploeg het geen invloed op die biodiversiteit van fynbos nie	5	4	3	2	1
Ploeg stimuleer uitheemse en onkruid spesies	5	4	3	2	1
Ek neem meer onkruid spesies waar in veld na herhaalde brande	5	4	3	2	1
Skaars fynbos spesies word selfs skaarser na daar geploeg is	5	4	3	2	1
Skaars fynbos spesies word selfs skaarser na daar ingesaai is	5	4	3	2	1
Veld van 4-5 jaar is oud en moet binnekort gebrand word	5	4	3	2	1
Fynbos wat nie gepluk kan word nie het geen nut vir my nie	5	4	3	2	1
Fynbos diversiteit is belangrik vir die sukses van my boerdery	5	4	3	2	1
Deur in te saai “help ek die natuur aan” om beter te vaar	5	4	3	2	1
Bewaring van fynbos is teenstrydig met my blombedryf	5	4	3	2	1
Ek speel ‘n rol in die bewaring van die strandveld	5	4	3	2	1

BLOMBEDRYF

☼ Pluk u u eie veld?	Ja	Nee
☼ Pluk u ander veld?	Ja	Nee
Indien wel, hoeveel hektaar?		
☼ Pak u self?	Ja	Nee
☼ Bemark u self?	Ja	Nee
☼ Indien wel, watter persentasie van die oes word uitgevoer?	Ja	Nee
☼ Wat is die hoof bestemming waarnatoe u uitvoer?		
☼ Hoeveel plukkers het u? Permanent		
Tydelik		
☼ Werk die plukkers ook in die pakstoor?	Ja	Nee

☼ Hoe word hulle vergoed?

Dagloon	Stukwerk	Stukwerk met gewaarborgde minimum loon

☼ Wat verdien 'n goeie plukker op 'n dag?	

☼ Kom ander mense by u pluk?	Ja	Nee
Indien wel, hoeveel het u in die afgelope seisoen uit blomme verdien?		

☼ Is aanplantings belangrik?	Ja	Nee	Weet nie

Watter soorte moet aangeplant word?

☼ Hoeveel aanplantings het u?		
☼ Is u bereid om die samestelling van u oes beskikbaar te stel?	Ja	Nee
☼ Is u bereid om enige koste syfers beskikbaar te stel?	Ja	Nee

☼ Gee die mark om hoe blomme geproduseer word?	Ja	Nee

☼ Indien wel, waarvoor kyk hulle?

Kwaliteit	Volhoubaarheid	Ander

☼ Stel u belang in die sertifisering van volhoubaarheid?	Weet nie	Ja	Nee
☼ Gebruik u Flower Valley se volhoubare oes metodes?	Ja	Nee	Weet nie

Indien wel, wat behels die stelsel?

Eind tyd ____________________

Studie van fynbos ekologie

Martina Treurnicht, ‘n M.Sc. student van Stellenbosch, bestudeer die effek van vuur en ploeg op die samestelling en toestand van fynbos veld. Haar studieleier is Dr Mirijam Gaertner wat jare lange ondervinding van die rehabilitasie van Duitse vliegvelde het.

1. Stel u belang om aan Martina se studie deel te neem? Ja/ Nee
2. Wil u graag terugvoering oor u grond ontvang? Ja/ Nee

Indien wel, verskaf asseblief u naam en telefoon nommer

____

‘n Beter Werk vir Water model

Werk vir Water ondersoek ‘n meer sinvolle manier om met boere saam te werk. Lauren Urgensen van die VSA doen die navorsing vir haar doktorsgraad. Sy is aan die Sosiologie Department op Stellenbosch verbonde.

1. Stel u belang om met Lauren te praat? Ja/ Nee
2. Stel u hoegenaamd in Werk vir Water belang? Ja/ Nee

Indien wel, verskaf asseblief u naam en telefoon nommer

____

APPENDIX 2:

Floristic data sheet used for recording environmental variables and vegetation cover in the vegetation survey

<table>
<tr><td colspan="4" align="center">5 x 5m / 25 m²</td></tr>
<tr><td colspan="2">Date:</td><td colspan="2">Plot nr:</td></tr>
<tr><td colspan="2">Farmer:</td><td colspan="2" rowspan="2">Location GPS:</td></tr>
<tr><td colspan="2">Farm name:</td></tr>
<tr><td colspan="2">Vegetation age:</td><td colspan="2">Total Projected foliage cover (%):</td></tr>
<tr><td colspan="2">Plot - Average height (m):</td><td colspan="2">Plot - Max height (m):</td></tr>
<tr><td rowspan="2">Slope (angle / aspect):</td><td rowspan="2">/</td><td colspan="2">Rockiness (%):</td></tr>
<tr><td colspan="2">Elevation:</td></tr>
<tr><td colspan="2">Open soil (%):</td><td colspan="2">Litter (%):</td></tr>
<tr><td colspan="4" align="center"><u>Growth form categories: Projected cover (%)</u></td></tr>
<tr><td>Graminoid (restios, grasses, sedges)</td><td></td><td>Resprouter</td><td></td></tr>
<tr><td>Geophytes (bulbous plants)</td><td></td><td>Reseeder</td><td></td></tr>
<tr><td>Herbaceous</td><td></td><td>Succulents</td><td></td></tr>
<tr><td colspan="2">Large shrubs (>100 cm)
Ericoid
Proteoid
Other</td><td colspan="2">Medium shrubs (50 – 100 cm)
Ericoid
Proteoid
Other</td></tr>
<tr><td colspan="2">Small shrubs (<50 cm)
Ericoid
Proteoid
Other</td><td colspan="2"></td></tr>
</table>

Species list (with % cover)			

APPENDIX 3:

Equations for diversity and evenness indices used in Chapter 3

Shannon diversity (Shannon and Weaver, 1949*) is a measure defined by:

$$H' = -\Sigma\,[p_i \times \ln(p_i)]$$

where p_i = the fraction of cover of a given species to the total cover of species in the community.

Simpson index of diversity (Simpson, 1949**):

$$D' = 1 - \Sigma\,[n_i\,(n_i - 1)\,/\,N(N-1)]$$

where n_i = the cover of the i th species, and N = the total cover of all species.

Pielou's evenness index (Pielou, 1966***):

$$J' = \frac{H'}{\log H_{max}}$$

where H_{max} = species richness.

* Shannon, C.E., Weaver, W., 1949. The mathematical theory of communication. University of Illinois Press, Urbana.

** Simpson, E. H., 1949. Measurement of diversity. Nature 163, 688.

*** Pielou, E.C., 1966. The measurement of diversity in different types of biological collections. Journal of Theoretical Biology 13, 131-144.

