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Aspects of the sustainability of the wild honeybush industry

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Declaration

I declare that this thesis is an original piece of work of which I am the sole author. No part of the work has been previously submitted for a degree at this or any other tertiary institution. The research was conducted with ethical approval from Rhodes University, SC2017/2018.

G.K. McGregor.

Date: 25 June 2024

Preface

The research presented in this thesis investigates the use of the wild honeybush resource. This preface gives some context and background to the research.

Parts of this research (Chapters Three and Four) based on work done for EADP696, commissioned by the Western Cape, Dept. of Environmental and Development Planning (DEADP), were presented in reports by McGregor 2017, five of which are in the public domain, available at: https://resources.gouritz.com/category/scientific-reports/. The original data from the Louterwater workshop, are used in Chapter Three, although the analysis and interpretation are new. The data on the harvest history of one harvest enterprise is presented in Chapter Four, with a completely new representation and analysis. A subsequent project commissioned by DEADP, (EADP817) brought together findings from the Louterwater workshop, some of the field surveys and the enterprise harvest history data (all of which are presented in this thesis) were used to produce the *Wild honeybush harvesting field guide*, available at: https://resources.gouritz.com/category/scientific-reports/. These reports are referred to frequently in the text in order to avoid any plagiarism issues.

The mapping methods and data, as well as field data collection approaches for this research, were used to develop resource assessments for *Cyclopia intermedia* and *C. subternata*, as part of DFFE project (T060). The reports are currently under review and will be available in the public domain in late 2024. The data presented in Chapter Five of this thesis (surveys of a cultivated population of *C. intermedia* and surveys of a population subjected to unregulated harvesting) are presented in the *C. intermedia* resource assessment as case studies (acknowledged as McGregor, 2024).

Various parts of this research were presented at quarterly meetings of the Honeybush Community of Practice (2019–2024), and the South African Honeybush Tea Association AGM (2016–2023) over the past eight years. The material was not published in the public domain but was available as slideshows with notes to members of those groups and shared on request.

Except for two reports, all of the work described above was single-authored by the researcher. For the T060 resource assessment, the researcher was the principal investigator and author of the reports, with support from other team members.

Layout of the thesis

In terms of the presentation of the thesis, each chapter is presented as a standalone piece, with a table of contents, introduction, motivation, aim, objectives, methods, results, analysis, discussion and summary. Each chapter ends with a reference list. All appendices are combined and located at the end of the thesis.

Abstract

Honeybush products are uniquely South African, derived from plants of the fynbos genus, *Cyclopia*. *Cyclopia intermedia* is the most widespread species, distributed across 11 496 km^2 of the Cape Fold Mountains, and provided the bulk of supply for the industry until 2022. While the industry is small, it is a locally significant industry affecting the livelihoods of harvesters, farmers and processors in the greater Langkloof region of the Eastern and Western Cape provinces of South Africa. The industry has evolved from a cottage one, to a commercial scale, and concerns have been raised over the sustainability of the wild resource specifically, and the industry in general.

The research aimed to improve our understanding of aspects of the sustainability of the wild honeybush industry. A mixed methods design was adopted, which allowed for the inclusion of data collection approaches and analysis which tell a richer story than one with a singular modus. Four objectives were identified, which entailed: (i) mapping the resource to establish the distribution range of *C. intermedia;* (ii) recording of local ecological knowledge (LEK) and traditional ecological knowledge (TEK) around best practice harvesting; (iii) assessing the sustainability of harvest enterprise types through analysis of yield history and harvester loads; (iv) identifying differences between harvested and unharvested *C. intermedia* populations.

Mapping of the resource drew on a variety of existing data sources, field mapping, GIS-based analysis, species distribution modelling and expert mapping to create a comprehensive and accurate map of the species distribution. The species is estimated to occupy a distribution range of 11 496 km^2, 49% of which occurs in formally protected areas. Based on local scale mapping by experts, 100km^2 is estimated to be in use for wild harvesting in the production area of the Langkloof.

Information on best practice harvesting was collected through in-depth interviews with harvesters, harvest managers, processors and farmers (in the field at harvest events) and through questionnaire surveys and focus group discussions at a honeybush stakeholder workshop. In combination with harvest event surveys at which harvester practice was observed and recorded, and surveys were conducted of the harvest yield and of plants in the harvested population, the information was used to produce the first formal account of best practice for sustainable harvesting of wild honeybush.

To assess the sustainability of harvest enterprises and associated harvester livelihoods, harvester managers were interviewed to create profiles of typical harvesting enterprises based on their practices and harvest yield histories. Of the three harvest enterprises considered, two showed sustained yields over time, while those of a large contract type enterprise were less sustainable with declining yields on three out of six farms. From a statistical analysis of the records it was found that the most effective team size was 10 or less harvesters in terms of livelihood sustainability. They could earn a fair livelihood (ZAR67 680.00) per annum, based on a 94 kg load per daily harvest event, sold to the processor at ZAR 5.00, for nine months of the year,

working a four-day week. For a team to operate sustainably, it was found that it should consist of experienced harvesters harvesting conservatively, at intervals of at least four years, and be responsive to local environmental conditions.

Detailed field surveys of *C. intermedia* plants at 38 sites representing harvested and unharvested populations were carried out to understand the impact of harvesting on the plants. A statistical analysis of the plant's dimensions related to the physical environment, fire and harvest history using generalised linear models revealed that while unharvested plants were slightly larger, only crown diameter and stem counts were significantly so. Seedlings were noticeably scarce at all sites, including recently burnt sites. A significant finding of the research was that in a fecundity survey, unharvested plants produced significantly more pods. The impact of this is unknown, but it has implications for management and the sustainable use of wild resources in the long term. Further understanding of the impact of harvesting came from surveys of cultivated stands of *C. intermedia* (different ages and harvest histories, but all harvested at three-year intervals) and surveys of a wild population, which was subjected to unregulated harvesting. For the cultivated stand: after 12 years, plants declined in all measured dimensions, while in the wild population, 45% of the plants died over a seven-year period. The surveys proved that a three-year interval or frequent, unregulated harvest is unsustainable.

The research was used to produce the wild harvesting guidelines, which have become the accepted standard for the industry. It has demonstrated that under the right circumstances, harvesting of the wild *C. intermedia* resource is broadly sustainable. However, there needs to be informed management of the use of the resource in terms of harvest team types and their protocols, particularly with regard to harvest intervals and possible interventions to improve seed production to achieve sustainable use of the resource in social, economic and ecological terms.

Acknowledgements

The topic of this thesis was conceived over dinner with fynbos experts Richard and Shirley Cowling. The discussion set me off on a honeybush research track, which opened an unexplored world of fynbos mountain landscapes and honeybush people. Over the years, the Cowlings have educated me in discussions around the subtleties of fynbos ecology, listened patiently to my endless stories about the intrigue of the industry and accounts of field trips and adventures in the mountains and helped shape my sometimes garbled but enthusiastic reports into workable ideas. I could not have asked for better friends and mentors.

I am indebted to the farmers and harvesters of the Langkloof and beyond: the custodians of the resource, and holders of honeybush knowledge. Their hospitality, good company and willingness to talk and share their knowledge of the place and the plant was generous. In particular, I pay tribute to the Nortjes of Melmont, whose honeybush enterprise represents a truly remarkable farm model that is sustainable in every way. From the late Quinton Nortje, I learnt more about wild honeybush farming, on-the-ground conservation and good farming practice and labour relations than from any other source.

I thank my student assistants who supported this and other honeybush-related research. In particular, master's students Wouter van der Walt, Matt Sephton and Roxy Starkey (in the early parts of this research project). In the latter part of this study: Tafadzwa Makhuza, Iris Vos, Thomas Vos, Camilla James and Tracey Pearson, joined me on adventures in the mountains of the Kouga, Baviaanskloof and Tsitsikamma. With their enthusiasm, inquisitiveness, willingness to adventure and all-round good company, they kept me in touch with the world they live in, and gave me hope for the future of this country.

To members of staff in the Geography Department – administratively and academically who supported the needs of my research I am grateful. Prof. Ian Meiklejohn provided encouragement, support and advice and many cups of coffee. Prof. Fred Ellery as my supervisor, helped shape this work into a thesis. I acknowledge the annual financial contribution made towards this research by the Rhodes University Research Committee.

Members of SAHTA received research reports enthusiastically and willingly invited me to visit their enterprises. In particular, I acknowledge the support of Mr Eugene Smith – who was chairperson of the organisation for the duration of this research.

I received excellent support from officials in government departments, in particular: Mr Albert Ackhurst of the Western Cape Department of Environmental Affairs and Development Planning, who has championed the honeybush cause and mainstreamed it into provincial policy; Mr Sam van der Merwe – retired agricultural extension officer, and Mr Gerrie Ferreira of the Eastern Cape Department of Environmental Affairs and Tourism who frequently gave input to the work, and used the products thereof. As a botanist and expert in conservation and sustainable use of natural resources in the biodiversity economy, Prof. Neil Crouch (South

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To my mother and father, Lianne and Lloyd McGregor: for all that I am, I thank them. Neither of them will see me graduate, but in the last year of her life, my seventy-four-year-old mother accompanied me on foot, on field trips deep into the mountains to count honeybushes, and partly sponsored the publication of the first printing of the *Wild honeybush harvesting field guide*. I am lucky to have a loving family at home on our farm, Craig Doone, some of whom accompanied me on field trips, and others who just kept the home fires burning.

And lastly, to Keith James who explored new mountain places with me, in search of honeybush. He knew how to make tea on the mountain (just in time…), built cairns on remote mountain slopes so that I could follow the route back to the sites, slept out with me in high places amongst the honeybushes and filled in haikus on my data sheets, but still managed to record the numbers (correctly)…. I am fortunate to have you in my life and I am deeply grateful for your love, humour, perspective and *joie de vivre.*

Erkenning

Die onderwerp van hierdie tesis het die eerste keer die lig gesien en is bedink tydens ’n aandete saam met fynbos kenners Richard en Shirley Cowling. Die gesprek was die begin van my navorsingspad met heuningbos en het die onontginde wêreld van Fynbos berglandskappe en die mense van heuningbos vir my oopgemaak... Oor die jare het die Cowlings my deur menigte gesprekke meer geleer oor die fynere punte van fynbos ekologie en geduldig geluister na my eindelose stories oor die intrige van die bedryf en verhale van velduitstappies en avonture in die berge en het gehelp om my soms onsamehangende maar entoesiastiese verslae in werkbare idees te omvorm. Ek kon nie vir beter vriende en mentors gevra het nie.

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Acronyms and abbreviations

AOO	Area of occupancy
ABS	Access and Benefit-sharing
AFI	Alternative food initiative
ARC	Agricultural Research Council
BABS	Bioprospecting, Access and Benefit Sharing
CBD	Convention on Biological Diversity
DALRRD	Department of Agriculture, Land Reform and Rural Development (Eastern Cape)
DEA	Department of Environmental Affairs (up until 2019)
DEADP	Department of Environmental Affairs and Planning (WC)
DEDEAT	Eastern Cape Department of Economic Development, Environmental Affairs and Tourism
DFFE	Department of Forestry, Fisheries and the Environment (since 2019)
DIFID	Department for International Development
DoA	Western Cape Department of Agriculture
The dti	Department of Trade, Industry and Competition
EC	Eastern Cape
EOO	Extent of occurrence
GIS	Geographic Information System
HCOP	Honeybush Community of Practice
IAP	Invasive alien plants
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPLC	Indigenous People and Local Communities
IUCN	International Union for Conservation of Nature
LED	Local Economic Development
LEK	Local Ecological Knowledge
MAP	Medicinal and Aromatic Plant
MODIS	Moderate Resolution Imaging Spectro-radiometer
NASA	National Aeronautics and Space Administration (United States federal government)
NDF	Non-detriment Finding
NEMA	National Environmental Management Act
NEMBA	National Environmental Management Biodiversity Act
NIKSO	National Indigenous Knowledge Systems Office (South Africa)
NRM	Natural Resource Management
NTFP	Non-timber Forest Product
PRA	Participatory Rural Appraisal
RCP	Representative Concentration Pathway
SA	South Africa
SAHTA	South African Honeybush Tea Association
SANBI	South African National Biodiversity Institute
SAPAD	South African Protected Areas Database
SDG	Sustainable Development Goal
SLA	Sustainable Livelihoods Approach
SSP	Shared Socioeconomic Pathway
TEK	Traditional Ecological Knowledge
TK	Traditional Knowledge
TM	Traditional medicine
TOPS	Threatened or Protected Species
TRAFFIC	Trade Records Analysis of Flora and Fauna in Commerce
UNCTAD	United Nations Conference on Trade and Development
WC	Western Cape
WCC	World Conservation Congress
WTO	World Trade Organization

Table of contents

Chapter 1 The wild honeybush industry

Contents

List of figures

List of tables

1.1 Introduction

1.1.1 Honeybush: a gift from the veld

The trademarked name 'Honeybush' is a 'proudly South African' product, and the common name given to 23 members of the fynbos genus *Cyclopia* from which honeybush tea and other products are made. The annual harvest of about 800 tonnes of wet material produces around 320 tonnes of honeybush tea (McGregor, 2023), a naturally sweet, honey-flavoured beverage consumed hot or cold. In 2022-2023 – for the first time in the history of the industry – the bulk of production (53%) came from cultivated stands of *Cyclopia subternata, Cyclopia longifolia* and *Cyclopia genistoides*. The remaining 47% of the annual harvest came from wild harvested populations of *Cyclopia intermedia, Cyclopia subternata, Cyclopia sessiliflora, Cyclopia maculata* and *Cyclopia plicata,* which are distributed across the Eastern and Western Cape fynbos biome (Figure 1.1). The bulk of the wild harvest (85%) comes from *C. intermedia* (or 'bergtee') populations, which is by far the most widespread and abundant of the species, with a distribution range covering nearly 12 000 km^2 of Cape Fold mountains stretching from Gqeberha in the east to Montagu in the west, occurring in areas where there is limited potential for any other agricultural use. In these production areas, most land exists in a relatively untransformed state, supporting biologically diverse ecosystems, and yielding many benefits, including soil protection, water production and maintenance, clean air and aesthetically valuable open spaces and wild places. It is a remarkable crop that requires no fences, no interventions and no artificial inputs of water or chemicals, which thrives on natural fire regimes and resprouts with conservative cropping. It is surely a gift from the veld. In the greater Langkloof and Tsitsikamma regions of the Eastern Cape and Western Cape, it forms a locally important industry for some farmers and a livelihood for the many traditional harvesters who supply the crop to five processing plants which process and sell in bulk or package and sell the tea locally and to the export market. All that is required for its maintenance is wise and conservative management of the resource, so that the use of the resource does not exceed its capacity to regenerate (Daly, 1996). This, then is the essence of this thesis: improving our knowledge of the plant in its natural and harvested state to know how it might be best managed by the people who use it, to ensure its capacity for regeneration and continued, sustainable use.

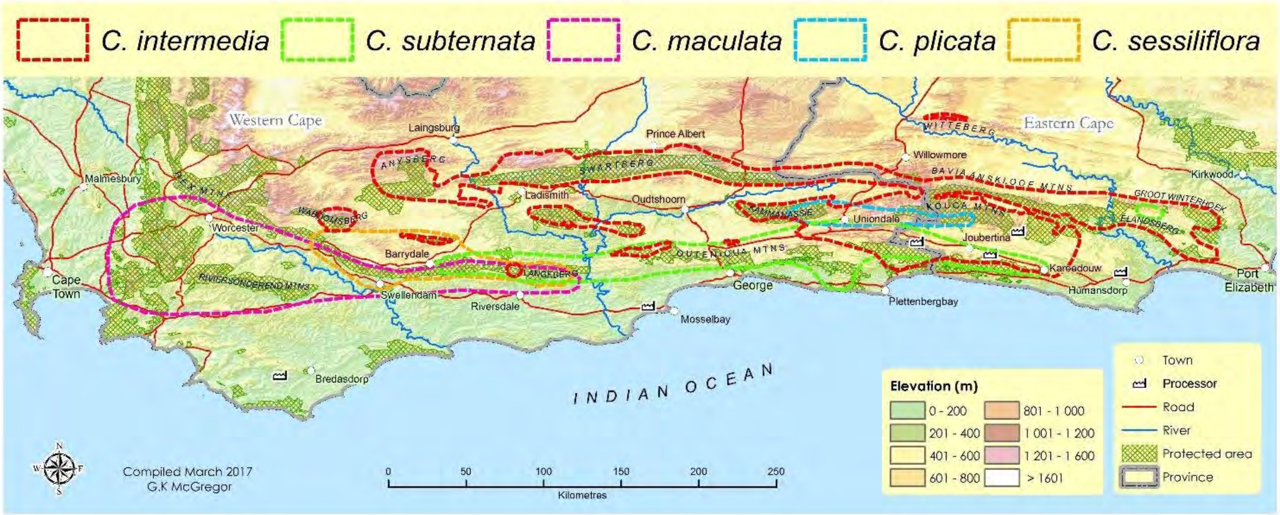

Figure 1.1: Distribution range of the five commercially important wild harvested *Cyclopia* species (McGregor, 2017a).

1.1.2 Human use of natural resources

The exploitation of terrestrial ecosystems has been part of the history of human development. However, our impact on natural systems has reached a stage where “Humans now dominate Earth, changing it in ways that threaten its ability to sustain us and other species” (Barnosky et al., 2012, p.52). In a massive global assessment of biodiversity and ecosystem services, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services report (IPBES, 2019a) presents evidence that human activities are behind the "dangerous" and "unprecedented" decline of the natural world (Díaz et al., 2019). The IPBES identified eighteen categories of services that nature provides that support quality of life: fourteen have declined in their capacity to support quality of life. In their summary of key findings of the report, Díaz et al. (2019) cite a figure of 70% for the extent of the earth's land surface altered by human activity. They identify the five direct drivers of change as: changes in land and sea use, direct exploitation of organisms (hunting, harvesting), climate change, pollution, and the spread of invasive alien species. This has happened despite the widespread recognition that many facets of human wellbeing are underpinned by nature (van Oudenhoven et al., 2018) and even though there has been a shift in our understanding from seeing the value of biodiversity as an external commodity that may influence human wellbeing to biodiversity as fundamental to human wellbeing (Naeem et al., 2016). Given the rate at which biodiversity continues to decline, the main challenges for humanity are to protect, manage and restore nature so that human wellbeing can be sustained, in balance with nature (Naeem et al., 2016).

Despite the bleak picture painted by the IPBES report, Ripple et al. (2017) point out that progress has been made in some areas:

- A global decline in ozone-depleting substances has been achieved, illustrating that decisive and united action can lead to positive change.
- Progress has been made in reducing extreme poverty and hunger.

- Investment in the education of girls and women has resulted in a rapid decline in fertility rates in many regions.
- The rate of deforestation has declined in some regions.
- The development and uptake of renewable-energy solutions has grown.

Díaz et al. (2019) believe that with an urgent and transformative approach that is innovative, adaptive and inclusive, which operates at all levels of governance, considers new and existing knowledge, and is inclusive of economic, sociocultural, demographic, political, institutional and technological causes of nature's deterioration, a sustainable global future is possible.

1.1.3 Natural resource use in South Africa

The situation in South Africa is not much different to that experienced elsewhere in the world: according to the National Biodiversity Assessment (NBA), the major environmental challenges facing South Africa align with global concerns: transformation of natural habitats, mostly for urban and agricultural expansion, biological invasions, pollution and waste, unsustainable natural resource use, and the overarching issue of changing climate (Skowno et al., 2019). Added to this is that South Africa, as a developing country with severe natural resource limitations, a growing population with a large poor contingent, and an economy with slow growth, must balance the demands placed on natural resources with economic development (Maitre et al., 2007). According to the NBA, natural systems are a major source of direct income to poor South African households, and generate significant value in the economy (Skowno et al., 2019). Millions of South Africans depend on harvested wild resources for food, medicine, firewood and raw materials for subsistence and commercial use (Cocks et al., 2012; Petersen et al., 2012; Shackleton & Shackleton, 2004) particularly where there are limited economic opportunities (Dovie et al., 2006). Overall, the ecosystem services provided by South Africa's terrestrial, freshwater and estuarine habitats are worth at least ZAR 75 billion per annum to South Africans (Turpie et al., 2017).

In a global scale dataset of anthropologically transformed biomes, 97% of South Africa is in the "Used" category which is defined as areas of urban and other dense settlements, dense agricultural settlements, lands used mainly for annual crops, lands used mainly for livestock grazing and pasture (Ellis et al., 2010). "Semi-natural" (anthromes consisting of inhabited lands with minor use for permanent agriculture and settlements) make up only 2%, and "Wildlands" – which are lands without human populations or substantial land use which retain their natural ecology – make up only 2%. In contrast, based on the 2013-2014 National Landcover data (DEA, 2014), Skowno et al. (2019) classify 79% of South Africa as "natural." The degree of transformation per biome shows that the Indian Ocean Coastal Belt is the most transformed at 64%, Grassland at 40% and fynbos at 31%.

Apart from the obvious intrinsic and economic value of healthy ecological infrastructure, South Africa is also bound to maintain biodiversity because it is a party to, and signatory of, the Convention on Biological Diversity (CBD, 1992). Wise management of our natural resources will help South Africa achieve the Sustainable Development Goals (SDGs) and other national and regional development goals (Cumming et al., 2017; Kubiszewski et al., 2017).

1.1.4 Honeybush sales and growth potential

Honeybush is mainly an export product, with 85% of tea produced exported to Europe, Japan and the USA while only 15% stayed on South African supermarket and farm stall shelves (Joubert et al., 2011; Mr Q. Nortje, honeybush farmer and processor, pers. comm., September 2018). The balance shifted during the COVID-19 pandemic period (2020-2022) when export markets were constrained, and the local market grew to around 25% of tea sold (McGregor, 2023). There is potential for growth according to anecdotal reports of enquiries for supply to various eastern countries in the order of hundreds of tonnes per year. There is proven potential for the adoption of honeybush extracts (tannins) in the alcoholic beverages market (Ms R. McKellar, Red Dawn IP, pers. comm., October 2019). Extensive research shows that honeybush as a nutraceutical (food with health benefits) has anti-inflammatory effects, anti-oxidant properties, anti-cancer treatment potential in female cancers, improves the immune system, and has a positive effect on diabetes Type 2 sufferers, amongst other beneficial effects (Joubert et al., 2019). Aside from the potential of these secondary products, there is a long history of therapeutic use of the tea for a variety of conditions. For nursing mothers and babies, it is a soothing herbal infusion which seems to ease digestive discomfort and constipation (du Toit et al., 1998); it can be used as a topical treatment for irritated skin (van Wyk, 2008a) and due to its expectorant effect, was used to treat coughs (van Wyk & Gorelik, 2017; Watt, & Breyer-Brandwijk, 1932).

As a drink, honeybush is part of an expanding global market for healthy hydration, representing a health and wellness trend driven by consumers who recognize the correlation between diet and health (Gupta et al., 2023). Shoup (2016) put herbal teas on the USA Top Ten superfood list along with seeds, avocados and nuts, and noted that "the beverage category has grown exponentially and tea is set to experience a lot of growth moving into 2017 and 2018." The sales growth of the group of commodities branded as plant-based waters was predicted to double by 2020, with global sales growth of 21% in 2016, amounting to sales of more than \$2.7bn. According to current market research by World Tea News (2024) the global fruit and herbal tea market will grow from a 2023 valuation of USD3.8 billion, to USD6.5 billion in 2030.

1.2 Research aim and thesis outline

With a natural resource, which is wild harvested, come many opportunities and challenges associated with sustainable use and management. This thesis aims to investigate aspects of the sustainability of the wild honeybush industry. The broad objectives form the aim of each chapter, addressed through a series of objectives supported by existing literature and suitable methods, as laid out per chapter described below.

Chapter One: The wild honeybush industry

The aim of this introductory chapter is to set the scene and motivation for the research in terms of the need for sustainable management of the wild honeybush resource. This is achieved through a review of literature on honeybush-related research to identify research gaps and provide a motivation for the research, and placement of the study in a philosophical and methodological framework.

This chapter reviews relevant literature, including scientific, technical and popular sources relevant to considering the sustainable use of an endemic fynbos species valued globally. It is, therefore, necessary to consider factors at international, national and regional scales. The literature review framework uses a conceptual model of the wild honeybush landscape (McGregor, 2017a) to focus the discussion. The chapter also reviews philosophical and methodological frameworks needed to frame the research, and ends with an overview of geographical characteristics of the primary study area: the greater Langkloof region.

Chapter Two: Mapping the resource

Before conducting this research, available maps of the distribution of honeybush species were limited to generalised, low-resolution maps in journal publications. *The primary aim of this chapter is to create an accurate and up-to-date map of the broad scale distribution range of* C. intermedia*, the likely area of occurrence at a medium scale, and at the local scale, the actual area of occupancy and utilisation of* C. intermedia*.* The methods used were desktop GIS techniques supported by existing botanical records, existing spatial datasets and expert mapping of known populations (harvested and unharvested) at local (1: 10 000 – 1: 50 000) to regional (1: 250 000) scales. These results were combined with a species distribution model (SDM) output for *C. intermedia* produced using the MaxEnt software. Desktop results were verified with field mapping of 38 populations. The results of the mapping exercise provided baseline information on the size and extent of the resource, the level of representation of *C. intermedia* in formally protected areas, and the extent of use of the resource mapped as harvested populations.

Chapter Three: Traditional and local ecological knowledge of best practice harvesting

Part of the motivation for this research was that formally recorded information on wild honeybush harvesting was limited. Knowledge of the practices of harvesting was (is) held by farmers and harvesters*. The aim of this chapter is to compile and analyse information about the harvest based on Local Ecological Knowledge (LEK) and Traditional Ecological Knowledge (TEK) that would contribute to a formal body of knowledge around harvesting to establish best practice guidelines for the sustainable harvesting of wild* C. intermedia*.* The information was gathered and processed using a mixed methods approach. One-on-one interviews were held with experienced harvesters, harvest managers and farmers. At a honeybush stakeholder workshop, participants participated in focus group discussions and answered questions about their knowledge of best practice harvesting. The results were quantified as a collection of graphs and discussed through thematic content analysis. The contents of this chapter and Chapter Four formed the basis of the guidelines for the sustainable harvesting of wild honeybush (McGregor, 2017a) and the wild honeybush harvesting field guide (McGregor, 2018a, 2018b).

Chapter Four: Sustainability of harvest enterprises and livelihoods

To understand the sustainability of the industry, it is necessary to get a perspective on the economics of harvest enterprises and harvester livelihoods. *The aim of this part of the research is to establish the sustainability of harvest enterprises through an analysis of different types of harvest enterprises and the actual practice of harvesting at harvest events.* Harvest team profiles were established for three types of harvest enterprises through in-depth interviews with three harvest managers who also provided harvest yield records for eight farms across several harvest periods. The data were analysed to assess the change in yield and harvester loads across harvest events. Field surveys at harvest events were used to collect data on actual harvest practices through transect walks and monitoring of harvester activity. The information was combined to estimate the area of veld needed annually to provide a single harvester with a livelihood.

Chapter Five: Characterising the Cyclopia intermedia *resource*

There is no formal record of the impacts of honeybush harvesting on the health of wild populations, and concerns have been voiced about population decline due to overuse. *The aim of the chapter is to characterise* C. intermedia *populations across the distribution range of C. intermedia to better understand the nature of the resource in its natural setting and under harvested conditions, and the impact of harvesting on the resource.* The biophysical environment was characterised through GIS-based desktop analysis of the range of the species, and field surveys of populations at 38 sites. Based on the measurement of plant allometry, the effect of fire, biophysical factors, and harvesting on plant vigour and fecundity were investigated through statistical analysis (GLM's). Two case studies further our understanding of the effects of unregulated harvesting on the health and vigour of a wild population, and short interval harvesting on the vigour of cultivated *C. intermedia.*

Chapter Six: Synthesis and conclusion

The final chapter puts forward a summary of the findings of each chapter of the research. It lays out the contribution of this research to the area of study from a theoretical perspective and highlights the applied nature of the research in terms of contributions to the industry and to the development of policy. It recognises some of the study's limitations and describes potential future research needed to improve understanding of the nature of the wild honeybush industry.

1.3 The wild honeybush landscape

The "wild honeybush landscape" was developed as a conceptual model by McGregor (2017a) to guide the development of wild honeybush harvesting guidelines in a project commissioned by the Western Cape Department of Environmental Affairs and Development Planning (DEADP) in 2016. The diagram frames the broader theoretical topics relevant to developing this thesis. Literature from the disciplines of ecology, sustainability science, agriculture, botany, biodiversity, GIS, livelihoods and natural resource management was used to develop an approach to understanding the sustainability of the wild honeybush industry and to identify suitable methods for data collection and analysis. All elements of the tree of knowledge fall under the broad topic of sustainability science – which caters for the complex combination of physical, biological and social systems that make up the wild honeybush industry. It is identified as a problem-driven field, with a focus on the direct use of natural resources and on the goods and services offered by functioning ecosystems, which includes consideration of the role of local ecological knowledge (LEK) and traditional ecological knowledge (TEK) in natural resource use and management (Kates 2011). Sustainability science also deals explicitly with developing and implementing policies that promote the sustainable use of ecological and social systems. The conceptual model (Figure 1.2) reflects the physical landscape of wild *Cyclopia* production. This system, in its entirety, needs to be understood to apply appropriate knowledge to the sustainable use and management of the wild honeybush resource.

Landowners and landusers (both private and state entities) are the foundation of the diagram as they make decisions about how the land and the resource should be used. In the landscape, the *C. intermedia* plants are located on the ground, in a mountain environment with certain favoured environmental conditions. The harvesters working on the landscape harvest deliver the raw materials to the processors, turning the resource into a commercial product. The clouds above the landscape are the three broad sectors of governance under which honeybush production operates: Conservation, Trade and Industry, and Agriculture, each of which has mandates implemented through various agencies responsible for developing policies and regulations affecting management, harvesting, and end-use of the product. Best practice guidelines, regulations, and permitting (represented as raindrops) taken up by honeybush stakeholders aim to ensure sustainable resource use. The tree of knowledge represents areas of science that inform our understanding of sustainable use and management of the resource to develop the industry.

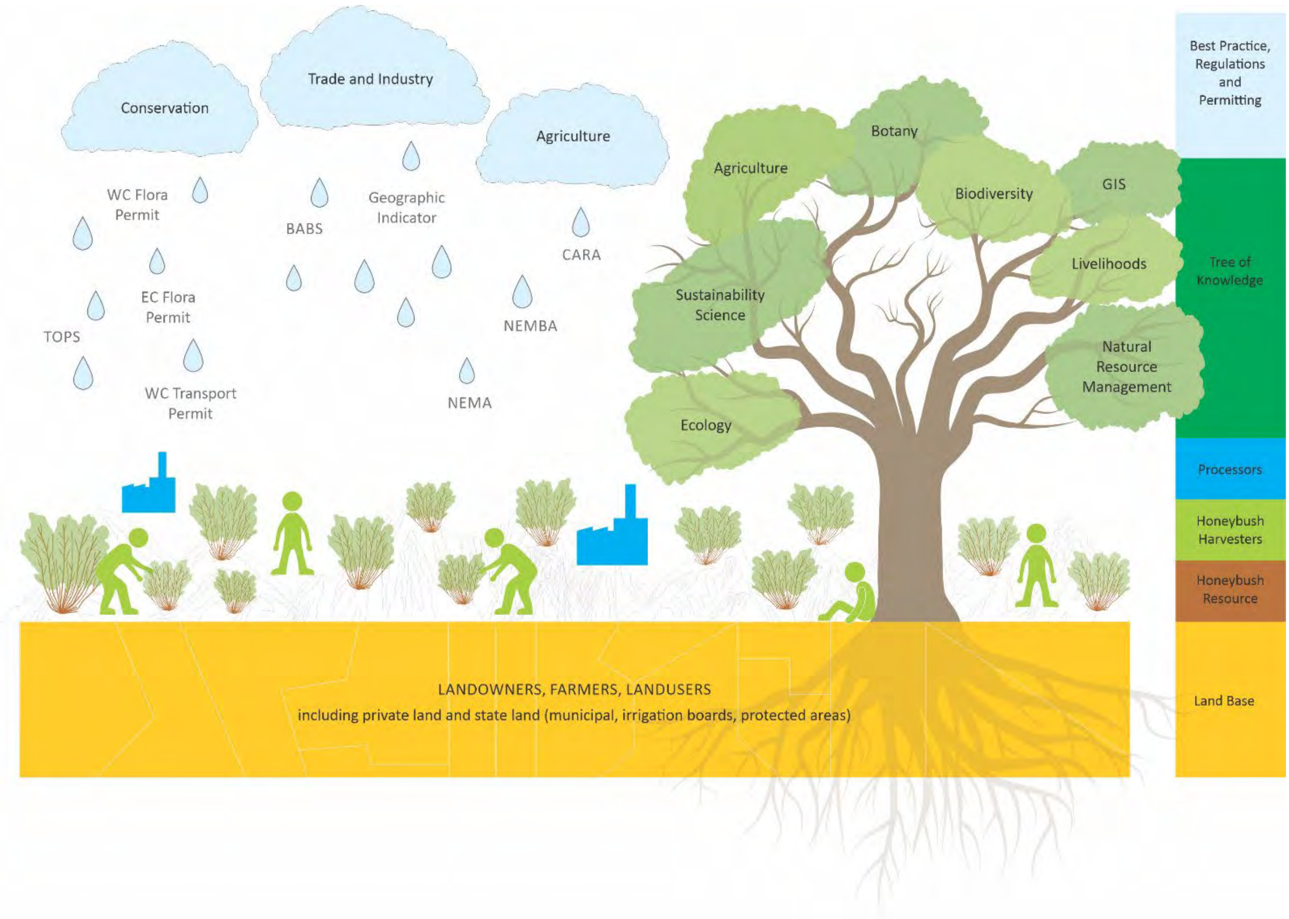

Figure 1.2: The wild honeybush landscape (McGregor, 2017a).

1.3.1 Literature on honeybush

While there is a substantial body of published literature on the phenolic composition and biochemistry of honeybush, as well as studies dealing with potential health benefits and the technological and quality aspects of herbal tea and extract production, the material that is most useful to the industry is found in other non-peer reviewed formats. Some of the key document types are described below.

1.3.1.1 Grey literature

In terms of the development of the cultivated honeybush sector, the "Farming with Honeybush: General guidelines" (Joubert & Joubert, 2012) is an important contribution of findings on best practice for cultivation, based on field trials and experience of researchers at the Agricultural Research Council (ARC). The South African Honeybush Tea Association (SAHTA) newsletters, annual general meeting (AGM) reports (which were both complied by the Agricultural Research Council), and AGM presentations form a useful set of resources, recording presentations on practical issues and advice such as soil preparation with fertiliser inputs, choosing the best sites for planting, use of pesticides and herbicides, use of AGRIWEAVE textiles, etc.

In the context of wild harvesting, the "Honeybush Tea Industry Development Project – Eastern Cape'' was commissioned by the Coega Development Corporation on behalf of the Eastern Cape Department of Environment and Tourism (EC DEDEAT). Two reports (not publicly available) were produced (Hobson &

Joubert, 2011), and presented an assessment of the industry and potential development (in the Eastern Cape), and LOWFT (2011) compiled an assessment of the sustainability of wild harvesting. Unfortunately, the LOWFT report was found to be lacking in its scientific approach by the EC DEDEAT and was not taken any further. These two reports are useful because they compiled material on many aspects of the industry and its prospects and information on wild harvesting and the wild resource.

A study commissioned by the Western Cape Department of Environmental Affairs and Development Planning (WC DEADP) in 2016 (EADP 696) resulted in the production of a series of five documents (de Villiers & McGregor, 2017; McGregor & Pierce-Cowling, 2017; McGregor, 2017a, 2017b, 2017c) which represented a substantial and up-to-date collection of material relevant to sustainable wild harvesting. They were the first comprehensive record of wild harvesting practices and related information, and were put out for use in the public domain. In a follow-up project (EADP 817), at the request of honeybush industry stakeholders, a basic field guide in Afrikaans and English, focusing on sustainable wild harvesting, was published (McGregor, 2018a, 2018b). This body of PhD research formed the basis for the compilation of those documents.

Another important piece of work commissioned by the Department of Environmental Affairs (DEA) in 2014 was that relating to “Traditional Knowledge Associated with Rooibos and Honeybush Species in South Africa” (DEA, 2014). The document was limited in that it included only some honeybush-producing areas and their communities. The report concluded that, based on the communities interviewed, the traditional knowledge (TK) of honeybush rests with the Khoi and San communities who originated in honeybush-producing areas. They further concluded that there was no evidence to refute the claim.

A collection of honeybush industry profile documents were put out annually or every two years by the National Department of Agriculture, from 2006 to 2016 (DAFF, 2010, 2013, 2014, 2015, 2016; NDA, 2006). The facts and figures in the reports are unreliable: figures given were not updated from year to year; there was incorrect use of units of measurement; and misrepresentation of annual production figures (which appeared to come from the rooibos industry) and were, therefore, out by thousands of tonnes. Unfortunately, these are the types of reports that newcomers to the industry and potential investors first come across.

1.3.1.2 Published honeybush literature

This review is based largely on the results of a SCOPUS search and several significant papers not captured by the search. The purpose of the review is to identify gaps in honeybush research, specifically with regard to knowledge and management of the resource to motivate this research. A SCOPUS search (July 2023) for honeybush-related research papers returns 203 papers from 1996 to 2023. The papers were grouped into five classes to understand the general research areas.

1.3.1.3 *Tea processing and product quality*

The focus of honeybush research is clear: 37.0% of research papers fall into the domain of biochemistry, mostly in the form of detailed analyses of the plant material extracts and trials using honeybush and honeybush extracts. In a review paper of 20 years of research work on the biochemical response of animal and human cells to honeybush extracts, Joubert et al. (2019) point out that it is the phenolic component of *Cyclopia* species that sets it apart from other herbal teas like rooibos, and gives it potential for other commercial uses. Studies reviewed focussed on phytochemistry (specifically phenolic composition), technological/quality aspects of extract and herbal tea production; in vitro and in vivo studies on the potential health benefits of honeybush extracts. de Nysschen et al. (1996) first identified the xanthone, mangiferin, and flavanones, hesperidin and isosakuranetin, as polyphenols common to all members of the genus *Cyclopia*, as well as other polyphenols found in honeybush (xanthones, benzophenones, dihydrochalcones, flavones, isoflavones, flavanones, flavanols and coumestans). Based on an analysis of selected polyphenols in *Cyclopia*, Louw et al. (2013) found *Cyclopia* to have phytoestrogenic potential. Its potential value as a chemo-preventative was explored by Joubert et al. (2008) and Magcwebeba et al. (2016). In a clinical trial (Choi et al., 2018) found that an oxidised *C. intermedia* extract, fermented with a lactic bacterium, had a positive effect on skin ageing, following the work of Im et al. (2014) and Petrova et al. (2011) on skin photo-protection and skin cell viability. The anti-diabetic effects of honeybush were investigated in the early 2000s leading to a patent application in 2007 (Larsen et al., 2008). The first paper on the anti-diabetic properties of honeybush (C*. intermedia*) was published by Muller et al. (2011). Information on subsequent studies relating to the anti-obesity and anti-diabetic properties of honeybush are summarised in Joubert et al. (2019). In a review paper, Jack et al. (2019) detailed the modulating properties of *Cyclopia* extracts against oxidative stress, hyperglycemia and obesity when used as a nutraceutical, concluding that *Cyclopia* is a potential source of anti-obesity compounds. Several Japanese researchers have investigated the immunomodulatory effects of honeybush extracts as a substance that may help the body fight cancer, infection or other diseases (Murakami et al., 2018; Yoshida et al., 2020; Shimbo et al., 2024).

Tea processing and product quality research in the general domain of agricultural and biological sciences make up 34.6% of published articles on honeybush. Research on tea quality was a direct response to issues in the emerging honeybush tea industry, where a lack of a quality grading system and standardisation of processing at the various tea processing plants was identified as a significant constraint to the industry (du Toit et al., 1998). This led to research on oven fermentation and drying of honeybush tea under controlled conditions at ARC Infruitec-Nietvoorbij, Stellenbosch, during 1995-1996 (Joubert et al., 2011). From the study results, an optimum fermentation temperature-time combination for *C. intermedia* was recommended to processors. Farmer and processor Quinton Nortje of Melmont Honeybush was the first to implement these recommendations, and following on-farm experiments, he adopted the rotating drum system, proposed by Joubert, to ensure controlled heating of the plant material during high-temperature fermentation for producing a good quality product. Years later, this aspect was revisited, and additional fermentation temperature-time combinations that would produce good quality tea from *C. intermedia* were demonstrated (Bergh et al., 2017). More recent work has focused on different fermentation approaches and quality control that affect the overall aromas and flavours of the tea, including the development of a flavour wheel for producing tea with a recognisable and consistent taste (Alexander et al., 2021; Erasmus et al., 2017; Theron et al., 2014). Furthering this work, du Preez et al. (2020) developed a comprehensive tea grading system.

Joubert et al. (2022) dealt with another aspect of honeybush processing aimed at preserving (preventing wastage due to mould growth) the freshly harvested plant material by pre-oxidation drying, while waiting for the oxidation stage. To speed up processing time, accelerated processing using higher temperatures under pressure as an alternative to the standard rotary fermentation process (Joubert et al., 2024). The new process, substantially reduced processing time and produced tea with enhanced sweet and fruity-sweet flavour notes.

While all of these papers focus on using and developing honeybush extracts, only a few note the need to cultivate honeybush as an alternative to, and to relieve the pressure on, the wild resource (du Toit et al., 1998; Joubert et al., 2011). Research on honeybush cultivation is significant to this research: successful cultivation can take the pressure off the wild resource and grow the industry.

An overview of the history of crop and product development is detailed in reviews by Joubert et al. (2008)and Joubert et al. (2011), with a comprehensive review of product research after 20 years of commercialisation by Joubert et al. (2019). du Preez & Joubert (2021) captured the history of the industry including many unpublished notes, in a colourful, illustrated online document.

Developing a sufficient understanding of how to “domesticate” a wild fynbos plant has not been without challenges. Professor Hannes (J.H.) de Lange must be credited with pioneering the process of domestication of *Cyclopia* (Joubert et al., 2011). More than 200 000 seedlings of 12 *Cyclopia spp*. were propagated and planted by de Lange at 64 locations on the West Coast and in the Boland, Overberg, Southern Cape, Little Karoo, Langkloof and Eastern Cape. (Joubert et al., 2011). The reseeder *C. subternata* showed promise for its rapid growth and potential for annual cropping, while a small selection of *C. longifolia* cuttings produced healthy plants characterised by rapid growth and with a mixed plant form of a reseeder and resprouter which could take heavier cropping. *C. intermedia* was trialled but was slow-growing and difficult to germinate. The Kirstenbosch variety of the resprouter *C. genistoides* also proved to be a most suitable candidate for cultivation (de Lange, 2002).

The collection of papers related to cultivation includes research on the improvement of genetic material (Bester et al., 2016); trials on best methods of propagation (Koen et al., 2017; Koen et al., 2021; Mbangcolo et al., 2013a, 2013b); trials on supplementation with minerals and nutrients (Joubert et al., 2007; Mndzebele

& Dakora, 2017); and harvesting trials, testing differences in species with regard to harvest times and its impact on biochemistry (du Preez et al., 2020; Joubert et al., 2014; Mabizela et al., 2020, 2022). A trial on the effect of short-term drought stress on *C. subternata* on plant composition, proteomics and product quality was conducted by Mabizela et al., 2023 while Mahlare et al. (2023) investigated the effect of severe drought stress. A critical and much-awaited piece of research on the harvesting yields of cultivated honeybush by North et al. (2017) showed that yields of 8.5 to 10.4 tonnes per hectare per annum could be achieved on *C. genistodes* and *C. subternata,* respectively. The importance of N_2 fixation activity by rhizobial bacteria in cultivated honeybush was investigated by Spriggs et al. (2003) and Postma et al. (2016). Understanding of pathogens of cultivated *Cyclopia* has been advanced by Halleen et al. (2022), who identified fungi causing dieback in *C. subternata,* while Daramola et al. (2020) identified root-knot nematodes that caused damage to honeybush. Karsen et al. (2022) presented an excellent review of existing knowledge around honeybush cultivation and promoted the need for continued research to improve cultivation to ensure the production of high-quality tea sustainably.

Only a few articles on plant ecology were returned by the SCOPUS search. Not included in the SCOPUS result is a key paper by Schutte (1997), which is a revision of the genus *Cyclopia* in which 23 species were identified and described with reference to their distribution, morphological, genetic and habitat characteristics, and mapped specimen collection localities. This paper formed the basis of our botanical knowledge of the genus. Schutte-Vlok's 1998 article brought the plight of honeybush to a wider audience, highlighting the decline of some species in some areas due to various human impacts, including road building, urban development, agriculture, over-frequent fires and unsustainable harvesting. du Toit & Campbell (1999) investigated the effects of fire on *C. longifolia* and *C. pubescens* seedling recruitment post-fire. Potts (2017) presented a discussion on “duty of care” concerning the conservation of genetic diversity in the emerging cultivated industry. Evidence supporting this cautionary advice was presented by Galuszynski & Potts (2020), who found that the genetic diversity of cultivated populations was low compared to wild populations. Both authors suggest that wild seed should not be translocated from its local mountain range. In the only published study on the effects of harvesting on *C. intermedia*, Lee et al. (2023) found that the largest plants, yielding the greatest biomass, were the most fecund and were found on gentler slopes with deeper soils located in dense fynbos communities. Grobler & Campbell (2020) found unexpectedly that the diverse roadside vegetation community of an endangered *C. pubescens* population positively affected pollination biology and fecundity of the species. A novel piece of work on the pollination ecology of *Cyclopia* tracked the pollination activities and successes of Xylocopid bees (Shaw-Bonner et al., 2023), finding that *Xylocopa capitata* was the most common and the most successful pollinator, while honeybees and several other insect taxa, were unsuccessful as pollinators.

What is immediately obvious – given the dependence of the industry on wild harvesting – is the lack of knowledge and research on wild harvesting practices and sustainability. Although there has been more literature on conservation, ecology and wild harvesting in recent years (2019 to 2023), this component is limited compared to the literature on phytochemistry, product quality, processing, cultivation and other topics.

1.3.2 Biodiversity and ecosystems

Maintenance of biological diversity is key to sustaining life on earth. Biodiversity, as defined by the Convention on Biodiversity, is "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and across ecosystems" (CBD, 1992, p4). As demonstrated by several researchers, maintaining biodiversity is essential to the supply of ecosystem services and not less important to support their health and resilience (Balvanera et al., 2016; Costanza et al., 2017; Turpie et al., 2017). In other words, biodiversity and sustainability are intrinsically linked: sustained life on earth depends on biologically diverse and functioning ecosystems which have become increasingly vulnerable in the face of human population growth, damaging pollution levels, transformation of land to agriculture for food supply, and declining water availability and quality (Barnosky et al., 2012; Foley et al., 2011; IPBES, 2019a; Marchese, 2015; Skowno et al., 2019).

1.3.2.1 Biodiversity under threat

Many initiatives at a local and global scale aimed at addressing declining biodiversity have not been as successful as intended (Cardinale, 2012; Foley et al., 2005; Kothari et al., 2014). The Sustainable Development Goals (SDG's) adopted by the UN in September 2015 aimed to improve human well-being while protecting, restoring, and sustainably using terrestrial ecosystems. Still, the combined effect of anthropogenically driven pressures of the Anthropocene (Crutzen & Stoermer, 2000) had already reached a "tipping point" (Russill & Nyssa, 2009) in what Barnosky (2012) terms a "critical transition", "beyond a safe limit" or a "planetary boundary" (Mace et al., 2014; Rockström et al., 2009; Steffen et al., 2015). Biodiversity has already experienced widespread and significant net losses with potential impacts on essential ecosystem services such as the production of biomass and pollination (Newbold et al., 2016). They warn that the recently proposed planetary boundary of biodiversity intactness has been exceeded within most biomes (especially grassland biomes), most biodiversity hotspots, and even some wilderness areas. Sanderson et al. (2002) identified a "Human Footprint" on 83% of Earth's land surface, defined as areas influenced by one or more anthropogenic forcings such as high population density, agriculture, and infrastructure. In the latest global review of biodiversity and ecosystem services, Díaz et al. (2019) report on the transformative change that is required to halt the threats to ecosystem functioning and biodiversity on a global scale. These threats are listed in order of severity as: agriculture, forestry, urbanisation, direct use of resources through harvesting, hunting, logging and fishing, climate change, pollution and invasion of non-native species (IPBES, 2019b).

Exploitation of terrestrial ecosystems is a feature of the history of human development to the extent that in the 21st century, only 24% of the earth's surface can be considered “wildlands” (Ellis et al., 2010). Working with the idea of natural biomes as determined by climate, soils and vegetation, these authors mapped the globe in anthromes (or human-made biomes) according to human use and transformation of the landscape since 1700. The map is based on three broad classifications of global land cover namely: “Used” anthromes (urban and other dense settlements, dense agricultural settlements, used mainly for annual crop, and lands for livestock grazing and pasture); “Semi-natural” anthromes (uninhabited lands with minor use for permanent agriculture and settlements); and “Wildlands” which are lands without human populations or substantial land use, which retain their natural ecology. By 2000, 55% of the earth’s ice-free land had been transformed into rangelands, croplands, villages, and densely settled anthromes, with a further 21% in a seminatural state. As would be expected, rates of change and extent of change vary geographically depending on the nature of the original biome. Arid and cold biomes retain a significant share (85%) of the total extent of wildlands, whereas savannas, shrublands and grasslands are 80% transformed into agricultural land and settlements.