APPENDIX 4:

Species information: plant family, species name, commercial use (*), regeneration mode, “Red List Status” (Raimondo et al., 2009) and mean cover in study sites (for abbreviations see Chapter 3)

FAMILY	SPECIES	Commercial use	RSE/RSP	RED LIST STATUS	C1[14]	C2[20]	BCS[10]	SP1[14]	SP2[20]	SP3[8]
Aizoaceae	*Carpobrotus acinaciformus*		RSP	LC	0	0.07	0.50	0.03	0	0.07
Alliaceae	*Tulbaghia alliacea*		RSP	LC	0	0.04	0	0	0.11	0
Amaryllidaceae	*Cyrtanthus angustifolius*		RSP	LC	0.17	0.25	0.03	0.07	0.14	0
Amaryllidaceae	*Cyrtanthus carneus*		RSP	**VU**	0.13	0	0.20	0	0.04	0
Anacardiaceae	*Searsia rosmarinifolia*		RSP	LC	1.27	0.18	0.07	0	0.71	0
Apiaceae	*Centella glabrata*		RSP	LC	0	0	0	0.17	0.07	0.11
Apiaceae	*Centella tridentata*		RSP	**EN**	0	0	0	0.03	0	0.04
Apocynaceae	*Microloma sagittatum*		RSE	LC	0.17	0.25	0.03	0.07	0.14	0
Asphodelaceae	*Trachyandra hirsuta*		RSP	LC	0.70	0.07	0	0.33	0.21	0.04
Asteraceae	*Phaenocoma prolifera*	*	RSP	LC	0.57	0	0.10	0.60	0.04	1.79
Asteraceae	*Syncarpha paniculata*		RSP	LC	0.30	0	0	0.47	0.14	0
Asteraceae	*Berkheya herbacea*		RSE	LC	1.07	0.21	0.17	0.17	0.11	0.04
Asteraceae	*Edmondia sesamoides*	*	RSE	LC	0.13	0.04	0.23	0.50	0.07	0.21
Asteraceae	*Gerbera sp.*		RSP		0.03	0.04	0.03	0	0.11	0
Asteraceae	*Senecio pinifolius*		RSE	LC	0.03	0	0	0	0	0
Asteraceae	*Metalasia densa*		RSE	LC	0	0.07	0	4.27	0	0.25
Asteraceae	*Metalasia muricata*	*	RSE	LC	0	0	0	0.23	0.04	0.39
Asteraceae	*Disparago anomala*		RSE	LC	0.03	0.82	0	2.17	0	0.36
Asteraceae	*Mairia coriacea*		RSP	LC	0.00	0	0	0.10	0	0.04
Asteraceae	*Helichrysum teretifolium*		RSE	LC	0.17	0	0	0.07	0	0
Asteraceae	*Senecio hastifolius*		RSP	LC	0.23	0.18	0	0.07	0.25	0
Asteraceae	*Corymbium glabrum*		RSP	LC	0.03	0.07	0	0	0	0
Asteraceae	*Gazania pectinata*		RSE	LC	0.43	0.07	0.23	0.87	0.39	0.04
Asteraceae	*Helichrysum sp.*		RSE		0.20	0.32	0.07	0.20	0.14	0.14
Asteraceae	*Oedera capensis*		RSE	LC	0.03	0.50	0.60	0.30	0.18	0
Asteraceae	*Helichrysum felinum*		RSE	LC	0.07	0	0	0.03	0	0
Asteraceae	*Stoebe cyathuloides*		RSE	LC	0	0.04	0.17	0.07	0	0.46
Asteraceae	*Haplocarpha lanata*		RSP	LC	0.03	0	0	0.03	0	0
Asteraceae	*Senecio umbellatus*		RSE	LC	0	0	0	0.03	0	0
Asteraceae	*Conyza sp.*		RSE	LC	0	0.04	0	0	0	0

Asteraceae	*Syncarpha vesita*	*	RSP	LC	0	0.04	0	0	0	0.61
Asteraceae	*Anaxeton asperum*		RSP	LC	0	0	0	0	0	0.29
Asteraceae	*Osteospermum polygaloides*		RSE	LC	0	0	0	0	0	0.14
Asteraceae	*Syncarpha canescens*		RSP	LC	0	0	0	0	0	0.04
Asteraceae	*Gymnodiscus capillaris*		RSE	LC	0	0	0	0	0	0.04
Asteraceae	*Ursinia paleacea*		RSE	LC	0	0	0	0	0	0.04
Boraginaceae	*Echiostachys incanus*		RSE	**VU**	0.10	0	0	0.03	0.04	0
Bruniaceae	*Brunia laevis*	*	RSP	LC	1.27	0.07	0.97	0	1.86	0.29
Bruniaceae	*Staavia radiata*	*	RSP	LC	0	0.04	1.13	0	0.39	0
Bruniaceae	*Berzelia laniganosa*	*	RSP	LC	0.13	0.61	0	0	0	0
Bruniaceae	*Berzelia abrotanoides*	*	RSP	LC	0	2.11	0	0	0	0
Campanulaceae	*Roella incurva*		RSP	LC	0.03	0	0	0.03	0.04	0
Campanulaceae	*Lobelia tomentosa*		RSE	LC	0	0.04	0	0.23	0	0.04
Campanulaceae	*Merceira leptoloba*		RSP	**NT**	0.03	0.14	0.07	0	0	0.04
Campanulaceae	*Wahlenbergia tenerrima*		RSE	LC	0.07	0	0.07	0	0.25	0
Campanulaceae	*Cyphia volubilis*		RSE	LC	0.03	0.07	0	0	0	0
Campanulaceae	*Lobelia pinifolia*		RSE	LC	0	0	0	0	0.71	0
Convallariaceae	*Eriospermum capense subsp. stoloniferum*		RSP	**VU**	0.03	0	0	0	0	0
Crassulaceae	*Crassula fascicularis*		RSE	LC	0	0	0	0.20	0	0.07
Cyperaceae	*Ficinia sp.*		RSP		1.83	1.93	1.17	0.17	1.64	0.71
Cyperaceae	*Tetraria cuspidata*		RSP	LC	2.10	2.21	0.57	1.27	1.00	0.75
Cyperaceae	*Tetraria bromoides*		RSP	LC	0.17	0.18	0.03	0	0.04	0
Cyperaceae	*Tetraria crinifolia*		RSP	LC	0.40	0.36	0	0.17	0.61	0.11
Cyperaceae	*Ficinia sp.*		RSP		0	0	0	0.10	0	0
Cyperaceae	*Ficinia oligantha*		RSP	LC	0.43	2.00	0.43	1.17	1.11	0.39
Cyperaceae	*Tetraria brachyphylla*		RSP	**NT**	0.13	0.04	0	0	0.18	0
Cyperaceae	*Ficinia bulbosa*		RSP	LC	0	0	0	0.07	0	0
Cyperaceae	*Ficinia indica*		RSP	LC	0	0	0	0.30	0	0
Droseraceae	*Drosera trinervia*		RSE	LC	0.67	0.75	0	0.13	0.25	0
Droseraceae	*Drosera cistiflora*		RSE	LC	0	0.04	0	0	0	0
Ericaceae	*Erica plukenetti subsp penicellata*	*	RSE	LC	5.10	1.79	3.67	1.80	1.54	0
Ericaceae	*Erica bruniades*		RSE	LC	3.60	4.50	3.13	0.13	1.61	8.93