1.3.2.2 South African Biodiversity

South Africa is recognised globally as one of 17 megadiverse nations, housing three of 35 global biodiversity hotspots: the Cape Floristic Region; the Succulent Karoo biome; and the Maputaland-Pondoland-Albany region (Mittermeier et al., 1997; Mittermeier et al., 2011; Mittermeier & Mittermeier, 2004). As defined by Myers et al. (2000), hotspots contain more than 1500 endemic vascular plant species, with only 30% of the original primary habitat intact, and are deemed vital to global conservation efforts. Although they cover only 17% of the earth, they are home to 77% of all endemic plant species, 43% of vertebrates (including 60% of threatened mammals and birds), and 80% of all threatened amphibians in settings already substantially transformed. These were seen to be areas where interventions were most needed, which would likely yield high returns if conservation efforts were focused (Mittermeier et al., 2011). Floral diversity is particularly high in South Africa, with about 20 500 indigenous plant taxa (7% of the world’s vascular plants according to the 2018 NBA), 65% of which are endemic (Marchese, 2015), while around half of the mammals, reptiles, amphibians, butterflies, and freshwater fishes found in South Africa are endemic.

The South African environment provides substantial, quantifiable benefits that are essential for the economic success of the country and the wellbeing of people, and may be a direct source of income for poorer households (Dovie et al., 2006; Shackleton & Shackleton, 2006; Turpie et al., 2017). The benefits of functioning and diverse ecosystems typically include provisioning, regulating, and cultural services (Millennium Ecosystem Assessment, 2005). In a study of the global ecosystem service benefits provided by intact South African ecosystems, Anderson et al. (2017) came up with an estimated value of USD 497 to USD 610 billion per year. This can be compared to South Africa's gross domestic product (GDP) of USD 350 billion in 2014 (Kubiszewski et al., 2017). In a more focused local study, Turpie et al. (2017) estimated that ecosystem services provided by South Africa's terrestrial, freshwater and estuarine habitats are worth at least ZAR 275 billion per annum to South Africans.

1.3.2.3 Provisioning services

As a provisioning service, the rangelands of South Africa support free-ranging livestock farming (the largest agricultural sector) across about 70% of the country's drylands (Scholtz et al., 2013), which are unsuitable for other types of production. The rich biodiversity of South Africa's indigenous flora – particularly the fynbos – provides harvestable renewable resources and opportunities for developing alternative and indigenous crops (Reinten & Coetzee, 2002). This natural vegetation also protects the soil and provides billions of cubic metres of good-quality water to the region for agricultural, domestic and industrial use. The fynbos is home to several uniquely South African products which support local export industries, such as the fynbos cut-flower industry, with an estimated annual value of ZAR 1 Billion (Dtic, 2023) and the rooibos industry valued at ZAR 420 million in 2022 (Bhobo, 2022). These industries rely on healthy, well-managed natural systems, although rooibos and fynbos cut flowers, and are now cultivated commercially. Even at a genetic level, South Africa's biodiversity has value: the checklist of food and fodder crop wild relatives for South Africa lists 1 593 species, subspecies and varieties, of which 258 are highly prioritised for conservation (Holness et al., 2019).

Many South Africans obtain a substantial portion of their daily food from the wild, contributing to food security in rural areas and as a means of making a livelihood (Shackleton & Shackleton, 2004). In a survey of wild products from the savanna, they found that 95% of households used wild spinach, 88% used wild fruits, 53% used insects and 51% used bushmeat for daily subsistence. There is an abundance of indigenous plants (±1 300 species or 6% of the total South African flora) with edible roots, stems, leaves, flowers, fruits, seeds or gums (Welcome & van Wyk, 2019). In a review of several South African studies, Shackleton & Shackleton (2011) give annual income values per household derived from natural resources collected in the wild that range from USD 160 to as much as USD 1130.

1.3.2.4 Cultural services

The cultural services provided by ecosystems are valuable in spiritual, aesthetic, and economic terms. Based largely on the aesthetic value of fynbos, the Western Cape eco-tourism industry produces 13% of the region's Gross Domestic Product (Chadwick, 2015). At a national scale, Turpie et al. (2017) put an annual value of ZAR 98.1 billion on tourism spending (foreign and domestic). They estimate that ZAR 25.2 billion of this comes from tourists visiting to experience the attractiveness of natural, intact ecosystems. In terms of the cultural value of biodiversity, Cocks et al. (2012) found that for Xhosa women and men, the experience of collecting plants in the forest fulfilled a spiritual need and contributed to mental well-being. In a survey of traditional grass (Turpentine grass) broom making and use in the Xhosa culture, Cocks et al. (2011) describe three important cultural uses of brooms; as a wedding gift, as a talisman against lightning, and for application of traditional medicine. Furthermore, the sale of brooms is an important source of income for poor rural Xhosa women. An overview of cultural values attached to plants, animals and special places is given by Skowno et al. (2019), which illustrates the broad cultural value of these biodiversity elements to a range of South African cultures in both rural and urban settings.

1.3.2.5 Regulating services

Only about 11% of South Africa is suitable for dryland and irrigated cultivation but in these areas many crops are dependent on biodiversity for critical regulating services such as pollination and pest regulation/control. High-value export fruit crops such as cherries and deciduous fruits do not set without pollination by managed or wild honeybees (*Apis mellifera scutellata* and *Apis mellifera capensis)* (Melin et al., 2017). In a survey of resource-poor small-scale farmers in the Eastern Cape, Skenjana & Poswal (2018) compiled a list of 23 local plants, 65% of which were collected in the wild, and used to prepare botanical insecticides against cabbage crop pests. Control of spider mites by naturally occurring predaceous mite species in apple orchards reduces the need for chemical applications and reduces the likelihood of pest resistance (Pringle, 2001; Pringle & Heunis, 2006).

In terms of regulation such as erosion control, Turpie et al. (2017) estimated that in the absence of protective natural vegetation, sediment yield from the land surface would increase 300 times with severe and costly impacts on infrastructure such as dams, reservoirs and harbours. Flow regulation that is provided by intact vegetation and wetlands which absorb rainfall and reduce water gradually, as well as reducing flood potential from excess runoff, is given an estimated ecosystem service value of ZAR 55.5 billion. The value of water provision, carbon and biodiversity provided by intact natural fynbos ecosystems in the Jonkershoek valley were estimated to far outweigh the value of commercial forestry (Chisholm, 2010). In the thicket biome, Mills & Cowling (2006) found that intact vegetation had very high carbon storage capacities of 76 t C ha^{-1} (biomass) to 130 t C ha^{-1} (soil).

Based on the 2013-2014 National Landcover (NLC) data (DEA, 2015), Skowno et al. (2019) have calculated the degree of transformation of South African biomes: the Indian Ocean Coastal Belt is the most transformed at 64.0%, then Grassland at 40.0% and then fynbos at 31.0%. Landcover can be used as an indicator of the integrity of habitats, biodiversity and, therefore, of ecosystem functionality. Impacts vary in time and space, as does the use of the landscape. Well-watered, low-lying areas with low gradients and good soils are desirable for agriculture or urban settlement, whereas rugged mountain areas with poor soils and broken topography remain in a relatively intact state. In addition, mountain lands are largely protected, having been set aside by the Mountain Catchment Areas Act of 1970 for water resource management (Mountain Catchment Areas Act, 1970). An analysis of the NLC 2018 data for the fynbos biome reveals that: 28,7% of the biome is totally transformed land made up of croplands (22,12%); old agricultural lands (3,15%); built-up areas and transport infrastructure (1,6%); as well as artificial water bodies, mines, quarries and dumps, plantations, and eroded lands. However, the fynbos is well represented in conservation terms, with a total of 19,1% (15 619km^2) of the area having formal protected status (DFFE, 2023).

The health of South Africa’s ecosystems is critical to human wellbeing and in economic terms. Maintaining a healthy ecological infrastructure can help South Africa achieve the United nations SDGs and other national and regional development goals (Cumming et al., 2017; Kubiszewski et al., 2017).

1.3.3 Policy and legislation (global, national, local)

The Strategic Plan for Biodiversity 2011-2020 (CBD, 2011) was adopted by the Convention on Biodiversity in 2010 in Nagoya, Japan, and entered into force on 12 October 2014. It set out a series of obligations that provide a legal framework for parties to implement the CBD objective of ensuring fair and equitable sharing of benefits arising from using genetic resources. Importantly, it also covered TK associated with these resources and benefits that might arise from their utilisation. In order to implement the plan, the Aichi Biodiversity Targets were set, consisting of five goals made up of 20 targets that serve to guide actions that will support biodiversity management at a national level (CBD, 2011). For example, *Strategic Goal C: Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity* (Target 12) requires that by 2020 the extinction of known threatened species has been prevented and their conservation status – particularly of those most in decline – has been improved and sustained. According to The Sustainable Development Goals Report 2024 (UN 2023), progress towards achieving the SDGs falls far short of what is required. In South Africa, some progress has been made towards increasing the inventory of taxa on the Red List, the expansion of protected areas and an increasing *ex situ* representation of threatened plant material in seedbanks and botanical gardens (SANBI, 2019). More recently, the Kunming-Montreal Global Biodiversity Framework (GBF) was adopted at COP 15, which builds on the previous Strategic Plan to achieve a global vision of a world living in harmony with nature by 20250 (CBD, 2022).

1.3.3.1 Applicable National Legislation

As a party to, and signatory of the international Convention on Biodiversity, South Africa is bound to conserve biodiversity, use resources sustainably, and share benefits equitably, and member countries need to put in place regulations and practices which support the achievement of the objectives of the CBD. The National Environmental Management Biodiversity Act (NEMBA) was promulgated in 2004 to enact into law its commitment to the CBD. Sections of South African law that apply to the honeybush industry in terms of sustainability are effected through the National Environmental Management Act (NEMA) 107 of 1998. For example, Section 43 provides the development of Biodiversity Management Plans (BMP) for utilised indigenous species. This legislation saw the publication (DFFE, 2022) and implementation of a BMP for *C. subternata* and *C. intermedia* under the Western Cape Department of Development and Environmental

Planning (DEADP), with support from the HCOP, SAHTA and other stakeholders. Section 56 of NEMBA gives the Minister power to publish a list of species that are threatened or in need of protection (TOPS) and lists restricted activities (Section 57) for which a permit from the authorities is required (including harvesting, propagation, transport, trade, etc.). Several honeybush species that are wild harvested and/or cultivated (including *C. intermedi*a and *C. subternata*) are listed in the 2023 listing, which was re-published in October 2023 for public comment. The TOPS listing is seen as a way to manage and monitor the sustainable use of honeybush species through a permitting system applicable across the distribution range of the resource.

Also of significance and relevant to this research is Act No. 6 of 2019, the Protection, Promotion, Development and Management of Indigenous Knowledge Act, 2019. The act aims to prevent the unauthorised use and misappropriation of knowledge developed over time by the country's indigenous communities and to promote the use of the knowledge in developing novel, socially and economically applicable products and services, provided there is appropriate involvement and compensation for the traditional knowledge holders. The Act aligns directly with the Aichi Biodiversity Targets 16 and 18, which deal respectively with the fair and equitable sharing of benefits arising from their utilisation and legislation for the protection, incorporation and integration of traditional people and their knowledge in biodiversity management. The Act has been acceded to by the President but has not yet commenced as the regulations for implementation are still under review.

After many years of negotiation, the Rooibos Industry and the traditional knowledge holders (Khoi and San communities) signed the Rooibos Benefit Sharing Agreement (RBSA), giving full recognition of the right of the TK holders to economic benefits from the Rooibos industry (Schroeder et al., 2020). Under the agreement, the Khoi and San beneficiaries would receive a 1,5% share of the farm gate price of rooibos sales, amounting to approximately ZAR12 million per year, as well as the benefit of job creation and upliftment of small-scale, traditional Rooibos farmers. The South African Honeybush Tea Association (SAHTA) is currently negotiating an industry-wide ABS agreement with the National Khoisan Council and the San Council. These achievements align with South Africa's commitment to the CBD, the Nagoya Protocol and NEMBA, 2004, specifically the Bioprospecting, Access and Benefit Sharing (BABS) Regulations.

1.3.4 Agriculture

Reliable access to a sufficient quantity of affordable, nutritious food is a global concern (Greyling et al., 2015). Agricultural development fuels economic growth, and is crucial to poverty alleviation and food security, but many developing countries have experienced slow or declining agricultural growth (Chang, 2009). In a survey of global agricultural lands, Ramankutty et al. (2008) show that croplands have reached their full potential, taking up 1.53 billion hectares, while pastures take up 3.38 billion hectares, covering 38% of global ice-free land. Most of the remaining land consists of deserts, mountains, tundra, urban settlements, and reserves considered unsuitable for agriculture. While agricultural development is necessary to ensure food security, it is also the single biggest threat to biodiversity (Díaz et al., 2019).

1.3.4.1 Agriculture in South Africa

Agricultural activities are an essential part of the South African economy and an important feature of the South African landscape. South Africa is self-sufficient in most major agricultural products and is a net exporter of agricultural products (Sibohlo, 2023). Most of South Africa’s land surface (69%) is suitable for grazing, and livestock farming is by far the largest agricultural sector in the country (BFAP, 2018), while only 12% of the country is suitable for the production of rain-fed crops (Vink & van Rooyen, 2009). While agriculture's overall contribution to GDP has declined over time, intensively farmed horticultural crops such as rooibos, nuts, citrus, deciduous fruits and table grapes have grown in gross value due to a high export value (BFAP, 2018). For example, in 2023, 51.3% of deciduous fruits were exported, making up 83.4% of the gross value of the crop. As a component of South Africa's GDP, the contribution from agriculture is small at only 2.6%, but relative to other economic sectors, agriculture employs 5.6% of the labour force (Stats SA, 2024). Agricultural activities play an important role in addressing food security and provide much-needed employment in rural areas (Musvoto et al., 2015). For example, in the rural provinces of KwaZulu-Natal and the Eastern Cape, agricultural sector employment makes up 25% and 21%, respectively. Furthermore, the sum of the contribution of agribusiness, which includes farming operations, input manufacturing, input suppliers, co-operatives, and food production, may be as high as 7.0% of the national GDP (Greyling et al., 2015). Investment in agriculture is widely recognised as a key precondition in achieving goals related to improving food security, creating jobs, creating wealth, and reducing poverty (BFAP, 2018; Chang, 2009).

In the Langkloof, defined as the study area for this research as the honeybush production zone, agriculture in the form of deciduous fruit production, mostly apples and pears, is the mainstay of the local economy (Schafer, 2014). Production is largely determined by the physical environment: deeper, fertile valley bottom soils along the drainage systems have been substantially transformed for cultivation of deciduous fruit, where yields can be 60-80 tonnes per hectare (Mr S. van der Merwe, Agricultural Extension Officer, pers. comm., October 2017). In 2020, the region supplied 16% of the national pear crop and 18% of the apple crop (DALRRD, 2020a, 2020b). Areas of fynbos (mainly Renosterveld vegetation types) on the gentler mountain slopes have been cleared for improved drylands, cultivation of fodder, and cereal crops. At higher elevations (e.g. the Suurveld in the eastern Kouga) where African surface veld occurs on more fertile soils, extensive rangelands support the rearing of sheep and cattle (Cockburn, 2018). Dairy farming is a feature of the Kromme valley in the lower eastern Langkloof. Tourism is a component of many farming enterprises and brought in up to one-fifth of income on farms where honeybush is harvested in the wild (McGregor, 2017d).

1.3.5 Use of GIS to organise, analyse and communicate information

GIS can be viewed as a framework to organise, communicate, and understand the geography of a place based on the collection, management and analysis of spatially referenced data. With its roots in the science of geography, GIS, through its capacity to integrate layers of different types of information, reveals patterns and relationships that might otherwise not be visible, enabling users to make better decisions (ESRI, 2023). GIS is a widely used technology in natural resources management, one of three 'original' areas of application (Jones et al., 1997). In its simplest form, it is a system of record, an inventory showing where things are on a map. In its intermediate form, it is a sophisticated database capable of storing volumes of spatial and attribute information about features. In its most complex form, analysis tools can be used for complex spatial analyses, scenario modelling, and predictive functions that reveal patterns that may not be evident without the power of GIS' spatial analytical capabilities (Robinson et al., 1995). In its modern form, it can integrate a suite of geospatial technologies that contribute up-to-date, high resolution and multi-format/spectrum spatial data. The availability of data and tools for observation, analysis, synthesis, and modelling of the earth (including GIS) has enabled the collection and collation of the kind of data that was required for the Biodiversity and Ecosystem Services Global Assessment, from which the impact of human activities on the earth could be quantified (Díaz et al., 2019). The starting point for a natural resource assessment should be a map-based inventory of the species' abundance and distribution (Schippmann et al., 2002). GIS was used to combine socio-economic and ecological data to develop a sustainable harvesting strategy for *Lippia graveolens* (a plant that produces essential oils and is rich in bioactive compounds) in Mexico (Irina et al., 2019). Gorman et al. (2008)) used GIS to support the development of a sustainable management plan for harvesting indigenous plant resources in Australia. In the context of this research, GIS was used throughout the research process, starting with secondary data analysis using existing spatial databases – now widely available for South Africa at moderate to high resolution. Apart from using the GIS as a database for all the spatial information collected for this research, the output in the form of maps is an effective form of communication (Mers, 2009) accessible to stakeholders across most literacy levels (Tversky, 2000).

1.3.6 Botany and ecology

The fynbos biome is the largest of the biomes in the Cape Floristic Region, covering some 90 000 km^2 (Manning & Goldblatt, 2012). All species of *Cyclopia* grow in fynbos (Schutte, 1997), the characteristic vegetation of the biome. Fynbos is a shrubby vegetation characterised by the presence of three plant types:

- proteoid shrubs, which are usually large-leaved species in the family *Proteaceae*, which form the overstorey (tallest shrubs) in mature veld (i.e. veld with a post-fire age of at least 8 years);
- ericoid shrubs that have small, hard leaves and comprise several thousand species in many families (e.g. *Ericaceae, Rutaceae, Rhamnaceae*); and
- restioids, rush-like plants in the *Restionaceae*.

Fynbos is associated with nutrient-poor soils derived from sandstones and quartzites of the ancient Table Mountain Group. However, some fynbos communities grow in coastal lowland settings on leached, aeolian sands and calcareous soils. Only one commercial species of *Cyclopia* is found in lowland fynbos, namely *C. genistoides* ("kustee" or "coastal tea").

1.3.6.1 Rainfall

While the fynbos biome is understood to grow under a winter-rainfall regime, this is not strictly true. Only the south-west and western parts of the biome receive more than 60% of their rainfall during the winter months (Bradshaw & Cowling, 2014). East of a line from Cape Agulhas in the south to Laingsburg in the north, the biome experiences year-round rainfall, although the spring and autumn months are the most reliably wet; hence the rainfall regime is better described as bimodal. West of the Knysna/Uniondale line, the summer months are driest, while eastwards, the lowest rainfall is recorded in winter. The majority of *Cyclopia* species grow in the bimodal rainfall region of the fynbos biome.

1.3.6.2 Fire

An important feature of fynbos, and a crucial management issue, is its evolution as a fire-prone vegetation community over more than a million years (He' et al., 2016). Without fire, most fynbos, especially on the deeper soils of the lower mountain slopes, would be colonised by forest and thicket. Under natural circumstances (i.e. without anthropogenic influence), fire-return intervals for most fynbos vegetation are in the order of 10-40 years (van Wilgen, 2009). The burn season varies according to climatic regime, with the western, winter-rainfall areas predominantly experiencing fires in the dry summer and autumn months. In the eastern part of the fynbos, where rainfall is bimodal, the western section also experiences mainly summer fires, while the eastern bimodal rainfall regions may experience fires at any time of the year, with a tendency for winter fires associated with hot, berg wind conditions (Kraaij & van Wilgen, 2014). Under human influence, the fire return intervals in many parts of the fynbos biome have become significantly shorter, owing to the massive increase in ignitions. In some cases, this is deliberate to improve the grazing value of veld, for example, in the eastern grassy fynbos. However, in most instances, fires are accidentally (or negligently) started by humans, or may be started by arsonists.

An analysis of fire occurrence data from medium resolution MODIS satellite imagery (NASA, n.d.) showed fire return intervals for the study area over the period of 2011 to 2017 to be in the order of 18 years (McGregor, 2017e). Some sites in the wild honeybush harvesting areas were found to have burnt twice in 15 years, which was potentially problematic in terms of the long-term persistence of diverse fynbos vegetation communities.

1.3.6.3 Growth form: reseeders and resprouters

For fynbos species, there are two main post-fire regeneration strategies: resprouting and reseeding (Keeley et al., 2011; Schutte et al., 1995). Resprouters regenerate from dormant, fire-resistant buds located on the plant's branches and stems, or below the ground, in lignotubers or rootstocks. In the case of reseeders, the plant is killed by fire (i.e. it is incapable of resprouting), and regeneration occurs via seeds which are either stored in the soil (as is the case for most ericoids) or on the plant canopy (as is the case for most proteoids). It is commonly assumed that resprouters are more resilient to fire since they regenerate vegetatively, whereas reseeders are much less resilient to fire since they depend entirely on seeds for population growth and persistence (Keeley et al., 2011; van Wilgen et al., 1992). Thus, a short interval burn, which occurs before reseeders have replenished their seed bank, will likely result in a sub-population decline. On the other hand, it is widely held, though possibly erroneously, that resprouters will not be affected by burning. The same applies to fire season when the timing of a burn is associated with conditions unsuitable for the germination of the seeds of reseeders. Recent research, which has monitored populations of fynbos reseeders and resprouters over many decades, has shown that populations of resprouters have declined more significantly than reseeders in the long term (Slingsby et al., 2017; Thuiller et al., 2007). The reason for this is unclear, but increased summer drought associated with climate change has been suggested as a possible influence through its impact on seedling recruitment (Heelemann et al., 2008). It is important to note that resprouters depend on some seed regeneration for population maintenance, as adult plants eventually die. As resprouters allocate more of their resources to lignotubers and other vegetative reproductive organs (rather than above-ground biomass), Verdaguer & Ojeda (2002) suggest that their seedlings are more vulnerable to drought.

1.3.6.4 Botanical description of C. intermedia

Cyclopia intermedia is a long-lived perennial which takes the form of an erect, robust shrub, up to 2 m tall, that sprouts after fire. The leaves are typically fine, arranged on the stem in a tri-foliate arrangement with leaflets that are lance-shaped to elliptic with slightly recurved margins (Figure 1.3). Flowers are about 12 mm long, bright yellow, and the calyx has almost rounded lobes with a leathery texture and a golden sheen (Vlok & Schutte-Vlok, 2010). The plants flower in spring time, varying from West to East of the fynbos biome by about one month (Barnado, 2014). *Cyclopia intermedia* is a resprouter, depending on resources stored in a lignotuber that enable it to regenerate vigorously after fire or harvesting.

Figure 1.3: *Cyclopia intermedia*: a) multi stemmed plant with about three years of growth; b) in flower and c) seed pods.

C. intermedia is the most widespread of the species in the genus, with a distribution that ranges across the Cape Fold mountains. The most western populations occur in the Waboomsberg (north west of Barrydale), the furthest inland in the Witteberg (north of Willowmore), and the most easterly in the van Stadens mountains, west of Port Elizabeth. Other mountain areas in which *C. intermedia* occurs include the Witteberg (between Laingsberg and Touws Rivier), Anysberg, Swartberg, Touwsberg, Rooiberg, Kammanassie, Kouga, Baviaanskloof, Langeberg, Outeniqua, Tsitsikamma, Elandsberg and Langkloofberge (Manning and Goldblatt, 2012; Schutte, 1997; Vlok, J., February 2017, pers. comm.). It grows abundantly in scattered stands on cooler southerly facing slopes of these mountains. This species is an essential part of the industry, accounting for 85% of the wild harvested crop, which makes up 47% of the annual tonnage of around 320 tonnes of processed tea (McGregor, 2023).

1.3.7. Livelihoods

Local economic development (LED) is defined as:

> "a participatory process that encourages and facilitates partnership between the local stakeholders, enabling the joint design and implementation of strategies, mainly based on the competitive use of the local resources, with the final aim of creating decent jobs and sustainable economic activities" (Tijmstra & Rodriguez-Pose, 2005, p.9)

The approach has been actively pursued by South African government agencies since 1994 in efforts to promote economic growth across the region where apartheid policies have left an unevenly distributed economic and developmental landscape. LED has not always met with success for several reasons (budget constraints, politics, corruption, amongst other factors) (Nel & Rogerson, 2016). Nonetheless, there are appealing elements of the approach, and in some instances – such as the conditions associated with wild flower harvesting on the Agulhas plain, which was linked to the biodiversity economy – it can be successful (Bek et al., 2013).

The potential to make a living from honeybush is well established, as evidenced by the many harvesters, farmers and processors who depend on the crop for a livelihood. The success of the industry can be measured in its growth from a cottage industry producing around 30 tonnes in 1996, to one that exports 75% of the annual crop of around 300 tonnes in 2023 (McGregor, 2023). The global 'healthy beverages' market is expanding rapidly to the extent that an international report by Mintel (SA Rooibos, 2023) claims that the majority of millennials are choosing tea over alcohol as a healthy and affordable drink that comes in many forms (including rooibos as a favourite). Trials on potential uses to alleviate a host of ailments are positive; and the proven use of honeybush extracts as a preservative in the alcoholic beverages industry (Ms. R. McKellar, Red Dawn IP, pers. comm. October, 2019) is a potentially huge area of development. Clearly there is potential for growth of the industry and secondary value-adding at a local level. If, as Howells (2005) noted, an effective demand for a product is a significant part of establishing LED, then the honeybush industry has great potential. EC DEDEAT, who manage the honeybush permitting system, views the honeybush industry as an opportunity for people in the poor rural areas of the Eastern Cape to participate at various levels – from harvesting through to production. As a result, much effort was put into an assessment of the industry potential, as reported by Hobson & Joubert (2011), who were commissioned by the EC DEDEAT. Hobson & Joubert (2011) and Joubert et al. (2011) advocate for the development of value-adding honeybush products at a local scale (packaging for retail), which would then carry a much higher value locally and for the export market. Diversifying a product range and investing higher up the supply chain will likely increase sales and profitability (Ahmed et al., 2013).

1.3.7.1 Sustainable livelihoods

One way to look at the sustainability of the honeybush industry is to view it from a livelihoods context. In broad terms, the livelihoods approach deals with how people make a living in different contexts. As defined by Chambers & Conway (1992, p.7), livelihoods encompass: "…the capabilities, assets (stores, resources, claims and access) and activities required for a means of living, made up of dynamic patterns which might involve adaptation and resilience to provide sustainable livelihood opportunities for the next generation. It is a useful research framework to inventory how rural people use natural resources and other means to make a livelihood (Lax & Joachim, 2013). Following these ideas, the Sustainable Livelihoods Approach (SLA) evolved as a framework to structure the analysis of rural development scenarios. Scoones (2009) advocated using the SLA as it catered for the complexity of activities and diversity of ways people make a living in contrast to more conventional approaches. The approach has been criticised by Morse & McNamara (2013), who note that despite its theoretical scalability, it can only be applied at a local or even single-family scale, while Attfield et al. (2004) criticise its failure to capture the ecological aspects of sustainability. In response, Natarajan et al. (2022) have proposed a sustainable livelihoods framework that caters to ecological elements and is more suitable for analysing rural livelihoods in the 21st century. The SLA approach was not used systematically, but a review of case studies dealing with rural livelihoods provided insights into how to view natural resource use in a rural area, like the Langkloof, where wild honeybush harvesting is an important livelihood for farmers, harvesters and processors. The research engaged extensively with stakeholders, placed value on local ecological knowledge, and included stakeholders in various capacities during the study.

1.3.7.2 South African context

Rural livelihoods in South Africa are made up of a mixture of activities, including using natural resources, farming, informal sector trading, social grants and wage income (Shackleton et al., 2000). van Schalkwyk (2015) noted that this mix of activities was essential to redeveloping rural areas into sustainable communities. Summarising the monetary value of natural resource use by households in seven areas of South Africa, Shackleton et al. (2011) gave estimates of USD 160 to USD 1130 per year, which accounted for one-third to half of total income and, on average, one-fifth of total income. Across six sources of income, Mugido & Shackleton (2019) found that the largest share came from social grants (38% – 63%), the second largest share came from wages (12% – 38%) and the next largest share was from wild resource harvesting, while agricultural contributions were the lowest.

Given the large portion of households in rural settings in South Africa, in the spatial planning arena, "there has been a renewed emphasis upon the region as the locus for economic, social and political action and the roles of institutions in local and regional development" (Pike et al., 2006, p.130). Structures have been established to support the regeneration of declining rural communities. Local authorities are required to implement LED strategies that typically take on a directly pro-poor focus, although to date, these projects have not been successful (Nel et al., 2009; Oranje, 2010; Rogerson, 2010). The promotion of these strategies, through on-the-ground projects, was taken up in the past by NGOs such as Agribusiness in Sustainable National African Plant Products (ASNAPP) and honeybush cultivation in Haarlem (Langkloof), Ericaville (near Plettenberg Bay) (Neven et al., 2005) while others have been promoted through national and local government funding such as Thornham Heuningbos (Thornham village, near Storms River), Kuyasa Amamfengu (near Clarkson) and Clarkson Heuningbos.

1.3.8 Sustainability science

At the 1972 UN conference on the human environment, the concept of "environmentally sound development" emerged to reconcile economic development with environmental integrity, and bring on board developing countries. Achieving economic and social development was deemed possible if environmental impacts were better managed (Strong, 2000). These ideas were encapsulated in the phrase "sustainable development", first formally articulated in "Our Common Future" (World Commission on Environment and Development, 1987, often known as the Brundtland report). At the 1992 Rio Earth Summit, the term became entrenched in the Rio Declaration, which detailed the principles guiding "sustainable development". The practical guidelines for achieving this were contained in Agenda 21 (UN, 1992). Since then, sustainable development has influenced three decades of global and local environmental policy-making, planning, research, implementation, and action. While there has been much criticism of the term (Daly, 2006; Kothari et al., 2014; Tulloch, 2013) the term sustainable development has appeared at the forefront of environmental thinking (Jordan & Voisey, 1998).

Contrasting views of sustainable development have become increasingly evident in recent years because, according to Kothari et al. (2014), sustainable development has failed to develop or protect people or the environment, particularly in poorer, developing countries. The prevailing lack of understanding of indigenous and local knowledge and its potential contributions to sustainable living has been identified by Mastrángelo et al. (2019) as a significant knowledge gap, potentially hindering the achievement of sustainability. Kothari et al. (2014) propose a move away from the global view of sustainability to alternative philosophies that come from traditional socio-ecological systems which are still in place, such as *buen vivir* in South America, *swaraj* in India and *ubuntu* in South Africa. The acknowledgement and promotion of indigenous knowledge is evident in the many documented accounts of sound environmental management by traditional societies (Henri et al., 2018). For example: Bonta et al. (2017) describe uses of indigenous knowledge about traditional veld management and fire use in Australia; Fernandez-Gimenez (2000) describes a flexible, mobile system of pastoral land use by Mongolian herders which has persisted over centuries; Groesbeck et al. (2014) recorded the success of the traditional mariculture practice of creating clam gardens for shellfish production in a limited space such that it contributes to food security in British Colombia.

There are many versions of what constitutes sustainability. Some consider only environmental change, while others connect environmental, social and economic dimensions (Scoones, 2016). Sustainability is often represented in diagrammatic form, with the three pillars of economic, social and environmental sustainability, which together support overarching sustainability (Purvis et al., 2019). Daly's (1996) definition is still valid: for renewable resources, the rate of harvest should not exceed the rate of regeneration (sustainable yield); for pollution, the rates of waste generation from projects should not exceed the assimilative capacity of the environment to remove them; and for non-renewable resources, the depletion of the non-renewable resources should require comparable development of renewable substitutes. He further suggested that development must incorporate qualitative (increase in quality of life) and quantitative (economic) growth.

Early research on sustainable yield management of renewable resources has been attributed to forest resource managers of the 17th and 18th centuries (Purvis et al., 2019; Scoones, 2015), where understanding of the balance of nature aimed at informing sustainable yield and resource management practices at a local scale (Holling, 1973; Ludwig et al., 1993). The scale at which sustainability is considered has expanded (Scoones, 2015) to approaches which include the idea of resilience (Folke et al., 2010) and more complex non-equilibrium systems views considering planetary scale processes and tipping points, beyond which change is likely irreversible and humanity will not be safe (Barnosky et al., 2012). These imbalances have come about because of unsustainable growth and consumption of resources in the geological epoch titled “the Anthropocene” (Crutzen & Stoermer, 2000).

'Sustainability science' has emerged as a well-recognised field of study that focuses on addressing the challenges of achieving sustainability (Bettencourt & Kaur, 2011; Fang et al., 2018; Kates, 2012) through multi-disciplinary approaches (Clark & Dickson, 2003). The term was introduced by the National Research Council (USA) in 1999, who defined it simply as the “science of sustainable development.” In a survey of 832 papers on the topic, Fang et al. (2018) classified research questions into five groups: the most common grouping dealt with sustainable development and human wellbeing, followed by references to the applied nature of the science with regular reference to decision makers and decision-making. Added to these are regular references to trends over time, giving sustainability science a strong temporal element. Kates (2011) describes sustainability science as primarily use-inspired, consisting of fundamental and applied knowledge components, to use this knowledge to drive societal action, while Bettencourt & Kaur (2011) note the geographic value of the science in bringing together contributions from cities to nations in very different developmental states. According to Kajikawa (2008), it is a diverse discipline covering ten core areas of research, including climate, biodiversity, agriculture, fisheries, forestry, energy and energy resources, water, economic development, health and lifestyle.

Often it is described as a science characterised by its research purpose rather than its philosophy or methods (Clark, 2007; Kates, 2011; Spangenberg, 2011). Nelson & Vucetich (2012) are critical of this approach, which they claim has reduced sustainability to a scientific endeavour which neglects human well-being. According to Dernbach & Cheever (2014), sustainability science fails to address the inherent contradictions in the notion of development that is sustainable. Regardless of the many criticisms of the concept – and its science – it is a feature of the 21st century and has focused the attention of scientists and policy-makers at a local and global scale on dealing with global environmental issues relating to the built and natural environment.

In the context of this study, the idea that scientific research underpins and informs the development of policy relating to sustainability means that it is a use-inspired science. Knowledge is a requisite for good decision-making (Cash et al., 2003; Nesshöver et al., 2016) and science – because of its objectivity – provides knowledge upon which policy-making and managerial actions can be founded. Translating this knowledge into action can be problematic, as Knight et al. (p 611, 2008) identified this shortcoming as the “research implementation gap.” Matzek et al. (2014) found that in the conservation planning context in Switzerland, while much effort is put into the accumulation of scientific information, it is not incorporated into management actions.

1.3.9. The Honeybush industry

1.3.9.1 Industry review

This section presents an overview of facts and figures relating to the industry, as collected from discussions with industry stakeholders, discussions and presentations at the Honeybush Community of Practice (HCOP) and South African Honeybush Teas Association (SAHTA) meetings, and minutes recorded at those meetings. It presents information that is not necessarily published but is nonetheless an important body of current, available and relevant information. The most recent review of the industry is an up-to-date set of industry statistics, based on interviews with processors (McGregor, 2023). Significant developments since the publication of the 2017 industry review (McGregor, 2017b) include the change from a wild-harvested base providing 80% of production in 2016, (20% cultivated) to a cultivated base making up 53% of production in 2023 (Table 1.1) with a subsequent decline in volumes of wild harvested material (63.30% of 2016 value for *C. intermedia* and 31.25% of 2016 value for *C. subternata*).

Table 1.1: A comparison of annual honeybush production statistics from wild-harvested honeybush in 2016 and 2023. The values given are based on processor estimates of tea processed rather than the PPECB statistics (McGregor, 2023), which are based only on exports.

Date	Total tonnes dry tea (processor estimate)	Total tonnes wet tea (processor estimate)	Wild crop as % of total tonnes	Wet tonnes wild *C. subternata*	Wet tonnes wild *C. intermedia*
2016	400.02	800.04	80	43.84 (≈ 10%)	412.67 (85%)
2023	292.50	585.00	47	13.75 (≈ 5%)	261.21 95%)

*In 2016, around 5% of wild-harvested material came from other wild-harvested species, which were not in use in 2023.
**Wet tea refers to the biomass delivered to the processor.

The change to a greater proportion of cultivated biomass for production is seen to be positive, as it is the obvious way to develop and secure the industry. A cultivated crop would ensure a consistent supply and predictable quality in larger volumes to meet the demand (Joubert et al., 2011; Potts, 2017) while taking pressure off the wild resource (McGregor, 2017b). A recent desk-top and 'expert mapping' survey of the cultivated industry (McGregor, 2019) estimated that 293.7 ha was under cultivation in 2019, with a total of 161.16 ha in production. A detailed breakdown of the figures is given in Table 1.2. Updated figures (Makhuza, 2024) indicate that most small farms have exited the industry and the total cultivation area is 320.7 ha. It is not known what portion of this area is actually in production, given the reduced market in 2024. Still, it represents a standing crop of around 1000 tonnes (estimated per ha yield of 3 tonnes) of honeybush material.

There is concern about the lack of reliable information available on cultivated honeybush production and guidance on implementing quality management systems to ensure the production of a product that is desirable and competitive on the international market (Du Preez et al., 2023). Another area of concern is the level of uncertainty and slow progress around reaching an agreement with traditional knowledge holders to comply with Access and Benefit Sharing (ABS) legislation (McGregor, 2023).

Table 1.2: The extent of cultivated honeybush production in 2019 (McGregor, 2019).

Province	Total Area (ha)	Production 2019 (ha)	Community enterprises	Private enterprises	Total no. of enterprises
Western Cape	256.4	145.0	8	17	25
Eastern Cape	37.3	16.6	3	9	12
TOTAL	293.7	161.6	11	26	37

The honeybush industry has not grown consistently or as much as anticipated when considered against a range of early cultivation figures, from 234 ha in 2006 (NDA, 2006) to 120 ha in 2011 (Hobson & Joubert, 2011) and 200 ha in 2006 (DAFF, 2016) to 321 ha in 2023 (Makhuza, 2024). Overall, the area under cultivation has increased, the volume coming in from wild populations has declined and production from successful cultivated enterprises has stabilised. Domestication of a wild plant of the fynbos has not been without its challenges, such as dealing with unforeseen infestations by pests, including Keurboom moth and leaf hopper damage (Mushore et al., 2023), fungal infections by *Neofusicocum australe* (Halleen et al., 2023) and several *Diaporthe* spp. which caused dieback, as well as damaging nematode infections (Daramola et al., 2021). The lack of growth in production is reflected in Table 1.3, which shows the potential production capacity in the industry, the nature of supply to the various processors, and records the exit from the industry of several long-serving processors.

Over the period of 2019 to 2023 (pers. obs), there are an estimated 25 teams, made up of around 130 harvesters currently harvesting in the greater Langkloof area, the Elands Valley, Tsitsikamma, Plettenberg Bay, Uniondale and Oudtshoorn. Of these, three are full-time contract-type teams of 10-15 members, and 15 are smaller family teams (four to six members). Resident farm staff harvest on seven farms involving a total of 25 to 30 staff in total in a part-time harvesting role, for as many weeks are required to bring in the annual crop. In total, there are around 130 harvesters who currently practice harvesting – once a year at least, for a total period of several weeks up to several months. Only about 40 of these harvesters would be considered full-time, spending up to nine months of the year harvesting.

Table 1.3: The status of honeybush processor facilities. Data is based on interviews with processors in 2023 (McGregor, 2023) and personal observations (2019-2024). The number of teams supplying a processor and their frequency of supply is variable and depends on demand.

Process. facility	Nature of enterprise	Source of material	Enterprise age (years)	Capacity	Processor status
P1	Cultivated and wild-harvested material	2 large contract teams, 5-7 small teams Own cult. supply and 8 farms	>25	V. Large processor (> 400 tonnes wet material/yr.)	Producing, capacity to process more
P2	Cultivated and wild-harvested material	Was 5-7 small teams & 5-6 cult. farms	>25	Large processor (> 50 tonnes wet material/yr.)	Closed 2024
P3	Mostly wild harvested material, some cultivated	Was 3-4 small teams 2-3 small cult. farms	>25	Medium processor (up to 50 tonnes wet material/yr.)	Closed 2024
P4	Mostly wild harvested material, some cultivated	3-4 small teams 1-2 cult. farms	>25	Medium (up to 50 tonnes wet material/yr.)	Producing, capacity to process more.
P5	Mostly cultivated material	Own cult. supply	< 10	Large processor (> 50 tonnes wet material/yr.)	Closed 2024
P6	Cultivated material only	Own cult. supply & 8 cult. farms	>25	V. large processor (> 100 tonnes wet material/yr.)	Producing, capacity to process more
P7	Cultivated material only	5 small cult. farms	< 10	Small processor (< 5 tonnes wet material /yr.)	Producing, capacity to process more
P8	Closed system, mostly own cultivated product with small quantities from other growers	Own farm supply & 4-5 farms	>25	Medium processor (up to 50 tonnes wet material/yr.)	Producing, capacity to process more
P9	Closed system, own wild harvested product only	Resident farm team	>25	Medium processor (up to 50 tonnes wet material/yr.)	Producing, capacity to process more

*Harvest team size varies from 10-15 harvesters in a contract team; 4-6 in a small family team, 5-10 in a farm staff team. Teams do move around from one processor to another, looking for the best price.

1.3.10. Use of wild resources

The two areas of research discussed here, NTFPs (non-timber forest products) and Medicinal and Aromatic Plants (MAPs), represent a large body of literature dealing with the sustainable use of mostly indigenous plants that are harvested mostly in the wild. Case studies are drawn from across the world (including South Africa), mainly in the context of rural livelihoods which exist in both developed and developing countries. Use, over-use and management, and the monetary value of the resources, are common themes, as is the development of appropriate policies for improved and equitable management. Supporting this research are a range of methods, from the survey of plant populations, to modelling of trade-offs between ecological and economic sustainability, to community engagement through participatory rural appraisal. In all these areas, one of the primary motivations is to mainstream sustainable use and management of these resources in the interest of conservation and protection of biodiversity, which is inclusive of the traditional ecological knowledge of the people who manage and use these systems. Insights from this body of research provided insights into assessing sustainability in the honeybush industry context.

1.3.10.1 Non-timber forest products (NTFP)

The term 'non-timber forest product' (NTFP) originated in a study of the economic value of NTFPs in Southeast Asia, where it included "…all biological materials, other than timber, which are extracted from forests for human use" (Belcher, 2003, p161). Examples of NTFPs include fruits, nuts, seeds, oils, spices, resins, gums and fibres (Marshall et al., 2006). Broader definitions (Marshall et al., 2006; Schreckenberg et al., 2006) include recognition of an NTFP as a self-replicating wild species that humans harvest for consumptive or non-consumptive use, which may not necessarily be indigenous but should not be domesticated and may be from any landscape or ecosystem. Their definitions also consider management conditions where use is managed by those on whose land the NTFP occurs, where the benefits contribute to local livelihoods and may, therefore, act as an incentive to conserve the species or site.

NTFP literature is useful in the sustainability of the honeybush industry because it provides methods and approaches to measuring the economic, social and ecological sustainability of natural resource use. An understanding of all three is key to sustainable use (Ticktin & Shackleton, 2011). There are many NTFP studies based on ecological surveys of NTFP sustainability (Caswell & Salguero-G Omez, 2013; Cunningham, 2001; Hernández-Barrios et al., 2015; Ticktin, 2004), but according to Chamberlain et al. (2019) few methods exist for inventory and assessment and long-term monitoring of NTFPS, and therefore there is a lack of evidence to show sustainable use. Due to this lack of data, Ticktin & Shackleton (2011) suggest that assessments of sustainability will need to be inferred from information that does exist on broad patterns of the species attributes, harvest systems, and nature of demand. In contrast, Stanley et al. (2012) claim that 63% of 101 studies reviewed showed ecologically sustainable harvesting, while Gaoue et al. (2016) made the point that ecological sustainability varied according to plant part harvested, resulting in <5 % (sustainability) for whole plants or bark harvest, to 80 % for fruits (Ticktin, 2004).

An aspect of plant ecology essential to understanding the sustainable harvesting of plants relates to plant vigour, which can be affected by the nature of the harvest and the parts that are harvested (Cunningham, 2001; Ticktin & Shackleton, 2011). For example, the effect of harvest of underground organs can be deadly, and only conservative harvesting with long recovery periods is sustainable (as is the case for *Nardostachys grandiflora* – a Himalayan medicinal herb (Ghimire et al., 2008). In contrast, the harvest of fruits and flowers can be sustainable at high intensities – such as in the case of Marula fruit harvest (*Sclerocarya birrea*), which can sustain a harvest of 92% of the fruits (Emanuel et al., 2005). Sustainability also relates to plant form and regrowth strategies: resprouter lifestyles are suited to harvest provided vital parts are left intact (Cunningham, 2001); slow-growing perennials tend to be more sensitive, whereas annuals/herbs which only reproduce once or over several cycles, are less sensitive (Ticktin & Shackleton, 2011). Selection through harvesting can impact populations by leaving less desirable specimens behind, thereby having a long-term impact on population genetics (Lee et al., 2023).

There are many studies which consider the economic aspect of NTFP's, weighing up conflicting or alternative uses in economic terms based on modelling (de Beer & McDermott, 1996; Dovie et al., 2006; Hernández-Barrios et al., 2015; Shackleton & Pandey, 2013). In the South African context, the literature makes an important contribution to understanding the many elements that make up rural livelihoods – finding that, on average, social grants form a large share, as do NTFPs and wages, while agriculture only contributes a surprisingly small share (Cocks & Wiersum, 2003; Mugido & Shackleton, 2019; Paumgarten, 2005). The socio-cultural value of NTFPs, for use by the harvesters themselves or for sale to other users, is also a major component of NTFP use, and forms a focus in NTFP research (Cocks & Dold, 2004, 2006; Kepe, 2007). Commercialisation of NTFPs has been widely promoted as an approach to rural development (Schreckenberg et al., 2006) since most rural livelihoods are dependent on natural resources (Scoones, 1998) and the majority of people in many developing countries depend on rural livelihoods (Chang, 2009). NTFP studies also give insights into ideas around the best approaches to the management of natural resources through government policy, NGO initiatives and community involvement (Cunningham et al., 2009; Marshall et al., 2006; Schreckenberg et al., 2006).

Assessment of sustainable NTFP use is complicated by the mix of human impacts incorporating intensity and frequency of harvest, economic incentives, lack of governance, and uncertainty in land ownership (Hernández-Barrios et al., 2015; Ticktin & Shackleton, 2011). Thus, assessing the sustainable use of commercial NTFPs must include the analysis of harvesting effects on both the biological attributes of the species and the key socio-economic components of its exploitation and commercialisation.

1.3.10.2 Medicinal and Aromatic Plants (MAP)

Another area of research that deals with the sustainable management of wild resources and offers insights into similar issues faced by the honeybush industry in terms of sustainable resource management is the body of work on MAPs. The term is defined by Schippmann et al. (2005) as referring to plants used in a medical sense or as condiments, food or cosmetics. Honeybush can clearly be classified as an MAP since a large part of the demand for the tea is as a healthy, sweet-tasting beverage, but increasingly, it is being sought for its therapeutic qualities. Much of the MAP literature overlaps with NTFP case studies, including ecological and economic sustainability and socio-cultural values of the products. In particular, MAPs contribute to a growing international market for alternative medicines and are often high-value products. Cunningham (2011) advocates for this approach in his discussion of winning characteristics that enable a high value for products: natural or organic labelling brings a high price to the export market, particularly for products under certification schemes. He promotes using the nutraceuticals market approach because it is proven to be a rapidly expanding market.

MAPs have been used for decades and serve both as a source of income and affordable health care in many developing countries (Baydoun et al., 2015; Dangwal & Sharma, 2011; Marshall, 2011). Most medicinal plant material is sourced from the wild (Leaman et al., 2007) and originates from developing countries (Roosta et al., 2017; Smith & Larsen, 2003). According to Astutik et al. (2019), the major suppliers of products are China and India from Asia, Egypt and Morocco from Africa, Poland, Bulgaria and Albania from Europe, and Chile and Peru from South America, while the major consumers are the U.S., Japan and Europe (Vasisht et al., 2016) with increasing use in Germany (Máthé & Máthé, 2008). In the context of the sustainable use of wild harvested MAPs, Schippmann (1997) delineated the elements of a management plan for MAP use. These included: a resource inventory of population abundance and distribution; threat assessment; biological studies on harvested and unharvested populations; yield assessment; reviews of local knowledge and harvest practices; reviews of harvest and trade trends; a review and revision of national regulations for resource utilisation; assessment of tenure and access in the context of resource use; and design and implementation of a management scheme including annual harvesting quotas, monitoring and re-evaluation of conditions as part of an adaptive management strategy. The elements of this management plan were instrumental in framing this research.

1.3.10.3 MAPs in South Africa

According to van Wyk (2008a), an estimated 3000 plant species are used in traditional medicine in South Africa, of which 38 species have been commercialised to some extent. At the same time, a portion of the remainder is traded informally. Wild indigenous plant species provide traditional and alternative health care options for many South Africans, particularly those with a lower socio-economic status (James et al., 2018). A widely cited figure from Mander et al. (2007) is that 70% of South Africans use traditional medicines (TM), particularly those in the lower socio-economic bracket with lower educational status (James et al., 2018; Mander, 1998; Mander et al., 2007). In a recent study, Oyebode et al. (2016) set out to update and verify this oft-quoted figure (which is similar across most lower- to middle-income countries of the world) in a survey directed by the World Health Organisation on TM use in six countries including South Africa. They found that less than 3% of South Africans still use TM as their most frequent source of care.

There are many documented traditional uses of honeybush or extracts thereof (Joubert et al., 2008; van Wyk et al., 2009), ranging from the treatment of coughs and cold symptoms to topical applications for skin irritation to the treatment of udder inflammation in cows (Du Toit et al., 1998). In some instances, the traditional uses are valid when compared with the biochemical analysis of the active ingredients of honeybush extracts. For example, the presence of the compound pinitol, identified by Ferreira et al. (1998), has an expectorant effect, and the anti-inflammatory effects are now well established (Magcwebeba et al., 2016).

1.4 Research philosophy and methodology

1.4.1 Engaged scholarship

'Engaged scholarship' was first described by Boyer (1996), who saw it as an approach comprised of engaged teaching, research, and service. In a recent review of research on the subject, Beaulieu et al. (2018) investigated the progress of engaged scholarship across 38 research papers dealing with engaged research. They viewed engaged scholarship as a way of increasing the legitimacy of universities, and as an approach to addressing the knowledge-to-action gap. They identified two core values common to all engaged research: social justice (a focus on individual and social wellbeing) and citizenship (academics engaged with wider society to deal with broader issues of public relevance).

Engaged scholarship has become an important topic in the South African higher education context over the past two decades. The 1997 White Paper on Education identified Community Engagement in universities as one of the three pillars of higher education (along with teaching and research). Universities are called upon to demonstrate social responsibility and commitment to the common good by making expertise and infrastructure available for community service programmes (Department of Education, 1997). A review of South African university websites in 2019 (this research) showed that by 2019 every higher education institution in the country displayed a page dedicated to engaged scholarship in some form – most often as Community Engagement. This research was conceived of as being engaged, in that it was designed to find answers to a real industry-based issue (sustainable use of a wild resource) with broader societal implications (maintenance of biodiversity and traditional livelihoods) through meaningful engagement with all levels of industry stakeholders.

1.4.2 Research philosophy

Two common philosophical research paradigms guide the approach to this research, influencing the choice of methods and types of analysis: positivism and interpretivism.

The positivist approach is what most natural sciences follow, based on the assumption that there is uniformity in nature and that reality is stable, observable and can be described objectively and explained in a way that is repeatable and generalisable (Kitchin, 2006). It lends itself to hypothesis testing and quantitative methods. It is assumed to have a high level of validity and reliability (Cohen et al., 2017). In contrast, the interpretivist approach focuses on subjective meaning, supported by the use of qualitative data. Key to understanding the interpretivisit approach, according to Schwartz-Shea & Yanow (2013) is that "…meaning-making is key to the scientific endeavour: its very purpose is to understand how specific human beings in particular times and locales make sense of their worlds" (p.10). The concern in the interpretivisit approach is with gaining a deeper understanding of something and its unique context, to such a degree that the researchers' involvement in the research affects the outcome.

Geography has been described by the American Association of Geographers as "…unique in bridging the social sciences and the natural sciences". It can be defined as the study of features of the earth's surface, which are an outcome of human activity and natural processes, as they occur in space and over time. It includes understanding the relationship between humans and the environment. This crossing of disciplines means that geography is often both positivist and interpretivist in its approaches, choice of methods, and analysis. A 'mixed methods' approach, combining qualitative and quantitative datasets and methods, is an obvious choice for a geographer to explore complex geographic research questions that no one method alone can fully explore. Using a mixed methods approach (Creswell, 2014; Hawthorne, 2017), it is possible to effectively combine data from disparate sources using very different collection and analysis methods. The ways in which data in mixed methods research is used are described by Creswell & Plano Clark (2011) as merging, connecting, and embedding data.

Many examples of the successful use of a mixed methods approach in dealing with natural resources management are relevant to this thesis. Pasgaard et al. (2017) investigated the relationship between ecosystem governance and the wellbeing of local communities adjacent to a protected area in Laos, South East Asia, in the Nam Et-Phou Louey National Protected Area. They concluded that a mixed method approach was the best approach to combining science, local knowledge and policy development. Their work demonstrated that managing natural resources is about so much more than science, and that the social context within which decisions are made, is crucial (Ntshotsho et al., 2015). In a review of 30 research articles on forest management approaches Myllyviita et al. (2013) concluded that mixing qualitative and quantitative methods generally yielded an improved understanding of complex systems and, therefore, greater benefits to society.

This research uses both positivist and interpretivisit approaches to adequately address the sustainable use of the wild honeybush resource, which is a complex of ecological, economic and socio-cultural elements. As a geographer, the researcher was well-equipped to mix methods in order to understand the complexity of the system. The overall approach to the research was designed according to the advice of Creswell (2014), in that quantitative methods in combination with qualitative methods, provide a better understanding of a problem than if either approach were used alone.

1.5 Geography of the study area

The study area, covering the full *C. intermedia* distribution range, extends across the Cape Fold Mountains from Montagu in the Western Cape to the north-west of Gqeberha in the Eastern Cape and as far inland as the Witteberg, north of Willowmore in the Eastern Cape (Figure 1.4). This thesis focuses on an area described by McGregor (2017a) as the wild production area (indicated in Figure 1.4), which covers the greater Langkloof region of the Eastern and Western Cape. In this production area, harvesting of wild *C. intermedia* (but also *C. subternata* and *C. plicata*) is an important local livelihood for the many harvesters, farmers and processors who depend on it for all or part of their livelihoods. The valley of the Langkloof runs from east to west, bounded by the Kouga Mountains in the north (highest point, Kougakop, 1712 masl), ending in the Kammanassie mountains to the west of Uniondale. Running parallel and inland from the coast, the Tsitsikamma Mountains (highest point Peak Formosa, 1675 masl) form the southern boundary, extending into the Langkloofberge south of Haarlem. Within the valley, a series of low hills create a diversity of micro-climates suitable for intensive agriculture, with wetter conditions on the north side of the Tsitsikamma Mountains than in the valley bottom, drying out inland towards the foothills of the Kouga. From The Heights (just south of Joubertina), the main streams that drain from the wetter Tsitsikamma slopes flow north and into the eastward draining Kromme River. The streams of the main Langkloof are captured by the Kouga, which drains east from near Uniondale, through the Bo-Kouga and the Middel-Kouga to the Onder-Kouga, where it takes a northeast bend (inland of Kareedouw), draining eastwards into the Kouga dam at the eastern end of the Baviaanskloof wilderness area. Below the dam, the stream joins the Groot River, which becomes the Gamtoos River. At the eastern extent of the distribution range, north west of Gqeberha, is an isolated production area in the Elands Valley, bounded by the Grootwinterhoek Mountains to the north (high point Cockscomb, 1758 masl), the Antoniesberg to the west and the Elandsberg to the south. Farms in this area supplied wild-harvested *C. intermedia* to a processing facility near Humansdorp, which closed in 2024. There is a string of small villages along the length of the Langkloof from Avontuur and Uniondale in the west to Kareedouw in the east.

The mainstay of the Langkloof economy is agriculture, which is based on deciduous fruit production for the export market. In 2020, the region supplied 16% of the national pear crop and 18% of the apple crop (DALRRD, 2020a, 2020b). The deeper soils in the valley bottom and on gentler slopes are intensively cultivated. The Suurveld region (on the edge of the north-eastern Langkloof), which includes the Suuranysberg and the eastern Kouga mountains, is primarily a small-stock farming area. An analysis of protected areas (DFFE, 2023) shows that extensive areas of land (49% of the range) fall under the management of Cape Nature, South African National Parks, and the Eastern Cape Parks and Tourism Agency. Farming enterprises that bring in wild honeybush also offered tourism services (accommodation, mountain bike, hiking and 4x4 trails), bringing in 1/3 to 1/6 of annual income (McGregor, 2017d).

At a local municipal level, the wild production area falls almost wholly within the Kou-kamma Municipality (EC109), with small areas falling within the Baviaans (EC107), Kouga (EC108), Sundays River Valley (EC106), George (WC044) and Bitou (WC047) municipalities. The Kou-kamma municipality includes the settlements of Clarkson, Joubertina, Twee-Riviere, Kareedouw, Krakeel River, Louterwater, Misgund, Nompumelelo, Sanddrif, Storms River and Woodlands. There are no large towns in the area, and the population density is only 12 people per km^2. The total population of the municipality in 2022 was 36 487 compared to 40 663 for the 2011 census (Stats SA, 2023), representing a decline of 1.1% per annum. The racial composition of the population was 65.3% Coloured, 25.6% Black African, 5.3% White, 3.5% Other and 0.3% Indian and Asian. The dominant language was Afrikaans (71.1%), followed by Xhosa (27.3%) and English (1.1%). Of the resident population, 99.2% were South African-born (mainly from the Eastern Cape), with 0.8% coming from outside of South Africa. Based on the 2016 Community Survey (Stats SA, 2016), the annual household income (median value) was R29 400, which is double the Eastern Cape median income of R14 600. According to the 2016 Community Survey (Stats SA, 2016) the economy of the area is centred around tourism and agriculture, with an employment level of 55.9% of the working-age populace (relative to an Eastern Cape employment rate of 26.03%), with 69% formally employed. Agriculture is the biggest employer (25.6% of jobs), followed by trade (19.5%) and community service (mainly government) at 15.9%. Data from the 2022 census shows reasonably good levels of service delivery, with 94.1% of people living in formal dwellings. 91.5% had water-borne toilets, 95.2% had piped water, 85.7% had weekly refuse removal, and 94.4% had electricity for lighting.

Figure 1.4: Features of the study area geography.

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Chapter 2 Mapping the resource

Contents

List of figures

List of tables

2.1 Introduction

The first in a list of steps, and standard elements of a management plan for medicinal and aromatic plant (MAP) utilisation, is an inventory of the resource in terms of population abundance and distribution (Schippmann, 1997). From a geographers' perspective, the obvious way to create an inventory in this context is through maps, which serve as an inventory in their simplest form and, in modern digital terms, as a database with sophisticated modelling and analysis capabilities (Robinson, 1995). The explosion of geospatial technologies has promoted the use of maps in many ways and a multitude of contexts. Vegetation maps are a crucial part of management and planning at local and global scales (Tierney et al., 2017) and in the context of biodiversity management, the mapping and modelling of biodiversity patterns is key to enabling the development and application of regulations developed for biodiversity management (Skidmore, 2017). One of the key actions in any biodiversity management plan is the creation of a distribution map of the species of concern plus the location of sites of harvest, over-harvest and problem areas. These are typical features of a resource assessment described for the completed *Aloe ferox* (Bitter Aloe) resource assessment (SANBI, 2021) with the same elements listed as part of the scope of a Department of Forestry Fisheries and the Environment (DFFE) project, which includes a rooibos and honeybush resource assessment. The South African National Biodiversity Institute (SANBI) is responsible for mapping species-level information and developing biodiversity plans at national, provincial, and local levels. One of the foundations of their work towards protecting biodiversity, as proclaimed on their website, is "…surveying, classifying and mapping South Africa's ecosystems and species" (SANBI, n.d.).

2.1.1 Motivation for mapping the resource

The motivation for this resource inventory exercise comes from the fact that the wild resource was the mainstay of the industry until 2019, supplying 75% – 85% of the annual honeybush crop of around 350 tonnes (McGregor, 2017a), but there were no reasonable estimates of the size or condition of the resource. By 2020 the cultivated sector contribution had increased to 30%, and by 2023, the contribution from the cultivated sector – at 53% –surpassed the wild product contribution (McGregor, 2023). Wild-harvested tea remains an important part of the industry as it is an organic product with potentially higher value. The pattern of higher intensity and frequency of harvesting, as resource use develops from subsistence-level use and trade to commercial exploitation, is a global problem with regard to many traditionally used plant species (Marshall, 2011). In the case of the honeybush industry, development from a cottage industry to a commercial one is shown in the growth of annual volumes from around 30 tonnes in 1998 (Schutte-Vlok, 1998) reaching 200 tonnes in 2005 and 2006, with a high of 632 tonnes in 2011 (Joubert et al., 2011), falling to 241 tonnes in 2016 (McGregor, 2017a), and dropping to 203 tonnes in 2022. There was a perception that wild honeybush is being rapidly depleted by uncontrolled and incorrect harvesting, which is evident in some areas (McGregor, 2017b; Mhlongo et al., 2022; Schutte-Vlok, 1998). The SAHTA (2010) Business Plan detailed a 'SWOT analysis of honeybush industry weaknesses', identifying that wild reserves were under pressure and that monitoring and policing of wild harvesting was challenging to implement. They also acknowledged that there was evidence that private landowners who obtained a meaningful proportion of their income from honeybush took the management and conservation of honeybush seriously.

It is anticipated that the demand for honeybush will increase as the use of the plant expands into other industries, including nutraceuticals, pharmaceuticals, alcoholic beverages (for its preservative properties, Danu, n.d.) and the healthy beverages market. The group of commodities branded as 'plant-based waters' was valued at around USD15 935 million in 2023 with an expected annual growth rate of 18.7% between 2024 and 2030 (ProfShare Market Research, 2023). According to SA Rooibos, in 2023, the millennial generation is more likely to choose a cup of tea over alcohol. Good quality tea is considered affordable and healthy by a generation prioritising functional food and beverages. The stability of the honeybush industry depends on processors being able to guarantee supply, but depending on a wild harvested crop is risky, partly because of the vagaries of drought and fire but also due to the informal nature of harvest supply agreements (Mr D. Mills, honeybush entrepreneur, pers. comm., November 2016; Mr M. van Dijk, director Cape Honeybush, pers. comm., June 2015). Furthermore, an inventory of the spatial extent and state of the wild resource and its production potential would assure buyers of the availability of the product and support market requirements for sustainably sourced products (ITC, 2019; Wynberg et al., 2015). Recent studies of European consumer behaviour have shown a shift towards healthier food preferences and concern for the environmental history of foodstuff production (Lang et al., 2022; Petrescu et al, 2020). In economic terms, businesses need reliable supplies of natural resources (Bové & Swartz, 2016), and confidence in supply is critical to investment.

2.2 Aim and objectives

This part of the research aims to map and characterise the *C. intermedia* resource in terms of its distribution and abundance. Since this research focuses on the sustainable use of the resource, it also maps the area of use (termed the production zone in this chapter or the wild production area indicated in Figure 1.4, Chapter One) and the level of protection in formally protected areas. The aim is achieved through the following objectives:

1. To create a distribution range map of *C. intermedia.*
2. To elicit information on the distribution of *C. intermedia* from those with expertise and appropriate knowledge, and to present it spatially.
3. To model potential areas of C. intermedia occurrence at a broad scale.
4. To map the wild honeybush production zone and the extent of the harvested resource.

An overview of the research covered in this chapter is presented in Figure 2.1. The diagram starts with the four objectives, followed by a summary of the methods used to achieve those objectives, leading to the main findings which are the basis of the key points of the discussion section. Concluding comments are carried through to Chapter Six: Synthesis and Conclusion.

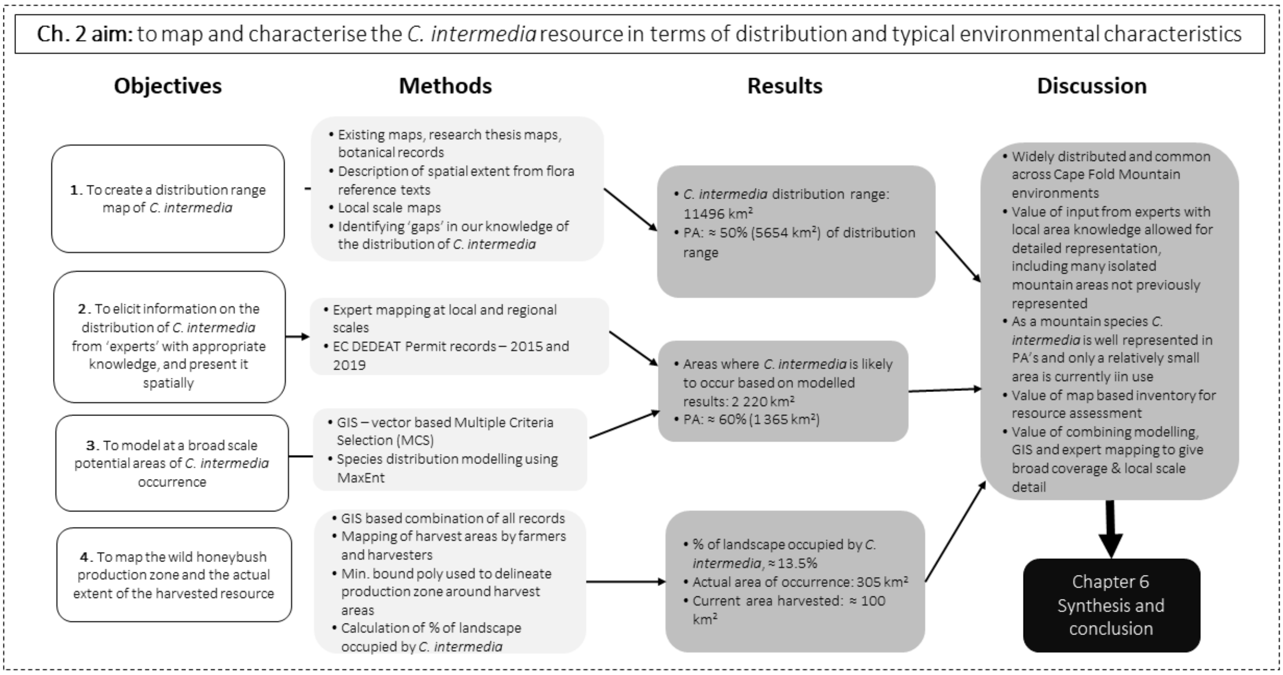


Figure 2.1: Overview and structure of Chapter Two.

2.3 Literature review

2.3.1 Biodiversity management and the use of mapping

GIS is considered an enabling technology in research on ecosystems, biodiversity and human interactions (Foley et al., 2011). In the latest global report on biodiversity and ecosystem services, Díaz et al. (2019) gave credit to the rapid advances in the generation of data and tools for observation, analysis, synthesis and modelling of fresh water, marine and terrestrial systems, which have made possible a high-resolution global view of environmental issues. All major biodiversity studies at a global (IPBES, 2019) and local level (Manning & Goldblatt, 2012; Skowno et al., 2019; Turpie et al., 2017) depend on the use of geospatial technologies, and tremendous advances have been made in our view of what's happening because of their availability. The use of new geospatial technologies and associated data have enabled measurement and monitoring, at global scales, of complex linkages between variables of agricultural-food-environment systems (Foley et al., 2011). Another interesting angle of data and knowledge contribution made possible through technology has been the evolution of citizen science (van der Wal et al., 2015). The raising of awareness around biodiversity has seen the acceleration of policies in biological monitoring, and the proliferation of the internet and associated applications have ensured that people interested in nature could contribute their skills, time and knowledge.

The science of biodiversity mapping has developed substantially recently (Hill et al., 2016). The occurrence of organisms in space is related to biotic and abiotic factors, which determine the potential growth and reproduction of a taxon in a geographical range where the species can exist because its ecological requirements are met (Huggett, 2004). The abiotic requirements of a species can be derived through an analysis of the combined set of abiotic conditions that exist at all sample localities of a species (Elith & Leathwick, 2009): this principle underpins the science of Species Distribution Modelling (SDM), which has made a significant contribution to furthering the automated range mapping of many taxa (Skidmore, 2017).

Various challenges are linked to mapping wild resources for management purposes, as Schippmann et al. (2002) noted. There is commonly a lack of information about the plants' genetic diversity, sustainable yield and, above all, their abundance and distribution. He also cites problems of open access to resource distribution and abundance that may lead to resource ‘mining’ rather than resource management. Furthermore, the lack of effective legislation in terms of control and monitoring for sustainable use also contributes to resource decline. Schippmann (1997) details a series of objectives that need to be met to successfully assess the state of a wild plant resource, as presented in Table 2.1 (left column). The objectives from this list, which are pursued in this research, are indicated in the right column.

Table 2.1: Objectives identified by Schippmann, 1997 for assessment of a wild plant resource, compared to objectives pursued in this research and other research undertaken by the researcher.

Objectives from Schippmann, 1997	In this research, or other research carried out by the researcher
Resource inventory of population abundance and distribution (through mapping).	DFFE, 2023 Chapter One; Chapter Five
Assessment of regional and global threat based on all available knowledge and expertise.	Chapter One; Chapter Five McGregor, 2017a DFFE, 2023
Biological studies (growth and regeneration rates, pollination system, seed dispersal, potential for confusion with similar species, etc.) and assessment of harvest impact on viability of individuals.	Chapter Five
Assessment of annual sustained yield	Chapter Four McGregor, 2017a
Review of local knowledge and harvest practices	Chapter Three & Four McGregor 2018a
Review of harvest and trade levels in the past and evaluation of market trends;	Chapter One McGregor, 2017b; McGregor, 2023
Revision of national regulations for the utilization in source country;	Chapter One, De Villiers & McGregor, 2017
Assessment of tenure and access;	Chapter Two DFFE, 2023
Design and implementation of management scheme: annual harvesting quota, seasonal or regional restriction	Not dealt with specifically, parts covered by the BMP (eg: domestication)

and on certain plant parts or size classes, domestication programme	
Installation of continuing monitoring and re-evaluation (adaptive management).	DFFE, 2023

* The scope of the project T060, (DFFE, 2023) requires that a Non Detriment Finding (NDF), a national scale Resource Assessment (RA) are carried out for *C. intermedia*. A monitoring plan will also be developed. The researcher is the Principal Investigator for these projects, in collaboration with the NGO Living Lands, sub-contracted by Kruger Swart and Assoc. to carry out these tasks.

2.3.2 Vegetation mapping

In one of the few books with detailed and practical instructions about how to go about botanical mapping, Pedrotti (2013) uses the term ‘geo-botanical mapping’ to describe the production of a geo-botanical map, which begins with field mapping and measurement, the collection of biotic and abiotic data, interpretation of the observations and finally, representation in a cartographic form. He notes the range of scales that it incorporates – from the level of individual plants (I), to population-level mapping, to the broadest unit (Level VIII) of higher phytogeographical units and biome-level mapping.

Traditional methods of vegetation mapping include field mapping, the use of aerial photos and, in recent years, remotely sensed imagery and automated classification procedures. These are approaches that have been used in developing national-scale vegetation maps in India (Roy et al., 2015); South Africa (Mucina & Rutherford, 2006) and China (Su et al., 2020). Many countries have a national scale vegetation mapping system–from traditional mapping to modern online databases with spatial and attribute data available on online platforms, including Japan, New Zealand, South Africa, Australia, United States and India. There is a good account for South Africa of the history of the development of vegetation databases and the conversion of those databases into digital maps: from the first nationwide vegetation ‘database’ created through the conversion of John Acocks’ work (1945 to 1975) to a digital form called ACKDAT (Acocks Data) (Rutherford et al., 2012). The ACKDAT database formed the base of the National Vegetation Map of South Africa, released in 2006, and updated and refined several times since (latest version – SANBI, 2018). These maps deal with South African vegetation at a vegetation community level and cannot cater to the detail required in a study of this kind, but can provide a valuable foundation for the likely location of *C. intermedia* populations.

There is no single guideline that informs a researcher of an appropriate method to map vegetation, but based on the knowledge of experts who do this (Prof. R. Cowling, botanist, pers. comm., October 2016; Mr. J. Vlok, botanist, pers. comm., February 2017), a sense of the landscape, intuition, knowledge of where the plant has been observed, use of topographic information, drainage systems, aspect, landuse and landform, can guide a botanist in sketching the outline of where a population is known to occur. Some formal guidelines are given in the *Field Methods for Vegetation Mapping* (USGS/NPS, 1994) where they note that prior knowledge will play a big role, the scale of mapping related to desired map output will influence the process, and that the mapper must be aware that areas may vary in biological and physical complexity. It is recommended that mapping is supported by GPS localities of existing, known populations (Nelson et al., 2015; USGS/NPS, 1994).

Scale is also an important consideration in mapping (Nelson et al., 2015), as is abundance of a population. For example, populations are recorded as made up of 50 plants or more, in the Custodians of Rare and Endangered Wildflowers (CREW) mapping guidelines.

2.3.3 Species distribution modelling with MaxEnt

As an alternative to conventional mapping, species geographic distribution maps can be produced using Species Distribution Modelling (SDM) software such as the freely available Maximum Entropy (MaxEnt) software (Phillips et al., 2006). SDM is based on the extraction of environmental characteristics which exist at the site of a known population, which are used to 'train' the model to identify sites where similar characteristics are found in the landscape (Elith et al., 2006). The result is a 'probability of occurrence' map presented on a scale of 0 to 1 where probability is defined as a measure of the likelihood that an event will occur (Lohner, 2019). According to Peters et al. (2014), species range maps created traditionally from large-scale field and herbarium surveys are being replaced by continuous and highly informative maps created through SDM. SDM is recognised as a valuable tool that can provide input to management and decision-making related to conservation efforts at various spatial scales (Midgley et al., 2003) and has been beneficial in generating scenarios for probable species distribution shifts under different climate regimes (Altwegg et al., 2014; Hannah et al., 2005; Phillips & Dudík, 2008).

One of the limitations of SDM is that, because there is often a spatial bias in distribution records (Hijmans et al., 2000) and the full range of environmental conditions is not well represented, ranges may be prone to errors of omission (Kadmon et al., 2004). Distribution models do not cater for the effect of factors such as dispersal limitations or species interactions on ranges. They might inaccurately predict the presence of species where they are absent (Graham & Hijmans, 2006). To overcome this limitation, a hybrid approach that combined the high spatial resolution of distribution modelling with expert opinion produced the best map (Hughes, 2017). Modelling often produces overestimates of species ranges (Hughes, 2017), but when improved with expert knowledge, it can produce a more accurate and relevant picture at the species level. The two forms of mapping are seen as complementary by Peters et al. (2014), who recommend that both form part of a species distribution analysis, together with historic locality records from a management and conservation perspective.

2.3.4 Expert mapping

There are a range of terms relevant to understanding expert mapping, including participatory GIS (PGIS), volunteered geographic information (VGI), community mapping, and participatory mapping. In the context of map-based data gathering, these concepts overlap – but all of these approaches can strengthen research (Aswani & Lauer, 2006; Debolini et al., 2013) and empower local stakeholders to contribute to problem-solving by filling in gaps in spatial and historical information gathering (Debolini et al., 2013). The term *expert* as used here, refers to people who have knowledge, insight and wisdom relating to a specific field or context, which has been gained through life experience and/or formal training or education and/or immersing themselves in the particular field or context (Collins & Evans, 2007; Kuhnert et al., 2010; Nowotny et al., 2001). It incorporates the idea that those who have worked with a given resource or lived in a certain area over multiple generations are accorded an equal footing in a scientific research context (Hall et al., 2009). With their detailed knowledge of the local environment, they may be described as expert observers of ground-level processes (Oliver et al., 2012).

Participatory GIS is described as a bottom-up approach (Goodchild, 2007) where stakeholders are involved in setting up and contributing to a research project by supplying information or knowledge about the affected area or issue through mapping. Representation of expert knowledge through mapping can facilitate participatory decision-making and give credibility to research through community advocacy (Aswani et al., 2018; Debolini et al., 2013; McCall et al., 2015). Goodchild (2007) introduced the term 'volunteered geographic information' (VGI), which is a form of geographical knowledge creation that allows individuals who are unqualified in GIS but who have valuable geographic knowledge to map their landscape (Dodge et al., 2011; Fagerholm et al., 2022). Through VGI activities, many thousands of people can collectively act as a geographically distributed data source. When combined with the strengths of geospatial data, the approach adds significant value by turning the nearly impossible task of mapping large extents into a manageable task (Dodge et al., 2011). It has become an important research tool that enables a better understanding of the world (Dodge et al., 2011) and contributions of valuable information from local stakeholders which might otherwise be unknown or unavailable (Colding & Barthel, 2019; Debolini et al., 2013; Grêt-Regamey et al., 2013). Purely traditional scientific approaches to gathering data for research are viewed as limiting to research (Hall et al., 2009), and there is an increasing realisation of the value of local ecological knowledge (LEK) or traditional ecological knowledge (TEK) in many research contexts.

Volunteers or local experts are often the only source of information, or may hold the most up-to-date and detailed information needed to solve a problem or manage a crisis (Holland et al., 2017; Reza et al., 2013). In the context of conservation planning, which is deemed to be data-rich and uses modelling approaches, it has been recognised that expert knowledge inclusion can improve outcomes (Cowling, et al., 2003; Grêt-Regamey et al., 2013). Conservation planning deals with challenges in gathering data for decision-making, including a range of stakeholders with differing backgrounds, a lack of funds for detailed studies, and the urgency of solving a problem. Expert mapping combined with systematic approaches has been shown to produce complimentary results (Cowling, et al., 2003) and can contribute to the acceptance of modelled results by participants (Grêt-Regamey et al., 2013). Given the scope, complexity and uncertainty of global environmental problems, it has become necessary to incorporate forms of knowledge other than western paradigms and systems of knowledge construction in dealing with environmental problems (Brody et al., 2003; Knight & Cowling, 2007; Raymond et al., 2010), which cannot be catered for in modelling approaches. For example, Reza et al. (2013) were tasked with creating habitat suitability maps for four vulnerable Malaysian large mammals. In the absence of existing data and maps and the urgent need for results, they used expert mapping integrated with GIS data to create the maps.

2.3.5 Existing estimates of the spatial extent of the resource

There are various maps and estimates of the honeybush resource, but figures do not cover the whole honeybush production area, and estimates are very general. A figure of 30 000 hectares (300 km^2) where wild honeybush grows is repeated in many reports (DAFF, 2013, 2016; NDA, 2006, 2011; SAHTA, 2010). A report by the Language of the Wilderness Foundation Trust (LOWFT, 2011) estimates that there is tea-bearing land across 85 000 ha (850 km^2) of privately owned lands in the Kouga, Tsitsikamma and Langkloof mountains and intermediary ranges. On the SANBI Redlist, Mhlongo et al. (2022) give an extent of occurrence (EOO) of 28 585 km^2 based on a polygon defined by peripheral species occurrence records. This maximum bounding polygon, constructed using the IUCN (2018) method, includes unsuitable habitat. A buffer about all occurrence records is generated to identify the actual area of occupancy (AOO). For *C. intermedia*, the AOO is 548 km^2 (Mhlongo et al., 2022).

2.4 Methods

2.4.1 Creating a distribution range map of *C. intermedia.*

A new, updated, and accurate distribution map was created based on the compilation of existing material, from generalised distribution maps to more detailed locality data and text descriptions of the species range. All information was converted to digital data formats and brought into a GIS.

2.4.1.1 Existing maps

A map of the distribution of five *Cyclopia* spp. (as revised by Schutte, 1995, with input from Prof. H de Lange), presented by Du Toit et al. (1998), was the most detailed distribution range map available and appeared to be the source of a newer colour map displayed on the SAHTA website in 2015 and 2023. Beyers (2016) produced a map of the *C. intermedia* distribution, which also served as a useful contribution to the compilation of the new distribution map. Low-resolution maps for all *Cyclopia* species, giving the best complete overview of all species, were available in a journal article by Schutte (1997), while a more recent map (Joubert et al., 2011) gave the localities of natural and commercially important honeybush populations and infrastructure (factories, nurseries, cultivated sites). All these maps were geo-referenced to existing spatial data in ArcMap 10.3, and point or polygon features were created using analog form. From this exercise the first detailed *C. intermedia* map together with a map of the five wild-harvested commercially important *Cyclopia* species was published by McGregor (2017b). Much of the work presented in this chapter contributed to the production of these maps. The 2017 *C. intermedia* map was subsequently updated as more data became available, although the revisions are not obvious at a low resolution.

2.4.1.2 Botanical records

At the start of the project in 2015, a dataset of all *Cyclopia* spp. localities was acquired from the Pretoria National Herbarium Computerised Information System (PRECIS) species distribution database. Of the 56 *C. intermedia* localities, 33 data points were considered useful and of adequate accuracy. The use of locality records stored in museums and herbariums is recognised as a standard way of developing a distribution or range map for a species (Williams et al., 2002). The 33 locality records were added to by creating locality records from Schutte, 1997, and Joubert et al. (2011) to make up 82 *C. intermedia* locality records.

2.4.1.3 Description of spatial extent from flora reference texts

Taking a description from a reference text is also an accepted way of creating a distribution map (Graham & Hijmans, 2006). The texts used for a broad delineation of the *C. intermedia* distribution were: Vlok & Schutte-Vlok, 2010 – *Plants of the Karoo*; van Wyk et al., 2009 – *Medicinal Plants of South Africa*; Manning & Goldblatt, 2012 – *Plants of the Greater Cape Floristic Region 1: The Core Cape Flora.* They formed a starting point for delineating the distribution polygons for *C. intermedia* using digital copies of the 1: 250 000 map series as a backdrop. From these maps, mountain range names, elevation and aspect were used to add detail to the process. The fynbos vegetation communities in which *C. intermedia* is found were extracted from the National Vegetation Map (SANBI, 2012) and served as a guide for the refinement of the distribution polygons.

2.4.1.4 Combing spatial data to produce the distribution range map

A cartographic model is a useful way to develop a logical approach to problem-solving in GIS, in the form of a flow diagram of input spatial data layers which are operated on using a series of tools or processes in sequence to produce an output (Berry, 1987; Buttenfield & Charisoulis, 2021). In Step 1 (Figure 2.1), the fynbos vegetation types where *C. intermedia* locality records occurred were identified through a 'spatial join', then added to the three collections (a to c above) of information (Step 2) together with details from Vloks' expert map (see Objective Two). Through overlay and some manual processing (Step 3), the distribution range polygons were produced and refined through generalisation (Step 4) to produce an aesthetically pleasing distribution range map.

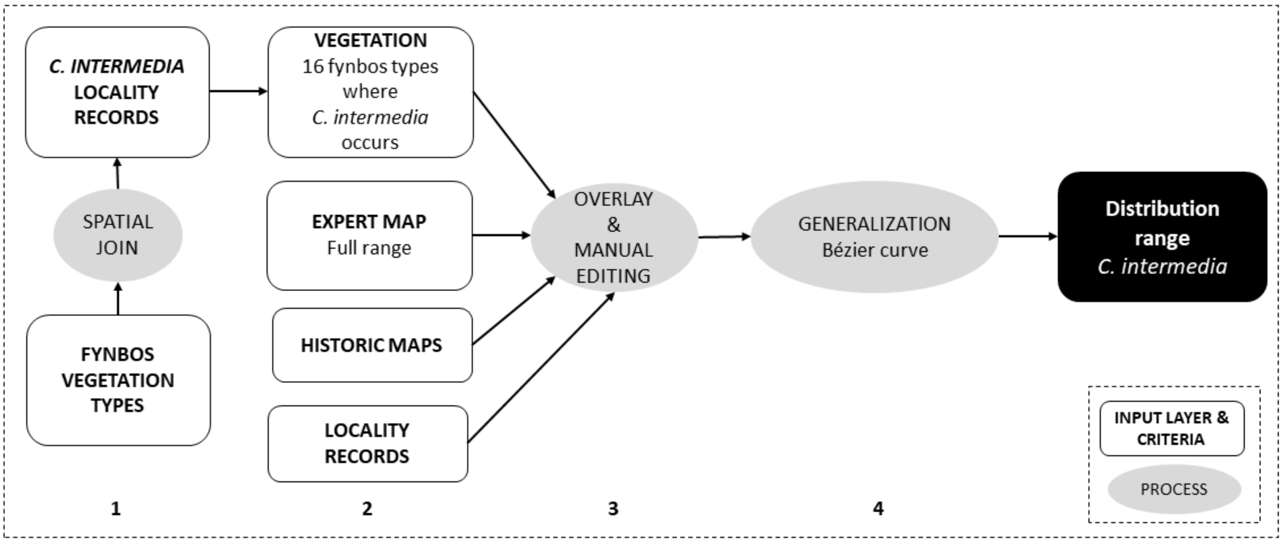


Figure 2.2: Model 1 – the sequence of inputs and processes run to derive polygons delineating the distribution range of *C. intermedia*.

2.4.1.5 Gap analysis

The distribution range map with existing locality records was used for a 'gap analysis' to identify localities where *C. intermedia* is (or has been) found and where it has not been found. In the spatial context of identifying places where something is lacking or an opportunity exists, gap analysis has been used in tourism planning (van der Merwe & van Niekerk, 2013), water resource management (Strosser et al., 2012) and agricultural yield assessment (van Ittersum et al., 2013). It is a common approach in conservation planning used to identify unprotected places or 'gaps' in the landscape rich in endangered species where conservation plan efforts should be focussed (Dudley & Parish, 2006; Scott et al., 2017). The method allowed for a systematic approach to filling in gaps in the spatial extent of the existing data to generate a new, improved distribution map. It contributed to planning a field programme to revisit known and new localities (i.e., gaps). In ArcMap 10.3 (Esri Inc., 2014), a hexagonal array with an area of 8 km^2 was generated and overlaid over the study area (defined by the maximum extent of known localities) so that cells with no locality data could be identified. To narrow down the selection to areas where the environmental preferences of *C. intermedia* exist, the empty cells (gaps) were overlaid on areas which met the physical habitat requirements of *C. intermedia* (Joubert et al., 2011). For practical purposes, the resulting gap cells were overlaid with the 1:50 000 road network (CD:NGI, 2016) to constrain the selection to sites where *C. intermedia* was likely to occur where it was accessible. Other site selections were based on practicalities such as ownership, access permission and knowledge of the EC DEDEAT honeybush harvest permit archive. The selection of survey sites became opportunistic as information became available from local residents who knew where honeybush populations occurred.

2.4.1.6 Protected area mapping

A register of formally protected areas was available in spatial data format on a quarterly schedule from the DFFE. Initially the South African Protected Areas Database (SAPAD), Quarter 4, 2016 (DFFE, 2016) delineated the proportion of the *C. intermedia* distribution range, which fell under formal protection. The level of conservation was noted as a significant feature in Schippmann's 1997 plan for natural resource assessment and is a feature of the CITES non-detriment finding (NDF) process (Rosser & Haywood, 2002), which allocates a high (positive) score when 15% or more of a resource occurs in a protected area. In 2024, the data was updated with information from state conservation agencies (ECPTA, SANParks, CapeNature) who had further areas of land under their management, not represented in the register. For each of the mapping levels (geographic range, potential occurrence and harvest zone) the proportion of land managed for conservation was calculated relative to the area of land outside protected areas. A list of the protected areas within the *C. intermedia* range is provided in Appendix 2A.

2.4.2 Gathering information on the distribution of *C. intermedia* from experts

2.4.2.1 Expert mapping

Using 'expert knowledge' to efficiently capture information about a widespread resource is a standard method, particularly in conservation planning. It allows for the rapid production of resource maps, where local knowledge is invaluable (Debolini et al., 2013; Grêt-Regamey et al., 2013; McCall et al., 2015). With the knowledge that the identification of stakeholders who have detailed and reliable knowledge of the issue at hand is critical to the success of an expert mapping exercise (Debolini et al., 2013) through attendance at several meetings (SAHTA AGM, July 2015; Gouritz Biosphere Reserve Quarterly Forum, November 2015; Honeybush Strategy Workshop Storms River, July 2015) and discussions with key honeybush industry stakeholders, several experts were identified who gave expert mapping input. Botanist, Mr J. Vlok was identified as able to provide input on the location of populations of *C. intermedia* across the entire distribution range on 1: 250 000 maps. Another 15 'expert mappers' produced local and regional scale delineations of honeybush populations, including six farmers with a history of harvesting; five farmers who participated in the EADP 817 wild harvesting information sessions; three harvest managers and a retired agricultural extension officer (complete list in Table 2.2). For regional scale mapping in the greater Langkloof area, 1:50 00 topographical map sheets were used as these were familiar to most experts. At the local scale, (per farm) customised digitally prepared 1:10 000 or 1:25 000 scale (dependent on farm size) base maps showing standard 1:50 000 vector features (contours, roads, rivers, dams, spot heights) on a photo map or topographic map sheet background were prepared. The base map was designed to be easy to read and had familiar additional landmarks (buildings, landmarks, gates, tracks etc.), for easy reference by the farmer. A further 22 local-scale harvest area maps were available from the 75 harvest permit records in the EC DEDEAT permit collection. Existing farm-scale honeybush harvest management plans (including detailed maps) were available for 10 farms managed in collaboration with the NGO Living Lands.

From all of these data collection sessions, paper maps of the Eastern and Western Cape were scanned and geo-referenced in ArcMap 10.3 to vector features (roads, rivers, towns) (CD:NGI, 2016). All the polygons of

C. intermedia populations were digitised, and attributes such as camp names and harvest history were added to create representations of the actual occurrence of *C. intermedia.* The data collected through expert mapping was used to input all the objectives listed in this chapter.

Table 2.2: Expert mapping data collection sessions delineating known areas where *Cyclopia intermedia* occurs, including the meeting type, expert name, nature of data captured and description of data and mapping scale.

Meeting type	Expert	Description of data captured
	Provincial scale mapping	
Contribution to the Wild Harvesting Guidelines for *C. intermedia* (McGregor, 2017)	Mr. J. Vlok, Botanist	Polygons of *C. intermedia* distribution across full extent at 1: 250 000; sites where populations have declined.
	Regional scale mapping	
Interview, mapping and field visit	Mr. S. van der Merwe, Retired Agric. Ext Officer	Polygons of *C. intermedia* populations in the middle Langkloof and Tsitsikamma at 1:50 000; sites of illegal harvesting; sites where yields have declined, good knowledge of populations across the Langkloof region.
Interview	Mr. D. Hodgson, Farmer	Polygons of *C. intermedia* distribution across the Bo-Kouga and upper Langkloof at 1:50 000; sites where populations have declined.
Interview and mapping	Mr. S. Scheepers, Farmer	Polygons of *C. intermedia* populations in Elands Valley at 1:50 000. Good historic knowledge of honeybush harvesting in the EV.
Interview and mapping	Mr. P. van Rensburg, Harvest manager	*C. intermedia* populations in the middle Langkloof and Tsitsikamma at 1:50 000; sites where illegal harvesting is an issue; sites where yields have declined. Good knowledge of populations across the Langkloof region
Interview, mapping and field visits	Mr. C. Schutte, Harvest manager	Polygons of *C. intermedia* populations on six farms, in the Bo Kouga, Haarlem and Uniondale area; mapped at 1:50 000
	Farm scale mapping (covering 44 farms, honeybush populations represented as polygons)	
Interview, mapping and field visit	Farmer 1	Polygons of *C. intermedia* populations, Farm 1, Middel-Kouga, , polygons of 'misty' zones, 1:10 000
Interview, mapping and field visit	Farmer 2	Polygons of *C. intermedia* populations on Farm 2 northern Tsitsikamma slopes, middle Langkloof at 1:10 000
Interview, mapping and field visit	Farmer 3	Polygons of *C. intermedia* populations on Farm 3 in the eastern Kouga at 1:20000
Interview, mapping and field visit	Farmer 4	Polygons of *C. intermedia* populations on Farm 4 in the Onder-Kouga depicted using Google Earth at approx. 1:10 000
Interview, mapping and field visit	Harvest manager 1	Markers to identify where honeybush populations grow well across Farms 5, 6, 7
Information session EADP 817 – mapping farm resources by interview (McGregor, 2018)	Farmer 5	Polygons of *C. intermedia* populations on Farm 8, Upper Langkloof, at 1: 8 000
	Farmer 6	Polygons of *C. intermedia* populations on Farm 9, western Baviaanskloof at 1:20 000
	Farmer 7	Polygons of *C. intermedia* populations on Farm 10, western Baviaanskloof at 1:8 000

	Farmer 8	Polygons of *C. intermedia* populations on Farm 11, upper Krom at 1:8 000, plus honeybush infrastructure
	Farmer 9	Polygons of *C. intermedia* populations on Farm 12, western Langkloofberge at 1:20 000
Mr. M. Sephton, 2020: Drawing up honeybush management plans for farms	10 farmers	Polygons of *C. intermedia* populations on 10 farms, middle and upper Langkloof, at high resolution (GPS mapping) and 1:10 000 (Google Earth mapping)
EC DEDEAT permits	22 farmers	Maps at various scales across the EC honeybush-producing areas with varying levels of detail from about 1:10 000 to 1:20 000

2.4.3 Modelling potential areas of occurrence of *C. intermedia*

2.4.3.1 Vector-based Multiple Criteria Selection (MCS)

To identify areas where *C. intermedia* was likely to occur within its distribution range, GIS-based multiple criteria selection (MCS) was used. The criteria for this exercise were based on habitat characteristics given in available literature on *C. intermedia* (mainly from Schutte, 1997; and Joubert et al., 2011, with expert input from Prof. R. Cowling (pers. comm., October 2016). Typically, a set of criteria must be met (hence the term multiple criteria selection, Jones, 1997), which can be quantified according to user-specified rules, and selected for in the model using Boolean or arithmetic logic. Various processes such as buffer, intersect, and query by attribute can produce outputs that meet the required criteria (Bolstad, 2016). The variables used (spatial data layers) and criteria (value range per variable) defined for this analysis are given in Table 2.3.

Table 2.3: Identifying areas suitable for *Cyclopia intermedia* growth using secondary data to refine the distribution range for the species.

Variable	Source	Scale of data	Refined *C. intermedia* criteria (incorporating ≈ 90% of records)
Vegetation type	National Vegetation map, (SANBI 2012)	1:50 000	16 fynbos vegetation types, NOT Renosterveld or Shale types classified as 5 main types plus 'others'
Elevation	SRTM 30m DEM, (NASA, 2012)	30m res.	350-1800m
Aspect	SRTM 30m DEM, (NASA, 2012)	30m res.	NOT flat, OR North or OR North West
Slope	SRTM 30m DEM, (NASA, 2012)	30m res.	NOT 0-5º or > 35 º
Landcover	NLC 2018, (DEA, 2019)	20m res.	All natural landcovers, NOT transformed

The modelling approach used to identify areas of potential *C. intermedia* occurrence within the distribution range polygons is shown in Figure 2.3. In the first step of the model, attributes for every layer were extracted (for raster data) or 'joined' (for vector data) to the *C. intermedia* locality records. From this dataset, the most common values per variable were identified based on the sorting of records (Step 2). This part of the model was run 3 times with the exclusion of the sum of the least common values for the layers making up 35%, 25% and 10% of the records, respectively. The criteria used in the final and preferred version of the MCS incorporated 85%-90% of the records. Polygons that met suitable criteria in the vector layers were selected (Step 3) or reclassified into suitable/or not suitable for *C. intermedia*. In step 4, the raster layers were masked, and the vector layers clipped to the *C. intermedia* distribution map to limit the spatial extent for each layer. In step 5, the raster layers were vectorised for input to the polygons where all criteria were met in all the layers, amounting to areas of land where *C. intermedia* would potentially grow.

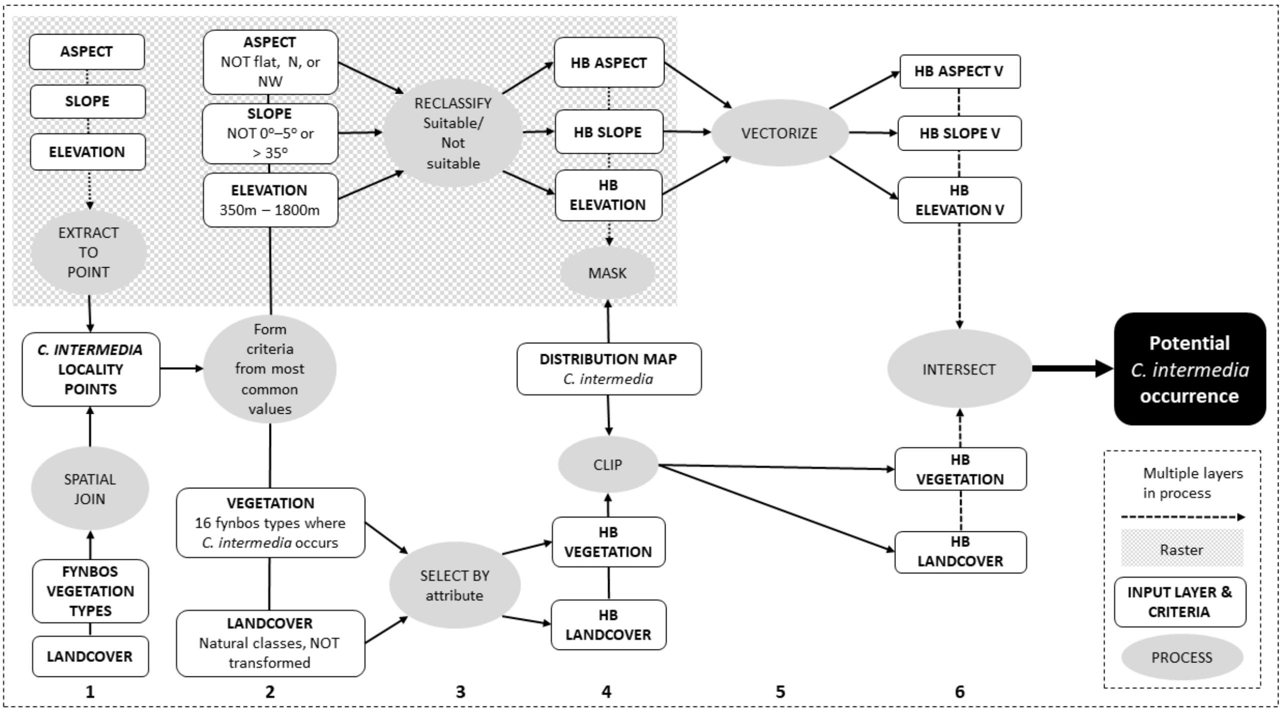


Figure 2.3: Model 2 - full MCS model identifying potential areas of *Cyclopia intermedia* occurrence within the distribution range based on selected criteria for environmental layers with that meet the range requirements of the species. The sequence of steps (1-6) is numbered in the diagram and described in the text. Both raster and vector layers are inputs to the model. The raster layer analysis is indicated by the grey chequered underlay; all other layers and process are vector based. Abbreviations: HB = honeybush, V = vector model layer.

2.4.3.2 Species distribution modelling using MaxEnt

In addition to the mapping exercise described above, a second distribution map in the form of a probability of occurrence layer was produced using the MaxEnt software for species distribution modelling. In the model, probability is defined as a measure of the likelihood that an event will occur. Species distribution mapping (SDM) is based on the extraction of environmental characteristics which exist at the site of a known population, which are used to 'train' the model to identify sites where similar characteristics are met in the landscape (Elith et al., 2011; Thompson et al., 2011). By using the bioclimatic variables (19 temperature and rainfall layers) as input to the SDM, climatic factors not included in the MCS mapping were incorporated in the modelling.

Running the model

In ArcMap 10.3, 441 *C. intermedia* locality data points were resampled to a set of 162 points to prevent spatial autocorrelation. The 19 BIOCLIM (Fick & Hijmans, 2017), global 30-second grids (≈ 1 km x 1 km) were reduced to a rectangular area covering the extent of the fynbosbiome. The fynbosbiome, consisting of 122 vegetation types (SANBI, 2012) in vector format, was converted to raster format to provide a restricted geographic extent for the model (as recommended by Anderson & Raza, 2010 and Thompson et al., 2011). The spatial reference for all data layers was set to geographic coordinates, referenced to the WGS84 datum.