Ericaceae	*Erica imbricata*	*	RSE	LC	4.93	1.86	1.43	4.13	1.57	2.57
Ericaceae	*Erica coriifolia*	*	RSE	LC	2.43	3.36	3.07	0.77	0.64	2.64
Ericaceae	*Erica cerinthoides*		RSP	LC	0.03	0.04	0.07	0	0	0
Ericaceae	*Erica viscaria subsp. longifolia*		RSE	LC	0.07	0.04	0	0.07	0.11	0
Ericaceae	*Erica nudiflora*		RSE	LC	0	0.07	0	0.03	0.04	0
Ericaceae	*Erica klotzschii*		RSE	LC	0.13	0	0	0	0	0
Ericaceae	*Erica muscosa*		RSE	LC	0	0.04	0	0	0	0
Ericaceae	*Erica sessiliflora*	*	RSE	LC	0	0	0	0	0	0.43
Ericaceae	*Erica curviflora*		RSE	LC	0.67	0	0.23	0	0	0
Euphorbiaceae	*Euphorbia tuberosa*		RSE	LC	0.13	0	0	0	0.04	0.04
Euphorbiaceae	*Clutia polygonoides*		RSP	LC	0	0	0	0	0.04	0
Fabaceae	*Aspalathus crassisepala*		RSE	LC	0.20	0.36	0.17	1.03	0.50	0.43
Fabaceae	*Podalyria myrtillifolia*		RSE	LC	0	0	0	0.03	0	0
Fabaceae	*Indigofera hamulosa*		RSE	LC	0	0	0.27	0.50	0	0
Fabaceae	*Indigofera angustifolia var. tenuifolia*		RSE	LC	0.13	0.11	0	0	0	0.04
Fabaceae	*Rhynchosia capensis*		RSP	LC	0.23	0.14	0	0.10	0.71	0
Fabaceae	*Indigofera porrecta*		RSE	LC	0.03	0.11	0.17	0.03	0	0
Fabaceae	*Aspalathus ciliaris*		RSE	LC	0.07	0	0	0	0	0
Fabaceae	*Amphithalea biovulata*		RSP	LC	0	0.07	0	0	0	0
Gentianaceae	*Sebaea micrantha*		RSE	LC	0	0.07	0	0.13	0	0
Gentianaceae	*Sebaeae exacoides*		RSE	LC	0	0	0	0.03	0	0
Geraniaceae	*Pelargonium betulinum*		RSP	LC	0.03	0	0	0	0	0
Haemodoraceae	*Wachendorfia paniculata*		RSP	LC	0.37	0.21	0.60	0.50	0.04	0.04
Haemodoraceae	*Dilatris pillansii*		RSP	LC	0	0	0	0	0	0.07
Hyacinthaceae	*Drimia media*		RSP	LC	0.70	1.29	0.40	0.90	0.93	0.04
Hyacinthaceae	*Lachenalia sp.*		RSP		0	0	0	0.03	0	0
Hyacinthaceae	*Albuca cooperi*		RSP	LC	0	0.04	0	0	0	0
Iridaceae	*Aristea oligocephala*		RSP	LC	0.37	0.29	0.53	0.03	0.18	0.18
Iridaceae	*Lanaria lanata*	*	RSP	LC	2.30	2.82	0.27	0.53	7.36	0
Iridaceae	*Bobartia longicyma*		RSP	**VU**	0.10	0.04	0.07	0.03	0	0.21
Iridaceae	*Aristea sp.*		RSP		0.13	0.07	0	0	0.04	0
Iridaceae	*Gladiolus carneus*		RSP	LC	0.17	0.18	0.37	0	0.21	0.21

Iridaceae	*Watsonia sp.*		RSP		0.07	0.04	0.07	0.07	0.07	0.04
Iridaceae	*Watsonia rogersii*		RSP	**NT**	0.07	0	0	0.03	0	0
Iridaceae	*Geissorhiza parva*		RSE	LC	0.13	0.25	0	0.20	0.18	0
Iridaceae	*Aristea bakeri*		RSP	LC	1.47	1.29	0	0.03	2.68	0
Iridaceae	*Gladiolus sp.*		RSP		0.07	0.18	0.10	0	0.07	0.07
Iridaceae	*Gladiolus bullatus*		RSP	LC	0	0.04	0.03	0	0.04	0
Iridaceae	*Tritoniopsis bicolor*		RSP	**VU**	0.13	0	0	0	0.04	0.04
Iridaceae	*Freesia caryophyllacea*		RSP	**Declining**	0.13	0	0	0	0	0
Iridaceae	*Aristea sp.*		RSP		0.07	0	0.03	0	0	0
Iridaceae	*Aristea sp.*		RSP		0	0.07	0	0	0.14	0
Iridaceae	*Aristea sp.*		RSP		0	0	0	0	0.04	0
Iridaceae	*Romulea sp.*		RSP		0	0	0	0	0.07	0
Iridaceae	*Tritoniopsis burchellii*		RSP	LC	0.13	0	0	0.07	0	0.07
Orchidaceae	*Disperis capensis*		RSP	LC	0	0	0	0.03	0.04	0
Orchidaceae	*Liparis capensis*		RSP	LC	0	0.04	0	0	0	0
Orchidaceae	*Satyrium sp.*		RSP		0	0	0	0	0.04	0
Oxalidaceae	*Oxalis stellata*		RSP	LC	1.73	1.36	1.43	1.33	2.64	0.21
Oxalidaceae	*Oxalis purpurea*		RSP	LC	0.60	0	0	0.10	0	0
Penaeaceae	*Penaea mucronata*		RSP	LC	2.53	3.36	1.13	0	0.68	1.18
Plumbaginaceae	*Limonium scabrum*		RSE	LC	0	0	0	0	0.04	0
Poaceae	*Festuca scabae*		RSP	LC	0	0	0	0.17	0	0
Poaceae	*Themeda triandra*		RSP	LC	0	0	0.10	0	0	0.11
Polygalaceae	*Polygala umbellata*		RSE	LC	0.60	0	0	0	0	0.21
Polygalaceae	*Muraltia stokoei*		RSE	**RARE**	0	0.07	0	0	0.07	0
Proteaceae	*Protea compacta*	*	RSE	**NT**	4.40	8.86	13.13	0.60	4.57	1.00
Proteaceae	*Protea longifolia*	*	RSE	**VU**	3.47	0	0.43	0.07	2.04	0
Proteaceae	*Leucadendron xanthoconus*	*	RSE	LC	4.33	5.21	9.13	10.60	2.43	1.64
Proteaceae	*Aulax umbellata*	*	RSE	**NT**	8.13	0	0.07	2.27	5.79	0.50
Proteaceae	*Serruria elongata*		RSE	**NT**	1.53	0.86	1.07	1.03	1.18	0.96
Proteaceae	*Serruria fasciflora*		RSE	**NT**	1.63	0.79	6.13	0.43	0	0.04
Proteaceae	*Leucadendron platyspermum*	*	RSE	**VU**	0	0	0	9.73	28.07	17.43
Proteaceae	*Leucospermum truncatulum*	*	RSE	**NT**	0	0	0.50	0.40	0.11	0