In MaxEnt, all prepared layers were added, and the 'auto-features' function was set (by default) to automatically calculate how complex (either a linear or quadratic analysis) the model could be based on the number of occurrence locations. Other default settings of 500 iterations and a 0.00001 convergence threshold were used with the *Cloglog* output format, which converts the raw predictions to probabilities and was recommended for use when a phenomenon has a fixed location, as is the case for plant species (Liu, 2022; Phillips et al., 2017). Five replicates of the model were run to derive an averaged probability of occurrence surface. For this study, Jackknife analyses (graphic outputs which reflect the relative contribution of each bioclimatic variable to the model result) and response curves (statistical outputs which indicate the accuracy of the model) were generated. The resulting surface was converted to GRID format in ArcMap 10.3 and reclassified into 10 classes with a lowest class of 0-0.1 and a highest class of 0.9– < 1 probability. The lowest (highly unlikely occurrence) was removed from the dataset. To derive areas from the data and for aesthetic purposes, the data was re-projected to a customised, commonly used South African projection: Albers Equal Area, Central Meridian 25^{o} East, Standard Parallels -24^{o} and -33^{o} South, referenced to the WGS84 datum.

2.4.3.3 Combining the MCS and SDM results

As represented in Model 3, Figure 2.4, the SDM surface was again reclassified to represent all areas where there was > 0.5% probability of occurrence (Step 1) to restrict the distribution to areas where the plant might reasonably be found (as recommended by Marx & Quillfeldt, 2018). The reclassified surface was intersected with the MCS layer (Step 2) to identify areas where the two models coincided, representing a greater likelihood of occurrence. To improve the validity of the modelling exercise, the farm harvest areas (local scale, actual occurrence data) and the complete set of locality records were overlaid with the modelled potential occurrence layer to identify missing areas of actual occurrence. Any missing area polygons were reselected from the MCS layer (Step 3) and re-incorporated (Step 4) into the final modelled potential area of occurrence.

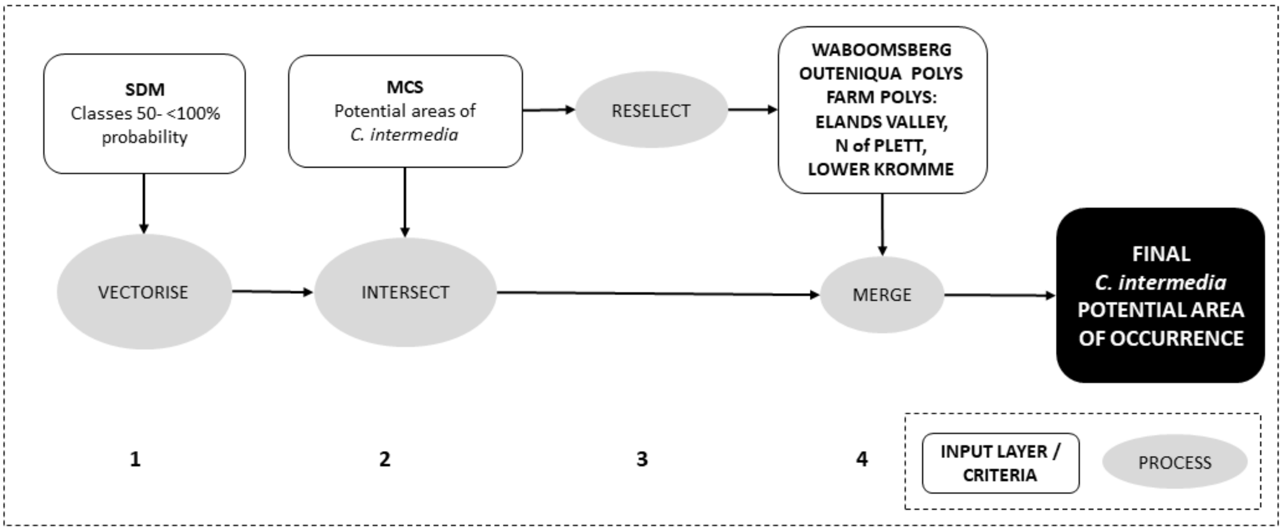


Figure 2.4: Model 3 - Combination of the results of MCS and SDM to produce a final potential area of *Cyclopia intermedia* occurrence.

2.4.4 Quantifying the harvested /potentially harvestable resource

To estimate the extent of the harvestable resource within the *C. intermedia* distribution range, a fourth model was used to create a harvest zone within which harvesting is known to occur. In Figure 2.5, Step 1, a minimum bounding polygon was delineated around the mapped farm harvest areas representing the harvest zone. In the process, areas of occurrence in the arid western part of the range, where commercial-scale harvesting does not occur (McGregor, 2017b) due to difficult access, distance from processing facilities and the prevalence of protected areas where no harvesting is allowed, were excluded. In Step 2, the input layer of modelled potential *C. intermedia* occurrence (Model 3) and the protected areas layer were clipped to the new harvest zone. In Step 4, the potential *C. intermedia* occurrence areas, the farm harvest polygons and protected areas were combined through 'union' to produce a single layer containing attributes of all input layers. The area of potential C. intermedia occurrence within and outside protected areas and actual farm harvest areas was calculated from this.

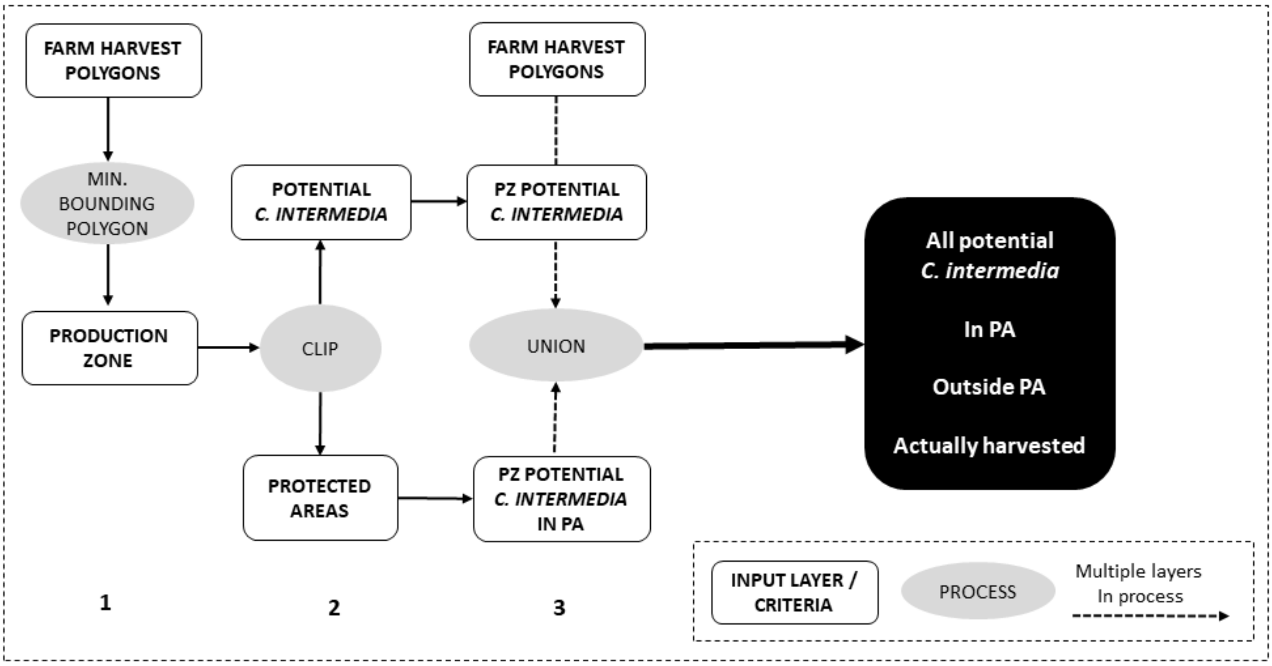
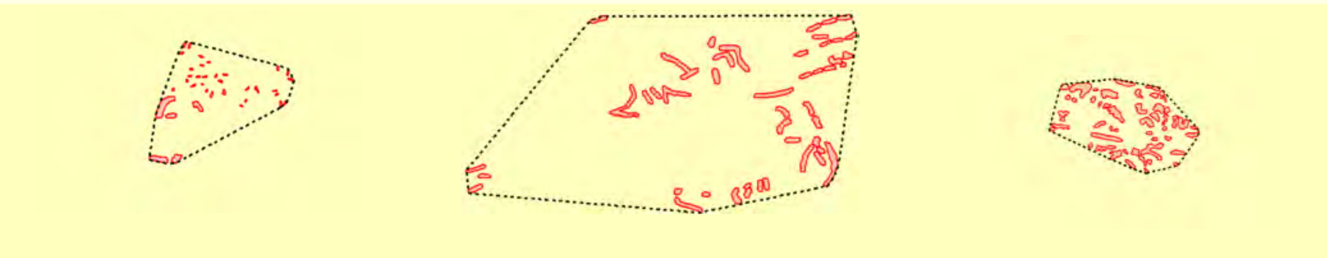


Figure 2.5: Model 4 – the process followed to identify the harvestable area within the *Cyclopia intermedia* range based on areas which are already harvested or are likely to be harvestable. Abbreviations: PZ= production zone; PA = protected areas

To verify the validity of the modelled results, the area of overlap between the potential occurrence layer and the mapped farm areas was calculated as a percentage. Then, to calculate the relative absence/presence of honeybush in the landscape, a minimum bounding polygon was defined around clusters of harvest areas as illustrated in Figure 2.6. From a total of 17 clusters of harvest areas (247 polygons), the average proportion of *C. intermedia* in the landscape was calculated for input to model the actual occurrence of *C. intermedia* across the whole production zone.

Examples of clusters of farm harvest polygons (in red) representing actual harvested honeybush patches, with a range of absence/presence proportions relative to a cluster boundary size (dashed black line). Diagrams are all at the same scale.



Boundary: 31.53 km²	**Boundary:** 184.27 km²	**Boundary:** 30.92 km²
Area of populations: 1.74 ha	**Area of populations:** 1228 ha	**Area of populations:** 660.35 ha
Area of presence: 5.39%	**Area of presence:** 6.67 %	**Area of presence:** 21.35%
Area of absence:: 94.61%	**Area of absence:** 93.33 %	**Area of absence:** 78.65% absent

Figure 2.6: Estimating the presence of *Cyclopia intermedia* in the landscape based on existing farm harvest areas

Working in the production zone, the output from Model 4 was used in combination with values derived from other parts of this research (detailed in Table 2.4) to estimate the area of the actual harvestable resource and the potential yield from the resource as detailed in Equations 2. 1 and 2.2.

Table 2.4: Values used to calculate the harvested and potential unharvested resource.

Factors for inclusion in the calculation of the harvestable resource	Values	Source
Area of production zone • In protected areas • Outside protected areas	1448 km^2 707 km^2 741 km^2	This chapter This chapter This chapter
Best practice harvest interval	4 years 5 years	McGregor 2017 This research – Ch 5
Ave. plant yield	0.590 kg	This research – Ch 4
Ave. plant density in harvested populations	765 plants / ha	This research – Ch 5
Mapped harvest area Estimated unmapped harvest area Total estimated harvest area	72 km^2 / 7200 ha 28% / ≈ 72 km^2 / 2800 ha 100 km^2 /10 000 ha	This chapter
C. intermedia presence in the landscape	13.74%	This chapter

Equation 2.1: Estimating the area of the actual harvestable resource based on the modelled potential area of occurrence and the relative presence of *C. intermedia* in the landscape of the production zone:

$$P_e = \frac{\bar{P}}{100} \times HZ_p$$

Where P_e is the estimated presence of *C. intermedia* in the production zone, $\bar{P}$ is the average presence of *C. intermedia*, in the landscape and HZ_p is the modelled potential area of *C. intermedia* in the production zone (km^2).

Equation 2.2: Estimating the potential yield from 10 000 ha of harvestable *C. intermedia* based on four- and five-year harvest intervals:

$$Y_p = a \times d_p \times kg$$

Where Y_p represents the potential yield in kg (wet material), a is the estimated farm harvest area (ha), d_p is plant density (ha), and kg is the plant yield (wet material) in (kg).

2.5 Results

2.5.1 Distribution range of *C. intermedia*

The first map in the results series (Figure 2.7a) shows available historical data on the distribution of *C. intermedia* at the start of this research. Existing maps were generalised, and failed to represent some mountain areas, for example, the Witteberg (northernmost population), the Waboomsberg (westernmost population) and areas along the Outeniqua Mountains. The map by Beyers (2016) did not capture the more southerly extent of the north-facing slopes of the Tsitsikamma Mountains (in the Langkloof) and the south-western mountain areas. The historic locality data was more widely distributed and produced an Extent of Occurrence of 24 249 km^2 (EOO, based on the maximum bounding polygon method described by the IUCN, 2018), which came within range of the current EOO of 28 585 km^2 (Mhlongo et al., 2022). The differences described may also be an artefact of the loss of accuracy in geo-referencing the generalised maps for digitising.

Figure 2.7b shows the extent of fynbos communities where *C. intermedia* was likely to occur. A refined vegetation layer excluded the valley bottoms (mostly Renosterveld vegetation types), the river valleys and kloofs where thicket vegetation dominated, and kloofs where patches of afro-montane forest grew. The boundaries of the selected vegetation polygons were useful in delineating the more refined shape of all the *C. intermedia* range polygons. Within this boundary, the extent of protected areas amounted to 5 654 km^{2,} representing close to half the species range. A detailed distribution range map, for orientation of the simplified graphic versions, is shown in Figure 2.8.

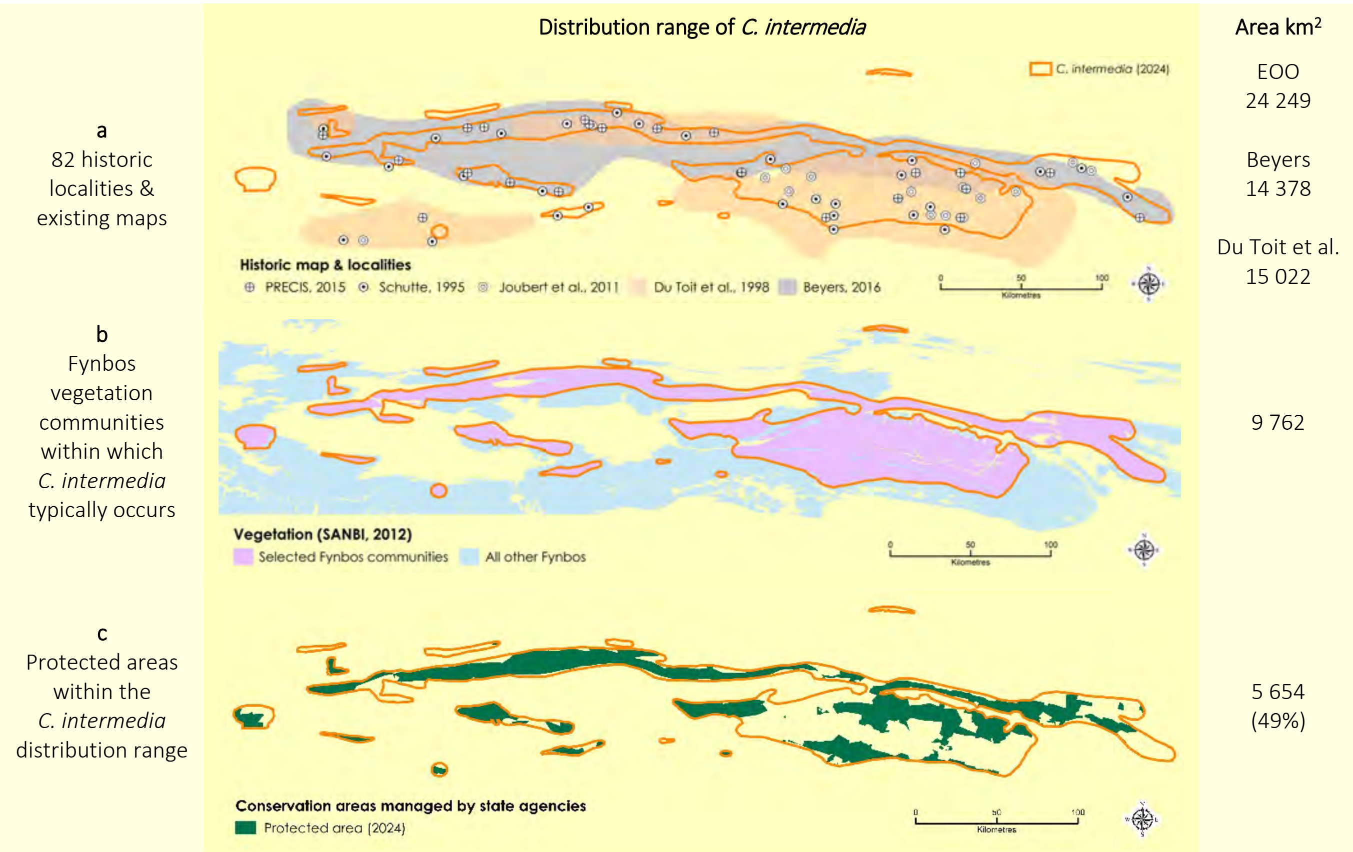


Figure 2.7: Establishing the geographic range of *Cyclopia intermedia.*

Figure 2.8: Distribution range of *Cyclopia intermedia* (11 496 km^2) in its final form (2024) with selected base map features for reference.

2.5.2 Expert mapping

The results of the expert mapping exercise are illustrated in Figure 2.9a and b. The collective effort of the expert mapping contributed significant value to mapping areas not represented in existing data, where each expert added their specific, local area knowledge. At the full range of the species distribution, Vlok mapped 2 531 km^2 of areas where *C. intermedia* occurred, representing a substantial contribution to delineating a full distribution map. Vlok's detailed knowledge of mountain localities was important in representing many mountain populations (in order from east to west): Waboomsberg, Witberge, Matjiesgoedberge, Anysberg, Warmwaterberg, Elandsberg, Klein Swartberg, Touwsberg, Rooiberg, Langeberg, Groot Swartberg, Gamkaberg, Kammanassie Mountains, Outeniqua Mountains, Witteberg, Baviaanskloof Mountains and Kouga Mountains. Areas not represented by Vlok were found at the south-eastern extent of the range in the Tsitsikamma Mountains and the far east of the range, in the Groot Winterhoek Mountains, Elandsberge and van Stadensberg.

The combined efforts of local scale expert mapping made up a further 570 km^2. Mapping at the local scale by van Rensburg and van der Merwe filled in details on the north-facing slopes of the Tsitsikamma (in the Langkloof). Scheepers contributed significant information on populations in the Elands Valley (the far eastern end of the range) that was unknown to other experts. Hodgson and Schutte filled in areas in the Bo-Kouga (not covered by Vlok), and in the Witteberg, west of the Langkloofberge, extending as far south as de Vlugt (east and west of the Prince Albert Pass to Plettenberg Bay). Local expert knowledge was biased towards experts in the Langkloof region because this research focused on the use of the wild *C. intermedia* resource, which is concentrated in the Langkloof.

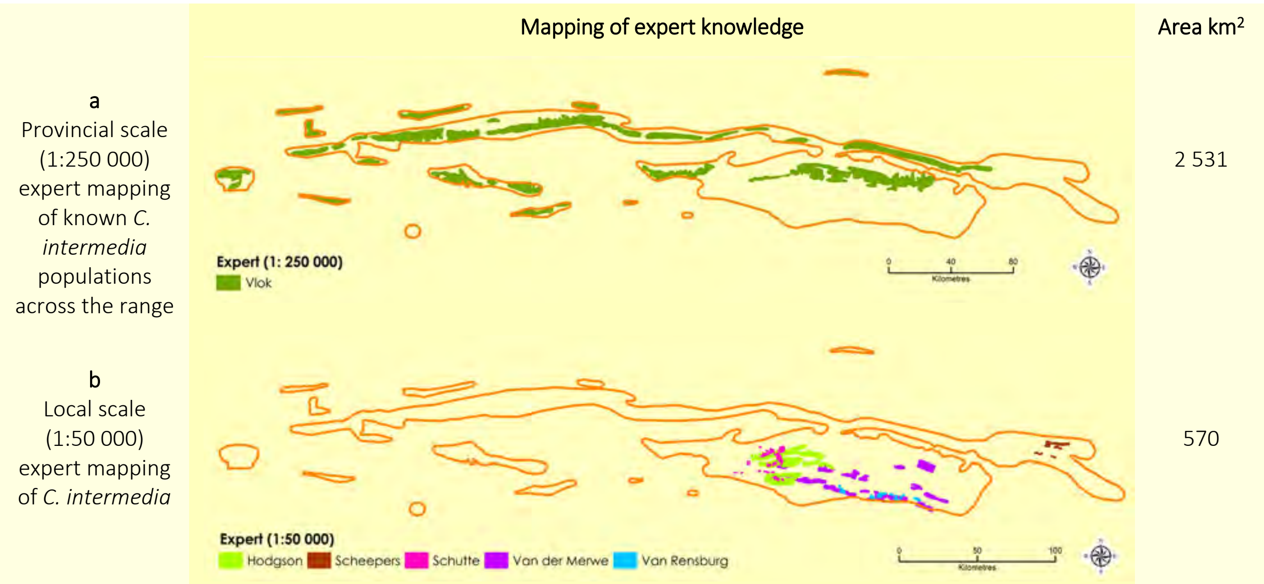
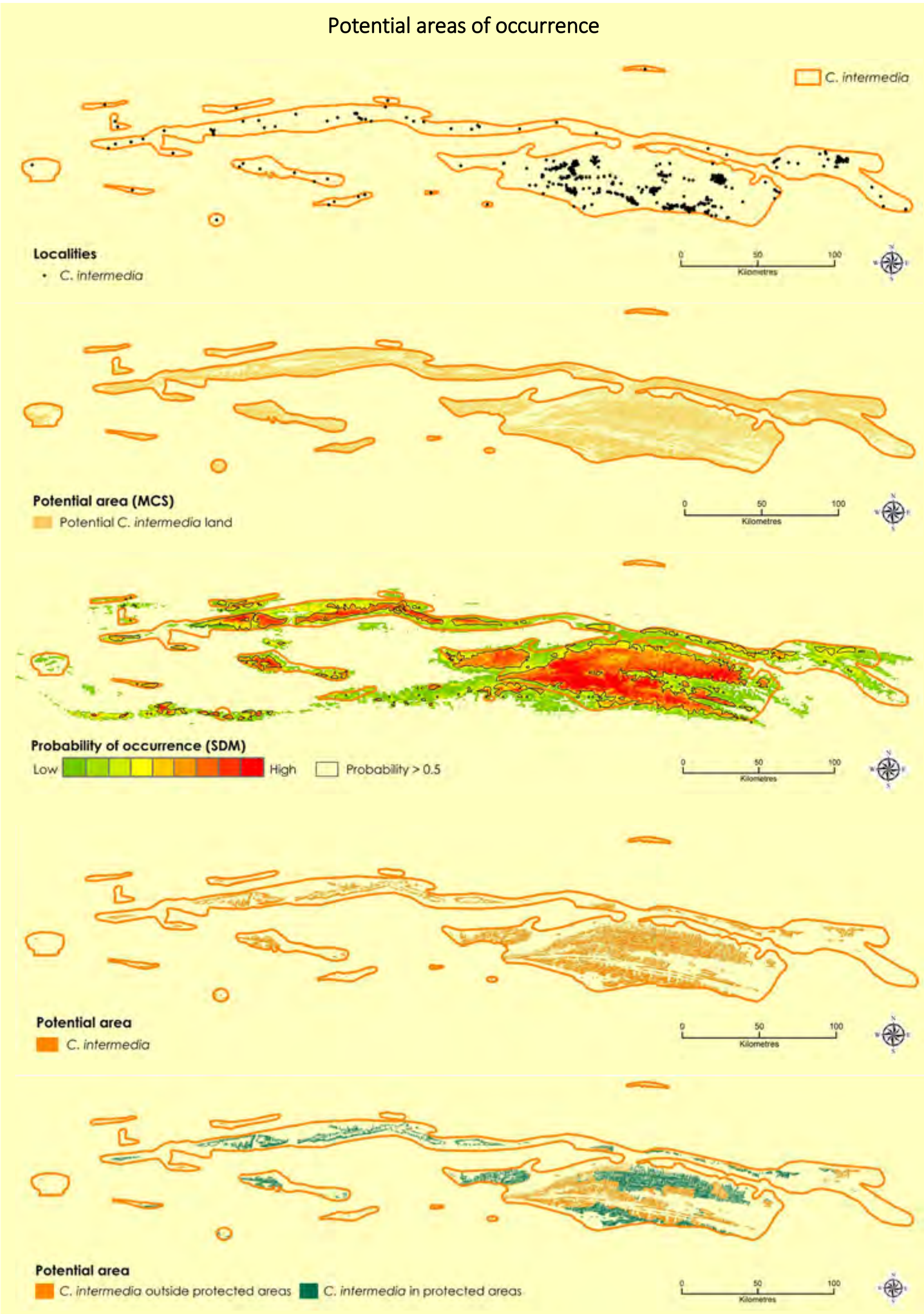


Figure 2.9: Mapping the resource using expert knowledge.

2.5.3 Modelling potential areas of occurrence of *C. intermedia*

Within the distribution range, the areas where *C. intermedia* was likely to occur were modelled to give a potential area of occurrence. For ease of comparison, the series of map-based results are presented first in Figure 2.10a–e, followed by results relating to the SDM and MCS modelling (Figure 2.11–13). A set of 541 locality records (Figure 2.10a) were used in an MCS process based on available environmental variables, to define the area represented in Figure 2.10b. A filtered set of locality records plus bioclimatic variables were input to a SDM (Figure 2.10c). The combined results of the MCS, plus high probability areas (0.5 to <1) from the SDM gave a likely area of occurrence of 2253 km^2 (Figure 2.10d). Based on this likely area of occurrence, the proportion falling within protected areas was estimated at 61% of the area (Figure to 2.10e).



	Area (km^2)
a Locality data from historic records (82), expert mapping (359), field mapping, (100)	541 (points)
b GIS based MCS: potential areas of occurrence of *C. intermedia*	4824
c SDM: probability of occurrence across the range, with areas of >0.5 probability outlined	Full extent 12 849 >0.5 4 754
d SDM & MCS combined - potential *C. intermedia* area	2253
e Proportion in protected areas, in potential *C. intermedia* area	1365 (61%)

Figure 2.10: Modelling the area of potential occurrence of *Cyclopia intermedia* within the distribution range.

2.5.3.1 Multiple criteria selection (MCS)

The analysis results (Model 2, Figure 2.3) carried out to produce the MCS layer (Figure 2.10b) are described below.

Landcover

Landcover within the distribution range was categorised mainly as untransformed (89.22%). The mountainous nature of the distribution range of *C. intermedia* means that only a small portion of the land found in the valley bottoms is suitable for intensive agriculture (3.6%), with adjacent hillslopes (shrubland and grassland) utilised as rangelands for livestock grazing and harvesting of wild *C. intermedia*. Settlements (built-up areas) in the rural landscape are small in number and spatial extent and make up less than 0.3% of the landscape. An example of landcover in a developed part of the study area in the middle Langkloof, is illustrated in Figure 2.11.

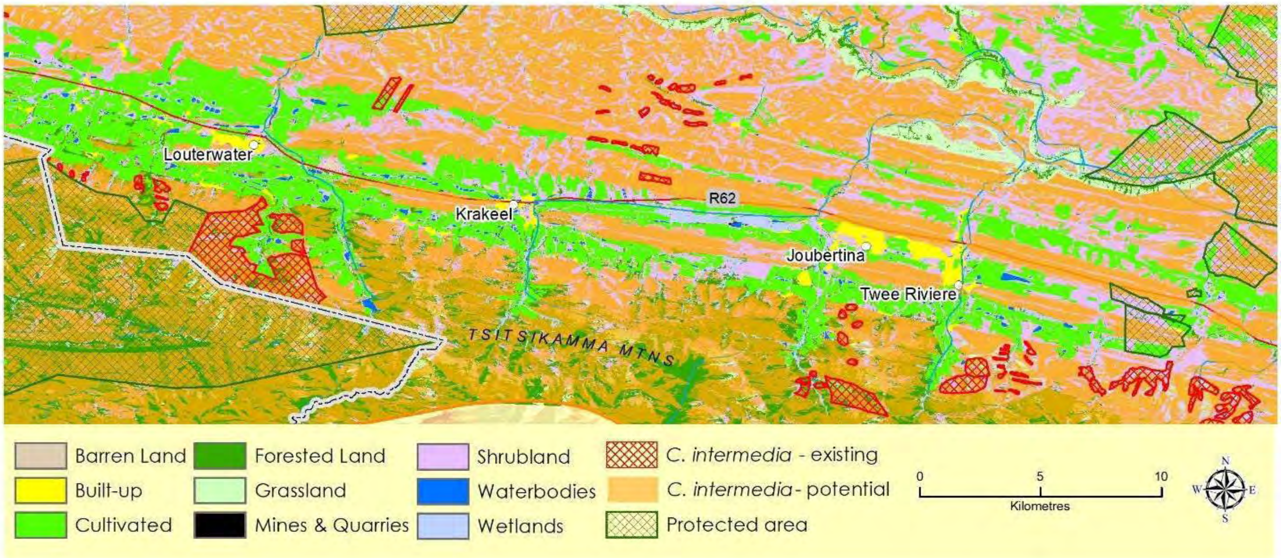


Figure 2.11: An example of landcover in the Langkloof within the *Cyclopia intermedia* distribution range.

Vegetation

Analysis of the vegetation communities in the *C. intermedia* range was based on expected frequency of occurrence in the full range (i.e. proportion of area in each vegetation community) relative to observed frequencies (proportion of localities per vegetation community). In Figure 2.12, where the orange bar (percentage of observed localities) was taller than the blue bar (expected frequency based on area of vegetation community as a percentage of the full range), there was a strong preference for that vegetation type. Locality records were found predominantly in three vegetation types – Kouga Grassy Sandstone Fynbos (36.35%), Kouga Sandstone Fynbos (24.67%) and North Swartberg Sandstone Fynbos (23.54%) making up 84.56% of the records. *C. intermedia* was less common in South Swartberg Sandstone F. (3.77%), Tsitsikamma Sandstone Fynbos (3.01%), and in the 12 vegetation types combined as 'Other Fynbos' communities (8.66%).

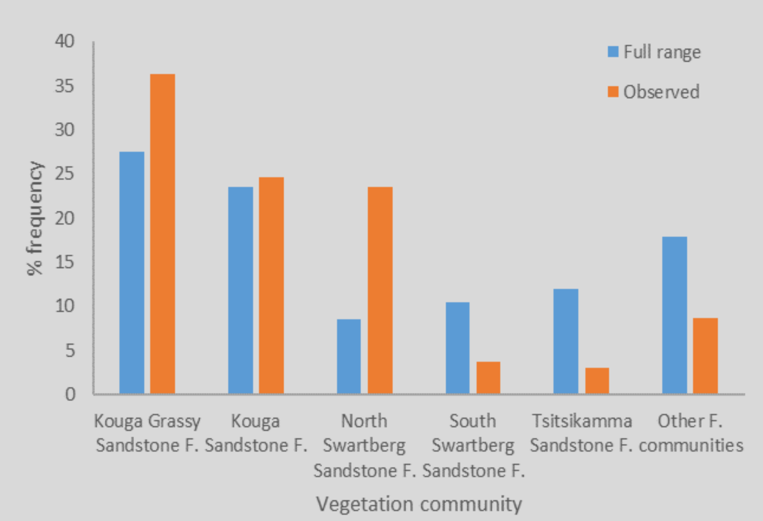


Figure 2.12: Vegetation communities in the *Cyclopia intermedia* distribution range

Slope aspect, slope and elevation

The preferred slope aspect, slope and elevation classes were extracted from existing locality data to identify areas within the distribution range where C. intermedia was most likely to occur. The results showed that while locality records existed for all slope aspects, most localities fell within (and showed a preference for) the range of south-easterly through to westerly (Figure 2.13a). Despite the availability of north and north-west facing slopes (i.e. high frequency in the full range), locality records were least common in these classes (i.e. low observed frequency). For the north-easterly, easterly and westerly classes, the proportion of records in the full range was about equal to the observed frequency. Locality records in the 'flat' class make up <0.02 of the records and are, therefore, not visible on the graph. There is a distinct preference for slopes in the range of 10–29° degrees (Figure 2.13b), despite the availability of flatter areas (0–9°), which comprise 29% of the full range, probably because all such sites have been transformed for agriculture. Where the slope became too steep (35° and greater), soils were likely shallow and poor in moisture content and, therefore, unsuitable *for C. intermedia* growth. The elevation category of 600–1199 masl (Figure 2.13c) was most commonly associated with *C. intermedia* populations, making up 86% of the observed records. In these areas, the observed frequency was greater than what was available in the full range, suggesting a habitat preference. However, since the higher elevation sites occurred in remote locations in protected areas rather than harvest areas (which had a greater representation in surveys), this may represent a bias in the data collection. Above 1600 m, there were no harvest areas; above 1800 m, there were no records of *C. intermedia*.

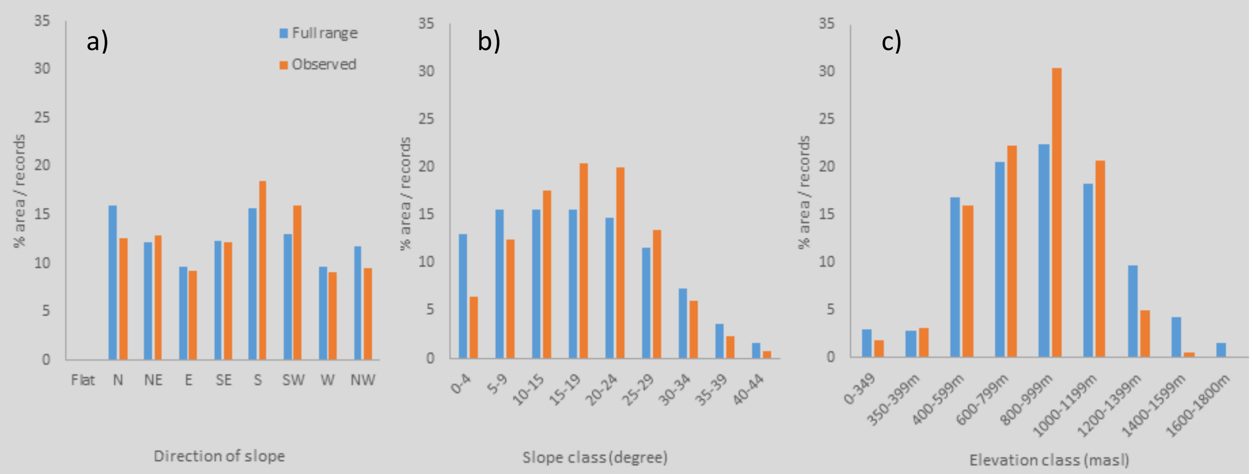


Figure 2.13: Physical variables in the *Cyclopia intermedia* distribution range and at the locality sites.

2.5.3.2 Species Distribution Model (SDM)

In manipulating the MaxEnt model output, cells in the 0–0.1 class of probability of occurrence were removed for a more realistic view of the data, covering an area of 12 849 km^2 and giving an 88% overlap with the distribution range map. On further inspection, and based on knowledge of the species, it was found that areas in the 0.1–< 0.5 class were mostly found on the fringe of the distribution range, often in areas where other *Cyclopia* spp occurred or did not coincide with expert knowledge mapped localities or existing location records. Areas in the 0.1–< 0.5 class were excluded, leaving areas with a likelihood of occurrence of> 0.5. The SDM failed to make strong predictions for the presence of *C. intermedia* in the Elandsberg (five farm harvest areas making up 229 ha), the Baviaanskloof Mountains, the Waboomsberg (expert knowledge), Witteberg (expert knowledge) and lower Kromme River area (farm harvest polygons). In some areas illustrated in Figure 2.14, the SDM made strong predictions of occurrence (>0.5) that did not coincide with the distribution range (and would therefore be excluded). In the areas illustrated, there is also an overlap of occurrence with other *Cyclopia* spp.: *Cyclopia subternata* is common in the Outeniqua Mountains (Figure 2.14a) and *Cyclopia sessiliflora* is endemic to the Langeberg (Figure 2.14b).

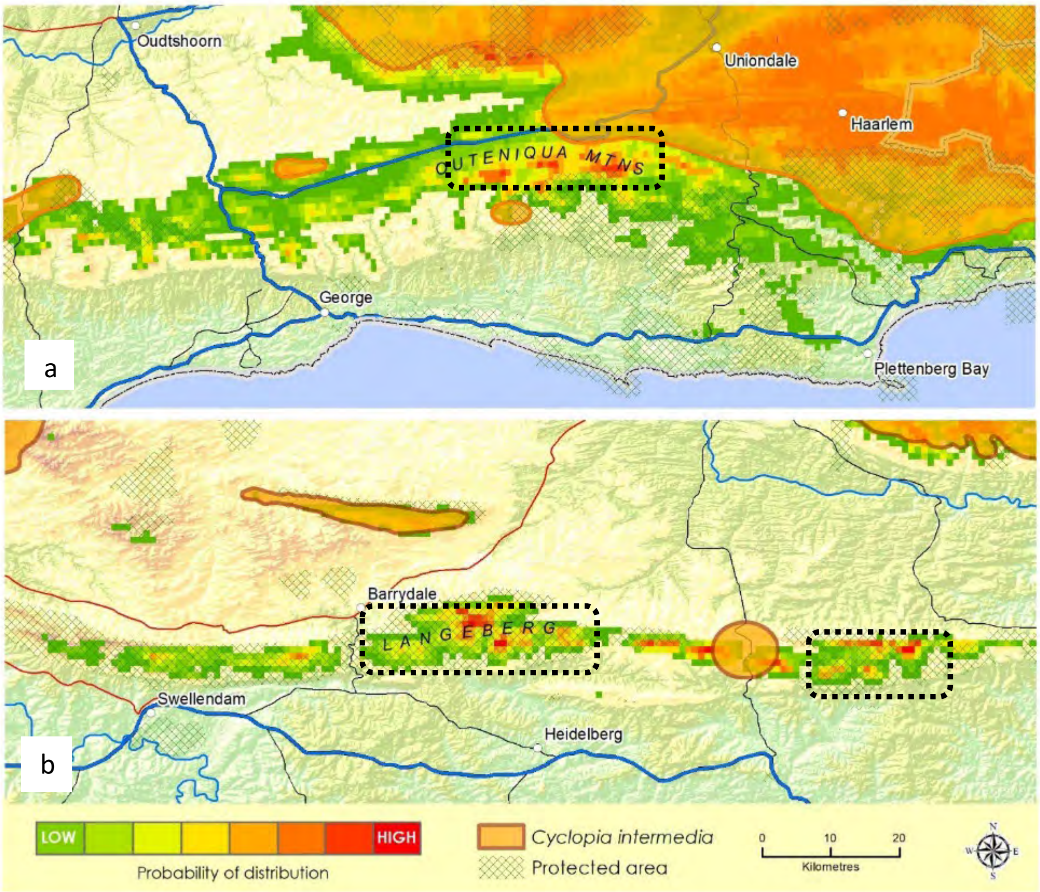


Figure 2.14: Examples of localities where the SDM gave high probabilities of occurrence, in areas that were not known to have populations of *Cyclopia intermedia* which were therefore excluded from the final modelled occurrence layer.

2.5.3.3 Combining the MCS and SDM

The area of overlap of the MCS and SDM layers amounted to 47% (2 216 km^2). By combining the MCS layer (based on environmental variables) with the SDM (based on bioclimatic variables), a refined estimate of the potential area of occurrence, accommodating more specific habitat requirements, was created. As a test of the validity of the modelled area of occurrence, the layer was overlaid with farm harvest areas (i.e. actual occurrence): 25 out of 45 farms had an area of overlap of > 70% (and as high as 90%), 9 farms showed a 50–70% overlap, and 3 farms showed an overlap of 40–50%. Seven farm harvest areas in the Elandsberg (EC) and Lower Kromme River were found to be missing from the layer as they had a low probability of occurrence in the SDM. Areas in the Waboomsberg and Witteberg (EC) where *C. intermedia* was known to occur were also not represented. In total, 37 km^2 of potential occurrence areas were reselected from the MCS model and added into the final modelled area of potential occurrence (2 253 km^2).

2.5.4 Quantifying the harvested /potentially harvestable resource

The area in which *C. intermedia* was harvested formed the focus of delineating a commercial harvest area (named the production zone), of 1448 km^2 (Figure 2.15a). Areas within this zone, mapped through expert mapping and on harvest permit applications, represented 70% – 75% of farm harvest areas (where *C. intermedia* actually occurs) for the Eastern Cape, as confirmed by the EC DEDEAT permit officer, Mr. G.

Ferreira (pers. comm., October 2019). Expert mapping by other farmers and harvest managers in the Western Cape (where permits are not required) covered around 70% – 75% of WC farm harvest areas, as confirmed by harvest manager, Mr. C. Schutte (pers. comm., November 2016). The total mapped area of farm harvest polygons amounted to 72 km^2 (Figure 2.15a), plus the estimated missing 25 %, which gave an area of around 100km^2 of *C. intermedia* populations which are harvested. Within the production zone, comprised mainly of the greater Langkloof region, extending east into the Kromme valley, north into the eastern Kouga and including the Elands Valley area, 49% of the land was within protected areas managed for conservation by state conservation agencies. In comparison, 51% (741 km^2) fell outside protected areas (Figure 2.15b).

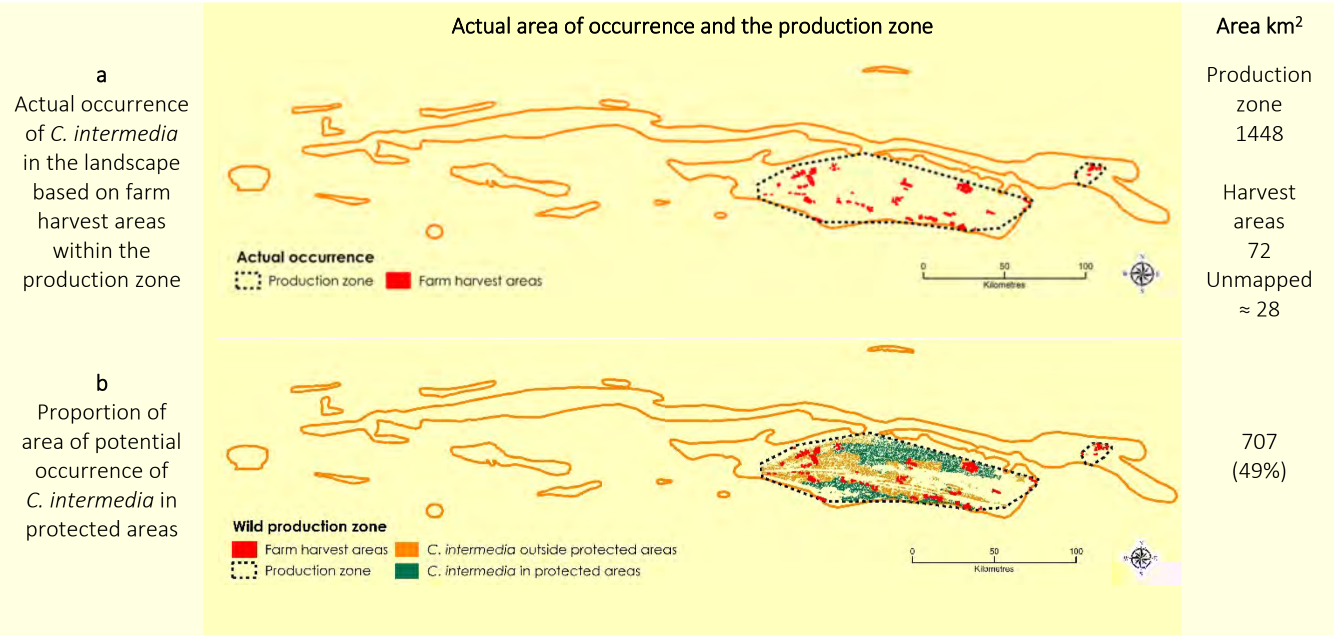


Figure 2.15: The area of wild harvesting of *Cyclopia intermedia* used for commercial production.

Estimating the size of the harvestable resource

Within the production zone, a calculation (Equation 2.1) to estimate the actual extent of the harvestable resource based on the modelled potential area of occurrence and the relative presence of *C. intermedia* in the landscape (13.47%), produced a figure of 99.8 km^2 (9 980 ha). The figure is nearly identical to the mapped farm harvest area of 100 km^2 (10 000 ha). Using this area of actual occurrence, the estimated potential yield from the harvestable area was 4 513 tonnes, based on an average density of 765 plants/ha and a per plant yield of 0.59 kg (Equation 2.2). In terms of best practice harvesting – a four-year interval between harvests would produce 1 128.375 tonnes annually, while a five-year interval would yield 902.7 tonnes annually. The proportion of *C. intermedia* land in the production zone, which falls in protected areas (49%), is close to the size of the area outside protected areas, therefore, the potential size (yield) of the resource under protection would be similar, at around 4513 tonnes.

2.6 Discussion

The overall aim of this chapter was to map the *C. intermedia* resource. From a set of only 33 existing botanical locality records, plus 49 historic map records, the locations of a further 459 populations were captured. By combining historical map data with existing historic locality records and fynbos vegetation community boundaries where *C. intermedia* is likely to occur, a distribution range map covered 11 946 km^2. To produce a more accurate estimate of areas where *C. intermedia* was likely to occur within the distribution range map, GIS-based modelling and SDM were employed. The resulting layer covered an extent of 2 253 km^{2,} with 61% of the area falling under protected areas. The most detailed data was provided by farmers and other experts who mapped the actual occurrence of harvested *C. intermedia* populations covering an area of 72 km^2. A further 28 km^2 was added to this figure, based on expert knowledge, to give a total area of harvested *C. intermedia* of 100 km^2 within the production zone of 1448 km^2. Data from the analysis of harvest yields (Chapter Four) and plant density (Chapter Five) were used together with the data generated through mapping to produce an estimated total annual harvest yield of 4 513 tonnes. If harvested every four years, the annual yield would be 1 128 tonnes. If harvested every five years, the yield would be 902.7 tonnes.

2.6.1 An updated distribution map

The lack of an up-to-date and accurate inventory of the distribution of *C. intermedia* was problematic in terms of biodiversity management, conservation and sustainable use of the resource, and was part of the motivation for this research. The updated distribution map may form a useful tool for the industry in terms of planning for future growth and assurance of supply, and would help address international market requirements for sustainable sourcing of products. The mapped data from this work formed the basis for planning and implementing a resource assessment of C. intermedia and developing an NDF for the species in 2023/2024 (DFFE, 2023). Both of these conservation and sustainable-use tools generate reports, which are internationally accepted forms of evidence of sustainable use, for input to biotrade agreements on the international market. As emphasized in the natural resource use literature, inventory through mapping of the resource is a first towards managing the sustainable use of natural resources (Cunningham, 2001; Schippmann et al., 2002). Although mapping of *Cyclopia* spp. had been carried out in the past and locality records existed, the tools and technology for accurate and extensive mapping (such as GIS and Species Distribution Software) were not in common use when Schutte (1997) produced her maps. In South Africa, botanical localities were based on the quarter-degree square system (QDS), which made for poor accuracy (¼ degree covers approximately 25 x 25 km). As promoted by Foley et al. (2011) and Díaz et al. (2019), the ability of spatial technologies to supply information of high temporal and spatial resolution has enabled advances in environmental management that have not been possible before. This research did not discard traditional approaches to mapping but used them in combination with the capabilities of GIS and SDM.

The distribution range map of *C. intermedia* shows the wide range of the species. Given the broad spatial occurrence of the species, it is not surprising that it provides a large share (≈ 95%) of wild harvested material supplied to the industry. Its distribution ranges across the Cape Fold mountains, spanning 500 kilometres of longitude, (20° 5' east to 25° 18' east) and 90 kilometres of latitude (33° 2' south to 33° 58' south). The most western populations occur in the Waboomsberg (north-west of Barrydale), the furthest inland in the Witteberg (north of Willowmore), the most easterly in the Van Stadens mountains, at the eastern end of the Elandsberg, west of Gqeberha. It is clearly a mountain species, occurring across the extensive east-to-west trending ranges of the Klein and Groot Swartberg, the Kouga, Baviaanskloof, Groot Winterhoek and Tsitsikamma mountains, and in many isolated populations in smaller ranges. There are still areas where formal locality records are absent, and evidence of occurrence is anecdotal. e.g. in the Eastern Cape Witteberg and Western Cape Witberg, the Western Cape Elandsberg, Rooiberg, Touwsberg and Waboomsberg.

2.6.2 The value of expert mapping

The use of experts in capturing knowledge of the distribution of the resource was critical to the success of this exercise. Expert mapping contributions representing 3172 km^2 of mapped information on the wild honeybush resource came from botanists, farmers and harvesters. Experts are valued for their specialist knowledge, insight and wisdom (Collins & Evans, 2007; Kuhnert et al., 2010; Nowotny et al., 2001). Each expert knew areas not covered by other experts and contributed to refining the map of *C. intermedia*. A further advantage of their participation was that the representation of local expert knowledge in this way gave credibility to the research through community advocacy (Aswani & Lauer, 2006; Debolini et al., 2013; McCall et al., 2015). Expert input across the range by botanist Jan Vlok identified isolated mountain areas that might not otherwise have been included. The experts made the task of mapping an extensive resource – covering nearly 12 000 km^2 – a manageable undertaking, with contributions of information that would otherwise be unknown or unavailable (Debolini et al., 2013; Folke, 2004; Grêt-Regamey et al., 2013). In particular, farmers who are expert observers of ground-level processes (Oliver et al., 2012) contributed substantially to mapping the actual occurrence of *C. intermedia* populations, which desktop modelling could not achieve. This local scale mapping enabled the calculation of the potential harvestable resource. The value of local knowledge is now widely recognised as complementary to scientific knowledge (Bohensky & Maru, 2011; Chalmers & Fabricius, 2007) and contributes to solutions for environmental problems in many places around the world (Díaz et al., 2018).