Proteaceae	*Mimetes cucullatus*	*	RSP	LC	1.27	0.93	0.83	0	0.75	0.32
Proteaceae	*Protea repens*	*	RSE	LC	0.07	0	0	0	0	0
Proteaceae	*Spatalla squamata*		RSE	**NT**	0	0	0.03	0	0	0
Proteaceae	*Spatalla curvifolia*		RSE	**NT**	0	0	0.03	0	0	0
Proteaceae	*Leucospermum cordifolium*	*	RSE	**NT**	0	0	0	0	0.14	0
Restionaceae	*Restio filiformis*		RSP	LC	0.40	1.21	0.87	0.20	1.21	0.50
Restionaceae	*Calopsis hyalina*		RSP	LC	2.80	0.54	2.47	0.43	0.43	4.79
Restionaceae	*Mastersiella digitata*		RSP	LC	2.33	4.07	2.33	0.97	0.79	0.25
Restionaceae	*Elegia stipularis*		RSP	LC	1.43	3.18	1.87	0	1.32	0.21
Restionaceae	*Willdenowia glomerata*		RSP	LC	0.23	0.11	0.23	0.13	0.36	0.18
Restionaceae	*Hypodiscus sp.*		RSP		1.27	0.89	0.10	0	0.61	0.29
Restionaceae	*Staberoha banksii*		RSP	LC	0.30	0.86	1.33	0	0.04	0.68
Restionaceae	*Ischyrolepis capensis*		RSP	LC	0.47	1.75	3.20	0.83	1.43	3.39
Restionaceae	*Elegia filacea*		RSP	LC	0.03	0	0	0.27	0.04	0
Restionaceae	*Hypodiscus sp.*		RSP		0.13	0	0	0.20	0	0
Restionaceae	*Thamnochortus lucens*		RSP	LC	0	0	0	0.67	0.11	0
Restionaceae	*Thamnochortus fraternus*		RSP	**NT**	0.10	0.29	0.87	0.97	0.25	1.18
Restionaceae	*Platychaulos major*		RSP	LC	0.03	0.07	0	0	0	0
Restionaceae	*Hypodiscus willdenowia*		RSP	LC	0.03	0	0	0.07	0	0
Restionaceae	*Willdenowia teres*		RSP	LC	0	0.07	0	0.13	0.04	0
Restionaceae	*Elegia juncea*		RSP	LC	0.53	0	0	0	0	0.07
Restionaceae	*Elegia tectorum*		RSP	LC	0	0	0.10	0.10	0	1.93
Restionaceae	*Hypodiscus sp.*		RSP		0	0	0.17	0	0	0
Restionaceae	*Thamnochortus sporadicus*		RSP	LC	0	0	0.07	0	0	0
Restionaceae	*Hypodiscus aristatus*		RSP	LC	0	0.07	0	0	0	0.54
Restionaceae	*Cannomois parviflora*		RSP	LC	0	0.07	0	0	0	0
Rhamnaceae	*Phylica dodii*		RSP	LC	0.20	0.07	0.27	0.27	0.14	0.93
Rhamnaceae	*Phylica ericoides*	*	RSE	LC	0.93	1.39	1.70	0.70	1.54	0.82
Rhamnaceae	*Phylica disticha*		RSE	LC	0.27	0.14	0	0.43	0.54	0
Rosaceae	*Cliffortia stricta*		RSE	LC	1.30	0.18	3.07	4.17	0.04	1.43
Rosaceae	*Cliffortia filifolia*		RSE	LC	0.10	0.21	0.07	0.03	0.39	0.07
Rosaceae	*Cliffortia falcata*		RSE	LC	0	0	0	0	0	0.07

Rubiaceae	*Anthospermum aethiopicum*	*	RSE	LC	0.07	0	0	0.10	0	0
Rutaceae	*Diosma hirsuta*		RSP	LC	0.03	0.04	0.33	0	0.25	0.04
Rutaceae	*Agathosma bifida*		RSP	LC	0	0.14	0.03	0	0	0
Rutaceae	*Agathosma serpyllacea*		RSE	LC	0	0.07	0	0	0.07	0
Santalaceae	*Osyris speciosa*		RSP	**VU**	0	0.07	0	0	0	0
Schizaeaceae	*Schizaea pectinata*		RSP	LC	0.03	0	0	0	0	0
Scrophulariaceae	*Microdon dubius*		RSE	LC	0.03	0	0	0	0	0.11
Sterculiaceae	*Hermannia rudis*		RSE	LC	0.23	0	0.03	0.07	0	0
Stilbaceae	*Kogelbergia verticillata*		RSE	**RARE**	0.07	0	0	0	0.96	0
Thymelaeaceae	*Gnidia juniperifolia*		RSP	LC	0.43	1.00	0.20	0	0.61	0.54
Thymelaeaceae	*Passerina corymbosa*		RSE	LC	0	0.14	0.40	1.00	0.04	3.68
Thymelaeaceae	*Lachnaea grandiflora*		RSP	**VU**	0	0.04	0.07	0	0	0
Thymelaeaceae	*Gnidia anomala*		RSE	LC	0	0	0.17	0	0	0.82
Thymelaeaceae	*Struthiola striata*		RSP	LC	0	0.04	0	0	0	0
Thymelaeaceae	*Struthiola ciliata*		RSP	LC	0	0	0	0	0.11	0
Unidentified	Unidentified		RSE		0.17	0	0	0	0.07	0
Unidentified	Unidentified		RSE		0.33	0.21	0	0.43	0.07	0
Unidentified	Unidentified		RSE		0.03	0	0	0	0.11	0
Unidentified	Unidentified		RSE		0	0	0.03	0	0	0

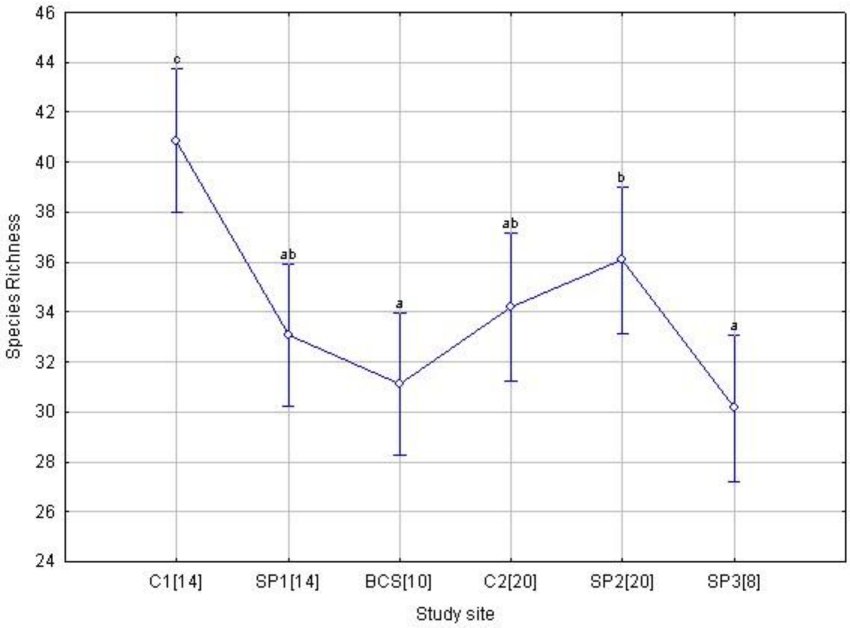
Abbreviations: **RSE = Reseeder**
RSP = Resprouter