2.6.3 Combining mapping methods

The potential area of occurrence of *C. intermedia* was produced through a combination of the high-probability areas identified in the SDM and the results of the MCS model. Combining the two results improved the estimate by including a more comprehensive range of environmental variables. The SDM introduced a layer that was produced using a statistical approach, rather than the MCS, based on criteria identified from the literature and refined by experts. The mapped area of potential *C. intermedia* occurrence of 2 253 km^2 was found to have a high degree of overlap (70%) with the majority of expert-mapped farm harvest polygons. This overlap in ecological modelling terms between the modelled output and the actual species occurrence suggests that the model accurately captured most of the species' actual distribution (Merow et al., 2013). The combination of traditional 'expert' mapping methods with SDM modelling was advised by Peters et al. (2014) and Graham & Hijmans (2006) as a sound approach to creating the best species distribution map. Both authors note that expert-drawn maps tend to overestimate the distribution range (as with the historical maps used). At the same time, the SDM delineates a zone of primary occupancy which is smaller in area (Peters et al., 2014). In the case of *C. intermedia,* the distribution range map indicated an area of 11 946 km^2, while the modelled area in the 0.5 – < 1 category was 4 754 km^2.

Distinct species boundaries are difficult to estimate (Peters et al., 2014), and SDMs often fail to account for species interactions (Graham & Hijmans, 2006). An example of this issue was illustrated in Figure 2.14, where the SDM predicted the presence of *C. intermedia,* although it did not occur there. In those areas, expert knowledge and historic locality records confirmed that the species was unlikely to be found. However, other *Cyclopia* species were common on the south-facing slopes of the Outeniqua Mountains north of Plettenberg Bay (Figure 2.14a) and in the Langeberg region north of Swellendam and Heidelberg (Figure 2.14b). The overlap of ranges is illustrated in the distribution map of commercially important *Cyclopia* spp, Ch 1, (McGregor, 2017a). The mix of methods – bringing in data from different sources, plus the knowledge of experts of different backgrounds – enabled the development of a comprehensive and reasonably accurate picture of the spatial extent of the *C. intermedia* resource at a local to national scale. Advantages associated with using modelling approaches include the fact that they allow for the revision of distributions over time (Peters, 2013; Baldwin, 2009) and are suited to further analysis which may be particularly useful in the context of generating scenarios for probable species distribution shifts under different climate regimes (Altwegg et al., 2014; Hannah et al., 2005; Midgley et al., 2003).

2.6.4 The harvestable resource

The mapped area of the harvestable resource within the production zone was based on the 72 km^2 of mapped harvest areas (from permits and expert mapping), plus an estimation of unmapped harvest areas of about 25% – 30%, making up a total of 100 km^2. Achieving this local level of detail of actual occurrence was made possible by expert mapping and the existence of permit records. Knowledge of the average yield per plant and plant densities across the species range enabled an estimation of the harvestable resource. This kind of data is typically lacking due to the informal nature of wild resource use (Cunningham, 2001; Papageorgiou et al., 2020) but can play an important role in managing and monitoring the sustainable use of the resource.

Once again, the combination of methods, including desk-top modelling, expert mapping and field surveys of the harvest, contributed to the production of a plausible estimate of the harvest.

2.6.5 Level of protection of *C. intermedia*

The extent of *C. intermedia* in protected areas was calculated at three levels of detail. At the level of a national resource inventory (the distribution range map), the area estimated to occur in protected areas was 5 654 km^2. At the modelled occurrence level, the area was estimated to be 1 365 km^2 (61%). Even at the local level, within the production zone, the potential occurrence of *C. intermedia* in protected areas was still high, at 49%. The existence of extensive protected areas in the range of this mountain species is partly explained in the Mountain Catchment Areas Act 63 of 1970 , which gave special protection to state and privately owned mountain lands for water resource management (Rabie & Burgers, 1997). In this mountainous terrain, development is limited, with most agricultural activities restricted to the valley bottoms with better soils and the surrounding, gentler slopes.

In terms of international standards for biodiversity protection, this represents a significant degree of security at all three scales. The CITES NDF process only requires a protection level of 15% of a species range (Rosser & Haywood, 2002) to award a maximum score. Although there is occasional illegal harvesting in protected areas, there was no evidence, either anecdotal or field-based, to suggest that it was problematic. The fact that the EC and WC have different permitting systems has been reported as problematic because there is no record of the origin of a harvest load when it is delivered to WC processors.

2.6.6 Limitations and recommendations

There is tremendous natural variability in the location, density and abundance of honeybush populations at a local scale; therefore, modelling either through GIS-based MCS or SDM is perhaps not the solution to 'mapping' the resource. Given the extent and nature of the terrain covered by the *C. intermedia* resource, it is simply not possible to estimate the size of the resource with certainty. The most accurate way of mapping is for local 'experts' (both landowners and harvesters) to map the areas of C. intermedia they utilise at a local scale. If every resource user had a permit with a map, the actual extent of the harvested resource would be known. Therefore, the permitting system (currently only applicable in the Eastern Cape) should be extended to include all wild honeybush harvesting areas. Given the availability of tools for mapping (mobile phones with mapping apps, access to software like Google Earth, the availability of South African topographic maps in digital or hard-copy), landowners who harvest honeybush should be compelled to map the extent of harvest areas on their land, as part of a sustainable harvest management plan.

2.7 Summary

The key findings of Chapter Two relate to the compilation of an updated and accurate map of the distribution range of *C. intermedia*, a refined area of where *C. intermedia* is likely to occur, and the delineation of a production zone representing the areas where the plant is currently harvested for commercial production. The chapter is underpinned by theoretical concepts related to the use of GIS and geo-spatial technologies to capture, model and analyse spatial data. The approach to compiling the data was mainly quantitative, but it included a substantial qualitative data collection component through interviews and expert mapping with stakeholders who had in-depth local or regional scale knowledge. The processing of the data was quantitative, based on GIS methods of data creation, manipulations and modelling to produce quantitative data on the extent of the wild honeybush resource.

Key figures produced through the analysis of the mapped data are listed below:

- The distribution range of *C. intermedia* covers 11 496 km^2 with 49% (5 654 km^2) in formally protected areas;
- The area where *C. intermedia* is likely to occur, is 2253 km^2 , 61% (1365 km^2) of which falls within formally protected areas;
- The area where commercial harvesting takes place, (called the production zone) covers an area of 1448 km^2 of which 707 km^2 (49%) falls within formally protected areas;
- The actual area in use for harvesting is estimated to be about 100 km2.

The value of this chapter is found in the map based inventory of the resource which may serve as a useful baseline for managing and protecting the resource.

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Chapter 3 Traditional and local ecological knowledge of best-practice harvesting

Contents

List of figures

List of tables

3.1 Introduction

3.1.1. Background

It is a common feature of natural resource use that there is incomplete and/or a lack of documented information on harvest knowledge, practices, and long-term impacts of harvesting both on yields and/or the sustainability of the resource (Hanazaki et al., 2018; Ingram et al., 2012). Without this kind of information, putting in place a framework for sustainable resource use is difficult (Ingram et al., 2012). To achieve sustainable use of a wild resource, it is necessary to understand the nature of harvesting practices and traditions. Such knowledge may be attained through developing an understanding of Local and Traditional Ecological Knowledge around the use of a resource (LEK and TEK). The term ‘traditional ecological knowledge’ (TEK) can be defined as a body of knowledge, beliefs, values and traditions about the natural world, based on generations of interaction and adaptation with the environment, which has been passed down through generations (Bruchac, 2020; Turvey et al., 2018). ‘Local ecological knowledge’ (LEK) defines the accumulated body of knowledge acquired through individuals' lived experiences and their interactions with the local environment (Turvey et al., 2018). Since the honeybush industry only entered a commercial phase in the late 1990’s (Joubert et al., 2011), there is limited formal knowledge regarding best practice use of the resource. Therefore, gathering and recording TEK and LEK around the use of the wild honeybush resource is the focus of this chapter, as depicted in Figure 3.1. The information gathered on best practice is further explored in Chapter Four, through an analysis of the nature of several harvest enterprises, and an inventory of actual harvest events, in order to verify best practice and assess the sustainability of harvester livelihoods. Furthermore, it is necessary to understand the impact of harvesting on individual plants and populations; this is covered in Chapter Five. The impacts of wild harvesting may vary from high to low, depending on the type of plant and the parts that are harvested, the social, cultural and economic setting, as well as traditional or formal controls of harvesting (Cunningham, 2001; Peters, 1994; Rosser & Haywood, 2002; Ticktin, 2004).

While successful traditional approaches to managing resources have been in place for generations (Hanazaki et al., 2018; Stanley et al., 2012; Tomasini & Theilade, 2019), the pressure of commercial trade in wild harvested resources, amidst economic, social and technological pressures and changes (Aswani et al., 2018; Early-Capistrán et al., 2020), has seen the erosion of many traditional management systems. Based on a global review of LEK papers, Aswani et al. (2018) found that 77% of 92 research papers reported a decline or loss of LEK, highlighting the need to formally record traditional resource use practices. In an assessment of the use of wild plant resources on Lemnos Island, Greece, Papageorgiou et al. (2020), concluded that local knowledge of harvesting practices, and management of wild plant resources, can provide invaluable input to developing plans for sustainable use, management, and conservation of plant populations. They did, however, indicate a need to record and document as much knowledge as possible before it was transformed or lost altogether.

On a global scale, the International Panel on Biodiversity and Ecosystem Services (IPBES, 2019) has identified the exploitation of organisms by harvesting as the second most significant threat to biodiversity loss after habitat destruction. The growing commercial trade of natural products has resulted in the harvest of increasing volumes from wild (plant) populations (Cunningham, 2001; Early-Capistrán et al., 2020; Papageorgiou et al., 2020; Shackleton et al., 2005). Harvesting of medicinal plant resources from wild populations has increased in Europe, North America and Asia as a function of an increasing demand of 8-15% per year (Liu et al., 2011). In South Africa, many plants are threatened by over-exploitation (Xego et al., 2016). The actual number of plant species threatened by the medicinal plant trade, according to the IUCN Red List criteria, is noted by Williams et al. (2013), as follows: of the 545 traded medicinal plant species, 1.3% (7 species) are extremely scarce and considered Critically Endangered, 54 species (8.7%) are considered Threatened, while a further 14.3% (78 species) are of conservation concern. Over 80% of South Africans still regularly use wild harvested plants for subsistence, medicinal use, and use in cultural rituals – making them a valuable resource worth protecting (Williams et al., 2013). The harvesting of plants for use and trade is often destructive, as shown through a Cape Town market survey which found that 70% of the 250 traded plant species were either killed or reproductively harmed in the harvesting process (Petersen et al., 2012). The growth in the trade of wild-harvested products has substantially contributed to improving the livelihoods of rural communities in the developing world. Still, this kind of growth without any clear understanding of, or guidelines regarding, sustainable yields and ecological impacts, is problematic (Shackleton et al., 2005; Williams et al., 2013).

3.1.2 Motivation for the research

The need to use biodiversity resources wisely because they contribute to human wellbeing is well established – as detailed in the Millennium Ecosystem Assessment (2005), the Millennium Development Goals (UN 2005), the Johannesburg Plan of Implementation (United Nations, 2002), and, most recently, by the IPBES (2019a). In a western-scientific discourse, the idea is viewed through the concept of ecosystem services (Costanza et al., 2017). More recently, the IPBES introduced the term 'Nature's Benefits to People,' (Díaz et al., 2015), later renamed 'Nature's Contributions to People' by Díaz et al. (2018). As defined by Diaz et al. (2018, p. 270), this is a broad concept which includes "…the contributions, both positive and negative, of living nature (diversity of organisms, ecosystems and their associated ecological and evolutionary processes) to people's quality of life." Shackleton et al. (2018) proposed that the time has come to consider NTFPs as biocultural keystone species, rather than just in terms of their ecology, biology, productivity, harvest potential, and use.

In terms of national policy, as a signatory to the CBD (1992), South Africa is bound to put in place the means to achieve the Aichi targets set out in the Strategic Plan for Biodiversity 2011-2020 (UNEP, 2010). More recently, the Kunming-Montreal Global Biodiversity Framework (GBF) was adopted at COP 15, which builds on the previous Strategic Plan to achieve a global vision of a world living in harmony with nature by 20250

(CBD, 2022). From a biodiversity management perspective, and in the context of this research, there are two Aichi targets that are important:

- Aichi Target 12 requires that all wild-harvested plant-based products should be sourced sustainably. It further details that this should be achieved through resource assessments, harvesting permits, autecological studies, harvesting guidelines, and monitoring.
- Aichi Target 13 requires that: 'Indigenous and local knowledge innovations and practices associated with plant resources (should be) maintained or increased as appropriate, to support customary use, sustainable livelihoods, local food security and healthcare.'

Achieving these targets is important because there is a danger of losing indigenous knowledge as young South Africans move away from rural lifestyles and traditions to take up urban lifestyles. Given the value that may be gained from bioprospecting, which is partly informed by knowledge of traditional practices, this type of information should be recorded before it is lost (Crouch et al., 2008).

To achieve the above goals of supporting the sustainable management of harvesting of wild plants, a list of requirements for an effective management system for wild plants (specifically Medicinal and Aromatic Plants or MAP's) by Schippmann (1997), is instructive. It should include sound scientific information, consideration of annual harvest quotas, seasonal or geographical restrictions, limiting of harvest to particular plant parts, size classes or ages, clarification of access, and user rights to the resources. Much of this information can only come from collating information about the nature of the harvest, from the perspectives of harvesters and other stakeholders. In combination with knowledge of the ecology of the plant, and experimentation in management techniques with harvester participation. Ticktin (2004) believes it is possible to develop guidelines that promote sustainable use and persistence of wild plant populations.

The availability of honeybush as a harvestable natural resource can, then, be seen as both an ecosystem service and one of 'Nature's Contributions to People' (Díaz et al., 2018) that contributes to the wellbeing and quality of life of stakeholders. Continued contributions from this natural resource will depend on managing use of the resource to provide a sustainable yield, where the rate of harvesting should not exceed the rate of regeneration (Daly, 2005). It is recognised that wild-harvested honeybush species are under pressure: of the six commercially important honeybush species, all are listed as declining (or decreasing) in the wild (SANBI, 2024, Table 3.1), with five of the species described as threatened by overharvesting. Schutte-Vlok & Raimondo (2016) have noted the need for proper regulation and management, and the identification of sites of over-harvest, to develop interventions that will ensure sustainable harvesting.

Table 3.1: Conservation status of commercially important *Cyclopia* spp. based on the SANBI (2024) Red List and the draft South African TOPS listing, 2023.

Species	Red List category 2024	TOPS list 2023*	Distribution and threats	Population status
Cyclopia genistoides	Near Threatened A2cd; B1b(iii,v)+2b(iii,v)	Protected	Restricted distribution, original honeybush tea, overharvested, no longer wild harvested, habitat loss through urban expansion and cultivation.	Decreasing
Cyclopia intermedia	Least concern	Protected	Wide distribution, abundant, threatened by overharvesting.	Declining
Cyclopia longifolia	Critically Endangered B1ab(iii)	Critically endangered:	Restricted distribution, threatened by land transformation, particularly forestry	Decreasing
Cyclopia maculata	NT, Near Threatened B1ab(iii)	Protected	Restricted distribution, threatened by overharvesting, alien invasion, impacted by water abstraction.	Decreasing
Cyclopia plicata	Endangered B1ab(iii,v)+2ab(iii,v)	Endangered	Restricted endemic distribution, overharvesting, altered fire regimes.	Decreasing
Cyclopia subternata	Least Concern	Protected	Overharvesting and illegal harvesting.	Decreasing
Cyclopia sessiliflora	Near Threatened B1ab(iii,v)+2ab(iii,v)	Not listed	Overharvesting.	Decreasing

*The 2023 TOPS listing was released on 3 February 2023, withdrawn on 31 March 2023, and republished on 13 October 2023 for public comment.

The review of literature (Chapter One) showed that honeybush research has focussed on cultivation research (for good reasons) and on potential uses for the product based on biochemical characteristics. However, by 2017, at the start of this research, it was evident that the cultivated sector would not be ready to supply the volume needed, and the wild resource that was the mainstay of the industry was showing signs of decline. To sustain supply, the wild industry needs to be protected in a formal process, through improved management for sustainability, such as developing guidelines for best practices of wild harvesting. The call for formal protection of the wild resource, plus the development of formal best practice recommendations, was repeated in various meetings, workshops and reports, by members of the stakeholder community (George Municipality, 2014; Hobson & Joubert, 2011; Living Lands, 2013; LOWFT, 2011; SAHTA, 2010). At the first meeting of the Honeybush Community of Practice (HCOP) in George, 2017, the sustainability of wild harvesting was identified as a critical issue. All these meetings were attended by representatives of stakeholder groups (farmers, researchers, government officials, harvesters, and processors), who collectively recognised this need. The need for sustainable use of the resource was also recognised by researchers in earlier publications (du Toit et al., 1998; Schutte-Vlok, 1998; Schutte, 1997).

This thesis was conceived in response to recognising threats to honeybush species. It was further promoted in November 2016 by a formal call for developing a set of harvesting guideline documents for the sustainable harvesting of wild honeybush by the WC DEADP. The key document produced in this exercise was the 'Guidelines for the sustainable harvesting of wild honeybush' (McGregor, 2017a) as well as four supporting reports (De Villiers & McGregor, 2017; McGregor & Pierce-Cowling, 2017; McGregor, 2017b, 2017c). Following the publication of these reports, and in response to a call for best practice guidelines in the vernacular of stakeholders at the Louterwater, a second project was funded by the WC DEADP in November 2017. The output from this project was the 'Wild Honeybush Harvesting Field Guide' (McGregor, 2018).

3.1.3 Aim

The aim of this chapter was to compile and analyse information about the harvest based on Local Ecological Knowledge (LEK) and Traditional Ecological Knowledge (TEK), that would contribute to a formal body of knowledge around harvesting to establish best practice guidelines for the sustainable harvesting of wild *C. intermedia.*

3.1.4 Objectives

1. To understand the honeybush industry in general, and specifically best harvesting practice.
2. To record and collate traditional and local ecological knowledge around best practice harvesting of honeybush.

An overview of the structure and content of this chapter is presented in Figure 3.1. Two objectives are addressed to meet the chapter's aim of capturing traditional and local ecological knowledge around best practice harvesting. Data was collected using qualitative methods, processed using thematic content analysis and a basic summary of statistics, with output represented as graphs. The discussion reflects on the findings in terms of the value of TEK and LEK and the utility of the methods used. The chapter ends with a summary of the main findings of the chapter, methodological approaches and theoretical context.

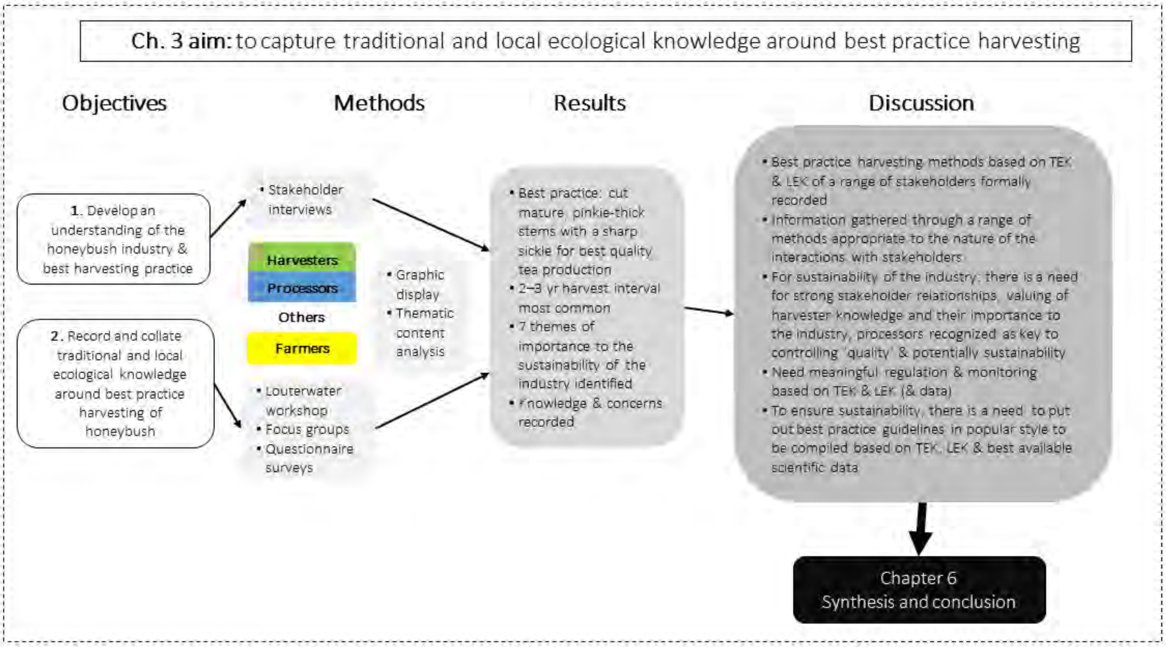

Figure 3.1: Overview of the structure and content of Chapter Three.

3.2 Literature Review

3.2.1 Overview of available methods

It is clear from a review of research dealing broadly with natural resource management that there is a tremendous range and mixture of both qualitative and quantitative research methods that are commonly used. The adoption of transdisciplinary, interdisciplinary and mixed methods approaches in this research context was necessary. In this chapter, qualitative methods were used to capture LEK and TEK as the best – and in some instances the only – available information on best practice harvesting. The literature review for this chapter deals with identifying and understanding approaches suited to capturing TEK and LEK. It presents examples of studies in natural resource management which used a mixture of qualitative and quantitative methods to capture knowledge about using natural resources.

3.2.2 Traditional and local ecological knowledge and their relationship to science

TEK and LEK are seen as valuable for various reasons: they provide the means to manage and use natural resources sustainably (Berkes et al., 2000); they provide social methods of protecting biodiversity through enforcement of totemism and taboos (Colding & Barthel, 2019; Kanene, 2016); and promote education around wise resource use through storytelling (Chigonda, 2018; Fernández-Llamazares & Cabeza, 2018). On a global scale, the value of indigenous and local knowledge are entrenched in policies that promote protection of biological biodiversity. Article 8 of the United Nations Convention on Biological Diversity explicitly states the need to '…respect, preserve, and maintain innovation and practices of indigenous and local communities related to sustainable use of biological diversity' (UNEP, 1992, p. 6). The Millennium Ecosystem Assessment report (United Nations, 2005) recognised the contributions of TEK to biodiversity conservation issues. In the Strategic Plan for Biodiversity 2011 (UNEP, 2010), contributions of TEK from indigenous communities are vital in achieving Aichi Target 18: 'Traditional knowledge respected.' The Global Environment Outlook: Environment for the future we want (GEO-5) (UNEP, 2012) emphasized the significant contributions made by indigenous knowledge to the conservation and sustainable use of biodiversity, and the relevance of TEK and LEK for the impact they have on social wellbeing and sustainable livelihoods. Most recently, the IPBES (2019b) found that, globally, indigenous peoples and local communities (IPLCs) have a crucial role in maintaining biodiversity and sustainable resource use. They noted that nature is generally declining less rapidly in indigenous people's land than in other lands, but is, nevertheless, declining, as is the knowledge of how to manage it.

Given the kind of global environmental challenges we face, it is essential to have access to the best available information and knowledge. Science contributes much to our understanding and ability to address many of these challenges, but given the complexity of these 'wicked problems' (Rittel & Webber, 1973), there is much that it cannot cater for. Alternative approaches to problem-solving are required, and TEK and LEK are recognized as essential, alongside science, for developing effective and meaningful action world-wide

(Ramnath, 2014). TEK and LEK can often support the sustainable use of environmental resources and build resilience in social-ecological systems (Russo et al., 2000; Turvey et al., 2018). Furthermore, many research projects on the use, inventory and assessment of the sustainability of natural resources depend on both scientific approaches and the inclusion of TEK and LEK. The fact that most wild harvesting guidelines are created with input from the best available scientific information combined with the knowledge of experienced harvesters who are TEK and LEK holders (Early-Capistrán et al., 2020; Malgas & Oettle, 2007; Papageorgiou et al., 2020), is evidence of this. In Brazil, detailed studies and recommendations for sustainable harvesting regulations, which combine LEK and ecological parameters, have been proposed for many wild-harvested plant species (Hanazaki et al., 2018a). The insight gained from bringing together methods that allow for the inclusion of traditional or local ecological knowledge (TEK and LEK) is now widely recognised (Russo et al., 2000; Schmidt & Ticktin, 2012; Turvey et al., 2018).

In a review of the literature on TEK and LEK and its relationship to scientific knowledge, several themes relevant to the pursuit of this research were identified. In some instances, combining TEK, LEK, and scientific methods can produce knowledge for more sustainable 'answers.' In a survey of perceptions of landcover change in the Willowvale district, South Africa, Chalmers & Fabricius (2007) found that local knowledge was remarkably consistent with that of scientists, and added considerable value to scientific understanding of the ultimate causes of land-cover change in the area. In a survey of wild plant management approaches in Prespa, Albania, Tomasini & Theilade (2019) found that there was a broad consensus between science-led assessment and LEK-based assessments. Harvesters had detailed, locally specific knowledge, and used a variety of indicators of sustainability linked to ecological, social and economic aspects to inform their practice and management. Their focus was on the harvestable resource, while science-based assessments tended to consider the health of the population as a whole.

While Dovie et al. (2000), advocate quantitative resource assessments, using ecological and botanical surveys, as crucial to putting in place sustainable management plans, they acknowledge that a holistic inventory must encompass the full range of traditional ecological knowledge too, including the history of use, sites of use, time and seasonality of harvest, and methods of care of the resource. They recognise the intrinsic value of historical knowledge of resource use, and knowledge around locally specific traditions, as essential to successful sustainable management. It is now appreciated that TEK and LEK enhance our understanding of the ecology of species (Martinez-Levasseur et al., 2017), and the inclusion of this knowledge in policy is essential to develop optimal future management scenarios (Pardo-de-Santayana & Macía, 2015).

In data-poor scenarios, TEK may be the only kind of knowledge available regarding the use of a particular resource. Vance et al. (2001), note the considerable contribution of experienced harvesters to developing harvesting guidelines for forest products, which was sufficient to inform management approaches in the absence of science-based knowledge. While the techniques had not been scientifically field-tested and monitored, they relied on the fact that the participating harvesters have worked with the plants for years to achieve sustainable harvest. Similarly, Early-Capistrán et al. (2020) found that where scientific data was lacking, LEK was a valuable source of information on historical trends and the use of small-scale fisheries. In many instances, in assessing the sustainability of harvest of wild plants, the only long-term information on best practice and history of use resides with the local and ecological knowledge holders (Schmidt & Ticktin, 2012).

In some cases, when science cannot provide answers, TEK can provide useful information. With reference to the phenomenon of delayed summer seasons on the Tibetan Plateau, a review of the LEK of Tibetan pastoralists produced answers that scientific approaches had not revealed. Pastoralists supplied evidence of shorter milking seasons, higher snow lines and changes over the long term in stocking rates driven by regional warming rather than the more widely cited land-use change rhetoric (Hopping et al., 2016). In the context of natural resource use in the Arctic and on the Tibetan plateau, Mistry & Berardi (2016) revealed that where indigenous land use practices dominate, deforestation is controlled, carbon stocks are maintained, and biodiversity is better than in adjacent lands.

There are instances where TEK and LEK are not adequate. In a survey of perceptions of landcover change in the Willowvale district on the Wild Coast of South Africa, Fabricius and Chalmers (2007) found that understanding by local experts of the causes of landcover change was somewhat simplistic. In a survey of the sustainability of fuelwood harvesting in Welverdiend village, Mpumalanga, Kaschula et al. (2005) used a mixed methods approach to gather data relating to the sustainability of use of three savannah fuelwood species. Their findings showed a poor correlation between science and local ecological knowledge, with many ambiguities in understanding what constituted sustainable use in the community.

The value of TEK can be realised if scientists and policymakers recognise the inherently flexible and holistic value of indigenous knowledge (Mistry & Berardi, 2016). As appropriate, and where feasible, local knowledge on conservation and use of wild resources should be collected, documented, and adopted as a basis for their management, and used together with the best available scientific knowledge (Russo et al., 2000). The use of local knowledge can be viewed as a practical and cost-effective way of gaining information that can be used to direct scientific research, thereby using research time and resources more efficiently (Cunningham, 2001). If regulations (e.g. harvesting guidelines) are to be beneficial and successful in achieving sustainable resource use, they must be developed and implemented in cooperation with local communities (Ostrom, 2009; Schmidt & Ticktin, 2012). There is broad consensus around the need to better understand the status and trends of biodiversity while acknowledging LEK's important role in establishing successful monitoring programs (Tomasini & Theilade, 2019).

3.2.3 Methods for gathering information on harvesting practices

A mixed methods approach is appropriate for geographical research and relevant because of the engaged nature of this research methodology, which is participatory and stakeholder-driven. A mixed methods research design allows for combining quantitative and qualitative approaches in data collection, analysis, and presentation, which provides a better understanding of a research problem than either method alone (Cresswell and Plano-Clark, 2011). Furthermore, according to Cresswell and Plano-Clark (2011), it is practical because people naturally combine inductive and deductive thinking, solving problems using numeracy and literacy.

In a review of literature on natural resource management (NRM), there is a tremendous range and mixture of both qualitative and quantitative methods that are employed - sometimes separately and sometimes in complementary ways - to deal with the complexities of natural resource use and management. According to Cresswell and Plano-Clark (2011, p. 21): 'The complexity of our research problems calls for answers beyond simple numbers in a quantitative sense or words in a qualitative sense. A combination of both forms of data can provide the most complete analysis of problems.' A methodological rule provided by Jick (1979), is that multiple methods should be used in <u>every</u> investigation. Acquiring information on the nature of wild honeybush harvesting depended initially on collaboration with industry stakeholders who had local and traditional ecological knowledge of the practice, history of use and management of the resource in the local environment. Capturing their knowledge, experience, practical know-how, and, in some cases, written records, was fundamental to developing knowledge and understanding of a system without formal, documented best practice.

A mixed methods approach is well suited to *transdisciplinarity*, which may be defined broadly as an approach that integrates knowledge across disciplines, including stakeholders from across society, leading to the creative and collaborative design of new problem-solving methods to deal with complex, modern problems (Bernstein, 2015). It is valuable because it incorporates the views of scientists and non-academic stakeholders (Rigolot, 2020; Scholz & Steiner, 2015), allows co-design of the research process, and leads to the co-production of knowledge (Padfield et al., 2019). Research partnerships that integrate and synthesize many different disciplinary perspectives can address complex problems because they offer joint problem definitions and fill knowledge gaps that science and single stakeholder groups alone cannot address (Scholz, 2020). Transdisciplinarity is critical to progress in sustainability science, as expressed by Kates (2001, p. 641) ,: '… progress in sustainability science will require fostering problem-driven, interdisciplinary research.'

Stakeholder engagement is fundamental to a successful transdisciplinary approach. NRM projects are mostly transdisciplinary by nature (Hakkreinen et al., 2022) because they deal with social-ecological systems, and NRM agencies recognise that stakeholder engagement is essential to achieving project outcomes (Brody et al., 2003; Talley et al., 2016). It has been found that research that takes care to identify and include stakeholders relevant to the purpose of the project and the participatory process, will have a positive influence on the engagement, the outputs and outcomes of the research, and the overall success of a project (Grimble & Wellard, 1997; Kellert et al., 2000). Stakeholder participation needs to be underpinned by a philosophy that emphasises empowerment, equity, trust, and learning, which can be achieved through a well-focused engagement with clearly defined and easily understood aims and objectives (Reed, 2008). Well-designed engagement offers participants many opportunities, including, amongst others: forming new partnerships and networks; taking ownership of the project; exploring, developing and broadening their own knowledge; raising awareness of issues; contributing to a transparent decision-making process, and accessing resources, including scientific knowledge (Durham et al., 2014).

There are various ways of selecting sample objects: for a scientific approach that is free of bias and may increase the credibility of the results, statistically based systematic random sampling is perceived as the most suitable approach for data collection. However, practical considerations often determine sampling approaches. There are no rules for sample size in qualitative enquiry (Patton, 2015). The choice depends on the aim of the research – whether breadth or depth is required, what you want to know, the purpose of the research, what's useful, how much information will give credibility, and the timing of resource availability. *Purposive sampling*, also known as subjective or selective sampling (Mace & Reynolds, 2001), is a non-random sampling approach based on the researcher's knowledge of the population, to give samples that can be assumed to be representative of the population (Lavrakas, 2012). *Expert sampling* is a purposive sampling approach used when experts in a particular field are sought based on their specific knowledge or expertise (Robinson, 2014). This approach is particularly useful with little observational evidence (Etikan, 2016). *Opportunistic or emergent sampling* is useful because it allows the researcher to follow opportunities for data collection and make decisions to take advantage of new opportunities during data collection. *Convenience sampling* is a type of non-random sampling often used for practical, logistical reasons of geography, access, cost and other practicalities (Etikan, 2016). All of these sampling approaches were relevant at different stages in this research.

3.2.4 Interview methods

Qualitative research methods, such as formal and informal interviews, allow for recording experiential responses, which contribute to a greater theoretical knowledge base (DiCicco-Bloom & Crabtree, 2006). The semi-structured interview is the most frequently used interview method in qualitative studies (Kallio et al., 2016; Kitchin & Tate, 2013) because it is versatile and flexible. It gives the respondent room to respond freely and allows them to provide detail (Weiss, 1995). If observations by the interviewer are included, and open and closed-ended questions are asked in the interview, the data can be analysed using quantitative and qualitative methods (Creswell & Plano Clark, 2011). Using a questionnaire survey allows for the rapid capture of focused information that can be quantitatively analysed (Williamson, 2018). Using a face-to-face approach to administer a questionnaire survey, the researcher can assist the respondents and address queries to maximise data quality and response rate (Horsfall et al., 2021). This approach may be beneficial when addressing respondents who are not literate but are enabled to participate with the assistance of the interviewer (Neuman, 2012). With regard to sample size when conducting interviews, Mason (2010) makes the point that the frequency of participant responses is not a measure of the worth of the data: the quality of the contribution from a small sample of knowledgeable participants is more valuable than a larger sample involving participants with limited knowledge.

There are various benefits to using a workshop to collect data. A workshop is a collaborative experience where a group of stakeholders, with mixed views and opinions, can learn, share and debate (Ahmed & Asraf, 2018; Ørngreen & Levinsen, 2017), facilitating the collection of rich data (Creswell and Poth, 2017). Practical benefits include the use of a single venue and the gathering of a variety of stakeholders. According to Ahmed and Asraf (2018), a workshop that provides for the collection of detailed field notes, and the perspectives of multiple observers, will potentially lead to the collection of credible and trustworthy data.

Focus group discussion is frequently used as a qualitative approach to gain an in-depth understanding of social issues (Nyumba et al., 2018). The most common type of focus group is a single focus group where a purposively selected group is guided by a facilitator to interactively discuss a topic to collect qualitative data (Nyumba, *et al*, 2018). Participants can contribute personal experiences, beliefs, perceptions, and attitudes on the topic under discussion, in a space where different paradigms and worldviews can also be expressed (Romm, 2017). It is a form of data gathering used widely across many different disciplines, and commonly in resource management, where it is particularly useful for bringing together scientific research and local knowledge (Kaschula et al., 2005; Modi et al., 2006; Nabahungu & Visser, 2013). It is perceived as a cost-effective and promising approach in participatory research (Morgan, 2003). In contrast to one-on-one interviews, focus-group discussion allows the generation of new ideas within a social context (Padfield et al., 2019). Focus group discussion relies on skilled facilitators, who must have skills and techniques to address the issues comprehensively (Breen, 2006; Gopnik et al., 2012). A summary of skills desirable in focus group facilitation (Nyumba et al., 2018) are: the ability to build rapport; good and active listening skills; good observation skills; good speaking and communication skills; good knowledge of the topic of discussion; flexibility to adapt to the flow of the discussion; and the ability to remain impartial.

Thematic analysis is a qualitative approach used to identify, analyse and report patterns or themes within data (Braun & Clarke, 2006). It is used as a tool across various fields of study and is widely used in the social sciences (Mihas, 2023). Braun and Clarke (2006) defined a six-step, iterative process for conducting thematic analysis: compiling the data, coding the data, searching for themes, reviewing themes, defining and naming themes, and locating exemplars. The approach is particularly suitable for interview analysis, providing a framework for a researcher to look for commonalities in the data, which can be grouped into themes to identify aspects of a research phenomenon mentioned frequently or in depth, and to understand how phenomena may be connected (Williamson et al., 2018). The method begins with the identification of provisional topics that evolve as codes are assigned, allowing the data to reveal itself (Mihas, 2023). *Content analysis,* while similar to thematic analysis (coding of words and identification of themes), extends to include quantification of the data (Guest, McQueen and Namey, 2012) through a frequency count of codes and themes. It is perceived as more practical and straightforward than thematic analysis, which is seen as more intuitive and faster to learn (Humble & Mozelius, 2022). A combination of thematic analysis and content analysis as *thematic content analysis* can provide greater insight into a dataset by retaining the integrity of a variety of individual responses while adding quantitative value through a frequency count of themes or codes (Marks & Yardley, 2004). Content analysis software like *NVivo* allows for the processing of large qualitative data sets, with capabilities based on content and thematic analysis principles (Dhakal, 2022). Volumes of data can be organised and analysed in depth, potentially allowing the identification of linkages which may not be apparent when using a more manual approach (Dhakal, 2022).

3.2.5 Mixed-methods case studies

In an investigation of the use of wild vegetables by rural households in rural Kwa-Zulu Natal, Modi *et al* (2006) used interviews and focus group discussion, followed by transect walks to gather information about plant use. Nabahungu and Visser (2013) captured farmers' knowledge and perceptions of agricultural wetland management in Rwanda using formal interview surveys and focus groups, followed by transect walks through the wetlands to collect physical data and validate information collected during the focus group discussions. In the Bosawás Biosphere Reserve in Nicaragua, Danielsen et al. (2014) successfully used interviews, focus group discussions and transect walks to gather information about natural resource use in the community. A 2 km transect walk was laid out to regularly monitor animals through observation by residents, which increased the amount of information that could be collected and empowered indigenous and local people by making them part of the research. In a survey of the sustainability of fuelwood harvesting in Welverdiend village, Mpumalanga, South Africa, Kaschula et al. (2005) used focus group discussions as well as mapping of resource use sites to collect information about the timing of harvest, harvest methods and plant knowledge, plus discussion of broader ideas around sustainability, society and politics. Parallel to this, biological data on three harvested savannah fuelwood species was collected. This mixed methods approach yielded data which showed that in several instances, there was a poor correlation between knowledge obtained by scientists, and indigenous knowledge.

In the village of Xanthia, Bushbuckridge Municipality (South Africa), Konz et al. (2009) used interviews and focus group discussions to gather information about important medicinal plant resources in the area. Purposively sampled participants, with knowledge and experience as herbalists, took part in transect walks to identify and locate plant specimens. Ngorima and Shackleton (2019), in an investigation of the use of the alien invasive tree *Acacia dealbata* in the Eastern Cape, used focus group meetings to develop an understanding of the use of natural resources in the area. The exercise included mapping the area's landscape, showing the location of stands of *A. dealbata*, plant densities, and preferred sites of use. Transect walks were conducted with older community members, who could contribute to a discussion around change in the landscape, with specific reference to invasion by the plant, old and current fields, and impacts of the plant on livelihoods.

3.3 Methods

3.3.1 Data collection

Information was collected through interviews with stakeholders from various localities within the honeybush distribution range associated with a range of activities, as indicated in Figure 3.1. The spread of localities shown in the map covers the area where most wild harvesting takes place and where processors who receive wild-harvested material are located. At the Louterwater workshop in January 2017, questionnaire surveys, focus group discussions, and general discussion sessions were used to gather knowledge about best practice harvesting.

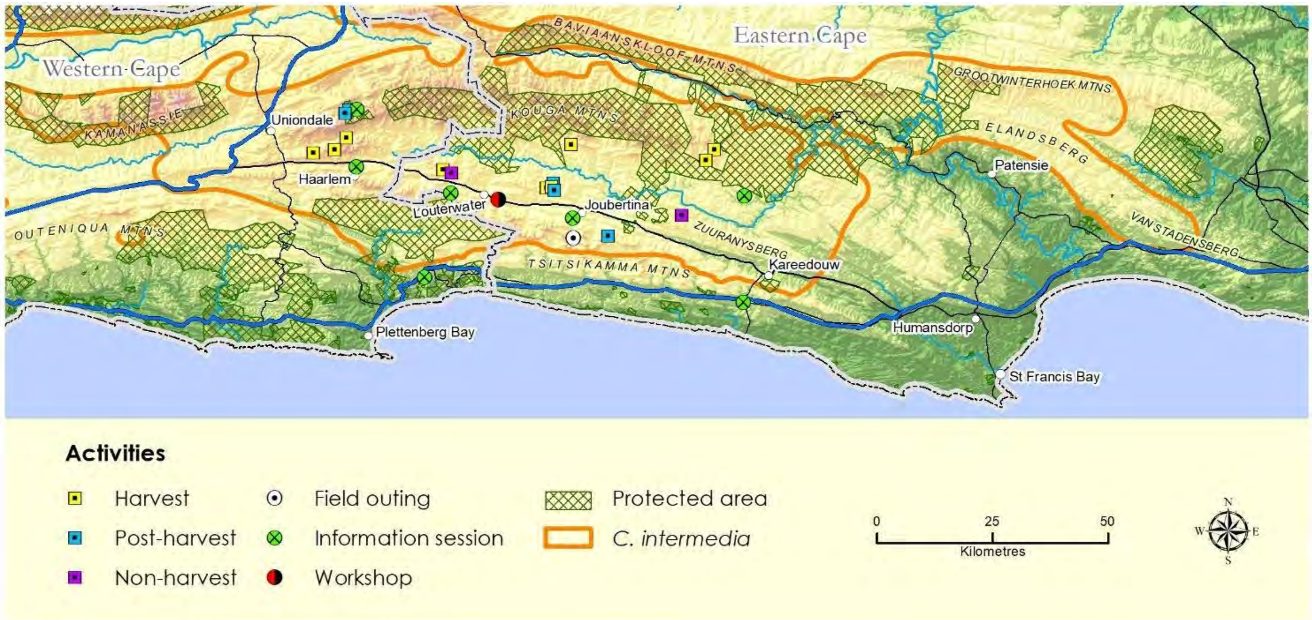

Figure 3.2: Location and types of activities supported by honeybush industry stakeholders, related to capturing data about 'the harvest'. A post-harvest event was a used as a method of checking the harvest practice, shortly after the event (Chapter Four). A non-harvest event was a visit to a harvest site where no harvest took place (plants were not ready to crop, bad weather, or permit not granted). Field outings refer to visits to harvest sites to demonstrate or learn about best practice harvesting, with stakeholders. The map is relevant to Chapters Three, Four and Five.

3.3.1.1 Interviews with stakeholders

Stakeholders in the industry considered to have industry knowledge and experience were identified through attendance at the SAHTA AGM in 2016 and through an interview with the EC DEDEAT permit officer. Stakeholders who indicated a willingness to participate in the research were then interviewed. One-on-one interviews were held with experienced processors, harvest managers, harvesters and farmers, to develop a broader understanding of the nature of the honeybush industry in terms of the harvest, including the physical environment, the socio-cultural and economic context, and stakeholder relationships. Throughout the project (2016 to end 2018), interviews were conducted with six processors (100% sample), eight harvest team managers (75% sample), twelve farmers (approx. 10% sample) and 21 harvesters (14% sample). Other knowledgeable honeybush stakeholders were opportunistically interviewed, such as a retired agricultural officer and several researchers. A list of respondents and the nature of the interactions is provided in Appendix 3a. In the interviews, information was recorded by shorthand note-taking, then analysed using thematic content analysis.

The interviews were a mixture of structured questions (the same set of questions as were addressed in the workshop) and unstructured, opportunistic discussion with the intention of covering broad topics related to the industry, including knowledge of harvesting, knowledge of plant ecology, experiences as a honeybush stakeholder, opinions on the state of the industry, and any other related topics. Interviews took place at the participants' home or workplace and in the field, lasting for over one to several hours each. All the information gathered contributed to developing knowledge of the best practice harvesting guidelines.

3.3.1.2 The Louterwater workshop

The workshop held on 31 January 2017 from 9.00 am to 2.00 pm in the village of Louterwater was an information-gathering exercise to develop harvesting guidelines. The workshop was attended by 50 stakeholders, including farmers, harvesters, processors, government officials (National and Provincial), researchers, and interested parties. Stakeholders were notified about the meeting by an advert in the local newspaper, via email, phone call, or in person. Flyers were distributed around the Langkloof two weeks before the meeting, and research team members in the Langkloof phoned or visited stakeholders to confirm attendance.

The workshop team was made up of the researcher, three student assistants (registered for MSc Degrees, researching various aspects of the honeybush industry), a botanist with honeybush industry experience, a botanist/farmer and four staff from the Flower Valley Conservation Trust, who had experience with developing the fynbos flower harvesting field guide. All team members were involved as facilitators, administrators and session convenors at the workshop.

Forms of engagement at the workshop

The wild honeybush wall-hanging, representing the biophysical landscape, allowed participants to place themselves on the wild honeybush landscape, and express their commitment to and expectations of the workshop. Stakeholders who could not attend the meeting, but supported the research effort and wished to express their commitment, were also represented on the landscape – their names and views were collected in pre-workshop interviews. The results of this exercise are illustrated with an image and a word cloud. Colour themes used in the wall hanging were used at activities in the workshop and maintained in the presentation of results: the background for harvester graphs is green, landowner/farmer data is on a yellow background, data from 'other' stakeholders is presented in graphic summaries on a white background. As only four processors were involved in the workshop, their questionnaire data is presented descriptively rather than graphically.

Stakeholders were grouped into focus groups of four to six according to their role in the industry, made up of processors (one group), harvesters (two groups), farmers (two groups), and 'others', namely government officials, researchers and interested parties (one group). Members of each group were assisted with filling in a questionnaire (Appendix 3b-e) on harvest knowledge, general knowledge, and opinions of the industry. All workshop material was prepared in Afrikaans and English and small group discussions were held in the preferred language of each group. All participants took part in facilitated group discussions on selected honeybush industry topics. Each focus group reported back to the full workshop group, in order to represent and record important contributions and discuss issues raised; this group meeting was held in a mixture of English and Afrikaans. Stakeholders were encouraged to record anonymous comments (positive or negative), on any aspect of concern regarding the honeybush industry in a comments box.

3.3.2 Data analyses

Information collected from the questionnaires covering harvesting practice is displayed as a series of graphs describing key points. Information from the focus group discussions, and the general workshop group discussion, are presented and analysed through a thematic analysis, carried out a set of codes to identify themes in all the collated material. Redundant data was removed, and only data relevant to understanding best practices and the industry in general was retained. These datasets include the results of interviews and questionnaire responses in the field, with a further eight harvesters and two more harvest managers. Where the information is relevant on a harvest team basis, that data is presented according to the six teams represented at the workshop.

The nature of engagement with individuals is listed in Appendix 3a; the location of all activities and forms of engagement aimed at gathering information about the harvest are presented on a map (Figure 3.2).

3.4 Results

3.4.1 The wild honeybush landscape wall hanging at the Louterwater workshop

The wall hanging layout and elements (Figure 3.3) are a simplified version of the wild honeybush landscape presented in Chapter One (Figure 1.2). It visually laid out the relationships between different role players in the industry, and between role players and the resource, for all participants to see. Yellow pages represented farmer comments, blue was from processors, green from harvesters, and white from all other stakeholders.

The contents of the written comments from 45 stakeholders are summarised as a 'word cloud' (Figure 3.4) – a form of content analysis where words are represented according to frequency of use. The prominence of the words: *sustainability*, *harvesting, tea*, *sustainable*, *knowledge* and *learn* clearly shows an interest in sustainability related to harvesting, and a desire to learn and acquire knowledge of this subject. The word *sustainability* was expected to be prominent since the workshop was advertised as a meeting designed to develop sustainable harvesting guidelines.

Figure 3.3: The wild honeybush landscape, displaying workshop participant contributions. Yellow = landowners, blue = processors, green = harvesters, white = all other stakeholders.

3.4.2 Harvester survey results

The harvesters' interviews reflect the experience of six teams plus two (retired) independent harvest managers. They represent a broad geographical spread across the honeybush harvesting area, from Tsitsikamma, Eastern Kouga, Kareedouw, Joubertina, Haarlem and Uniondale. Quotes attributed to particular harvesters are indicated with their initials, as listed in Appendix 3a.

Figure 3.4: Word cloud created from stakeholder notes recorded on the Wild Honeybush Landscape wall-hanging.

Of the members of the harvester group, two described themselves only as managers. Six are managers and harvesters, and thirteen are only harvesters (Figure 3.5a). In two teams, the manager is an experienced, retired harvester, who only advises the team on-site. There are a small number of experienced female harvesters (approximately one in ten, Figure 3.5c) who most often use young, physically fit males as carriers. Most teams operate on a contract basis, offering their services to farmers (58%, Figure 3.5f). Some of these are 'family' teams of four or five members who share harvest responsibilities and income. Others are larger, and members operate independently within the team. The remainder are full-time staff on farms where harvesting is one of their responsibilities, amongst other agricultural activities.

The average age across the teams is 37 years, with a minimum age of 18 years and a maximum age of 62 years (Figure 3.5g). In terms of team size, the minimum size is four members, the maximum size is fourteen, with an average team size of seven members. Each team is typically led by a harvest manager responsible for acquiring a permit, organising access, and transport. This team member is experienced and acts as mentor, giving directions to younger team members (pers. comm.: JH1, JH2, IK). JH2 sees harvesting as a way to keep young people out of trouble, and tries to include at least one youngster in his team on every harvest. The average duration of harvesting experience is 15 years, although two harvesters have 40 years of experience each (Figure 3.5h). Two harvesters at the session were only just beginning as harvesters and are still in a learning phase. Knowledge and experience of harvesting methods are most commonly passed on to harvesters by family, friends, and other harvesters (68%, Figure 3.5d). Some have attended training courses (14%).