(Raimondo et al., 2009) **LC = Least Concern**
VU = Vulnerable
NT = Near Threatened

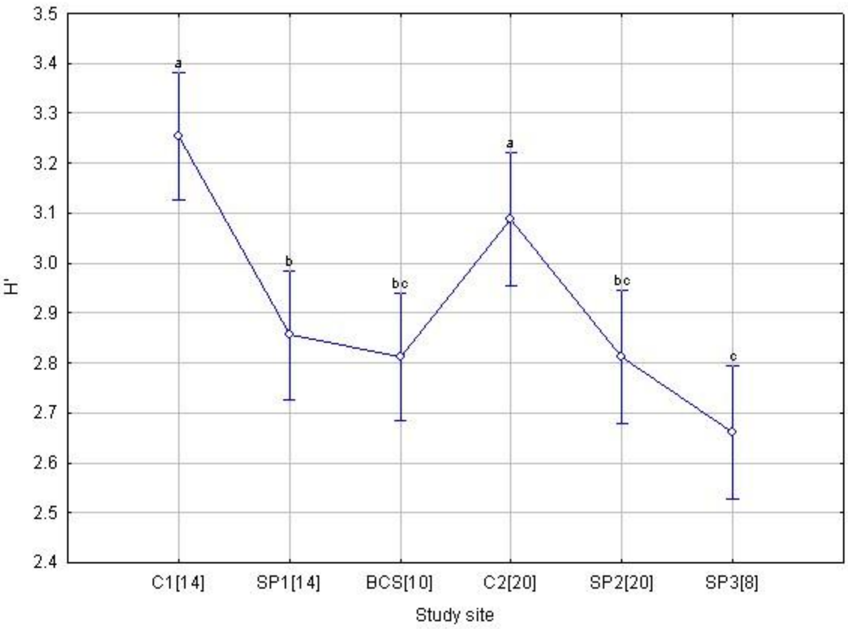
Site abbreviations – see Chapter 3

APPENDIX 5:

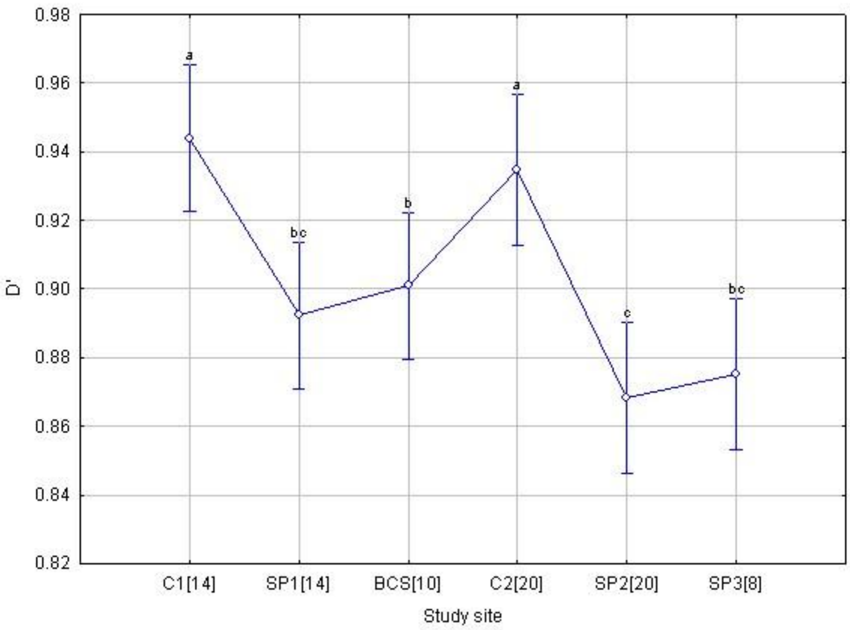
Additional results: Graphs showing significant differences in species richness, diversity (Shannon: H’, Simpson: D’) and evenness (Pielou: J’) (see Chapter 3)



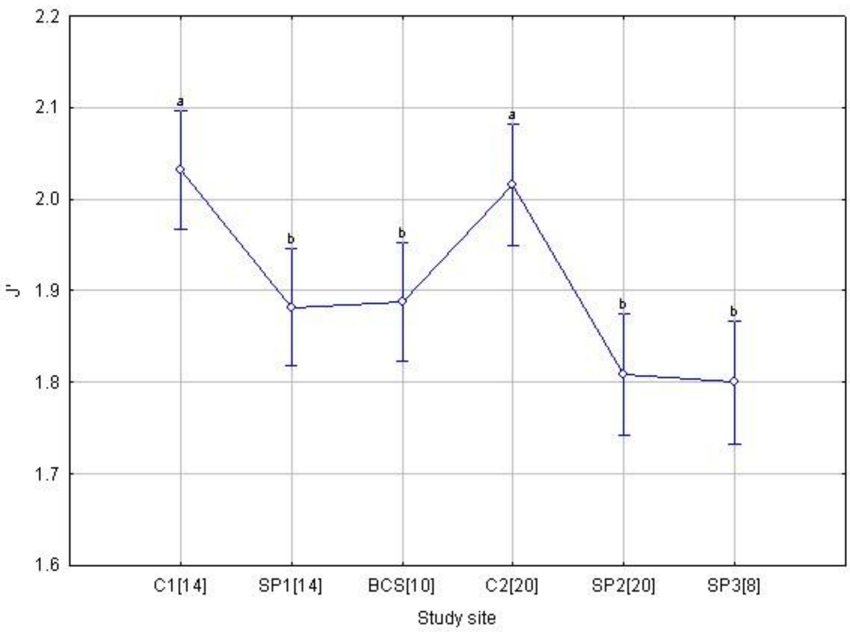
Statistical comparison of mean species richness for the control (C1[14], C2[20]), shallow ploughed and augmented with *L. platyspermum* (SP1[14], SP2[20], SP3[8]) and augmented with *P. compacta* (BCS[10]) sites. Individual sites vary in post-fire age indicated in brackets. Letters in superscript show where significant differences exist between treatments (ANOVA with *post-hoc* Fischer's LSD test; P < 0.01). Vertical bars denote 0.95 confidence intervals.



Statistical comparison of Shannon diversity (H') for the control (C1[14], C2[20]), shallow ploughed and augmented with *L. platyspermum* (SP1[14], SP2[20], SP3[8]) and augmented with *P. compacta* (BCS[10]) sites. Individual sites vary in post-fire age indicated in brackets. Letters in superscript show where significant differences exist between treatments (ANOVA with *post-hoc* Fischer's LSD test; P < 0.01). Vertical bars denote 0.95 confidence intervals.