Of the harvesters interviewed, 41% consider themselves full-time harvesters. The part-time harvesters (59%) find employment as seasonal fruit pickers, in administrative roles at packing/processing facilities, or as casual labourers (Figure 3.5e).

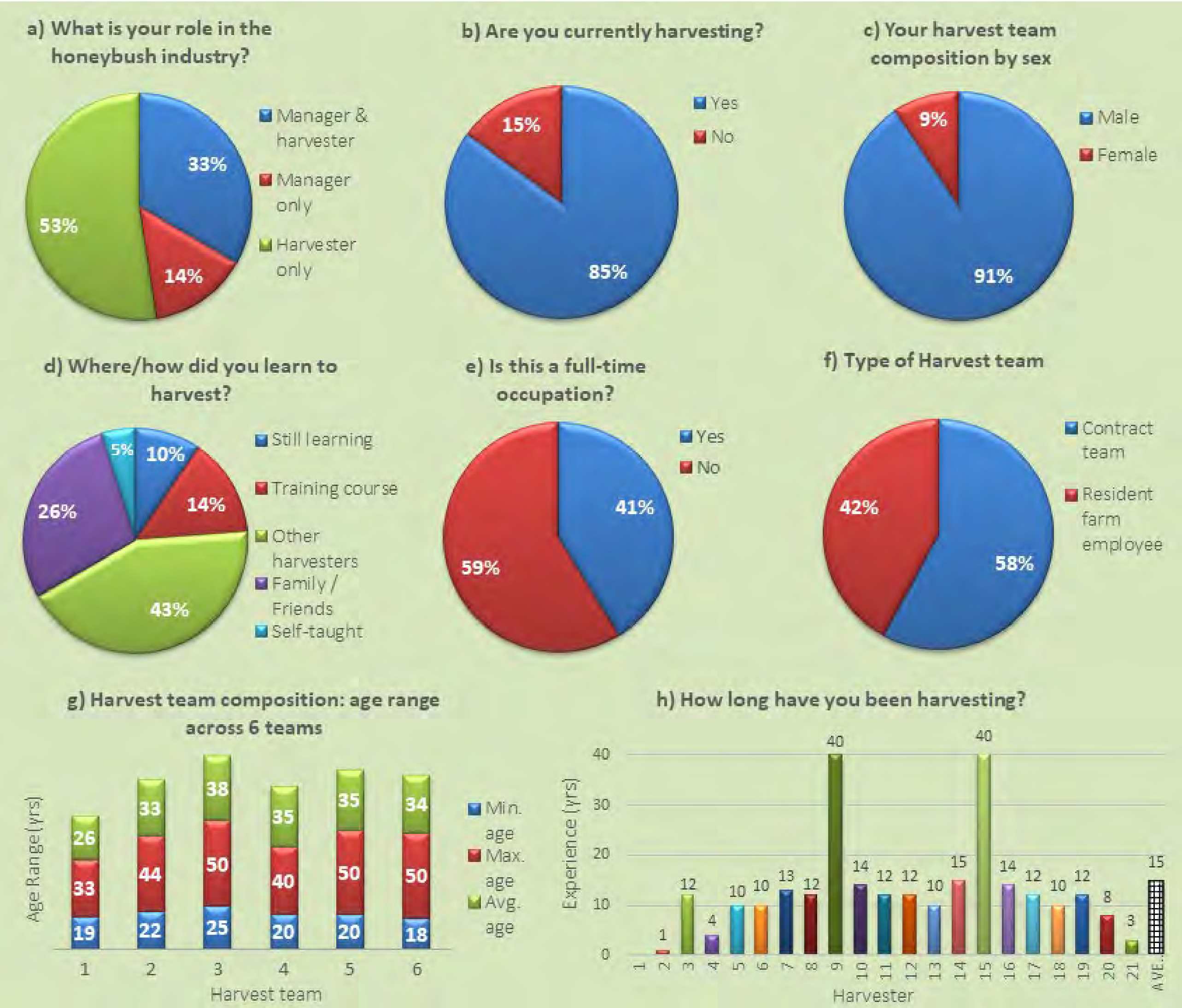

Figure 3.5: Harvester team background information.

The most commonly harvested species is *Cyclopia intermedia* – although four of the six teams also harvest *C. subternata* (Figure 3.6a). One team harvests *C. maculata* and *C. plicata* as well. Travel distances to sites vary from 5km to 80km (Figure 3.6b) – beyond this, the cost of travel is too great. For smaller teams, around 40 km is the limit in terms of travel cost. The harvest week is short even for full-time teams, occupying three days on average, most commonly four days, but up to five days for one team (Figure 3.6c). The harvest day varies from five to ten hours, with six hours being the most common (Figure 3.6e). Return walking distance to the harvest site is, on average, three kilometres (Figure 3.6d). Harvesters are compensated for long walk-ins at some sites, but the ideal is to keep to a short walk-in. Actual harvester loads vary from 30 to 200 kg, with an average of 106 kg (Figure 3.6f).

Figure 3.6: Harvester responses to questions about harvest logistics.

Stem colour is an important characteristic in harvesting, ranging from green (too young to harvest), to orange and brown. Harvesters favour stem colour ranges from orange to brown to dark red, but, as reported by harvesters, stem colour seems related to environmental factors, so that at some sites, mainly orange stems will be harvested, while at others, mostly brown stems are harvested. Orange to brown-coloured stems, most commonly 8 mm in diameter (not shown in graphs), are favoured by 85% of harvesters. One harvester described the most desirable stem size as "the thickness of a pinkie finger." Another harvester pointed out: "If it (the stem) is too thick, the processors don't want it." Young, green stems are undesirable as they make poor-quality tea, but one harvester claims that he cuts green stems because they are easy to cut. The number of stems harvested is not relevant except in so far as it is a better return on effort to cut many stems in one cut with a sickle, such that plants with only a few stems are often left uncut. Stem length is relevant for practical reasons – a short stem of less than 50 cm tends to fall out of the bundle when transported, therefore, the desirable length is greater than 50 cm. Most of the harvesters interviewed harvest plants that are two to three years of age (62%) while 19% harvest at three, four or more years of age (Figure 3.7a). As one harvester noted: "Cut the plant at 3-5 years, because if you cut earlier, you kill the plant."

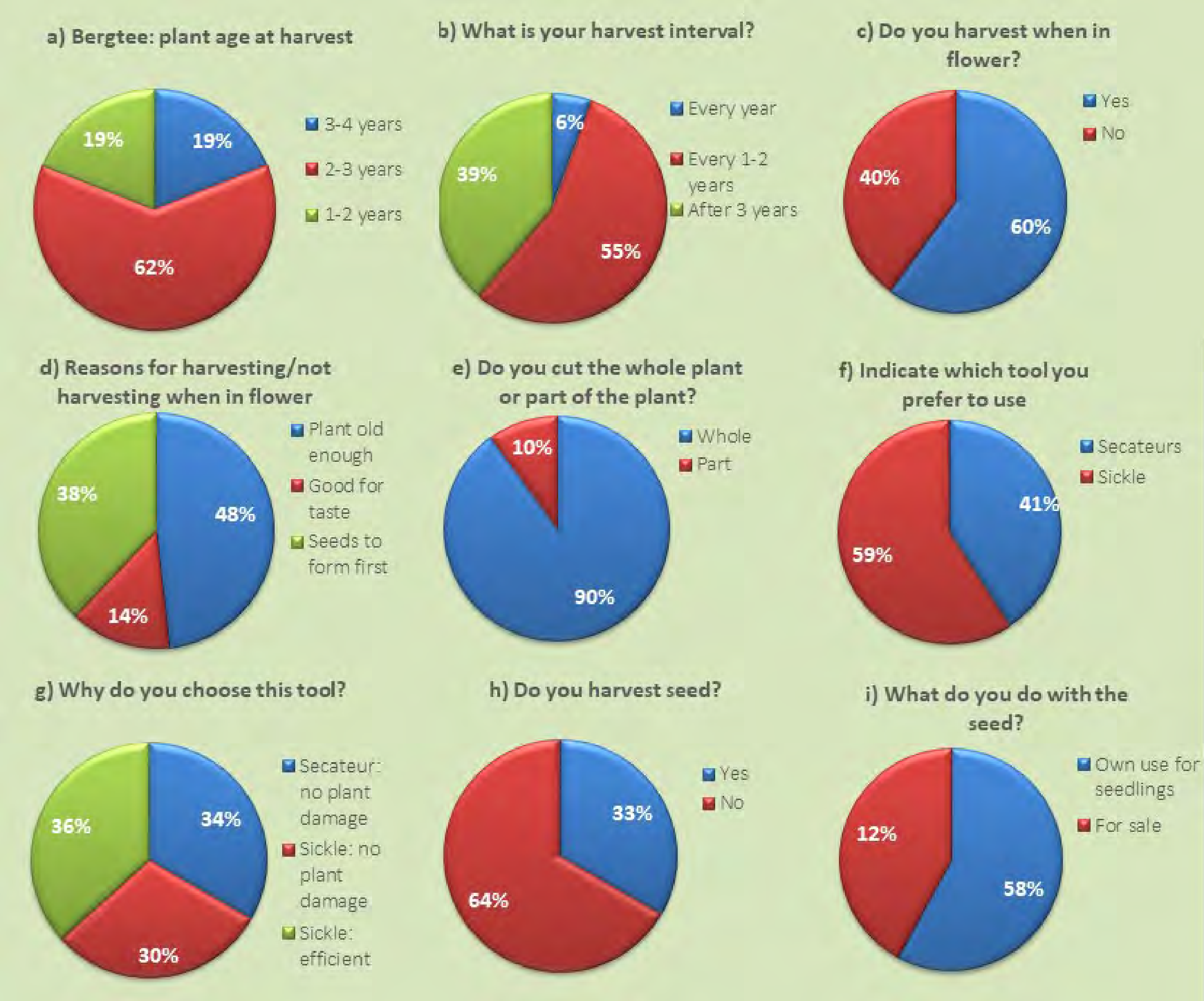

Figure 3.7: Harvester responses to questions relating to best practice harvesting.

Harvest interval varies from once every year to once in more than three years (Figure 3.7b). Most of the harvesters harvest when the plants are in flower (60%) because it indicates that the plant is old enough to harvest (Figure 3.7c). Still, some harvesters recognise that the plant must be left to set seed and should not be harvested in flower (38%, Figure 3.7d). In the words of two harvesters: "Plants need to set seeds to be sustainable" (JH1), and: "We also leave plants with flowers so that the seed can be spread and replant itself. This helps with growing more tea" (JL). Or, as practised by one harvester, if the plant is cut with seed pods on it: "Throw the seed off back into the veld."

The favoured harvesting tool is a sickle (Figure 3.7f) because it is efficient (36%) and does not damage the plant (34%, Figure 3.7g). However, 30% of harvesters consider secateurs to be less damaging. One experienced harvester used both tools in harvesting, favouring a sickle, but using secateurs for selective stem cutting in plants with a mixture of living and dead stems. A limited number of harvesters (33%) harvest seed (Figure 3.7h), which they use mainly to prepare seedlings (Figure 3.7i) for cultivation, or to practice wild augmentation: "We collect seed so that we can plant seed in areas where there isn't currently tea."

Based on the harvester surveys, when out in the field, there is a sense that harvesters are invested in their trade, with 60% of the harvesters valuing the benefits of working in nature (Figure 3.8a). As expressed by one harvester: "To be out in the mountains is hard work, but I like to be there in the nature where I am my own boss. It is also about the smell of the veld and being out in the nature" (HJ).

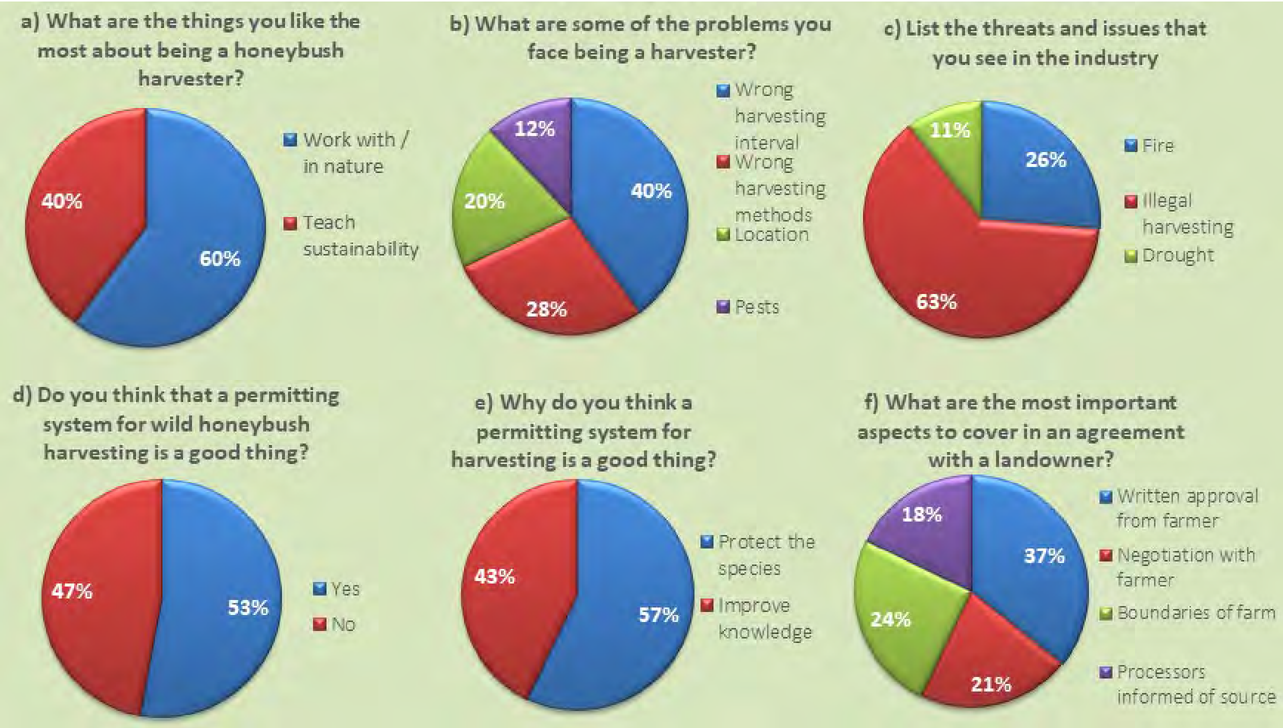

Figure 3.8: Harvester responses to questions about broader (harvester) issues.

Some of the problems harvesters face are summarised in Figure 3.8b, but some explanation is needed. Concern around unsustainable harvesting intervals relates mainly to illegal harvests at sites between scheduled harvesting times by reputable harvesters. This careless use of the resource makes reputable harvesters angry: "Those outsiders who do not have the right knowledge cut the plants we have left for the next harvest before they are old enough, and then it looks like we do not know the correct way to harvest" (JH2), and "It is mostly others who do this who have come in from other places" (JH1). Furthermore, illegal harvesting is considered to be a threat to the industry by 63% of harvesters (Figure 3.8c).

Responses of harvesters to the idea of a permitting system were mixed (Figure 3.8d & e). Reservations around permitting relate to mistrust of the administration of such a system, rather than the principle of it: "It is difficult to get to an office and get a permit when we should be out harvesting. And what if we can't get a permit? Then even if we have planned a harvest, we can't do it" (MC).

And in terms of the benefits of a permit system:

> If it will help keep out the *skelm* (dishonest) harvesters and help us with access to honeybush then it is good. If you don't have a permit, you could harvest wherever you want to make money quickly. But with the permits we know how much and where the tea is coming from. (DD)

Harvesters are aware of the need for comprehensive agreements with farmers as they need to have good relations with landowners and to build long-term trust. Negotiated written agreements in which farm property boundaries are indicated (Figure 3.8f) are important in building a good relationship:

> In this area there are no fences anymore and we can't tell where we must stop harvesting. It is an excuse used by poachers from outside this area to say there are no fences and that means they can harvest in our harvest areas. (JH2)

> To harvest you need approval from a farmer for it in a letter. You must have the farmers details and information about the boundaries of the farm. (JL)

3.4.3 Farmer survey results

Farms on which honeybush harvesting takes place are variable in size, from a few hundred to 6 000 hectares (Figure 3.9a). Typically, for large farms, only a small portion of the land consists of honeybush crops, ranging from 6% to 50%, with an average of 22% (Figure 3.9b). Most farms have supplied wild-harvested honeybush for 14 years or less (Figure 3.9c). This aligns with the honeybush industry growth period, which picked up steadily from 15 tonnes in 2004, to an average annual production of 350 tonnes from 2008 to 2018. Production quantities per farm are variable – ranging from 2–60 tonnes, with an average of 19 tonnes per farm (Figure 3.9d). From the results, it is clear that, with one exception, honeybush is not a primary agricultural enterprise. However, in all cases, it contributes to the overall livelihood of the farming enterprise (Figure 3.9e). More importantly, the use of the honeybush resource justifies keeping on full-time labour (Figure 3.9f), with 41% of farms using resident staff for harvesting. Less than half of the respondents were harvesting at the time of the workshop Figure 3.9g)

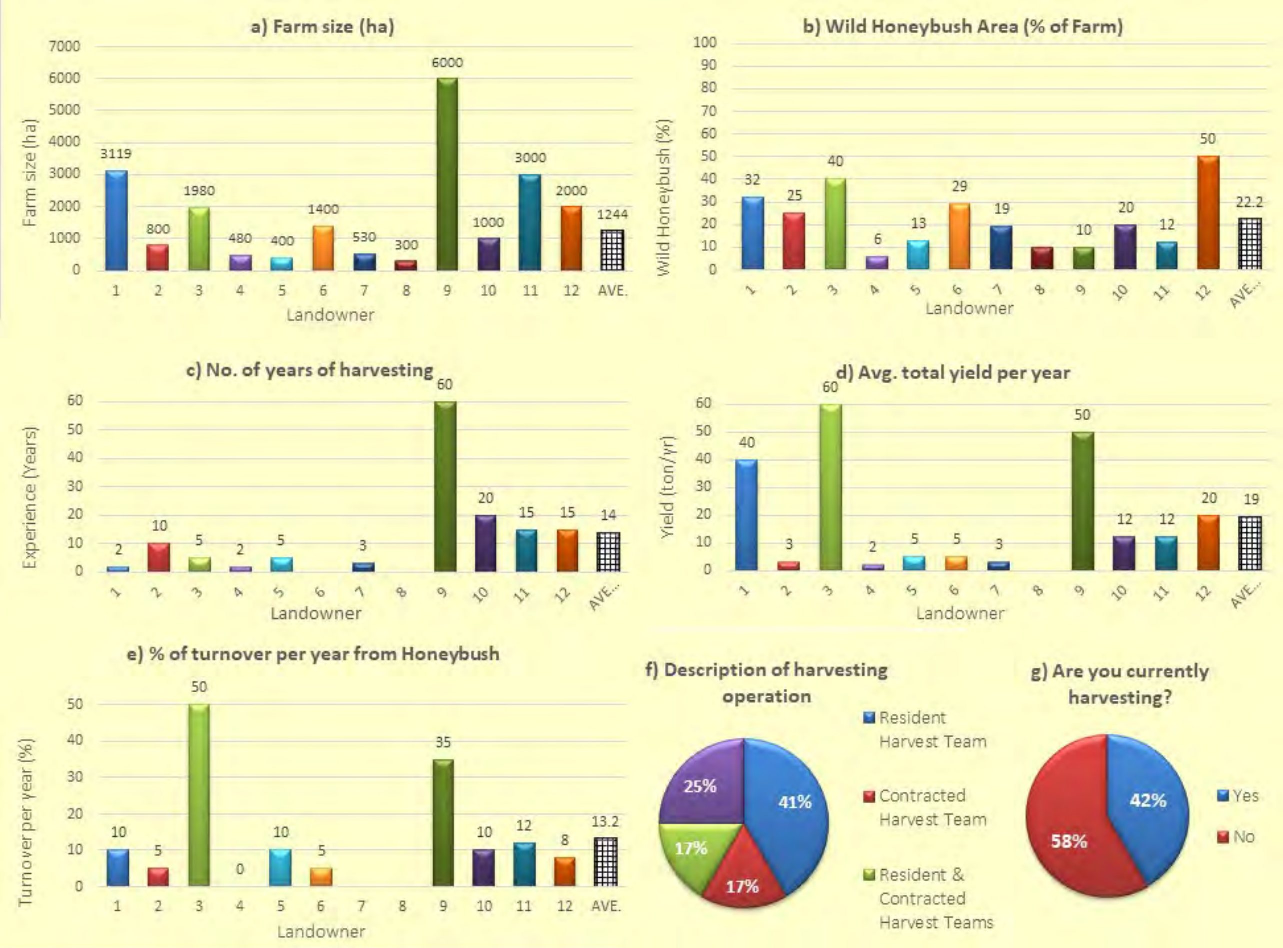

Figure 3.9: Farmer responses to questions relating to the nature of the honeybush enterprise on farms.

Of farmers who participated, 58% consider two to three years as a harvestable plant age, while 33% would harvest plant material older than three years (Figure 3.10a). Responses on harvestable plant height were similar: 50 cm or longer is best (Figure 3.9b), while most (95%) agree that stems should be pencil thickness or slimmer (Figure 3.10, F4e). All respondents agreed that the stem colour should be dark shades, and not green. With regard to harvesting in flower, 55% of farmers harvest when in flower (Figure 3.10d), and 92% prescribe cutting the whole plant (Figure 3.10e). 80% of farmers advocate using a sickle (Figure 3.10f).

In the focus group discussion, in response to questions about best practice, farmers specifically included the fact that they actively promoted best practice harvesting through training their harvest teams (67%). In comparison, 55% of farmers used slides to move harvest material up and down steep slopes, avoiding damaging road construction. Figure 3.11a shows that 42% of farmers would increase harvesting effort in response to an increase in price, and of that group, 87% think they could do this without damaging the resource (Figure 3.11c). None of the farmers interviewed had recorded changes in harvest yield over time or could not answer the question (Figure 3.11b). Most of the farmers interviewed (67%) take responsibility for checking the harvesters' work in the field (Figure 3.11d). Beyond this, 73% of the farmers check the load when it is brought in (Figure 3.11e) in terms of (Figure 3.11f) the age of harvest material, foreign matter (sometimes other plants, but also stones or other objects added to increase harvest weights) and harvester load (necessary as this relates to piece-meal payment for the load).

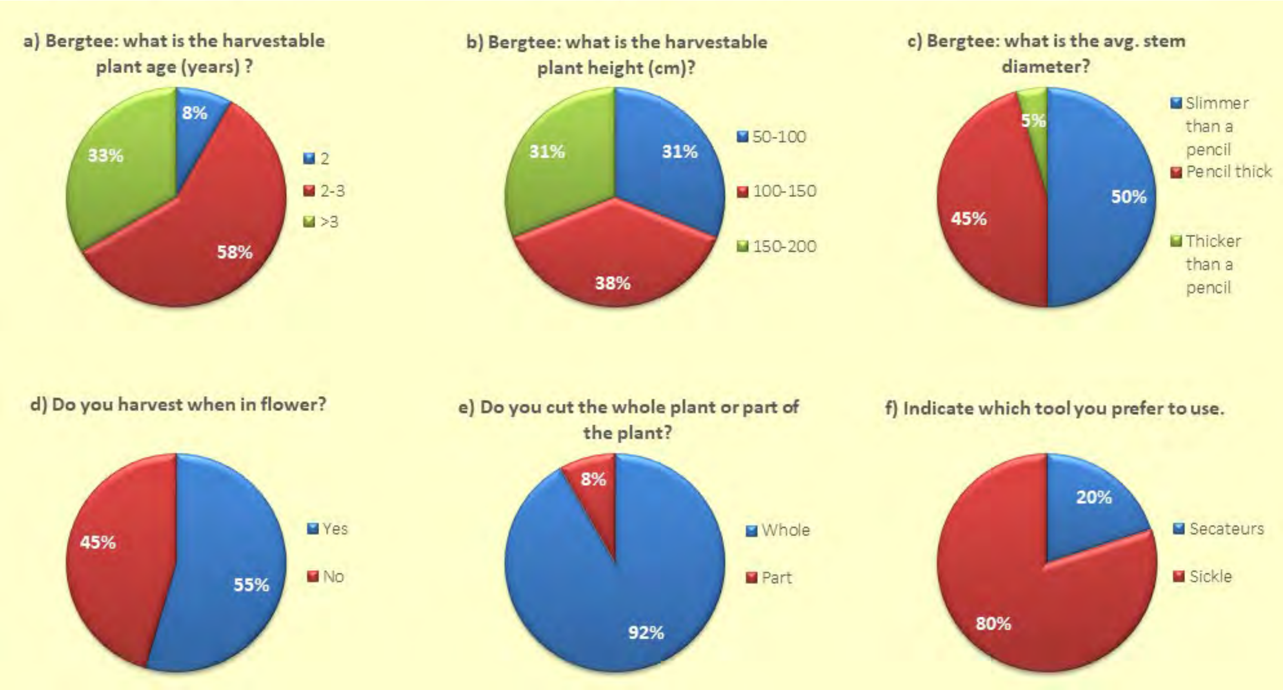

Figure 3.10: Farmer responses to questions relating to harvesting best practice.

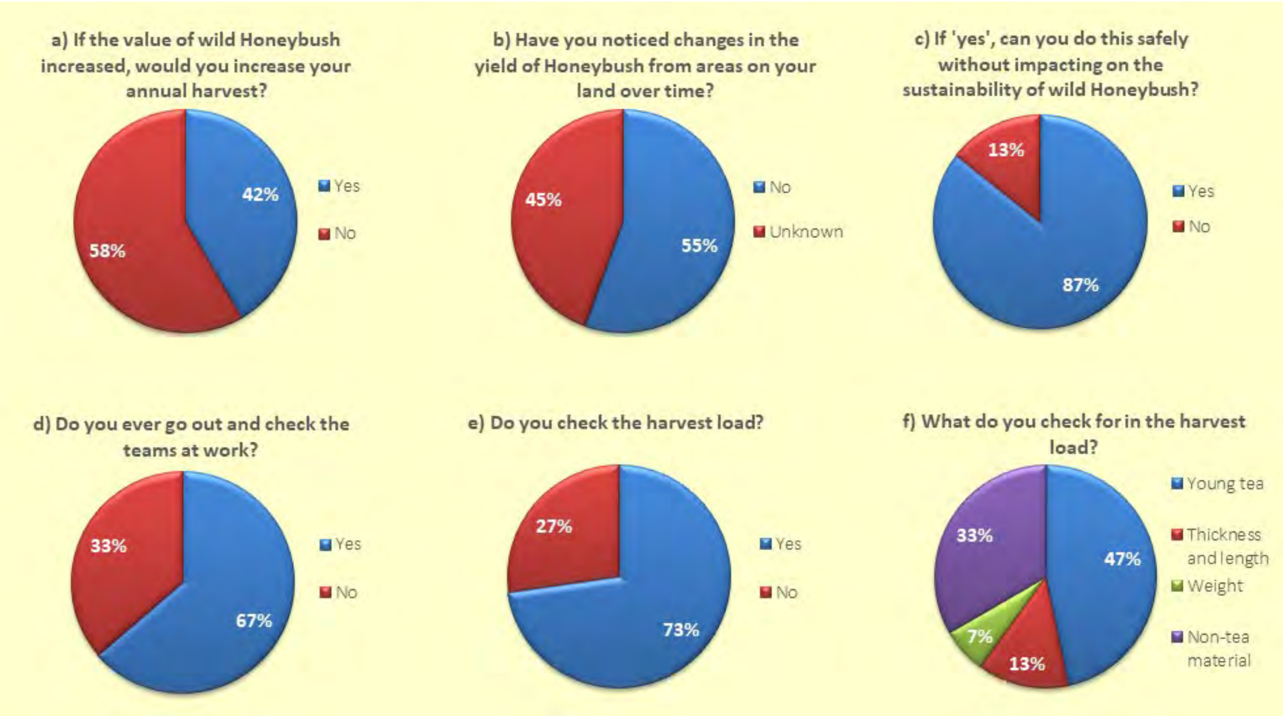

Figure 3.11: Farmer responses to questions relating to issues of sustainability and managing the harvest.

As shown in Figure 3.12a, 42% of farmers perceive natural factors to threaten the industry, followed by illegal harvesting (38%). In terms of the most significant single threat (Figure 3.12b), illegal harvesting and unsustainability are seen as equally substantial threats (each cited by 40% of the respondents). With respect to what information should be in the wild harvesting guidelines (Figure 3.12c), a large proportion

(41%) of farmers support the need for better information about ecological principles, then information on best harvest practices (37%), and lastly, feel that better information on permitting and legislation (22%) should be available. In terms of monitoring and permits, while 43% of farmers favour self-regulation, 33% say that government agencies should be in charge, and 24% think that permits should be checked by processors (Figure 3.12d).

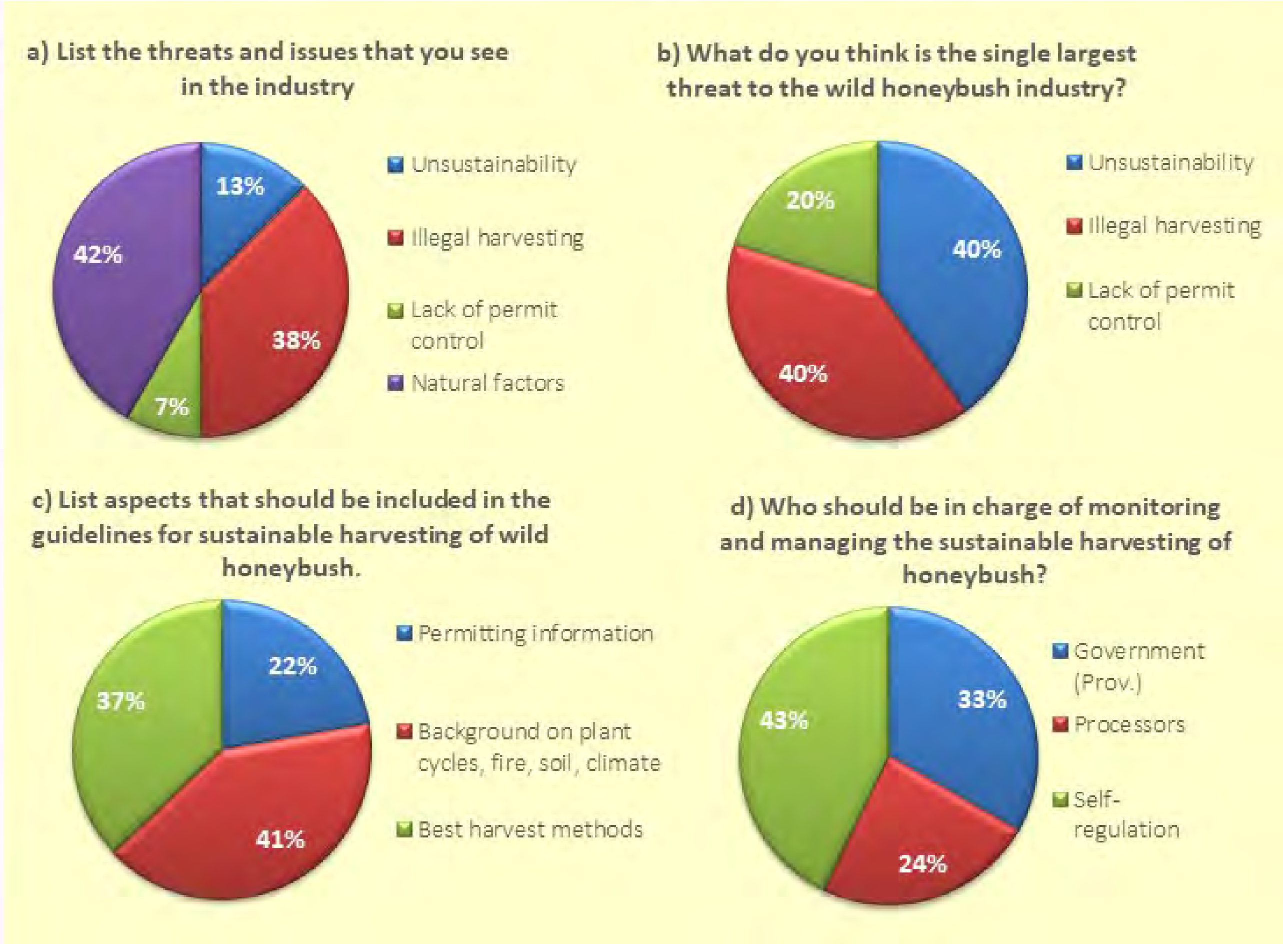

Figure 3.12: Farmer responses to questions regarding broader issues in the industry.

3.4.4 Processor survey results

The group consisted of four processors representing a complete sample of processors handling wild-harvested material and processing 75% of average annual honeybush production. Given the small number of participants, results are presented as a discussion rather than as graphics. The requirements of the processing plant are an essential feature of establishing best practice guidelines because they must be able to process efficiently and produce a quality product, which is directly related to harvesting protocols.

Production from *C. intermedia* is the major part (if not all) of the crop that is handled by the respondents. Sustainable use of wild-harvested tea is important, as it meets client demand (predominantly discerning international clients), and the cultivated sector does not yet produce enough tea to reduce dependence on the wild crop.

In terms of *stem size,* the ideal diameter for a stem suitable for harvesting is the same as a pencil; thinner stems are typically young, which means that the tea will lack flavour. However, stems that are too thick ruin the cutting blades in processing. All processors agreed that *darker-coloured stems*, ranging from yellow to orange to brown, are desirable, as they indicate the processed tea's age and flavour. Besides the fact that green stems give poor flavour, their high moisture content can cause problems in processing. *Plant age* and *condition of plant material* (freshness) were recorded as the most critical factors in determining tea flavour, followed by stem diameter and colour. In this regard, one processor commented: "The quicker the tea comes in post-harvest, the better the quality. When the tea is too old and has thick woody stems, the taste is also weaker" (GF).

With regard to *flowering time,* one processor contested the myth that honeybush in-flower produces better-flavoured tea. It is true that flowering plants are easier to harvest as they are conspicuous in the veld. One processor commented that flowers should not be included in the harvest material, and another believed plants with pods produced poor-quality tea.

Downtime and *busy times* are important elements of managing a processing plant, and all the processors agreed that winter harvesting is generally avoided due to rain, which makes for difficult harvesting conditions. A wet crop is undesirable as it affects the quality of the tea and adds the need to air-dry the material before processing. Three of the four processors noted trends of increased delivery around holiday seasons (Easter and Christmas) driven by desire for extra income, and out of fruit picking season (August to November) when seasonal employment ceases and financial need is greatest.

All the processors are involved with and train harvesters in best practice for harvesting. Three of the four processors were prepared to be involved in a monitoring programme which would benefit the whole industry. They all thought that the current permitting system, although limited, was an important step in the right direction, and according to one processor, a decline in deliveries from new suppliers to the processing plant has reversed. All the processors were very supportive of the idea of a set of formal, best-practice harvesting guidelines based on existing knowledge and scientific data, which would benefit the industry in the long term by maintaining tea quality and, therefore, the image and marketability of the industry.

One processor went so far as to say that the processors should enforce the guidelines, as they are able to accept or decline harvested material. With regard to declining production in terms of wild-harvested tea, one processor had this to say: "Less tea is being harvested. Tea is dying due to the drought and bad harvesting practices. Easily harvested areas are being overharvested while the areas which are difficult to get to are being harvested less often" (MB).

In terms of maintaining sustainable yields from wild populations, one processor believes that: "Insurance of sustainable plant growth in the wild can be achieved by planting additional plants into the field in and around where honeybush already grows" (GF).

3.4.5 Other stakeholder survey results

The group of ‘other’ stakeholders were made up of representatives from government agricultural departments (Western Cape Dept. of Agriculture, National Dept. of Agriculture, Eastern Cape Department of Agriculture, Land Reform and Rural Development) government departments dealing with conservation and the environment (South African National Biodiversity Institute, Department of Environmental Affairs and Planning (WC), Department of Environmental Affairs, Eastern Cape Department of Economic Development, Environmental Affairs and Tourism, CapeNature), members of the Khoisan group, and members of the Tsitsikamma Honeybush Tea Association. In total, 16 questionnaires were submitted. In this group, involvement with the industry was mainly a supporting role (25%), with 25% giving agricultural advice and 25% acting as conservation managers. 12% of the group were involved in the management of bioprospecting, and several considered themselves newcomers. In terms of the length of time of being involved with the industry, one respondent had been involved for eight years, but on average, the time of involvement with the industry was three years, while the most common duration of involvement was one year or less.

Most of the questions discussed by this group were related to sustainability issues. Given the group's background, they did not give explicit input on what constituted best practice but focused more on achieving it through their knowledge of plant ecology, broader conservation issues, policy and regulatory frameworks.

The main concern concerning the industry (Figure 3.13a) is unsustainable harvesting (35%). Second, there is uncertainty around regulations (24%) due to poor dissemination of information. Illegal harvesting is not a significant concern and was only mentioned by 17% of respondents. Some respondents (14%) saw the current permitting system as problematic because it prevents access to the resource by some communities. This pattern is repeated in Figure 3.13b, where respondents are mostly knowledgeable or involved in training and awareness around sustainability issues and the need for better monitoring and regulations. These themes also come through in Figure 3.13c, where ideas on how to deal with issues in the industry are mostly related to the development of harvesting plans (22%), engagement with stakeholders (17%), and better government support, for example through the development of Biodiversity Management Plans. Other ideas relate to improved regulations, the need for training related to understanding the sustainability of harvesting, and the need to monitor the resource. The themes of evaluation and monitoring continue in responses shown in Figure 3.13d, where 57% of respondents see the difference between the Eastern Cape and Western Cape permitting requirements as problematic. In Figure 3.13e, 36% per cent of respondents support a uniform permitting system, stricter regulations (23%), and more specific regulations for species harvested plus harvest quotas per species (19%).

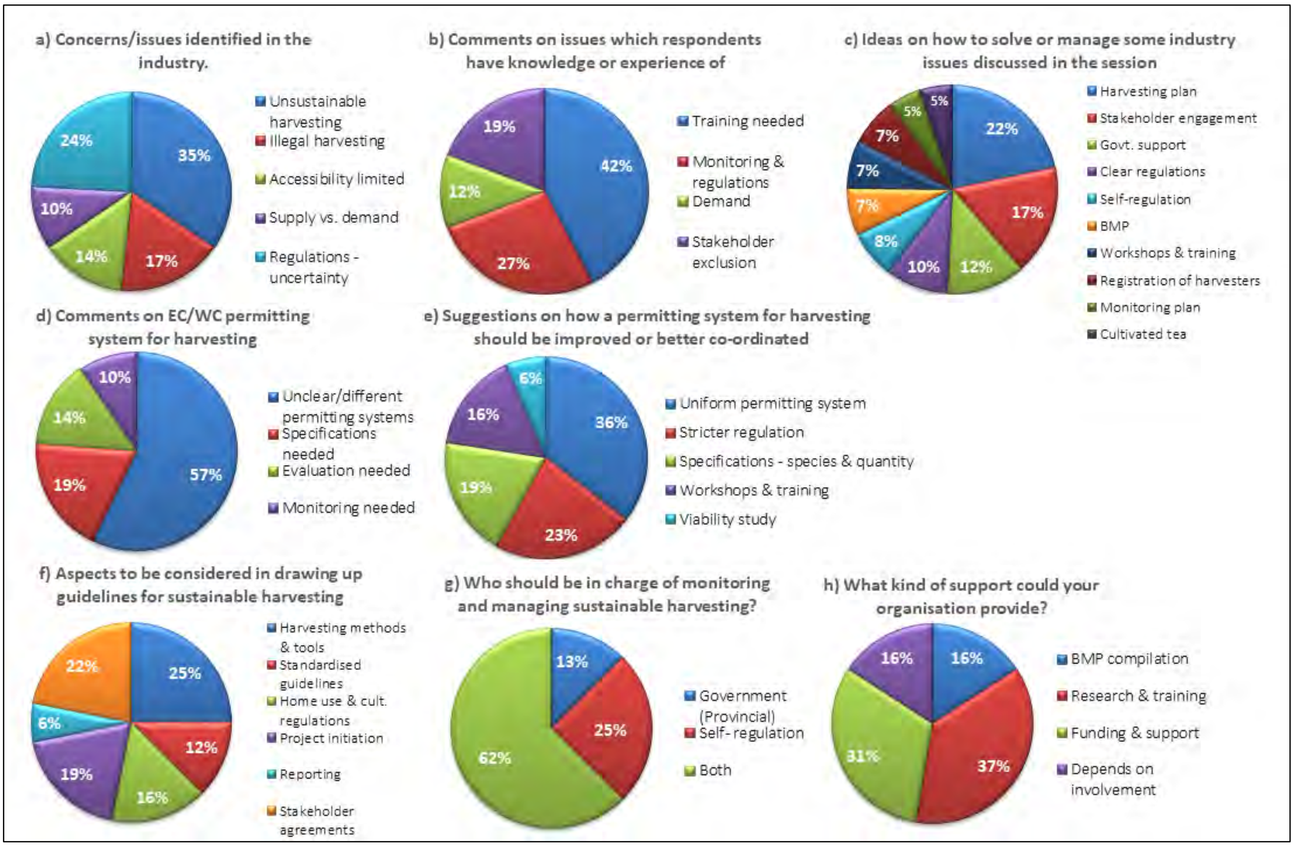

Figure 3.13: 'Other stakeholder' responses to questions in the questionnaire.

Most respondents (75%) supported harvesting guidelines, while 25% reserved judgment on supporting such guidelines. In the list of aspects that should be considered in sustainable harvesting guidelines (Figure 3.13f), detailing harvest methods and tools were seen to be most important (25%), with stakeholder agreements being the second most important element (22%). Reporting was seen as least important (6%). The majority of respondents (62%, Figure 3.13g) thought that both self-regulation and government regulation at a provincial level should form part of a sustainable harvesting approach. As reflected in Figure 3.13h, most respondents were willing to play a role in supporting sustainable harvesting through research and training (37%), funding and support (31%), and involvement in the development of a Biodiversity Management Plan (16%). Those who said, 'Depends on involvement' were willing to carry out training and education and to support cultivation efforts in their own communities.

3.4.6 Thematic content analysis of workshops and interviews

Seven themes were evident in the discussions with stakeholder groups other than harvesters, farmers, and processors.

3.4.6.1 Opinions about best practice wild harvesting guidelines

There was a general consensus that the time had come for some form of best practice guidelines for wild honeybush harvesting to be put forward (more than 50% of stakeholders agreed on this). It was noted that various meetings had been held where these discussions happened, but nothing had yet come out from these (comment by a harvester, supported by an experienced official and a processor). Some of the comments which support the value of guidelines are:

> We will take a young man with us to harvest and show him the best way. But if someone comes from outside who does not know – then he should have to find out this information before he is allowed to harvest (JH1).

> Establishment of harvesting guidelines should come from harvesters and farmers' experiences plus from the science of it. This will benefit all people involved in the honeybush industry (DD).

> We want a sustainable plan for harvesters that will increase their value to the industry and allow them to get better paid (JL).

> A farmer who has little knowledge of honeybush will allow people to harvest when approached, even if it is less than a year since previously harvested. If they [the farmer] don't have a good relationship with a specific harvester, they will allow others to harvest as well. If he has better information, he will be able to manage his honeybush properly (JL).

There was also some scepticism expressed about the development of guidelines in one of the focus group discussions: "There is a need to know that these guidelines are created with regard for harvesters and their essential role in the industry, as well as with economic opportunities for rural communities in mind" (DD).

The processors were of the opinion that guidelines would be helpful in establishing pre-harvest best practice knowledge amongst harvesters, so that when unsuitable crop material was delivered, processors could rightfully turn away crops that had been incorrectly harvested. They were also of the opinion that standardisation of harvesting would be good for the industry in terms of the quality of the tea produced, which would be consistent if all harvested material was of a similar desirable age and stage of growth. One harvester gave a valuable perspective on including the broader context of wild harvesting when developing the guidelines:

> The wild harvesters and the economy linked with harvesting is essential to providing economic opportunities for rural communities. This must be a strong part of the thinking and provide context when working to develop guidelines for wild honeybush harvesting (PVR).

3.4.6.2 State of the industry

There was a widespread view expressed that honeybush populations are declining. Three individuals noted that they have observed a decline in wild honeybush populations. Several harvesters commented on the fact that populations of honeybush have declined in areas where they used to harvest, now requiring them to travel further and walk deeper into the mountains: "The honeybush is harvested too often in our area by too many people, so we must look further away for places to harvest and work harder to get what we used to get" (JH2).

The above comments were supported by estimations from two processors who have recorded a decline in the volume of material delivered to the factory over the past three years (2014 to 2016), which they admitted could also be linked to the implementation of the permit system. Restrictions through permitting for the Eastern Cape have caused increased tea delivery to the Western Cape for processing where there is no permitting system (observation by a farmer of pick-up trucks loaded with harvested tea, registered in the Eastern Cape travelling in the Western Cape).

Several stakeholders commented on the fact that cultivation and wild harvesting together are essential for the future growth of the industry. One of the processors noted that the wild-harvested material will always be important because it produces high-quality tea. This was reinforced by comment from a harvester who noted that Bergtee is called 'Die heuningbos' ('Die' translated from Afrikaans as 'the' definite article and 'heuningbos' - 'the honeybush') because it is the tea on which the industry is based and for which it is known.

Many harvesters, farmers, and other parties are interested in cultivation and came to the workshop hoping to improve their understanding of the industry and to pick up information on cultivation. In the words of five of the participants:

> We want more ground to cultivate on and to also create more jobs. I want to learn how to do this because in this way the idea is to conserve the nature and to not kill the wild honeybush (IK).
>
> I want to learn more about honeybush processes. I want enough land to have a nursery and cultivate. I want to get involved even if it's small scale. I think this will be better than wild harvesting because it will not harm nature (MC).
>
> I want to know about a sustainable plan for harvesters and find out more about cultivating honeybush and even setting up a special nursery for honeybush (SL).
>
> The use of cultivation and wild harvesting together is essential for the future growth of the industry (CS).
>
> In order to stay sustainable (as a harvester) we must move into the cultivated section and use our skills there (HJ).

The threat of alien invasive plants in wild honeybush lands was raised by processors and harvesters, particularly regarding the Haarlem and Formosa areas in the western part of the Eastern Cape. There was consensus amongst the focus groups that invasive alien plants – hakea, pine and black wattle – pose an immediate threat to honeybush populations. The second main area of concern related to the impacts of climate change and the uncertainties around what might happen. One farmer noted that the increased incidence of veld fires was a sign of changing climate, with potential impacts on honeybush populations as a concern. One processor noted the reduced incidence of rainfall across the Langkloof, which he saw as evidence of changing climate. One harvester noted that although the rainfall patterns might be changing, there is still enough moisture for honeybush: "There is always some rain up in the mountains, and that is where the honeybush grows, where there is always enough rain even if it is dry down in the valley" (GS).

The idea that cultivation is key to the future of the industry raised some interesting concerns amongst harvesters who have seen the crop diminishing and blame this on the fact that:

> The uninformed farm owner isn't always using the same teams in the correct intervals to harvest. And so he will not get the same crop every year. We know how to harvest wild tea which is good quality tea and cultivated tea is not the same (DD).

There is a general desire to have collaboration between all stakeholders:

> We must create the same language under the fynbos blanket so that there is uniformity in discussion and knowledge sharing, the industry must work together as a whole (PVR).
>
> Wild harvesting carries a very nice story that benefits the industry as a whole. It is that product which is wild bergtee which consists of sought-after characteristics which the industry currently prefers (TK).

The points that were listed as necessary for the whole industry include: understanding honeybush ecology through research and monitoring; enabling individuals to stick to newly created guidelines through education and sharing of information; creating a system of registration and verification for harvesters and for farmers who use the resource. In the words of one of the participating officials: "The business of Honeybush must stay sustainable even for the little guy (i.e., the harvesters)" (ES).

Many participants felt that government has a significant role in developing and promoting the industry sustainably. One stakeholder noted that: "Government must buy into the idea of this industry and must help with support of sustainability," (GF), and another: "The government must come in and help" (JL).

3.4.6.3 Relationships between stakeholders

The relationship between farmer and harvester is straightforward, where the farmer has a well-defined agreement with an experienced harvest team, which he uses regularly. He values their knowledge about harvest methods, harvest history and intervals on that farm, the best way to access sites, and their respect for land parcel boundaries. All of these factors make for an efficient and sustainable harvest.

This relationship between farmer and harvester is strained by unethical harvesters who approach a careless farmer who is most likely motivated by profit, who can easily be convinced to allow anyone to harvest at any interval. Harvesters see this lack of knowledge on the part of the farmer as problematic: "The farmers sometimes don't have the knowledge to even find their own honeybush, most harvesters have better knowledge. Without us, they wouldn't be able to harvest," (DD); and "Farm owners are getting most of the money with doing no work" (SL).

The need for better communication between farmers and harvesters was explicitly articulated in several ways: "Farmers and harvesters should both have an informed harvesting schedule" (ES); "We need honest, fair practices from all parties involved" (QN); and "Farmers and the land user/harvester need better communication and trust" (FH).

The importance of the harvester community and their role in maintaining a sustainable system is emphasized: "As rural communities, some have real generational ties/links in wild fynbos harvesting for generations and I would like to see this done in a sustainable way" (O2); and "We want to see something happen on the ground level not just high up with farm owners and researchers" (GS).

One harvester went so far as to suggest that because harvesters are knowledgeable, they should be issued permits rather than farmers: "Permits should be issued to the harvesters not the farmer, the permit must be in the harvester's name" (DD).

There is a perception amongst harvesters that illegal harvesting is carried out by outsiders who come into the local area without knowledge, who do not care for the plants, and seek only profit. They make things difficult for other harvesters who lose out on the crop and earn a bad reputation. However, as one harvester pointed out, it is up to individual harvesters to build their reputation: "A harvester's reputation can be controlled by themselves if they use the permits correctly and do a good job" (JH2).

Interestingly, one harvester sees formal harvesting guidelines as useful because they can educate these kinds of people about how to harvest correctly: "But if someone comes from outside who does not know, then he should have to find out this information before he is allowed to harvest" (JH1).