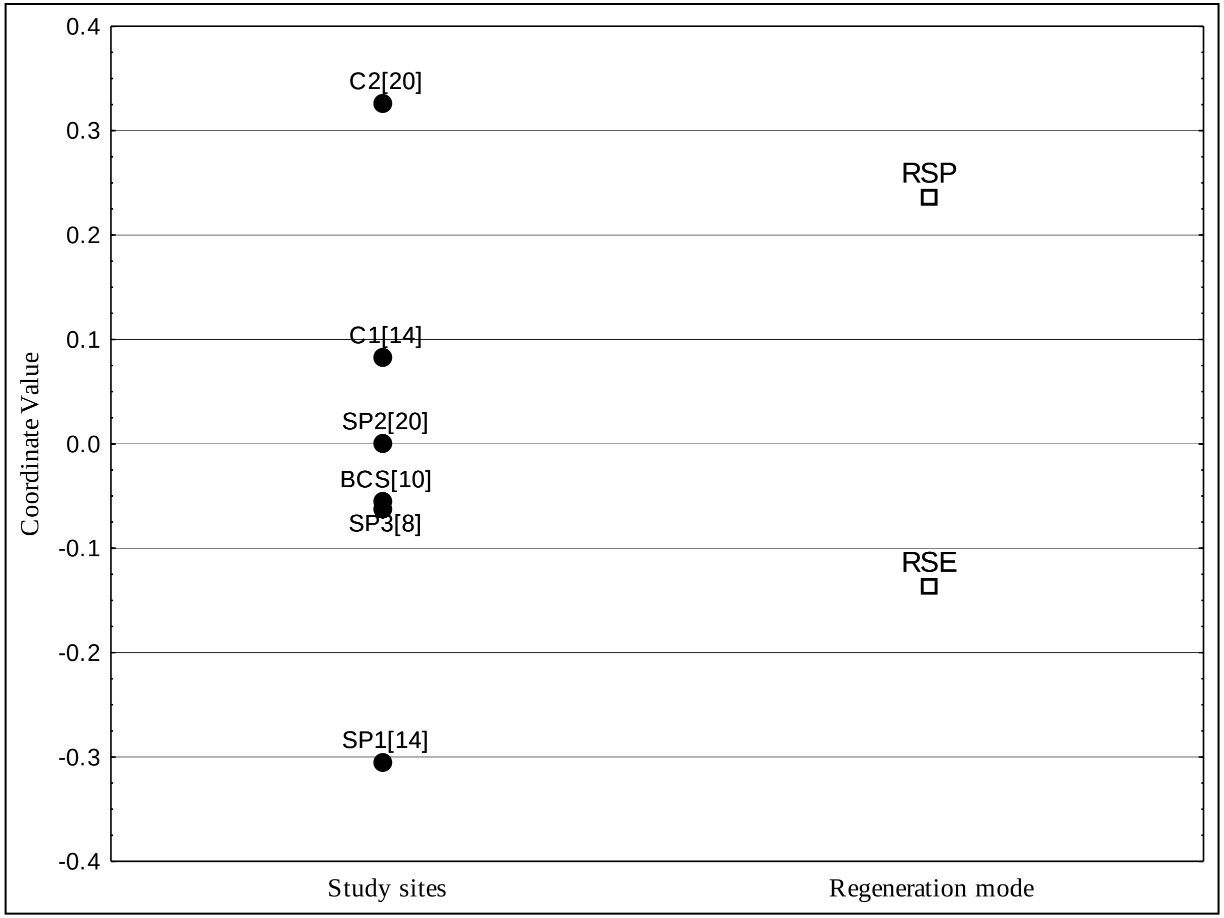
Statistical comparison of Simpson diversity (D') for the control (C1[14], C2[20]), shallow ploughed and augmented with *L. platyspermum* (SP1[14], SP2[20], SP3[8]) and augmented with *P. compacta* (BCS[10]) sites. Individual sites vary in post-fire age indicated in brackets. Letters in superscript show where significant differences exist between treatments (ANOVA with *post-hoc* Fischer's LSD test; $P < 0.01$). Vertical bars denote 0.95 confidence intervals.



Statistical comparison of Pielou's evenness (J') for the control (C1[14], C2[20]), shallow ploughed and augmented with *L. platyspermum* (SP1[14], SP2[20], SP3[8]) and augmented with *P. compacta* (BCS[10]) sites. Individual sites vary in post-fire age indicated in brackets. Letters in superscript show where significant differences exist between treatments (ANOVA with *post-hoc* Fischer's LSD test; $P < 0.01$). Vertical bars denote 0.95 confidence intervals.

APPENDIX 6:

Additional results: Correspondence analysis (CA) showing the relationship between study sites and the cover of different regeneration modes (reseeders and resprouters) (see Chapter 3)



Correspondence analysis (CA)[34] showing the relationship between study sites and the cover of different regeneration modes (reseeders and resprouters). Study sites include; control sites (C1[14], C2[20]), broadcast sown site (BCS[10]) and shallow ploughed sites (SP1[14], SP2[20], SP3[8]). Study sites vary in post-fire age indicated in brackets [ ]. Regeneration modes are abbreviated by RSE (reseeders) and RSP (resprouters).

[34] Eigenvalue: .03237 (100.00% of Inertia)

APPENDIX 7:

Additional results: Summed cover (across all study sites) for 31 dominant species (dominant species was defined as having >50% cover across all study sites)

Species	Family	% cover (summed: all study sites)
Leucadendron platyspermum	Proteaceae	783
Leucadendron xanthoconus	Proteaceae	491
Protea compacta	Proteaceae	474
Erica bruniades	Ericaceae	313.5
Aulax umbellata	Proteaceae	245
Erica imbricata	Ericaceae	241.5
Erica plukenetti	Ericaceae	205
Lanaria lanata	Iridaceae	189
Erica coriifolia	Ericaceae	187
Calopsis hyalina	Restionaceae	166
Ischyrolepis capensis	Restionaceae	159.5
Mastersiella digitata	Restionaceae	156
Cliffortia stricta	Rosaceae	151
Serruria fasciflora	Proteaceae	134.5
Penaea mucronata	Penaeaceae	128
Oxalis stellata	Oxalidaceae	126.5
Elegia stipularis	Restionaceae	115.5
Tetraria cuspidata	Restionaceae	114.5
Ficinia ***sp.***	Cyperaceae	107.5
Phylica ericoides	Rhamnaceae	102.5
Serruria elongata	Proteaceae	96.5
Protea longifolia	Proteaceae	88
Ficinia oligantha	Cyperaceae	79.5
Aristea bakeri	Iridaceae	78
Passerina corymbosa	Thymelaeaceae	75
Metalasia densa	Asteraceae	68.5
Brunia laevis	Bruniaceae	64.5
Restio filiformis	Restionaceae	63
Drimia media	Hyacinthaceae	61.5
Mimetes cucullatus	Proteaceae	59.5
Thamnochortus fraternus	Restionaceae	53

APPENDIX 8:

Additional results: Column totals for the correspondence analysis (variable: plant family) (see Figure 4.1)

Family	C1(14)	C2(20)	BCS(10)	SP1(14)	SP2(20)	SP3(8)	TOTAL
Aizoaceae	0.0000	5.0000	75.0000	10.0000	0.0000	10.0000	100
Alliaceae	0.0000	0.0000	0.0000	25.0000	75.0000	0.0000	100
Amaryllidaceae	30.0000	6.6667	23.3333	23.3333	16.6667	0.0000	100
Anacardiaceae	58.4615	0.0000	3.0769	7.6923	30.7692	0.0000	100
Apiaceae	0.0000	50.0000	0.0000	0.0000	16.6667	33.3333	100
Apocynaceae	26.3158	10.5263	5.2632	36.8421	21.0526	0.0000	100
Asphodelaceae	52.5000	25.0000	0.0000	5.0000	15.0000	2.5000	100
Asteraceae	14.4492	43.6338	6.8670	9.7282	5.8655	19.4564	100
Boraginaceae	60.0000	20.0000	0.0000	0.0000	20.0000	0.0000	100
Bruniaceae	16.4706	0.0000	24.7059	30.9804	24.7059	3.1373	100
Campanulaceae	9.2593	14.8148	7.4074	12.9630	51.8519	3.7037	100
Convallariaceae	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100
Crassulaceae	0.0000	75.0000	0.0000	0.0000	0.0000	25.0000	100
Cyperaceae	22.1574	14.1399	9.6210	27.4052	18.6589	8.0175	100
Droseraceae	37.7358	7.5472	0.0000	41.5094	13.2075	0.0000	100
Ericaceae	26.0491	10.6448	17.8096	16.7349	7.8813	20.8802	100
Euphorbiaceae	57.1429	0.0000	0.0000	0.0000	28.5714	14.2857	100
Fabaceae	12.6582	32.2785	11.3924	13.9241	21.5190	8.2278	100
Gentianiaceae	0.0000	71.4286	0.0000	28.5714	0.0000	0.0000	100
Geraniaceae	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100
Haemodoraceae	20.3704	27.7778	33.3333	11.1111	1.8519	5.5556	100
Hyacinthaceae	16.8000	22.4000	9.6000	29.6000	20.8000	0.8000	100
Iridaceae	22.3776	4.1958	6.1538	20.5594	43.4965	3.2168	100
Orchidaceae	0.0000	25.0000	0.0000	25.0000	50.0000	0.0000	100
Oxalidaceae	25.5474	15.6934	15.6934	13.8686	27.0073	2.1898	100
Penaeaceae	29.6875	0.0000	13.2813	36.7188	7.4219	12.8906	100
Plumbaginaceae	0.0000	0.0000	0.0000	0.0000	100.0000	0.0000	100
Poaceae	0.0000	45.4545	27.2727	0.0000	0.0000	27.2727	100
Polygalaceae	64.2857	0.0000	0.0000	7.1429	7.1429	21.4286	100
Proteaceae	15.5825	15.7708	19.6821	9.7469	26.3962	12.8216	100
Restionaceae	16.7774	8.2503	22.5914	20.4319	10.2436	21.7054	100
Rhamnaceae	14.0468	14.0468	19.7324	15.0502	20.7358	16.3880	100
Rosaceae	12.7660	38.2979	28.5714	3.3435	3.6474	13.3739	100
Rubiaceae	40.0000	60.0000	0.0000	0.0000	0.0000	0.0000	100
Rutaceae	3.4483	0.0000	37.9310	24.1379	31.0345	3.4483	100
Santalaceae	0.0000	0.0000	0.0000	100.0000	0.0000	0.0000	100
Schizaeaceae	100.0000	0.0000	0.0000	0.0000	0.0000	0.0000	100
Scrophulariaceae	25.0000	0.0000	0.0000	0.0000	0.0000	75.0000	100
Sterculiaceae	70.0000	20.0000	10.0000	0.0000	0.0000	0.0000	100
Stilbaceae	6.8966	0.0000	0.0000	0.0000	93.1034	0.0000	100
Thymelaeaceae	4.9242	11.3636	9.4697	12.8788	7.9545	53.4091	100

APPENDIX 9:

Additional results: mean cover of plant families across all study sites

	Family	# of species	*Natural*		*Treatments*			
			C1[14]	C2[20]	BCS[10]	SP1[14]	SP2[20]	SP3[8]
1	Aizoaceae	1	0	0.07	0.50	0.03	0	0.07
2	Alliaceae	1	0	0.04	0	0	0.11	0
3	Amaryllidaceae	2	0.30	0.36	0.73	0.10	0.29	0.07
4	Anacardiaceae	1	1.27	0.18	0.07	0	0.71	0
5	Apiaceae	2	0	0	0	0.20	0.07	0.14
6	Apocynaceae	1	0.17	0.25	0.03	0.07	0.14	0
7	Asphodelaceae	1	0.70	0.07	0	0.33	0.21	0.04
8	Asteraceae	27	3.37	2.43	1.60	10.17	1.46	4.86
9	Boraginaceae	1	0.10	0	0	0.03	0.04	0
10	Bruniaceae	4	1.40	2.82	2.10	0	2.25	0.29
11	Campanulaceae	6	0.17	0.25	0.13	0.27	1.00	0.07
12	Convallariaceae	1	0.03	0	0	0	0	0
13	Crassulaceae	1	0	0	0	0.20	0	0.07
14	Cyperaceae	9	5.07	6.71	2.20	3.23	4.57	1.96
15	Droseraceae	2	0.67	0.79	0	0.13	0.25	0
16	Ericaceae	11	16.97	11.68	11.60	6.93	5.50	14.57
17	Euphorbiaceae	2	0.13	0	0	0	0.07	0.04
18	Fabaceae	8	0.67	0.79	0.60	1.70	1.21	0.46
19	Gentianaceae	2	0	0.07	0	0.17	0	0
20	Geraniaceae	1	0.03	0	0	0	0	0
21	Haemodoraceae	2	0.37	0.21	0.60	0.50	0.04	0.11
22	Hyacinthaceae	3	0.70	1.32	0.40	0.93	0.93	0.04
23	Iridaceae	18	5.33	5.25	1.47	1.00	11.11	0.82
24	Orchidaceae	3	0	0.04	0	0.03	0.04	0
25	Oxalidaceae	2	2.33	1.36	1.43	1.43	2.64	0.21
26	Penaeaceae	1	2.53	3.36	1.13	0	0.68	1.18
27	Plumbaginaceae	1	0	0	0	0	0.04	0
28	Poaceae	2	0	0	0.10	0.17	0	0.11
29	Polygalaceae	2	0.60	0.07	0	0	0.07	0.21
30	Proteaceae	13	24.83	16.64	31.37	25.13	45.07	21.89
31	Restionaceae	21	10.10	13.18	13.60	4.97	6.61	14.00
32	Rhamnaceae	3	1.40	1.61	1.97	1.40	2.21	1.75
33	Rosaceae	3	1.40	0.39	3.13	4.20	0.43	1.57
34	Rubiaceae	1	0.07	0	0	0.10	0	0
35	Rutaceae	3	0.03	0.25	0.37	0	0.32	0.04
36	Santalaceae	1	0	0.07	0	0	0	0
37	Schizaeaceae	1	0.03	0	0	0	0	0
38	Scrophulariaceae	1	0.03	0	0	0	0	0.11
39	Sterculiaceae	1	0.23	0	0.03	0.07	0	0
40	Stilbaceae	1	0.07	0	0	0	0.96	0
41	Thymelaeaceae	6	0.43	1.21	0.83	1.00	0.75	5.04