There is a widely held perception that control of sustainability, including monitoring and regulation, can come from the processors. They have requirements in terms of best processing practice about the product – the most important of which are stem thickness (maximum size = pencil thickness), the age of a plant (mature tea gives best tea flavour), species of honeybush, and age of the harvest since previous cutting. In the words of one processor: "Harvesters must know before they come to the factory that their plants will be rejected if it's not up to standard" (GF).

There is recognition amongst farmers and harvesters that the processors are in a position to keep a database of all harvesting that gets processed: "They have to keep financial records of every load received and have a long-term picture of harvesters and farmers who deliver" (PVR); and "The processors have to know who has permits and who can actually bring crop into them; therefore they must follow up on the issues related to permits" (JH1).

The processors recognise that they are in a good position to handle a harvest database:

> Harvesters already have a lot of administration to do in order to get and sell their processed material - let's help them by using data which they already capture to keep records of the plants coming in. We also believe that maps would be a useful way to pinpoint where the tea comes from. Using this system and the data will create a system of ownership (MB).

SAHTA is perceived as being non-welcoming to harvesters, partly because of the membership fee. It is also viewed as having a particular agenda concerning the development of guidelines, registration and accreditation. Some harvesters questioned what the creation of the guidelines is really about – if it will improve or worsen conditions for harvesters. They raised several questions to be asked of SAHTA:

> How receptive is the industry (SAHTA) to providing an ear to the wild harvesting sector and its quest for sustainability? How does the industry recognise and value the contribution from the wild? Does the will exist to look after the sustainability of wild harvesting? (O1)

However, as explicitly expressed by SAHTA – it values harvesters:

> An experienced harvester is essential to sustainable use of honeybush: he has good knowledge of the plant and the method of harvest and productivity. He knows where the honeybush is and how to get there to optimise harvest time (ES).

SAHTA sees the value of a process that accredits and or registers harvesters with suitable experience and knowledge who practice sustainable harvesting. This is seen as beneficial to farmers – who get the services of a reputable team; and harvesters - who gain consistent access to more harvesting areas. Members of the harvester community supported this kind of approach, which would benefit them. The exact means of achieving this was not detailed, but having a set of best practice guidelines would indicate issues and measures to work with.

Harvesters are critical of farmers who are not knowledgeable and don't take care to use experienced harvesters, oversee the harvest, or build a long-term relationship with a harvester team. In a similar vein, SAHTA takes issue with farmers who do not manage their honeybush use sustainably and are not members of SAHTA, where they might learn to be better managers of honeybush: "If someone new buys a farm and wants to be an environmentally conscious farmer, there is no existing information on how you should best use honeybush, that is why we need this information" (O3).

3.4.6.4 Knowledge of ecological and conservation principles

All harvesters interviewed know the need for best practice and generally take their cue from the harvest manager or farmer. As reflected in their stated practice, there is an understanding of the need to let plants recover for one to three years or more (Figure 3.7b). In an attempt to determine readiness to harvest, all harvest managers/farmers should undertake a site assessment before harvesting – based on harvest history (formal or informal record), interval since last harvest, knowledge of local climatic conditions, and on the state of the veld. If the site is unsuitable for harvest (if plants have already been removed illegally, the veld is unusually dry, or plants are not looking vigorous), they will move on to another site. One farmer admitted that he would like to understand more about *Cyclopia* species' ecology to be able to make better-informed decisions for the long-term health of the enterprise, rather than just using his local knowledge and experience.

Fire is important to a harvester, because it promotes resprouting, improves yield at a site, and clears a harvest site of competition. Half the harvesters interviewed recommended that fire should be used every five or six years, to promote honeybush growth and make harvesting easier. There is recognition that controlled burns would increase *C. intermedia* growth and get rid of plant competition, which hampers harvesting efforts.

Many harvesters understand the need to keep a healthy soil seed store (38%; Figure 3.7d) to allow new plants to grow, but there is a misunderstanding around resprouting versus germination. An experienced harvester (QW) took the researchers to a place where the team had not harvested for 15 years because there was no honeybush there. He pointed out that one year after a fire, there was a healthy population of *C. intermedia* bushes at the site, perceived by the harvester as being new plants. On closer inspection, it appeared that this was a dense *Leucadendron salignum* thicket, cleared by fire, which allowed the outcompeted but nonetheless substantial *C. intermedia* plants to re-sprout.

While there is a general understanding of the need for sufficient time for the plant to recover after harvesting (a range of one to four years; Figure 3.7b), the aboveground biomass is commonly used as an indicator of readiness to harvest. With vigorous resprouting, a plant can appear large enough to harvest (1 m tall with 50 stems and a crown of 80 cm in diameter) within 18 months of harvest or fire, and the stems may appear yellow/orange in colour. Only 20% of the harvesters interviewed knew that at least three to four years of recovery between harvests is needed for high-quality harvest material, and complete plant recovery.

While all harvesters knew harvesting in protected areas is illegal, half of the harvesters believed there should be an opportunity to harvest there. They gave the following explanations: "The fences don’t exist and we can’t tell if we are in the nature area or not so sometimes we harvest there anyway" (JH1); "There is so much tea there in the nature areas and harvesting makes it grow even more, so harvesting can be a good thing"

(Harvester Group 2); and "Where protected land is next to our harvest site, it (harvesting) should be allowed because we take care of our harvest site and we will also take care with the protected site" (JK).

A further aspect of local knowledge that was evident was that harvesting knowledge is area and species-specific: *C. intermedia* harvesters admitted to knowing very little about *C. subternata* harvesting, but knew that it should be treated differently. Harvesters familiar with *C. subternata*, from the Tsitsikamma, knew that *C. intermedia* was abundant and widespread and could be cropped completely, which made it an attractive harvesting option. Farmers also acknowledged that their honeybush knowledge was area-specific.

3.4.6.5 Understanding and applying sustainability principles

A key message that emerged was the role of experienced farmers and, particularly, harvesters, in managing the sustainable use of the resource: "The methods [for guidelines] must come from the harvesters so that there can be sustainability" (Harvester Group 1).

Many farmers and harvesters believe they practice sustainable harvesting based on their extensive knowledge and experience. Most farmers and harvesters recognise the need to adjust harvesting in the face of changing weather patterns.

Some experienced harvesters are critical of farmers who lack knowledge about honeybush harvesting and grant permission to harvest irresponsibly. Farmers who lack knowledge about the practice of sustainable harvesting rely on the advice of experienced harvesters, who are, therefore, critical of the process. Suggested ways in which sustainable harvesting can be achieved include monitoring the harvest by the farmer, clear delineation of harvest boundaries, and developing a good relationship with a harvest team. Furthermore, sustainable harvesting can be achieved using the same harvester team, with a well-defined harvest interval that allows for uniformity of good practice over time.

3.4.6.6 The role of regulation and monitoring

In principle, there is support for sustainable harvesting and developing a code of practice or guidelines for sustainable practices. However, harvesters have questions about the ultimate objective of this process. It does not necessarily improve the number of harvesters, given their day-to-day concerns around access to the resource, fair pay, and fair working conditions.

There is recognition amongst all stakeholders that government departments should take the lead in regulation and monitoring. Participants also recognised that conservation officials need to be better equipped to promote, monitor, and, if necessary, enforce sustainable practices in honeybush harvesting. The idea that there should be local monitoring, by local residents who have LEK of the area and the resource, was supported by farmers and harvesters. A workable set of ideas around an approach to monitoring from one of the harvester focus groups was recorded as follows:

> Harvest monitors should be trained to accompany harvest teams in the field, they could be equipped with smartphone technologies which would allow mapping and reporting on the harvest. Funding for this kind of exercise could come from a tea tax where every kilogram of wet tea attracts a 20c tax. It is in the interests of harvest teams to support this kind of system because they will then be responsible for protecting their own reputation (Harvester Group 1).

Motivation for this was expressed through the need to capture and account for variability concerning harvest intervals and yield quotas, which should account for different climatic conditions in other areas.

Participants were critical of farmers who do not check on harvesters, which results in them being able to do whatever they want in the veld (over-harvest plants or harvest from inappropriate areas). Harvesters who have a good understanding of honeybush harvesting and resting want protection from incompetent harvesters, and they recognise that a system of harvester accreditation would help control this problem. It was suggested that the lead harvester/harvest manager be registered to ensure traceability. Issues around the current permitting were noted – primarily that the EC DEDEAT permitting system is limited and allows for exploitation, partly because it only deals with Eastern Cape harvesting.

3.4.6.7 Call for guidelines

Out of the Louterwater workshop came a call for a popular 'field guide' version of the Guidelines, in English and Afrikaans. This idea was brought up at the general discussion sessions and repeated in comments submitted anonymously in the comments box. The need for guidelines that would be available and accessible to all stakeholders was promoted by government officials too, who recognised that it would improve their knowledge about the industry and their ability to contribute to managing a sustainable industry. The need for, and value of, a set of formal guidelines is represented in the following stakeholder comments: "This workshop shows that change is to come" (ES); "What will happen with the work from the workshop? We want to see the end result of the workshop in something useful" (DD); "We would like to see all this information collected here today written in language that anyone can understand and in Afrikaans" (JL); and "We have enough knowledge between us to keep honeybush harvesting sustainable but we must do that formally so that everyone has the same information" (O3).

3.5 Discussion

Important elements that emerge from this research are presented in Figure 3.14. The diagram presents significant processor contributions in blue, farmer contributions in yellow shades, and harvester contributions in green. Where harvesters and farmers overlap, the colours are merged in the middle (bottom) block of the figure. The broader context issues recorded by 'other' participants are presented in a wide frame at the top of the diagram.

3.5.1 Best practice harvesting from TEK and LEK

Most stakeholders recognise the crucial role that processors can play in managing sustainability, through their requirement for quality tea. Their position in Figure 3.14 is illustrated as overarching, with adherence to best practice by farmers and harvesters feeding into their specifications for a quality product. The single most important characteristic of quality tea (as listed in the blue box) is mature harvest material (not green stems), which can only be achieved through adequate harvest intervals. Producing a consistent quality tea for consumers is a persistent concern in the industry, and is the topic of most of the research on *Cyclopia* spp*.* (De Beer et al., 2022; Joubert et al., 2017).

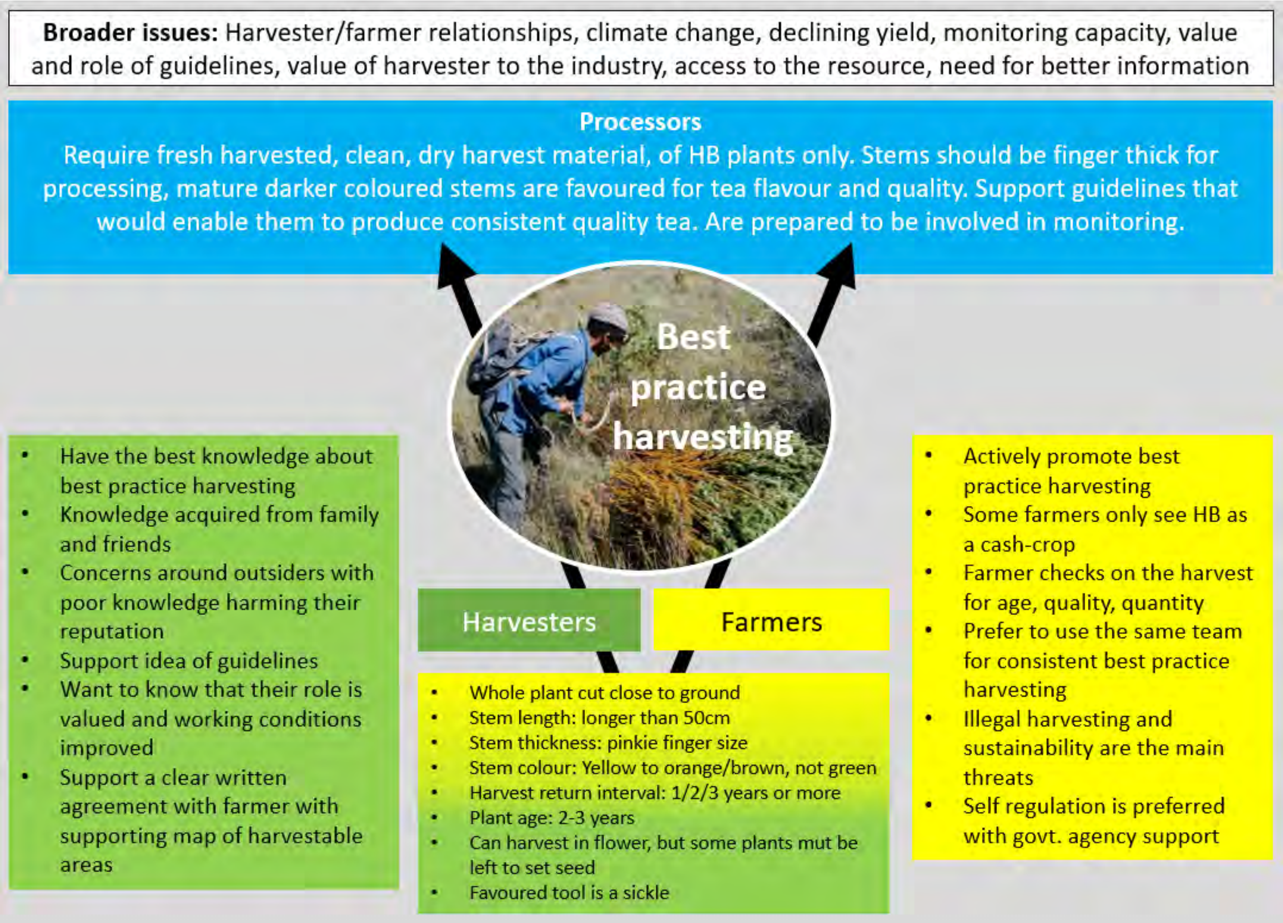

Figure 3.14: Summary of knowledge around best practice harvesting collected through interviews and in focus groups at the Louterwater workshop.

In the middle/bottom box, best practice harvesting guidelines from the harvester and farmer TEK and LEK show that average harvest intervals are one, two or three years, while average plant age may be two to three years. This practice is not sustainable based on evidence presented in Chapters Four and Five, and needs to be addressed. It is an example of where TEK and LEK are not adequate for sustainable resource management (for similar examples, see Chalmers & Fabricius, 2007; Kaschula et al., 2005), and this practice needs to be refined regarding the collection of longer-term ecological data, as recognised by Dovie et al. (2000) and Kaschula et al. (2005). Other best practices, like the choice of pinkie-thick stems and long stems, have practical implications: thick stems are problematic for processing machinery, while short stems tend to fall out of the harvest bundles. Cropping the whole plant close to the ground is advisable as it ensures vigorous regrowth because this simulates the natural effect of fire in the resprouter plant form (Bond & Midgley, 2001), while resprout vigour of fully cropped plants is measurably greater in comparison to part-cropping (Lee et al., 2023).

Amongst harvesters (green box in Figure 3.14), concern about relationships with landowners is commonly voiced through their desire to be recognised as valuable to the industry. Harvesters are critical of farmers who control access to the resource but lack knowledge of best practice. These farmers do not value harvester experience, and award permission-to-harvest carelessly to inexperienced teams, leading to unsustainable resource use. In South Africa, resource degradation is commonly linked to unfair access to resources, which may result in selfish and careless resource use (Puttick et al., 2011; Shackleton et al., 2001). Harvesters also raised concerns about the role of inexperienced outsider harvesters, who lack knowledge and create a negative impression of harvesters through poor harvest practices. Concern about outsiders lacking in TEK is not an uncommon feature in wild resource use, as noted by Williams & Kepe (2008) for the buchu industry, Wynberg et al. (2003) for the marula industry, and Melin et al. (2017) for the aloe industry.

The yellow box presents a summary of important information presented by farmers. Many farmers actively support and promote sustainable harvesting, consistently using a reputable harvest team and carrying out regular quality checks of harvested material. However, as acknowledged by SAHTA, some farmers are driven by financial incentives and are careless in their management of the honeybush resource. In the agricultural context, the adoption of approaches with short-term economic benefits is often chosen above approaches with longer-term benefits to the environment (Piñeiro et al., 2020). Pressure on the resource caused by increased market demand and financial imperatives has been identified as a feature of wild resource use (Chen et al., 2016; Schippmann et al., 2002).

Across all stakeholder groups there was broad in-principle support for the publication of best practice harvesting guidelines. There were reservations from some harvesters and farmers about how they might be negatively affected, and broader concern from all stakeholders about the implementation of regulations or guidelines. While government support was viewed as necessary, there was a strong argument from harvesters and farmers that self-regulation by stakeholders, with locally relevant knowledge, would constitute a workable approach. Self-regulation based on communities with strong TEK or LEK surrounding the use of a resource is promoted by Malgas (2022) and is considered successful where local leadership is strong (Ostrom 2009). A characteristic of local ecological knowledge is that it can provide the best available specific understanding about the use of the resource (Cunningham, 2001). The value of locally relevant expertise in developing management approaches to wild resource use has been promoted by Early-Capistrán et al. (2020), and Malgas & Oettle (2007). If regulations (such as harvesting guidelines) are to be beneficial and successful in achieving sustainable resource use, they must be developed and implemented in cooperation with local communities (Ostrom, 2009; Schmidt & Ticktin, 2012).

The group of 'other' stakeholders had a vital role to play with regard to their knowledge of the broader context of wild resource use, scientific knowledge of the plant as a fynbos species, knowledge of industry-relevant policy and regulations, and experience of similar industries. While local ecological knowledge can provide valuable input in some areas of knowledge, it typically does not offer a broader context and understanding of patterns and practices across the full range of the species (Cunningham, 2001).

In the context of knowledge around best practice harvesting, the only information that existed at the beginning of the research resided with LEK and TEK stakeholders. This is the case with many examples of wild resource use (Early-Capistrán et al., 2020; Schmidt & Ticktin, 2012; Vance et al., 2001). Without formal, recorded data, the information from TEK and LEK sources is invaluable. Ideally, as social-ecological data becomes available in time, this should be supplemented with the scientific information needed to fully understand the sustainability of using a wild resource (Dovie et al., 2000; Hanazaki et al., 2018). As advocated by Crouch (2008), a formal record of this type of information should be created before it is lost. However, LEK will continue to contribute to the preservation of best-practice. Vance et al. (2001) note the considerable contribution made to developing harvesting guidelines by local harvesters of forest products.

3.5.2 Use of appropriate methods

The combination of methods used to gather information on best practice harvesting is worthy of discussion, as suitable choice and application of methods contributed to generating the desired results.

In planning for the workshop, care was taken to notify and include a broad spectrum of participants to increase the likelihood of a successful outcome (Grimble, 1997; Kellert, 2000). Purposive sampling of experts, chosen for their particular knowledge and expertise of the industry (Robinson, 2014), was used to establish a solid framework for designing the workshop session. As a result, the workshop was well-focused, with clearly defined and easily understood aims and objectives (as advocated by Reed, 2008).

The workshop setting brought together stakeholders from various environments. Sensitive issues such as farmer-harvester relationships were aired to some degree in a transparent way. SAHTA gained a better understanding of the harvester perspective, as noted with appreciation by the SAHTA chairperson. Focus group sessions as a commonly used method of knowledge sharing in NRM (Modi et al., 2016; Nabahungu and Visser, 2013) created a non-threatening small group environment where differing views could be aired. The groups were purposively selected to allow for language and experience similarities (Nyumba et al., 2018). Questionnaire surveys allowed for the rapid collection of data that could be presented quantitatively

(Williamson et al., 2018 and 2002) by putting information into numbers. The face-to-face administration of the questionnaires enabled illiterate participants to contribute meaningfully, as recommended by Neuman (2012).

Semi-structured interviews with identified stakeholders proved versatile and flexible, as Kallio et al. (2016) and Kitchin & Tate (2013) noted. As a form of data collection, they allowed for the inclusion of detail (Weiss, 1995) reflected in the rich data collected. The subsequent thematic analysis identified commonalities and differences between stakeholders (Braune and Clarke, 2006). The researcher can develop trust with participants through mutual enthusiasm, knowledge and learning (Lain, 2017).

3.5.3 Evaluating the success and shortcomings of the workshop

Within three months of the workshop, the *Guidelines for the sustainable harvesting of wild honeybush* (McGregor 2017a) and four other documents relating to the sustainable use of the wild honeybush resource were available online (De Villiers & McGregor, 2017; McGregor & Pierce-Cowling, 2017; McGregor, 2017b, 2017c). The fact that the workshop session led to the output of a concrete product such as this was considered a positive feature by workshop participants (as expressed in workshop discussion sessions and recorded in the comment box submissions). The level of education and awareness around sustainable honeybush harvesting was noticeably greater after the workshop, as evidenced in improved submissions for harvest permit applications (Mr. G. Ferreira, EC DEDEAT permit officer, pers. comm., October 2018). In January 2018, the wild harvesting guidelines material was presented as a draft *Wild Honeybush Harvesting Field Guide* at 10 information sessions to around 100 stakeholders. These groups comprised 40 of the 50 participants from the Louterwater workshop, who were willing to contribute further to an endeavour that was valuable to them. At these sessions, participants gave input to the version of the wild honeybush harvesting field guide, which was made available in digital and published in English and Afrikaans (McGregor, 2018a, 2018b).

Although the facilitators worked through the questionnaires with participants, the questionnaire format was not ideal for some harvesters. There was not always enough time for participants to fully discuss and give information they would like to have shared. There is a sense that for the harvesters in particular, their voice was not always heard or valued. One-on-one interviews with more harvesters, using the same questionnaire, may have yielded better results because clarity could have been sought.

The questionnaires were developed when the researcher’s knowledge of harvest practices was limited. As the gathering of information around harvesting progressed, it became evident that questions about best practice, such as cropping interval, how often harvesters visit a site, and the proportion of the crop taken at each harvest, needed further interrogation. The success of an information-gathering exercise like this would have been improved with field visits on the day, with participants to clarify and verify the meaning of much of what was recorded. Due to accessibility issues, this was not possible, although participation at harvest events after the workshop (Chapter Four) served to clarify how different teams operate.

Some harvesters who might have chosen to participate in the meeting were not involved, possibly due to a lack of contact by the organisers or the meeting not being held at a suitable time and place. Harvester communities from the Tsitsikamma harvesting areas (including Plettenberg Bay and Knysna) who harvest both *C. intermedia* and *C. subternata* were not represented, despite being invited to the meeting. Harvesters from the Elands Valley were not represented, and knowledge of harvesting in that area was based on a limited questionnaire survey in 2015 (Pearton, 2015). It is known that harvesters from these areas use slightly different methods of harvesting, which are therefore not represented. Lower-ranking harvesters were not represented for reasons unknown. The assumption was made that harvesters who attended gave fair representation for this stakeholder group, but this may not have been the case.

3.6 Summary

The aim of the chapter was to compile TEK and LEK regarding best practice harvesting of wild honeybush held by stakeholders in the honeybush community. The primary approach was qualitative: experts were purposively selected, and in-depth interviews were held to capture knowledge about the industry and their harvesting experience. In a workshop setting, focus group discussions and questionnaire surveys were used to collect information from stakeholders across four groups (harvesters, farmers, processors and other interested parties). Information from the discussion sessions was collated and coded through thematic content analysis to bring out the central themes of opinions on the idea of guidelines, the state of the industry, relationships between stakeholders, knowledge of ecological and conservation principles, understanding and applying sustainability, and the role of regulation and monitoring. Quantitative data was collected through questionnaire surveys of harvest best practice and related industry knowledge and analysed using descriptive statistics to identify important elements relating to best practice harvesting. The key findings were that *C. intermedia* populations could be harvested at two to three-year intervals. Stems should be pinkie or pencil-thickness stems (for efficient processing), and green stems were an indicator of harvest material that was too young to produce quality tea. While there was general support for a set of guidelines, there were some reservations about how it might negatively affect harvesters and who would enforce/regulate best harvest practices. Key issues in the industry identified by the participants included concerns around declining wild resources, the need for promotion of cultivation, and how threats related to invasive alien plants and climate change might impact livelihoods.

The practical ideas that informed this part of the research – were borrowed from the literature on sustainable livelihoods. More specifically, the method of using a workshop setting and focus groups to bring stakeholders together was borrowed from participatory rural appraisal case studies, often in the context of natural resource management. Theoretical ideas around the value of TEK and LEK came from the literature on non-timber forest product (NTFP) research and natural resource management.

The Louterwater workshop set the scene and drew commitment from the industry regarding the planned research, the production of guidelines for wild harvesting, the inclusion of holders of TEK and LEK in the extended research project and the compilation of the final field guide and harvesting guidelines. It also established relationships with farmers and harvest teams willing to accommodate the researcher as an observer at harvest events (Chapter Four).

3.7 References

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Chapter 4 Sustainability of harvest enterprises and livelihoods

Contents

List of figures

List of tables

4.1 Introduction

4.1.1 Background

Various wild-resource-use researchers advocate for the assessment of the sustainability of wild resource use through the collection of quantitative data from longer-term ecological studies (Chamberlain et al., 2019; Ticktin, 2004) and/or an analysis of the economic and social aspects of sustainability (Hernández-Barrios et al., 2015; Stanley et al., 2012). Chamberlain et al. (2019), in the context of wild resource use in the USA, claim that despite all the work that has been done, few methods exist for inventory and assessment of wild harvesting. As a result, there is limited evidence to show that harvests are sustainable in economic, social or ecological contexts. This chapter continues from Chapter Three, which established best practice for sustainable harvesting based on TEK and LEK, with an investigation of wild honeybush harvesting enterprises in terms of sustainability of yields and harvester livelihoods over time. Stakeholders identified through the interview process in Chapter Three volunteered to have researchers accompany them on field outings to actual harvest events to conduct an inventory of the harvest. A summary of the chapter contents is provided in Figure 4.1.

Many wild-harvested materials are commercial products that can significantly contribute to households' cash economy. Commercializing wild-harvested products has been widely promoted as an approach to rural development (Schreckenberg et al., 2006), and most rural livelihoods depend on natural resources (Scoones, 1998). In developing countries, rural livelihoods provide for the majority of people (Chang, 2009). For example, in South Africa, many millions of people depend on harvested wild resources for food, medicine, firewood, and raw materials for subsistence and commercial use (Petersen et al., 2012; Shackleton, 2004), particularly where there are limited economic opportunities (Dovie et al., 2000). In a review of several South African studies on wild resource use, Shackleton et al. (2011) gave annual average income values per household derived from natural resources collected in the wild that range from USD160 to as much as USD1130.

However, as de Mello et al. (2020) noted in a survey of literature on the use of wild-harvested products, there are many cases in which use and/or commercialisation has resulted in negative social-ecological impacts. The causes of these impacts may include poor ecological management practices, insufficient economic returns, and a lack of policies supporting commercialisation (Belcher & Schreckenberg, 2007; Ticktin & Shackleton, 2011). In a review by Stanley et al. (2012) of 101 studies from 2000-2010 in Latin America (52%), Sub-Saharan Africa (25%) and Asia (23%), 63% of the studies showed that harvesting was sustainable (ecologically) while only 18% were found to be unsustainable. Of the 71 articles that presented financial elements, two out of three met or exceeded the defined sustainable economic threshold. In their more recent review of the sustainability of wild harvesting, (Gaoue et al., 2016) showed that the most commonly reported sustainable harvest limits estimated by authors ranged from <5 % for whole plants or bark harvest to 80% for fruits (Ticktin, 2004).

4.1.2 Motivation for the research

There is occasional anecdotal evidence of declining yields from wild harvested *Cyclopia intermedia* populations provided by farmers and harvesters. The species is reported as 'declining' on the SANBI Red List, and Schutte-Vlok & Raimondo (2016) have noted the need for proper regulation and management, and identification of sites of over-harvest to develop interventions that will ensure sustainable harvesting. While there may be anecdotal records of declining populations at a site (e.g. Mr T. Kritzinger, farmer, pers. comm., September 2016; Mr E. Smith, farmer, pers. comm., January 2017, Mr D. Hodgson, farmer; pers. comm., October, 2014; Mr G. Ferreira, permit officer, DEDEAT, pers. comm., October 2014), from the industry's perspective it matters to establish the facts about, and broader nature of, the change. However, there is limited existing information on actual changes in harvest yields and the impact of this on harvest enterprises, practices and livelihoods.

4.1.3 Aim

The aim of this part of the research was to assess the sustainability of harvest enterprises through an analysis of different types of harvest enterprises, and the actual practice of harvesting at harvest events. An analysis of these results gave perspective on the sustainability of the harvesting enterprises and associated livelihoods related to the use of the *C. intermedia* resource.

4.1.4 Objectives

1. To assess different types of honeybush enterprises based on harvest history and management approach to establish the sustainability of harvest enterprises.
2. To carry out an inventory of the harvest and harvest team practices based on harvest event records and monitoring of harvest events to establish the sustainability level of harvester livelihoods.

An overview of the structure and content of the chapter is presented in Figure 4.1. Two objectives were addressed to meet the aim of the chapter. Data was collected using qualitative and quantitative methods. Harvest history data was analysed using descriptive statistics, while harvest enterprise information was used to create a profile of the enterprises. An inventory of harvest events was conducted through observation and survey to assess harvest livelihoods and harvest practice. The chapter ends with a summary of the chapter's main findings, methodological approaches and theoretical context.

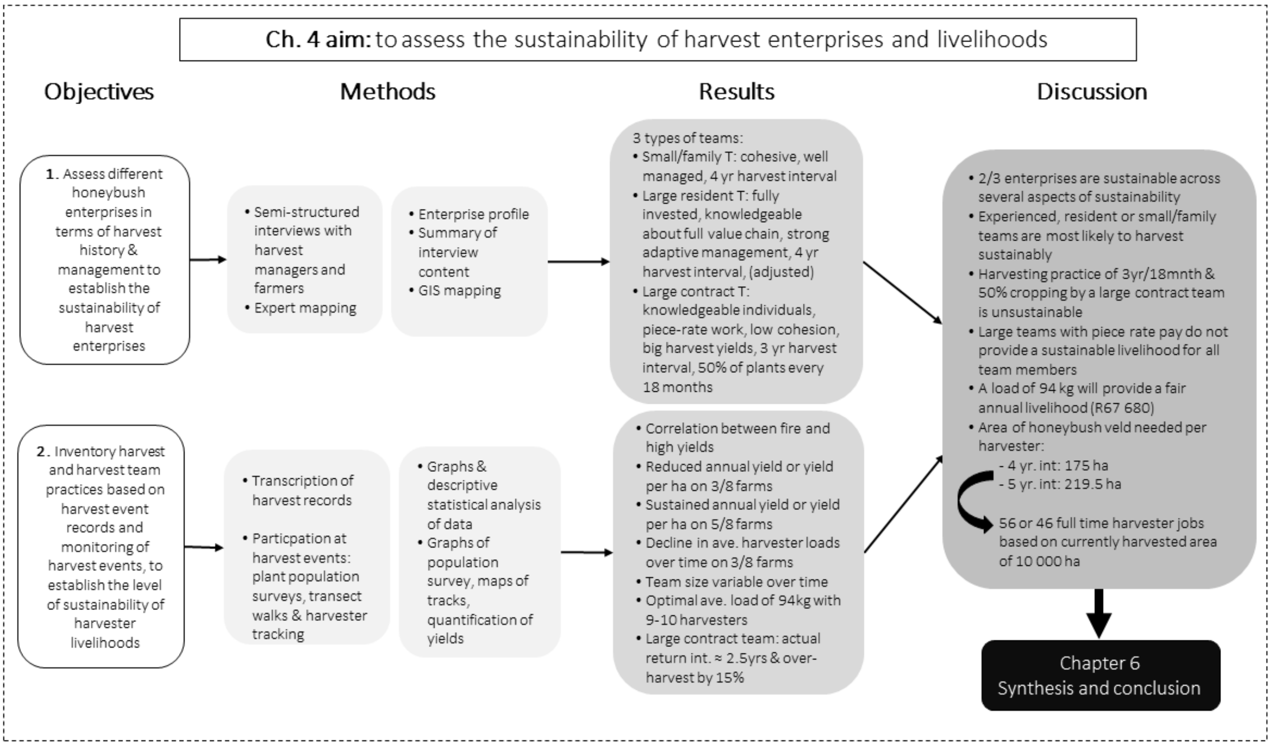

Figure 4.1: Overview of the structure and content of Chapter Four.

4.2 Literature Review

4.2.1 Livelihoods and the honeybush industry

The sustainability of the honeybush industry may be viewed in a livelihoods context, which deals with how people make a living in different contexts (Scoones, 2009). Livelihoods encompass: "…the capabilities, assets (stores, resources, claims, access and activities required for a means of living…" (Chambers & Conway, 1992, p. 7). A livelihood is sustainable if it persists despite shocks and stresses, maintaining its capacity and capabilities and providing livelihood opportunities for the next generation (Chambers & Conway, 1992). Within this context, there is a need to inventory how rural people use natural resources and other means to make a livelihood (Lax & Joachim, 2013).

The success of the honeybush industry can be measured in its growth from a 'cottage industry', producing around 30 tonnes in 1996, to one that exported 85% of the annual crop of around 350 tonnes in 2017 (McGregor, 2017), declining to around 300 tonnes in 2023 (McGregor, 2023). While the industry is small compared to the South African Rooibos industry (15 000-20 000 tonnes per year, of which 50% is exported), it is a locally important livelihood for the many harvesters, farmers and processors who depend on it for a partial or full livelihood. The global 'healthy beverages' market is expanding rapidly in response to a wellness trend of consumers who recognize the correlation between diet and health (Gupta et al., 2023). Trials on potential uses of extracts from several *Cyclopia* spp. to alleviate a host of ailments are positive, and the use of *Cyclopia* spp. as a preservative in the alcoholic beverages industry is promising (Ms R. McKellar, Red Dawn

IP, pers. comm., September 2019). Effective demand for a product is a significant part of establishing local economic development (Howells, 2005), indicating good industry growth potential.

Cyclopia intermedia has served as the mainstay of the industry for thirty years, and as the most widely used, fully organic tea, and when processed carefully, is synonymous with premium quality tea (Mr D. Brunette, Processor, pers. comm. September 2019). In 2023, for the first time, with several large cultivated honeybush (mostly *C. subternata* and *C. longifolia*) enterprises coming into production, demand for the wild resource is lower. This may also represent a shift in consumer choices and a demand for tea from other *Cyclopia* spp. In a report by Hobson and Joubert (2011), commissioned by the EC DEDEAT, the honeybush industry offered opportunities for people in the poor rural areas of the Eastern Cape to participate at various levels – from harvesting to production. Rural areas, like the honeybush producing regions of the Eastern and Western Cape, are the economic backbone of most developing countries (Alemu, 2012). Most rural livelihoods are by necessity diverse, relying on many livelihood strategies and income streams (Angelsen et al., 2014), some of which are farm-related and others not (Neves & Du Toit, 2012). Although rural livelihoods are most often agricultural and relate to food production, the people involved are often the least secure in terms of food security (Lemke et al., 2012). Rural livelihoods in SA are made up of a mixture of activities, including the use of natural resources, farming, informal sector trading, social grants, and wage income (Shackleton et al., 2000).

4.2.2 Ecological and economic sustainability of wild harvesting

In a review of ecological and economic aspects of wild harvested products, Stanley et al. (2012) found that in 66% of articles reviewed, wild product gatherers earned more than the local wage and exceeded a threshold of economic sustainability as measured by the international absolute poverty line (USD2.15 per day, in 2022, The World Bank, 2022). Most research focused on Latin America and showed enterprises to be ecologically sustainable (82.6%) based mainly on short-term population, individual-level, studies. It was noted that issues such as tenure security, the impacts of changing economic conditions, climate change, and pressure on the health of the wild resource due to extraction were likely to be a feature of the future.

Hernández-Barrios et al. (2015) conducted an economic and ecological assessment of the impact of harvesting on *Chamaedorea ernesti-augustii* (Ernest August's palm). All plants were tagged, and stem length, leaf number and rachis length of the newest mature leaf were measured to assess recovery after harvest. The plants were harvested by traditional harvesters biannually over a two-year monitoring period. They found that a biannual, intermediate defoliation level of up to 50% of palm leaves was economically and ecologically sustainable. More intensive harvesting resulted in reduced-size regrowth leaves, which were undesirable to the market. Higher levels of harvest gave greater profit but caused the decline of the resource. They further highlighted the need for scientific information and governmental regulation to ensure sustainable harvesting, which should include community-based management strategies.

Schmidt & Ticktin (2012) monitored the sustainability of golden grass harvesting in Brazil over three years. Study sites were chosen in collaboration with experienced local harvesters, who participated in an experimental early harvest and a traditional late season harvest. The surveys included an inventory of the population, harvest yield over time, and an assessment of harvest impact on the plants (consisting of counting of upturned grass rosettes versus intact, cut plants). Early harvest, as practised by new artisans, was found to increase the risk of uprooting and plant mortality, which was compounded by traditional burning practices.

4.2.3 Methods of assessing wild resource use

Given the complexity of the wild honeybush landscape, a mixed methods approach was identified as the most suitable way to capture information about the industry. A mixed methods approach is commonly used in natural resource management contexts (Danielsen et al., 2014; Kaschula et al., 2005; Modi et al., 2006). The combination of qualitative and quantitative approaches to the collection and analysis of data promotes a better understanding of the research problem (Creswell & Plano Clark, 2011), while combining both forms of data provides the most complete analysis of problems. While Dovie et al. (2000) promote the value of ecological and botanical surveys to resource assessments, they acknowledge that to be holistic; resource assessments must be accompanied by TEK, which includes harvest history and a record of harvest practice.

In a survey of the sustainability of fuelwood harvesting in Welverdiend village, Mpumalanga, South Africa, Kaschula et al. (2005) used focus group discussions as well as mapping of resource use sites to collect information about the timing of harvest, harvest methods and plant knowledge, plus discussion of broader ideas around sustainability, society and politics. Parallel to this, biological data on three harvested savannah fuelwood species was collected. This mixed methods approach yielded data showing that there was a poor correlation between knowledge obtained by scientists and indigenous knowledge in several instances. In an investigation of the use of wild vegetables by rural households in rural Kwa-Zulu Natal, Modi et al. (2006) used interviews and focus group discussion, followed by transect walks to gather information about plant use. Nabahungu & Visser (2013) captured farmers' knowledge and perceptions of agricultural wetland management in Rwanda using formal interview surveys and focus groups, followed by transecting through the wetlands to collect physical data and validate information collected during the focus group discussions. In the Bosawás Biosphere Reserve in Nicaragua, Danielsen et al. (2014) successfully used interviews, focus group discussions, and transect walks to gather information about natural resource use in the community. A two km transect walk was laid out to regularly monitor animals through observation by residents, which increased the amount of information that could be collected and empowered indigenous and local people by making them part of the research.

Using a transect walk is a standard participatory research method of mapping, observing and describing the location and distribution of resources and features in a landscape. In practice, it is a method that uses controlled walks in the community geographical space to collect spatial information, including geographic features, information on land use, information on vegetation distribution and social aspects of resource collection (Pánek, 2015). The output can be a map or a list of individual elements identified during the field survey (de Zeeuw & Wilbers, 2004). It is ideally suited to NRM, and particularly useful for a harvest inventory (Cunningham, 2001), where a topic may be discussed followed by a practical demonstration of knowledge and activities relating to the resource under discussion.

In a commercial context, GPS tracking of harvesters or fruit pickers is a standard method to document piece-rate work. Ampatzidis et al. (2016) describe a complete Harvest Management Information System (HMIS), which collects, processes and allows for immediate (real-time) visualisation of harvest data via automatic upload to the cloud, so that payment for services can be immediately calculated in a paper-free system. Technological advances have allowed for the deployment of systems that can measure workers' movements (amongst other variables), empowering harvesters to manage their efficiency and productivity, and ensure that they are accurately compensated (Ampatzidis et al., 2012). A highly sophisticated mechanical fruit harvester developed for use in the agro-tourism sector was described by Putra et al. (2022). The gadget combined a specialised harvesting tool (secateurs) with GPS tracking (deployed on the harvesters' mobile phone) and IoT sensors recording fruit weight, size and condition. All the data were uploaded to the management system in real-time. Amongst other things, the results showed high levels of accuracy in estimating yields, which the farmer could use to assess harvester efforts and estimate overall harvest yields. The data also served to inform future interventions with regard to optimising production from individual trees, and showed promise for use in other similar agricultural industries (Putra et al., 2022).

4.2.4 Wild resource harvesting in South Africa

Examples of research on other South African wild plant harvesting enterprises further our understanding of, and gives insights into, the nature and state of wild harvesting enterprises in South Africa.

Aloe ferox is tapped for the extraction of aloe sap and is used for a variety of traditional medicines, cosmetic products, and beverages. Export estimates vary, but range from 600 tonnes per annum to Europe and North America (Sachedina & Bodeker, 1999) to a 324 tonnes annual average export to 27 countries, from 1994 to 2003 (Knapp, 2006). In the Western Cape, the majority of harvesters were freelance tappers, although resident farm staff also harvested wild populations on the farms where they were employed. The best practice was to harvest five or six leaves per plant with a scythe, leaving an adequate stub and avoiding damage to the vascular tissues of the main stem (Sachedina & Bodeker, 1999). In the Eastern Cape, Melin et al. (2017) identified the majority of tappers as unemployed women on government grants, earning extra cash income from tapping. In the Seymour region of the EC, tappers were reported as working an average of seven to ten hours a day to collect eight litres of bitters. Of the tappers interviewed, 15% were unaware of harvest best practices, and were potentially harvesting unsustainably.

Since marula fruit (*Sclerocarya birrea*) is harvested from the ground, issues of ecological sustainability are not significant (Wynberg & Laird, 2007). In Bushbuckridge, Makhathini and Northern Namibia, the harvesters were mostly women who collected, processed and traded marula fruits, commonly using the income to pay school fees. Harvest protocols varied across communities (Wynberg et al., 2003; Wynberg & Laird, 2007), but access to land was a common issue. In Bushbuckridge, outsiders to a community where the fruit is harvested were discouraged from harvesting. As the commercialisation of marula harvesting develops, over-utilisation of the resource and competition for land use may threaten the livelihoods of traditional harvesters and the communities that depend on it (Wynberg et al., 2003; Wynberg & Laird, 2007). For the Bushbuckridge area, Shackleton (2004) gave detailed information on the nature of the marula harvest and trade in marula beer. The harvest season was only two to three months when fruit collection and trade in marula beer was intensive. There were no restrictions on harvesting (except where a tree is located on the land of an individual and permission to harvest is required). Collectors (almost exclusively women) operated individually, gathering 70–140 kg of fruit in a 2½-hour collecting trip about two to three times a week, amounting to around 1876 kg per trader per season. Collection and processing costs were minimal (largely personal labour) except for transport costs to the market to sell the marula beer. The average net income for a trader in a season was calculated as R500, amounting to about 14% of annual household income (Shackleton, 2004).

Fynbos flowers (from the *Bruniaceae*, *Asteraceae*, *Ericaceae* and *Proteaceae* families) are harvested from wild and cultivated populations as ornamental flowers for the export market (Privett et al., 2014). The industry provides income to local communities and private landowners/farmers by employing around 3000 harvesters (Privett et al., 2020). Teams may be resident farm staff or informal harvesters in small and large teams. Blokker et al. (2015) refer to these as 'bakkie (Afrikaans word for 'pick-up truck') harvesters' – a team of seven or eight members who fit into the cargo bin of the truck. In this very competitive market, a lack of communication between stakeholders is an issue in the industry that now favours cultivated production and neglects wild harvest enterprises. Wild harvesters do not benefit from an export product value chain and have little say in what their product is worth, even though the industry has to meet exacting requirements from overseas buyers. Harvesting is controlled through permits issued by Cape Nature (Blokker et al., 2015; Privett et al., 2020), but a lack of capacity limits enforcement of regulations. Guidelines developed by Privett et al. (2020) recommend that only adult plants older than five years should be harvested; 50% of the foliage should be left per plant, and certain listed species may not be harvested.

Buchu (*Agathosma* sp.) is a fine-leaved fynbos shrub mainly harvested in the wild to produce oil used in medicine, cosmetics, and food. Research on the plant's biology and traditional knowledge has shown that the best results are achieved by harvesting three to four years after previous cropping or after a fire, enabling the plants to re-establish their carbohydrate reserves for regrowth (De Ponte Machado, 2003). According to Williams & Kepe (2008), in the Elandskloof community, harvesting Buchu on communally owned land is an important livelihood. Harvesters can earn between R30 and R60 per kilogram from this high-value crop. During the harvest season, they may bring in 10 to 60 kg per day on about 10 days per season (December to February), amounting to between 100 and 600 kg of harvest per household. According to official records, about 300 tonnes of wet buchu is harvested annually to produce 250 kg of distilled oil, primarily for export. Harvesting is controlled through a permit system managed by Cape Nature. Threats to the industry include destructive harvesting (uprooting of the entire plant), poor cutting procedures, and over harvesting or harvesting in the wrong season. Non-resident harvesters are also seen as a threat by the community. Trade in buchu supplements, formal income from fruit picking, and other farm work is primarily carried out by men (69%). Competition for resources is high because they fetch such a good price. Williams & Kepe (2008) showed that 87% of community members knew about concerns around the sustainability of Buchu harvesting, and 80% of harvesters indicated that they had noticed a decline in resource availability in the past five years. Most locals saw fire as the most significant threat, followed by theft and unsustainable harvesting.

In a study of baobab (*Adansonia digitata*) fruit harvesting in northern Limpopo (South Africa), Venter & Witkowski (2013) recorded that most of the harvesters were unemployed rural women aged 30 to 49 years, residing in informal settlements, who use baobab fruit harvesting as an important source of cash income. In the study area, there were about 400 harvesters who collected fruit from the ground. Collection sites were located in communal rangelands with no access issues. About 90% of the harvesters walked to known areas, while 10% used donkey carts. Harvesters had some ecological knowledge of the plant and knew that cutting down trees was forbidden. The baobab income is significant for alleviating poverty and supporting local livelihoods in the study area.

4.3 Methods

4.3.1 Data collection

4.3.1.1 Enterprise profile and harvest history

Three types of honeybush harvest enterprises were identified based on interviews and workshop results (Chapter Three). An example of each type was identified for further investigation based on a) the willingness of the harvest manager/farmer to participate; b) the availability of a harvest history for that enterprise; c) the opportunity to participate in a harvest event with the team (Objective Two, harvest inventory, this chapter).

Data collected on each enterprise included:

- Background information on the enterprise, typical harvest practice and a map of harvested populations or patches per farm (Chapter Two – Mapping the resource).
- Profile of the harvest team.

- Harvest history – as available for eight farms (ME, KP and six farms for UN) including: yield per harvest period or per harvest event; fire history per harvest site; number of harvesters per event.

4.3.1.2 Inventory of the harvest

Plant population surveys: At each harvest site, three belt transects of 10 x 25 m or 10 x 50 m were laid out. *Cyclopia intermedia* plants in each transect were located with a GPS, marked with a numbered tag and measured in terms of plant allometry and plant condition. The belt transects were harvested by a harvester harvesting as per normal. Harvested individual plants were counted and weighed to give a yield per plant and potential yield per unit area. The remaining unharvested plants were counted.

Transect walk with harvesters: during a one-hour transect walk with a selected harvester, questions from the workshop questionnaire (Chapter Three) were addressed. Harvesting practices were observed, and the number of plants harvested versus those not harvested was recorded.

Harvest event mapping: selected harvesters carried a GPS for the duration of the harvest day to 'track' and quantify their use of the harvest area. In total, 34 harvester tracks and territories were recorded across seven harvest events. With the larger teams at ME1 and 2 and MP1 and 2, it was only possible to track some of the harvesters at each event, but there were few enough harvesters at the other harvest events (KP3, EB, NA) to track all the harvesters.

4.3.2 Data analysis

4.3.2.1 Enterprise profile and harvest history

The enterprise profile is given as a summary of interview contents relevant to understanding the harvest enterprise. Key information per enterprise is presented in tabular form.

Descriptive statistics were derived from the datasets to characterise the patterns in harvest yield over time. All analyses were conducted in Microsoft Excel (Microsoft Corporation, 2016). The main outputs from these analyses are exploratory box and whisker plots, supported by an ANOVA test to derive a significance value (P) and (where relevant) a regression analysis. A trendline based on a linear model is used in some cases to identify the potential direction of change in variables.

The datasets were not identical in format because of the different practices per harvest team type. Some data manipulation was necessary to derive uniformity of units for some of the analyses. For example, it was most meaningful to convert the yield per year or harvest period to a yield per hectare where accurate yields per patch and harvest were recorded.

4.3.2.2 Inventory of the harvest

Plant population surveys – served to ‘quantify’ harvest practice by calculating the proportion of plants harvested versus those not harvested, and relating these values to professed harvest practice. Plant yields were used to derive an average yield per *C. intermedia* planting, and estimate the area of honeybush-bearing veld needed for a harvester to make a livelihood.

Transect walk with harvesters – information gathered via the questionnaire survey was input to results in Chapter Three. Harvest practice was observed to confirm what was described as best practice. Information on plants recorded as harvested/not harvested was used to quantify the use of the resource at a harvest event, and confirm the professed harvest practice of the harvest team.

Harvest site mapping – GPS tracks of harvesters were imported into ArcMap 10.8 and used to generate harvest territories per harvester by generating a Convex hull polygon around each harvester's tracks. Yield per harvester, and time spent harvesting (from the GPS data) was converted to an estimated yield and effort per unit time, and tabulated. The nature of the terrain in terms of accessibility (as described by the harvesters) was noted for use when interpreting the results.

4.4 Results

4.4.1 Enterprise profiles

The period of history overlaps for all three teams, but the team type and their harvest practices are different, as shown in Table 4.1. The ME enterprise represents a team of experienced harvesters in full-time employment serving multiple aspects of the farm enterprise. They harvest the same area every three to five years, taking 80-90% of the crop at each harvest. The farm is large enough to provide flexibility in the harvest schedule to respond to a change in environmental conditions (e.g. fire or drought effects) or a change in demand for the product.

Table 4.1: Comparison of the main characteristics of three honeybush harvesting enterprises.