APPENDIX 10:

Additional results: Column totals for the correspondence analysis (variable: dominant species) (see Figure 4.2)

Species	C1[14]	C2[20]	BCS[10]	SP1[14]	SP2[20]	SP3[8]	TOTAL
Protea compacta	13.9241	26.1603	41.5612	1.8987	13.5021	2.9536	100
Protea longifolia	59.0909	0.0000	7.3864	1.1364	32.3864	0.0000	100
Leucadendron xanthoconus	13.2383	14.8676	27.9022	32.3829	6.9246	4.6843	100
Aulax umbellata	49.7959	0.0000	0.4082	13.8776	33.0612	2.8571	100
Brunia laevis	29.4574	1.5504	22.4806	0.0000	40.3101	6.2016	100
Erica plukenetti	37.3171	12.1951	26.8293	13.1707	10.4878	0.0000	100
Serruria elongata	23.8342	12.4352	16.5803	16.0622	17.0984	13.9896	100
Erica bruniades	17.2249	20.0957	14.9920	0.6380	7.1770	39.8724	100
Erica imbricata	30.6418	10.7660	8.9027	25.6729	9.1097	14.9068	100
Erica coriifolia	19.5187	25.1337	24.5989	6.1497	4.8128	19.7861	100
Phylica ericoides	13.6585	19.0244	24.8780	10.2439	20.9756	11.2195	100
Cliffortia stricta	12.9139	1.6556	30.4636	41.3907	0.3311	13.2450	100
Serruria fasciflora	18.2156	8.1784	68.4015	4.8327	0.0000	0.3717	100
Lanaria lanata	18.2540	20.8995	2.1164	4.2328	54.4974	0.0000	100
Ficinia ***sp.***	25.5814	25.1163	16.2791	2.3256	21.3953	9.3023	100
Tetraria cuspidata	27.5109	27.0742	7.4236	16.5939	12.2271	9.1703	100
Oxalis stellata	20.5534	15.0198	16.9960	15.8103	29.2490	2.3715	100
Restio filiformis	9.5238	26.9841	20.6349	4.7619	26.9841	11.1111	100
Calopsis hyalina	25.3012	4.5181	22.2892	3.9157	3.6145	40.3614	100
Mastersiella digitata	22.4359	36.5385	22.4359	9.2949	7.0513	2.2436	100
Elegia stipularis	18.6147	38.5281	24.2424	0.0000	16.0173	2.5974	100
Penaea mucronata	29.6875	36.7188	13.2813	0.0000	7.4219	12.8906	100
Ischyrolepis capensis	4.3887	15.3605	30.0940	7.8370	12.5392	29.7806	100
Leucadendron platyspermum	0.0000	0.0000	0.0000	18.6462	50.1916	31.1622	100
Metalasia densa	0.0000	1.4599	0.0000	93.4307	0.0000	5.1095	100
Passerina corymbosa	0.0000	2.6667	8.0000	20.0000	0.6667	68.6667	100
Drimia media	17.0732	29.2683	9.7561	21.9512	21.1382	0.8130	100
Ficinia oligantha	8.1761	35.2201	8.1761	22.0126	19.4969	6.9182	100
Thamnochortus fraternus	2.8302	7.5472	24.5283	27.3585	6.6038	31.1321	100
Mimetes cucullatus	31.9328	21.8487	21.0084	0.0000	17.6471	7.5630	100
Aristea bakeri	28.2051	23.0769	0.0000	0.6410	48.0769	0.0000	100

APPENDIX 11:

Additional results: mean cover of all dominant species (by 50% cover; included in Figure 4.2) across all study sites

Mean cover of 31 dominant species occurring in study sites; control (C1[14] and C2[20]), broadcast sown with *P. compacta* (BCS[10]) and shallow ploughed and broadcast sown with *L. platyspermum* (SP1[14], SP2[20], SP3[8]). Study sites vary in post-fire age indicated in brackets.

		Natural		*Treatments*			
Species	Family	C1[14]	C2[20]	BCS[10]	SP1[14]	SP2[20]	SP3[8]
*Metalasia densa**	Asteraceae	0	0.1	0	4.3	0	0.3
*Brunia laevis**	Bruniaceae	1.3	0.1	1.0	0	1.9	0.3
Ficinia sp.	Cyperaceae	1.8	1.9	1.2	0.2	1.6	0.7
Tetraria cuspidata		2.1	2.2	0.6	1.3	1.0	0.8
Ficinia oligantha		0.4	2.0	0.4	1.2	1.1	0.4
Erica plukenetti	Ericaceae	5.1	1.8	3.7	1.8	1.5	0
Erica bruniades		3.6	4.5	3.1	0.1	1.6	8.9
*Erica imbricata**		4.9	1.9	1.4	4.1	1.6	2.6
*Erica coriifolia**		2.4	3.4	3.1	0.8	0.6	2.6
Drimia media	Hyacinthaceae	0.7	1.3	0.4	0.9	0.9	0
Lanaria lanata	Iridaceae	2.3	2.8	0.3	0.5	7.4	0
Aristea bakeri		1.5	1.3	0	0	2.7	0
Oxalis stellata	Oxalidaceae	1.7	1.4	1.4	1.3	2.6	0.2
Penaea mucronata	Peneaceae	2.5	3.4	1.1	0	0.7	1.2
*Protea compacta**	Proteaceae	4.4	8.9	13.1	0.6	4.6	1.0
Protea longifolia		3.5	0	0.4	0.1	2.0	0
*Leucadendron xanthoconus**		4.3	5.2	9.1	10.6	2.4	1.6
Aulax umbellata		8.1	0	0.1	2.3	5.8	0.5
Serruria elongata		1.5	0.9	1.1	1.0	1.2	1.0
Serruria fasciflora		1.6	0.8	6.1	0.4	0	0
*Leucadendron platyspermum**		0	0	0	9.7	28.1	17.4
Mimetes cucullatus		1.3	0.9	0.8	0	0.8	0.3
Restio filiformis	Restionaceae	0.4	1.2	0.9	0.2	1.2	0.5
Calopsis hyalina		2.8	0.5	2.5	0.4	0.4	4.8
Mastersiella digitata		2.3	4.1	2.3	1.0	0.8	0.3
Elegia stipularis		1.4	3.2	1.9	0	1.3	0.2
Ischyrolepis capensis		0.5	1.8	3.2	0.8	1.4	3.4
Thamnochortus fraternus		0.1	0.3	0.9	1.0	0.3	1.2
*Phylica ericoides**	Rhamnaceae	0.9	1.4	1.7	0.7	1.5	0.8
Cliffortia stricta	Rosaceae	1.3	0.2	3.1	4.2	0	1.4
Passerina corymbosa	Thymelaeaceae	0	0.1	0.4	1.0	0	3.7

* Indicates a species used commercially by wildflower industry (Conradie, 2009)