Enterprise code	Team type	Period of record	Harvest periods	Harvest patches/farms	Harvest practice	Location
ME	*Resident farm staff*, 12–14 part-time harvesters. Managed by the farmer.	2000–2020	3 to 5	1 farm, 36 patches, 650 ha	80-90% of plants every 4 years	Eastern Kouga only
KP	*Small family team*, 4–6 part-time harvesters. Managed by the farmer.	2008– 2016	3	1 farm, 9 patches, 71 ha	80-90% of plant every 4 years	Joubertina
UN	*Large contract team*, 8–15 members. Full-time harvesters. Managed by a harvest manager.	2003–2017	4 to 6	6 farms, 57 patches, 1245 ha	50% of plants every 18 months	Uniondale – Elands R., Kammanassie, Hartbees R., Bo-Kouga

At KP, the harvest is carried out by a small, efficient, experienced family team employed every four years to harvest the same patches. The UN team is a large team of full-time harvesters who form the team's core, plus extra, less experienced team members as needed. They cover many different farms, working on a three-year harvest interval with 18 months between harvest events, at which they crop 50% of the older (three-year-old) plants in a population.

Definitions of the terms used in this harvest data analysis are listed below:

- Harvest period:
  The time taken to completely harvest a patch (ME) or a whole farm (UN and KP). Periods vary from several days over a month for a patch, to many weeks of continuous or interrupted harvesting at a farm scale. It is equivalent to the n^{th} time a patch is harvested. Yield per harvest period is recorded as tonnes or kilograms, depending on the size of the enterprise.
- Harvest yield
  The total yield in kilograms harvested at a single harvest event.
- Yield per hectare
  The patch size or area of honeybush harvested across a farm mapped in hectares, related to the yield over the harvest period for that patch or farm. Recorded as kilograms per hectare.
- Harvest event
  A single day of harvesting. The yield (kilograms or tonnes) per event is recorded. Many harvest events make up a harvest period.
- Post-fire (harvest)
  The first harvest, three to four years after a fire event.
- No-fire (harvest)
  A harvest where the last disturbance was a harvest, not a fire.
- Harvester load
  The average weight (kg) of honeybush harvested by a harvester at a harvest event. Calculated as the harvest yield divided by the number of harvesters.

4.4.1.1 ME: Honeybush enterprise profile

The farm is located in the Eastern Kouga and has been producing high quality, wild harvested, organically certified (since 1999) *C. intermedia* tea at an on-site processing facility, for three generations, with a major focus on honeybush production since 1996. Annual production is in accordance with an organic certification limit of 25 tonnes of processed tea, with an average annual production of 20 tonnes produced from 40 to 50 tonnes of wet harvested material. The bulk of production is bought annually by an international buyer, with a long established, stable relationship with ME. Production is directly aligned with this demand. The crop is harvested from Eastern Kouga mountain lands, 20 km from the home farm settlement in the valley where the processing plant is located.

The harvest team consists of 12 to 14 harvesters aged 18 to 65, who harvest only *C. intermedia* for one day a week, weather permitting, with an average of 30 harvest days per year. Many of the team are members of an extended family, with two or three generations working together. Staff are involved in all the stages of tea production and processing through to tea packaging. They are also fully engaged in all aspects of the broader farming enterprise, including care of stock, and the maintenance of farm infrastructure. They have extensive knowledge and experience in managing fire, with regard to planned burns, fire break preparation, harvesting ahead of a fire, and fighting runaway fires.

The farmer is closely involved in every aspect of the honeybush enterprise, as was his father. The current farmer is supported by his son, who now takes much of the responsibility for running the farm. It is the practice on this farm for the farmer to harvest alongside the team in the field and work in the processing plant, thereby ensuring intimate knowledge of all that is happening in the honeybush enterprise. The involvement of staff in all aspects of the honeybush enterprise gives the enterprise an advantage: staff fully understand the implications of best practice harvesting that yields a high-quality product for a sustainable enterprise. The farmer sees his role as custodian of the land and the honeybush resource – to use it for the benefit of the community in a sustainable way and to care for the place so that it might be used by others and by future generations.

It is the practice on this farm to harvest a honeybush patch every four years, except in periods of drought when harvesting is delayed until conditions improve. All plants large enough to stay in a bundle are harvested, amounting to about 80-90% of a population (smaller plants which would tend to fall out of the bundle are left uncut). The total load per harvest is limited to ≈1300–1400 kg, which is the truck's capacity to transport the harvest from the mountain lands to the processing plant in the valley. The load size also relates to the factory's capacity for the most efficient processing and production of high quality tea. The lands are actively managed through the conservative use of fire. Blocks are burnt every 13 to 14 years, when conditions are suitable, to rejuvenate the veld and to ensure that if a wildfire comes through the farm, some of the crop will be spared. The income from the honeybush enterprise is essential to keeping 15 permanent staff and their families housed in individual dwellings, all connected to essential services (water and solar power), plus partly funding education for children in the settlement through substantial logistical and financial support of the local primary school.

4.4.1.2 KP: Honeybush enterprise profile

The farm is located in the Joubertina area and has produced harvest material from wild populations of *C. intermedia* for 12 years. Each harvest period produced an average of 10.5 tonnes from 71 ha of honeybush-bearing veld on a 1000 ha farm. The farmer sells the crop to one of two nearby processing plants weekly during the harvest period.

The harvest team is a small family unit of four members from the Tulpieskraal settlement, 15 km away. They are occasional harvesters, finding employment for most of the year as fruit-pickers in the Langkloof valley. The two men are experienced harvesters (20 years), and the two women, who act mainly as bundlers and carriers, have harvested for 8 and 12 years, respectively. The team spends around eight weeks a year harvesting, subject to demand. They are the only team who harvest on the KP farm. Harvesters earned a piece rate pay of R2.00 per kilogram of harvested material at the time of the survey (2016).

The farmer has other enterprises on the farm, plus part-time formal employment. He is experienced and knowledgeable about the plant, and takes time to harvest in the field alongside the harvesters to ensure that best practice is followed. Harvesting takes place every four years, and fire is used conservatively as a management tool, to improve the veld for grazing of stock and honeybush production. A planned burn occurred in October 2016 (after the harvest and before plant population surveys were carried out for this study in 2016) after 16 years of no fire on the farm.

The farmer works with a harvest interval of four years to give the plants time to recover between harvests. The team harvest about 80% of the plants, leaving behind smaller plants, but at the time of surveys for this research, all plants were cropped ahead of the planned burn in October 2016. The farmer has a system of rough tracks to access sites by vehicle (tractor) to transport the load. Where the terrain is too rugged for tracks, he uses a wire slide that runs from a high point near a harvest site to a loading site, thus ensuring that the load-carrying distance for the harvesters is never more than 1 km.

4.4.1.3 UN: Honeybush enterprise profile

The team is the largest and most active 'contract' team in the Langkloof area, operating in the Western and Eastern Cape across 14 to 16 farms, in the Bo-Kouga, Kammanassie, Elands Rivier and Hartbees Rivier areas. Travel distances to sites are not more than 80 km from Uniondale. The team brings in about 65% of the wild *C. intermedia* crop for a large processing plant in the Langkloof, which produces around 200 tonnes of processed tea per year, made up of 80% wild harvested material (2017). The harvested material is collected weekly by the processing plant.

The harvest team consists mainly of middle-aged men in the age range of 35-55 years. The core of the team comprises eight to ten harvesters, who work four days a week for nine months of the year. Harvesters are often goal-driven, working when funds are needed for school fees, family events or travel. Harvesters earned piece rate pay of R1.50 per kilogram of harvested material, with an extra R1.00/kg for difficult access sites at the time of the survey (2016 and 2017). As needed, the team increases to accommodate around 15 harvesters. Still, the logistics of managing a bigger team are complicated in terms of the transport required for the team and the harvest load. Younger harvesters are taken on periodically, but they can be problematic in terms of perseverance and a desire to harvest as much as possible without considering best practice.

‘Outsiders’ who do not have local knowledge are hardworking but less desirable because of their lack of experience.

Managing the harvest team has been a full-time occupation for the harvest team manager since early retirement in 2002. He grew up on one of the farms surveyed in this dataset and has had many years of experience working with both cultivated and wild honeybush enterprises. He sees himself as an experienced honeybush harvester, who is in a position to deal with the logistics of a harvesting enterprise, including the provision of suitable (4x4) transport, maintenance of relationships with farmers for access to harvesting sites, and a stable purchase agreement with a processing plant. He is knowledgeable about the resource, passing on that knowledge to harvesters to ensure that best practice is followed, thereby supporting sustainable employment opportunities for the harvesters. He indicated that there are sites where yields are declining, likely linked to persistent drought conditions. When demand for the crop is low, he finds contracted employment for the team doing fencing and firebreak clearing.

It is the practice of this team to work on a three-year harvesting cycle, revisiting a site every 18 months to remove 50% of the mature (three-year-old) plants in a population. This approach spreads the number of workdays and reduces harvest intensity, thus leaving some plants to flower and set seed. It reduces the risk of loss to fire, as in the event of a fire, only half the crop is lost. Two to three months of the year, considered unfavourable for honeybush harvesting (very hot, cold or wet periods, and annual holiday periods when the factory shuts down) are taken up with other short-duration contract jobs, harvest vehicle maintenance, and harvest site access track maintenance.

Details about the data available for each enterprise are given in Table 4.2. The availability of data influenced what analysis could be carried out. The common data sets included: mapped data at different levels of detail, harvest yield across harvest periods, fire history, and harvester load data.

Table 4.2: Comparison of Data available per enterprise for harvest history analysis.

Enterprise code	Map data	Harvest yield	Fire data	Harvester load data
ME	Expert map – accurate delineation of 36 harvested patches, 650 ha.	Per patch (x36) for 2000–2020, 3 to 5 harvest periods. Suitable for analysis.	Detailed fire history of honeybush patches from 1996–2020 based on combined data from MODIS, LANDSAT and Sentinel2.	Yield per harvest event is standard (≈ 1300–1400kg), not measured per harvester. Consistently ≈ 100kg per team member.
KP	Expert map – accurate delineation of 9 harvested patches, 71 ha.	Per patch (x9), 2008 –2016, 3 harvest periods. Suitable for analysis.	No fire in the period of record.	Harvest team of 2 men and 2 women (mainly to carry and bundle). Estimate based on overall yields across a 5 week harvest period.

UN	Expert map – moderately accurate representation of 57 patches across six farms, 1245 ha.	Per farm, per harvest event, 2005–2017, 4 to 6 harvest periods. Suitable for analysis.	Moderately accurate representation from MODIS, anecdotal evidence.	No. of harvesters per event, max., min. and ave. load in kg per harvester per harvest event, over 587 harvest events.

4.4.2 Harvest history

The ME harvest data is a valuable record of the harvest yields of a full-time honeybush enterprise over 20 years. The records were available as an excel spreadsheet as the organic certification of the enterprise requires digital record keeping. Additionally, accurate mapping of the honeybush patches (by the farmer), an analysis of fire history using online mapping of fire occurrence, and the farmers' intimate knowledge of the fire history of the farm all make for a robust dataset. An example of the data available per honeybush patch is shown in Figure 4.2.

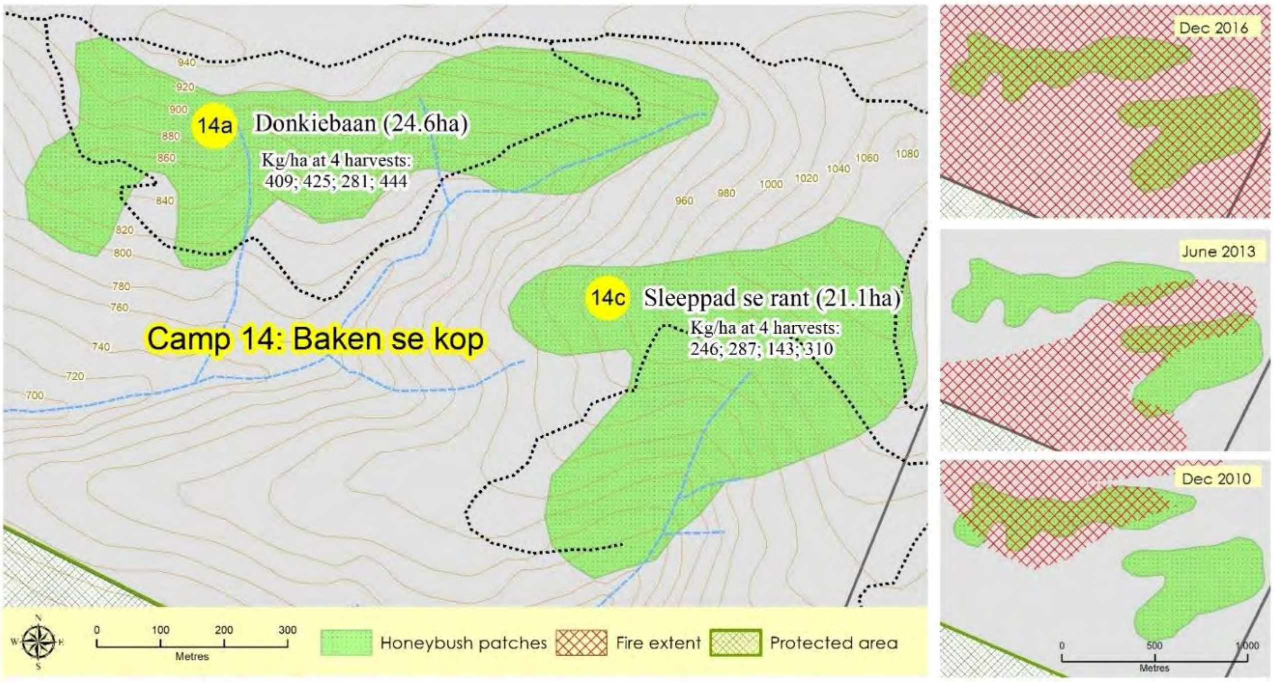

Figure 4.2: Illustration of data available for ME showing mapped honeybush patches, fire extent on three dates and harvest yield per harvest period for each patch over 20 years.

4.4.2.1 ME: Harvest history

The total annual yield for ME (Figure 4.3) shows a downward trend in harvest yield per year (R^2 = 0.208), indicating a poor fit for the model. A single-factor ANOVA shows that the variability from year to year is significant ($P < 0.050$). While the data reveals a decline in production annually over the period analysed, the farmer explains the variation in production in terms of change in demand and the need to prioritise other farming activities periodically.

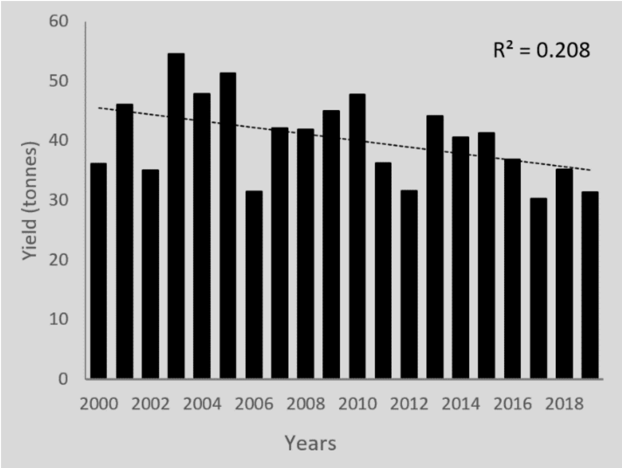

Figure 4.3: Annual yield per year from 2000 to 2019.

4.4.2.2 ME: Effect of fire on harvest yield

An examination of the effect of fire also partly explains the pattern of variability of production from year to year. The figures in Table 4.3 show that nine of the ten above-average (40 tonnes plus) annual yields are recorded when 6% to 50% of the honeybush area was burnt in periods three to five years prior to the harvest. An exploratory analysis of the data, using a box and whisker plot (Figure 4.4), shows no overlap of the box and whisker plots for 'Post-fire' vs 'No-fire' harvest conditions. A single factor ANOVA comparing annual yield under 'Post-fire' versus 'No-fire' conditions (P = 0.002) indicates that fire significantly affects harvest yield. When the percentage of burnt honeybush land (Table 4.3, column 4) is compared to the nine above-average annual harvest volumes as a percentage above the average yield, there is a strong correlation (r = 0.740). The data shows that fire management practices applied on this farm positively affect harvest yield.

Table 4.3: ME - fire history related to above-average harvest yields. Only above-average yields are shown. The total honeybush land on the farm is 650 ha, and the average annual yield of harvested honeybush is 40 tonnes.

Year	Yield (tonnes)	Fire	% HB area burnt	% inc. yield above 40 ton ave.
2001	45.99	Post 1996 fire, 100 ha of HB burnt	15	+13
2003	54.50	Post 1999/2000 fire, 321 ha of HB burnt	50	+27
2004	47.82	Post 2000 fire, 97 ha of HB burnt	15	+16
2005	51.32	Post 2002 fires, 143 ha of HB burnt	22	+22
2007	42.09	Post 2002–2003 fires, 78 ha burnt	12	+5
2009	41.88	* Lag effect from 2002 and 2003, 78 ha burnt	12	+4
2010	44.97	Post 2006 fire, 40 ha burnt	6	+11
2011	47.66	No fire effect **	6	+16
2014	44.10	Post 2010 fire, 65 ha of HB burnt.	10	+9
2016	41.25	Post 2013 fires, 65 ha of HB burnt.	8	+3

* Some of the areas burnt in 2002–2003 were only harvested in 2009.** Explained by the farmer as a response to market demand which correlates with overall high demand across the industry in 2010–2012 (McGregor, 2023).

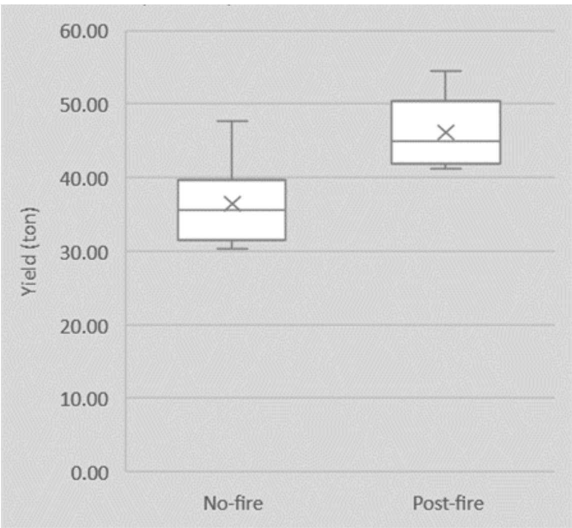

Figure 4.4: ME – box and whisker plot comparing harvest period yields with and without the effect of fire.

4.4.2.3 ME: Analysis of harvest yield per hectare

A more detailed analysis of yield per hectare per harvest period (i.e., the nth harvest of a patch) shows a different and more meaningful trend in the context of harvest sustainability. The complete overlap of the box and whisker plots (Figure 4.5) across five harvest periods indicates little difference from one harvest to the next, in terms of yield per hectare.

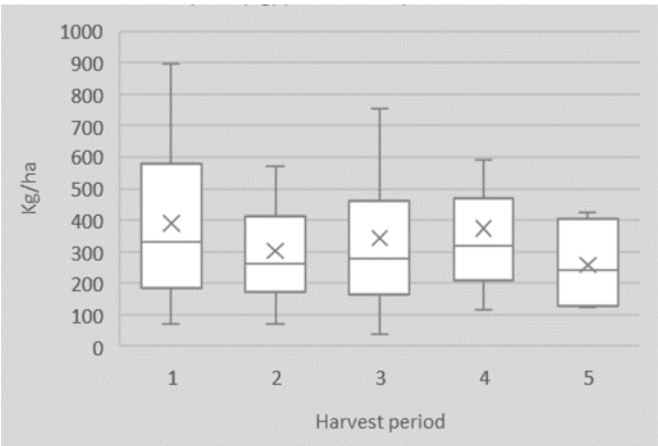

Figure 4.5: ME - a box and whisker plot comparing yield per hectare across all harvested patches per harvest period.

Average yield ranges from 257 kg/ha to 390 kg/ha over the five harvest periods. A single-factor ANOVA of the data shows no statistically significant change in yield between harvest periods (P = 0.410) when measured as yield per hectare.

Across the 21-year history, out of the 35 patches, 11.43% of patches have been harvested five times, 37.14% have been harvested four times (most common frequency), and the remaining 51% (17 patches) have been harvested one to three times, with an average interval across all patches of 6.5 years. Even for those patches harvested five times, the interval is always greater than four years.

Since rainfall data was available for the harvest history period from a nearby weather station (Zuuranys), it was used to check if rainfall might explain above-average yields (kg/ha) per harvest period (Figure 4.6).

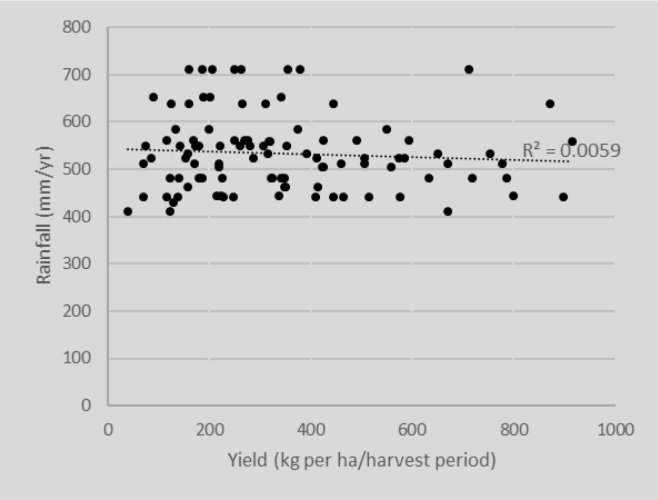

Figure 4.6: ME - comparison of rainfall and yield per hectare at each harvest period.

Exploratory data analysis showed that the correlation between yield/ha and rainfall was very weak (r = -0.077), indicating that rainfall was not a good predictor of increased yield.

4.4.2.4 ME: Analysis of harvester load

Using a harvest team in permanent employment, with vehicle size and processing capacity as determinants of harvest event yield, means that the average harvester load does not change over time. The harvest team brings in a load of 1300 to 1400 kg per harvest event, regardless of team size. The load is spread amongst the team of harvesters, bundlers, carriers and drivers, and amounts to about 108 kg per team member (based on 12 team members bringing in 1300 kg).

4.4.2.5 KP: Harvest history

The total harvest yield for three harvest periods at KP (Figure 4.7) shows variability across harvest periods from 10 000 to 12 000 kg, but there is no significant trend. Figure 4.8 shows the yield per patch across the three harvest periods. There is variability in patch size, hence differences in yield per patch. Eight of nine sites show the highest yield in period two, but there is no significant trend.

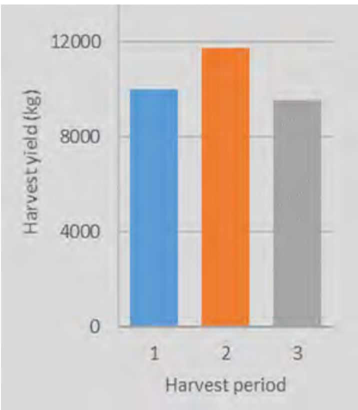

Figure 4.7: KP – total harvest yield across three harvest periods.

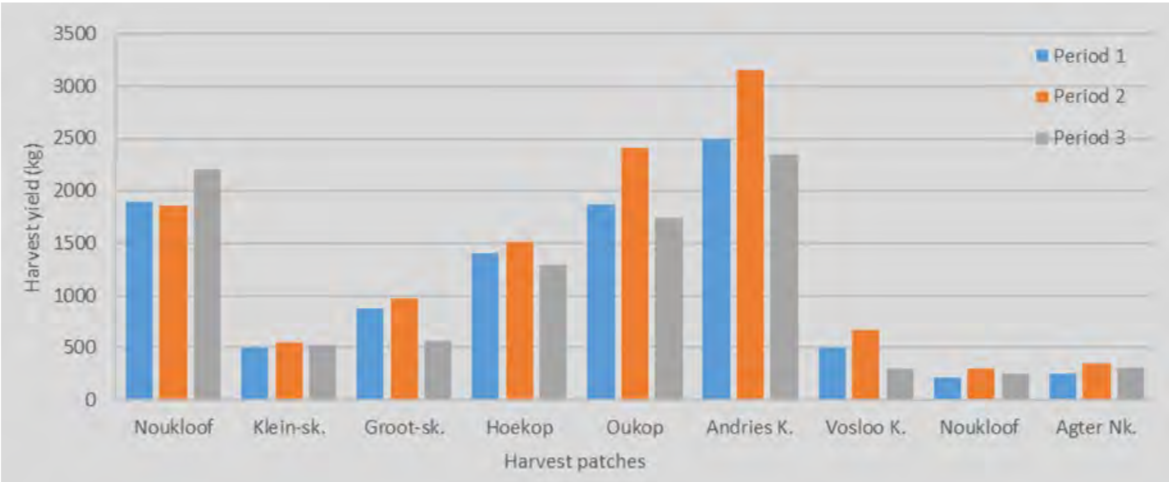

Figure 4.8: KP – yield per patch across three harvest periods.

4.4.2.6 KP: Analysis of harvest yield per hectare

The box and whisker plots comparing yield per hectare for each harvest period (Figure 4.9a) and total yield per harvest period (Figure 4.9b) show largely overlapping boxes, with not much variation in the average values, indicating that there is unlikely to be a significant difference in yield over time. A single factor ANOVA of total yield per harvest period (P = 0.830) indicates that harvest yield does not change significantly from one period to the next.

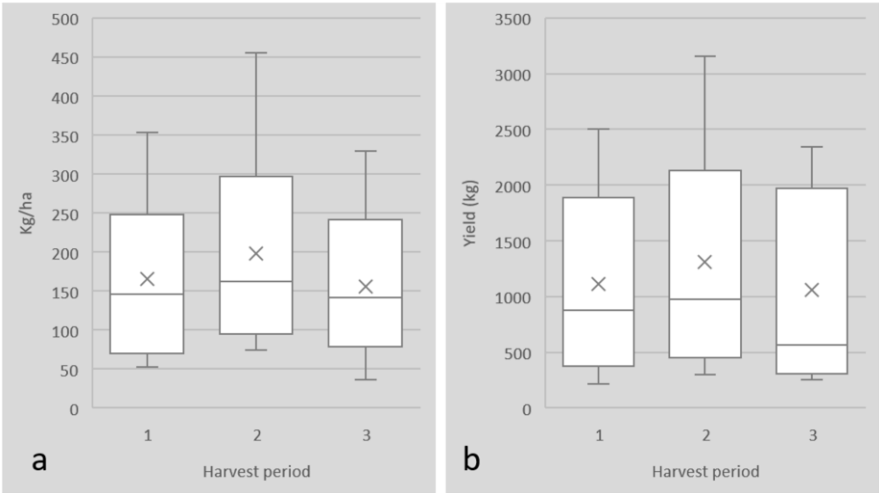

Figure 4.9: KP – box and whisker plot comparing a) yield per hectare across patches for each harvest period; and b) total yield per patch in kg per harvest period.

An ANOVA of yield per hectare per patch also shows no significant change between harvesting periods (P = 0.690). Although the average yield per hectare varies from 198 kg/ha in 2008 (Harvest period 1) to an average of 145 kg/ha in 2016 (Harvest period 3), differences are not statistically significant. The farmer gave further insights into yield patterns across the three time periods. In 2008, the demand for honeybush was moderate, so harvesting effort was moderate. There was a peak in demand from 2010 to 2012 (the factory would call and offer to take whatever was available), so the harvest effort was increased. In every instance, the 2012 yield is highest – except for the Noukloof patch, where the yield is highest in 2016 at 2205 kg. Although demand was still high in 2016, the harvest took place in the midst of a severe drought (the annual rainfall at KP was 300mm in 2016, compared to an expected average of 600mm), and the veld (which had not burnt for 16 years) was moribund. In most harvest sites, the *C. intermedia* had become tall and leggy and was outcompeted by surrounding shrubs (Figure 4.10).

Figure 4.10: KP honeybush bearing veld – 16 years without fire. Orange flags indicate honeybush plants growing in-between taller Protea bushes.

4.4.2.7 KP: Analysis of harvester load

Based on the available data, the harvester load for the KP harvest team can only be estimated. The four-person team harvested for five to six weeks over four days per week, per harvest period. The approximate yield per day and load per harvester is indicated in Table 4.4. It ranges from a low of 119.13 kg per harvester (harvest period three), to a high of 147.25 kg per harvester (harvest period two), with an average load per harvester for this enterprise of 130.5 kg. Despite the differences in average loads, the variation is insignificant across the three periods (P = 0.800).

Table 4.4: KP team – approximate harvester loads for the team, based on available data.

Harvest period	Total yield (kg)	Approx. yield per day (kg) based on 20 harvest events per harvest period	Approx. load per harvester (kg) per harvest event
1	10 010	500.50	125.13
2	11 780	589.00	147.25
3	9 530	476.50	119.13

4.4.2.8 UN: Harvest history across six farms

Descriptive statistics of the harvest event yield over time show that the values are randomly variable – linear models never yield an R^2 value of more than 0.6507, and these values have no statistical significance. Based on a linear model (Figure 4.11), Farm Two (orange) and Three (grey) show a positive slope – indicating a pattern with potential increased yield over time. They have a harvest return interval of two and ¾, and three years, respectively. Farm One (blue), Four (yellow), Five (dark blue), and Six (green), show downward slopes indicating a pattern of potential decreased harvest yield over time. The return harvest interval for these six farms is 2 to 2.5 years.

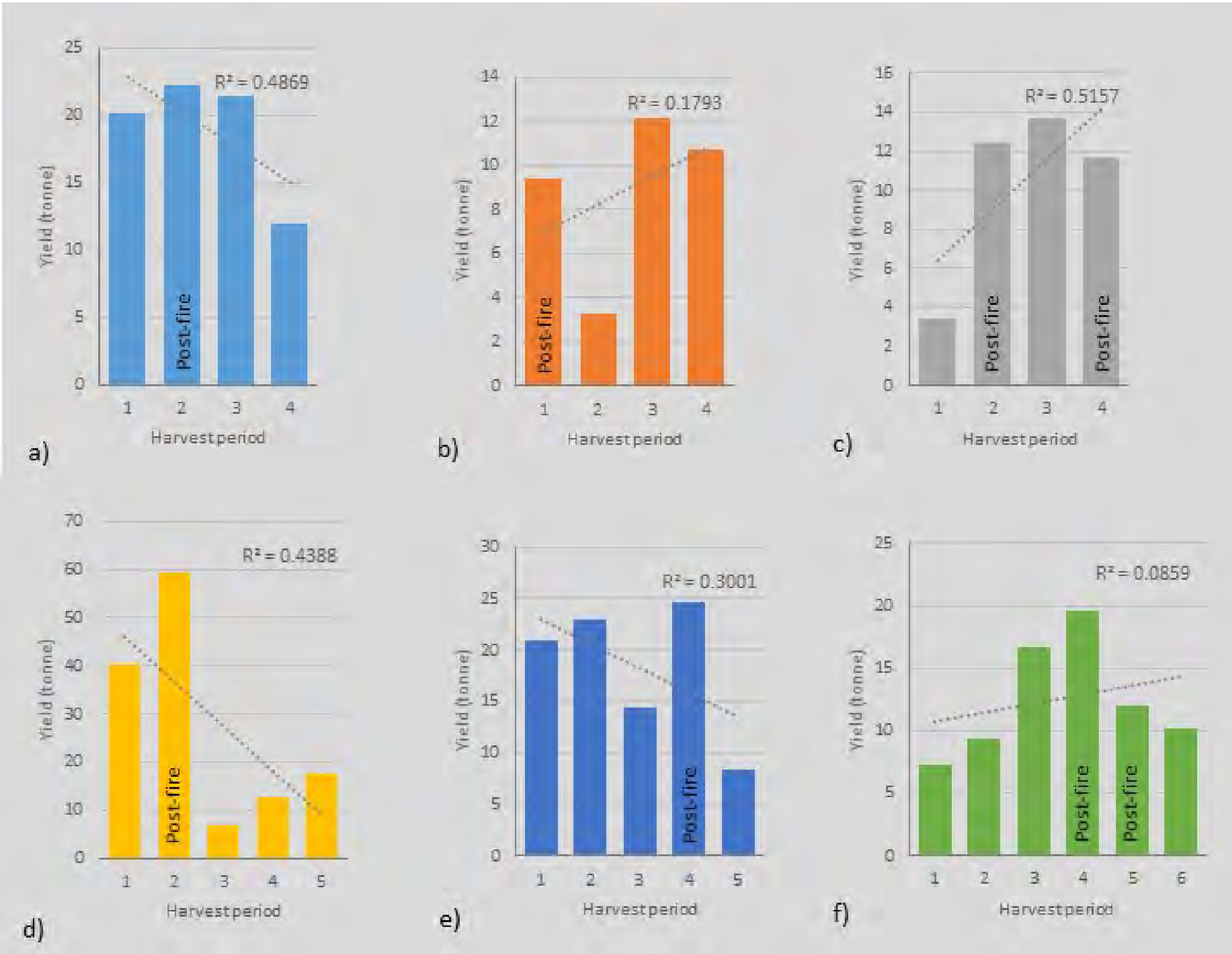

Figure 4.11: Harvest yield history across six farms harvested by the UN team. a) Farm 1; b) Farm 2; c) Farm 3; d) Farm 4; e) Farm 5 and f) Farm 6. Four to six harvest periods are represented.

The harvest periods in the dataset were not uniform and were defined by the harvest manager based on his written records. Harvest periods and access to the resource on a farm can change with a change in ownership of the farm, resulting in a highly variable harvest yield per harvest period and across harvest events. For example, on Farm Three (Figure 4.11c), a low first yield is partly the result of opportunistic illegal harvesting on the farm before the new landowner took up residence, ahead of the first harvest that the UN team carried out. On Farm Four, low yields in periods three, four and five reflect a new landowner limiting access to the areas available for harvest by the UN team.

4.4.2.9 UN: effect of fire on harvest yield

The harvest manager noted high (above average) harvest event yields per farm correlated with a post-fire harvest event. The box and whisker plots (Figure 4.12) show an overlap between harvest yield in a 'Post-fire' period and harvest yield in a period with 'No-fire,' suggesting that the relationship is not significant. However, the plot's average yield values ('x') are quite different ('No-fire' = 13.5 tonnes, 'Post-fire' = 23.2 tonnes). A single factor ANOVA (P = 0.040) suggests that fire does have a significant effect on yield, increasing it substantially. The bar charts of harvest yields per farm (Figure 4.11) further illustrate this relationship: while fire may reduce the biomass available in the short term, within two years, yield increases typically. For all but one farm (Farm Three), the period with the highest yield is a post-fire period.

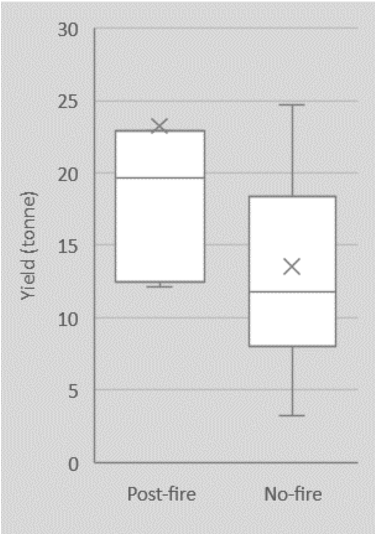

Figure 4.12: UN - box and whisker plot comparing harvest yield across farms with and without the effect of fire.

4.4.2.10 UN: Yield per hectare per farm

The area of honeybush bearing veld per UN farm was mapped at 1: 50 000 and was not as accurate as for ME and KP, with only a 50% overlap of expertly mapped patches compared with field surveys of populations. Despite this, the total area per farm was within 10% of the actual harvestable area of honeybush-bearing veld (confirmed by the harvest manager). The data on yield across harvest periods was not linked to individual patches; therefore, an analysis of yield per hectare shows the same pattern of results as yield across harvest periods and is thus not considered beneficial.

4.4.2.11 UN: Analysis of harvester loads

In order to assess harvester livelihoods, the average harvester load is meaningful because it is a relative value that is applicable across all farms, all periods and all harvest events. Assuming a consistent effort, the harvester load per day will also be a good measure of resource availability. The focus of this analysis, then, is harvester loads across harvest events. The descriptive statistics for average load per harvester, and indices of variability, are shown in Table 4.5. There is a high degree of variability in the harvest yields across the 587 harvest events, with a standard deviation of 321.62 about the mean harvest yield of 784.09 kg. There is moderate variability in harvester load with a standard deviation of 38.31 about the mean load of 94.06 kg. The average number of harvesters is 8.5 (rounded to 9), with a low standard deviation of 2.09, indicating that the mean is an acceptable average value for the dataset.

Table 4.5:UN - descriptive statistics of harvest variables across 587 harvest events.

Per harvest event	Mean	Max.	Min.	Std. dev.	Std. error
Harvest yield (kg)	784.09	2098.00	50.00	321.62	13.67
Team size	9	19	2	2.09	0.08
Harvester load (kg)	94.06	237.00	5.00	38.31	1.62

For the UN dataset, records of the number of harvesters per event and total harvest event yield allow for the calculation of average harvester load at each event. From this data, it is possible to investigate change over time per harvest event, in terms of harvest team size and harvester load, to reveal further insights into this critical aspect of sustainability. Figures 4.13 and 4.14 show values relating to the number of harvesters in a team, the most common team sizes, and the relationship between team size and average harvest load. In Figure 4.13, the most common harvest team size is nine (making up 20% of harvest events). This figure, together with teams of seven (13.1% of harvests), eight (19,6% of harvest events), and ten (16,4% of harvest events), team members operate at 70% of the harvest events. Team size is determined by the availability of harvesters at the time and sometimes the availability of transport.

A linear model shows a good fit for the relationship between team size and average team member load (R^2 = 0. 820). As the team size increases, accessibility to, and availability of, the harvestable resource declines, and it follows that there is a strong negative correlation (r = -0.891) between the number of harvesters and harvester load (as harvester numbers increase, loads decrease). Further analysis shows that the mean number of harvesters per event fluctuates across all harvest periods from 2003 to 2017, as shown in the partial overlap of boxes (Figure 4.15). In period one, the mean number is eight harvesters per event, which increases to a mean of 11 harvesters per event in period six, with periodic fluctuations. A single-factor ANOVA shows that the variation in harvester numbers is significant (P = 0.030). While the increase in harvest team size over time may be significant, there is only a low positive correlation between harvest load and the total yield per harvest event (r = 0.305).

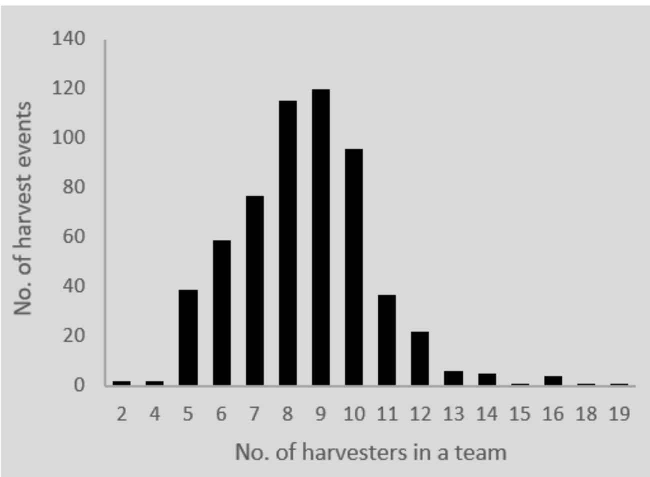

Figure 4.13: Number of harvest events attended by teams of various sizes.

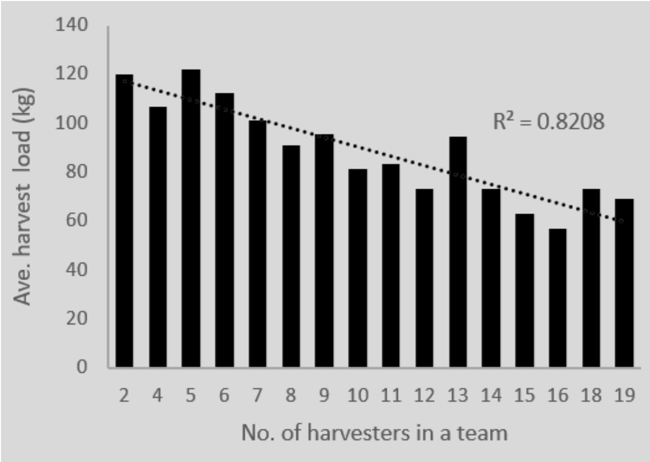

Figure 4.14: The average harvester load at harvest events, relative to the size of the harvest team.

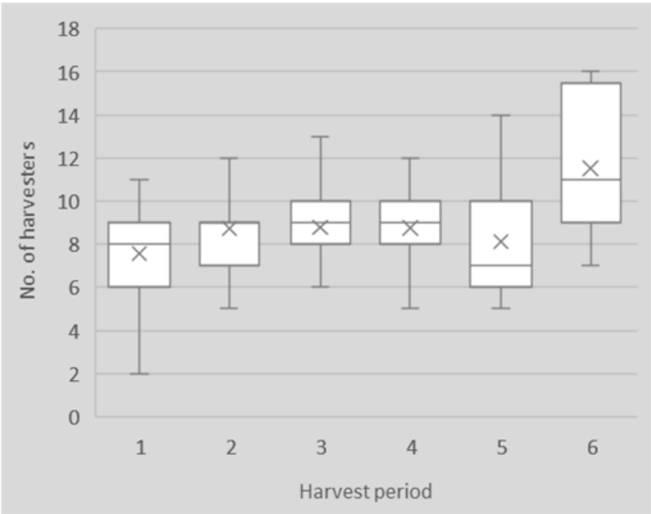

Figure 4.15: Box and whisker plot showing the variation in harvest team numbers over time. The mean team size per period is indicated with an 'x.'

Resource availability is not considered an issue as the harvest areas on the six farms analysed in this data set are large, taking weeks or months to harvest. The team size can be flexible, and the harvest days on the farm can be adjusted accordingly. However, there is an optimum team size with average harvester load (Figure 4.14). For teams of up to 10 members, the mean harvester load is 94 kg per day, whereas, for 11 to 19-member teams, the mean load is only 74 kg.

4.4.2.12 UN: Analysis of harvester load per farm

The box and whisker plots (Figure 4.16) per farm illustrate the change in mean harvester load over time on individual farms. The difference in harvester loads across harvest periods on Farm Two, Four and Five is statistically significant ($P < 0.05$ based on an ANOVA). On Farm One and Three, the difference between the harvest periods is insignificant. When only the first and last harvest period harvester loads are analysed with a t-test, the decline in harvester load is significant on all farms ($P < 0.05$).

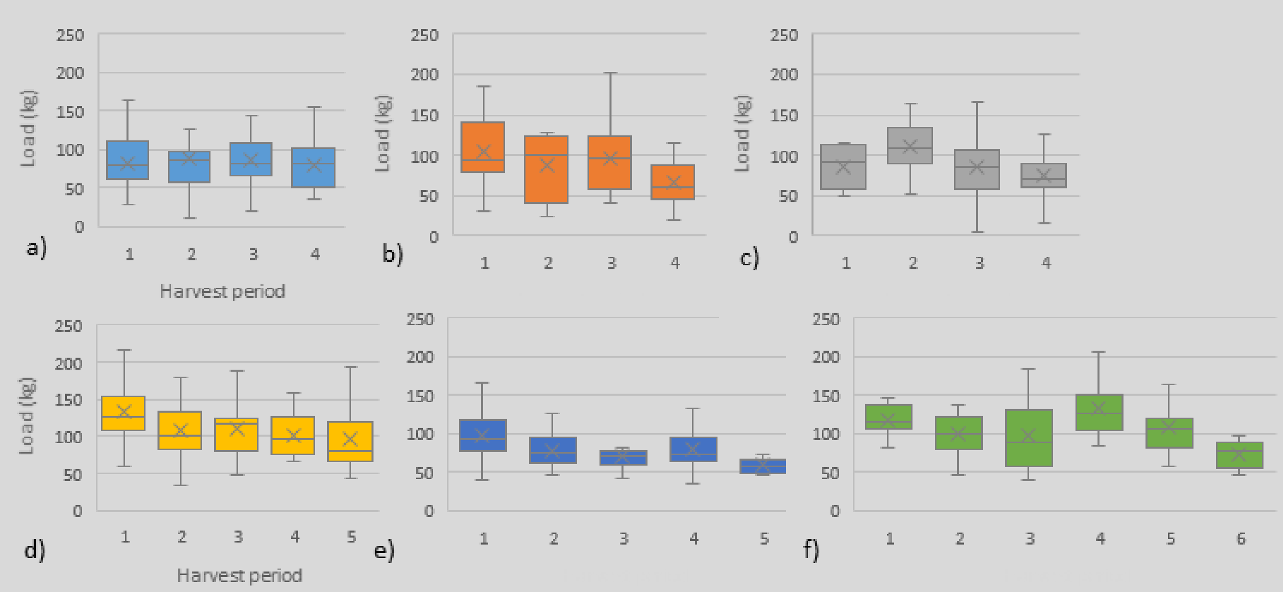

Figure 4.16: UN - box and whisker plots for average harvester load per farm, per harvest period. a) Farm 1; b) Farm 2; c) Farm 3; d) Farm 4; e) Farm 5 and f) Farm 6. The scale remains constant across the graphs. The mean is indicated with an 'x.'

4.4.3 Inventory of the harvest

4.4.3.1 Description of harvest teams

The harvest events represent three types of harvest team, identified through the Louterwater workshop surveys (Chapter Three) and noted in the farmer and harvest manager surveys, Objective One, Table 4.1. The harvesters at EB and KP3 were both small family-type teams. The full-time contract team type (three harvest surveys) and the farm staff team type (two harvest surveys) comprised more or less the same harvesters at each event. Further details of the teams, their professed practice, and the harvest events at which surveys took place are detailed in Table 4.6.

Table 4.6: Profiles of harvest teams who participated in the harvest event surveys.

Team type	Nature of employment	Team size	Description	Harvest practice	Harvest event
KP/EB Family team	3 to 4 days per week, 3 months per year. Income shared.	4-6	Led by a senior family member (or the farmer) who organises, permits, transport, payment.	Full harvest (approx. 80% of population) every 4 years.	EB, KP3
UN Full-time contract team	4 days per week, 9 months per year. Payment per kg.	12-15	Led by a harvest manager who organises sales, permits, transport, payment.	50% harvest every 18 months. Adjusted according to landowner requirements and env. conditions.	MP1, MP2, NA
ME Farm staff	1 day per week, average 32 days per year. Monthly salary plus benefits.	10-15	Led by the farmer. Full-time staff involved in all aspects of the honeybush value chain, plus other agric. enterprises.	Full harvest (approx. 80% of the population), each patch harvested every 4 years, adjusted for prevailing env. conditions.	ME1and2, ME3

4.4.3.2 Plant population survey

The results of the belt transect surveys of plant dimensions (Figure 4.17) show clearly that the harvested plant dimensions for all variables - height (a), average crown width (b), and number of stems (c) - are greater than the dimensions of the unharvested plants. Practical explanations support the dominance of small plants in the unharvested set: plants that are shorter than 50 cm in height tend to fall out of the bundles, and small plants of only a few stems are not worth the effort of cutting when there are bigger plants available. The plant heights are greatest at EB and MP1, which is typical of sites where fire has been absent for eight or nine years, causing the *C. intermedia* to become tall and leggy as it competes with taller shrubs (*Leucadendron* sp.) and small trees (*Protea* sp.) as illustrated in Figure 4.20a and 4.20d. Despite the competition, the crown size at these sites is also greatest (Figure 4.17b), although the average number of stems is lowest at around eight (Figure 4.17c). Stem colour was also recorded as an indicator of suitable harvest age. At all sites, only brown-, orange- and yellow-coloured stems were recorded. No young, green stems were recorded in the surveyed populations.

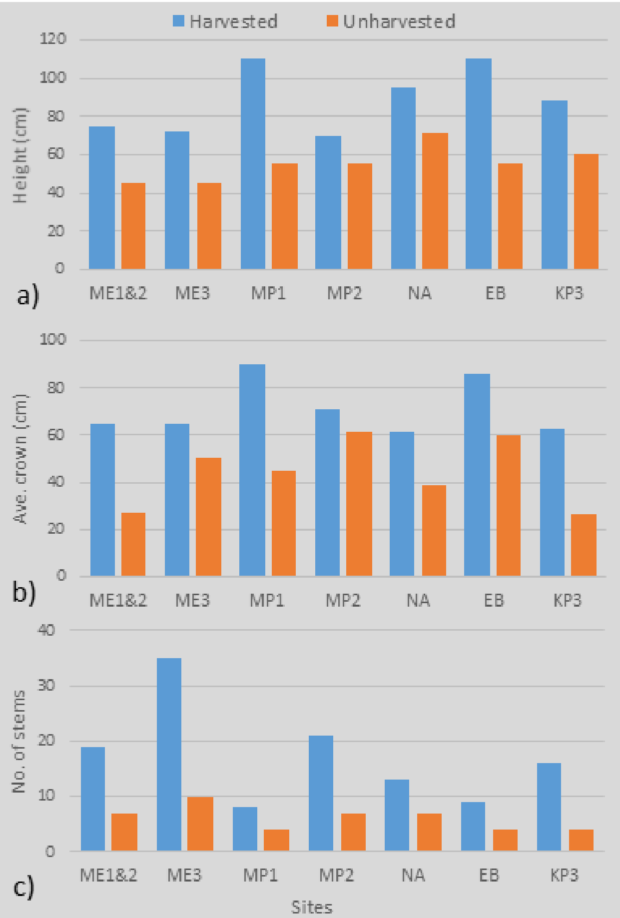

Figure 4.17: Comparison of harvested and unharvested plant dimensions. a) Plant height; b) Ave. crown; c) Average number of stems.

The proportion of harvested versus unharvested plants (Figure 4.18) at each survey and on transect walks (illustrated in the map in Figure 4.19) is important, because it relates to the planned harvest approach recorded in Table 4.6 (50% of plants every 18 months, or 80% of plants every four years). Despite a professed practice of harvesting 50% of the plants every 18 months (a practice which spreads employment opportunities and reduces the risk of losing a whole crop to fire), results of the surveys at MP1, MP2, and NA show a 67%, 72% and 58% harvest of the population respectively. For example, Figure 4.19 shows the NA site with two belt transects and two track transects where the overall proportion of plants harvested is 58%.

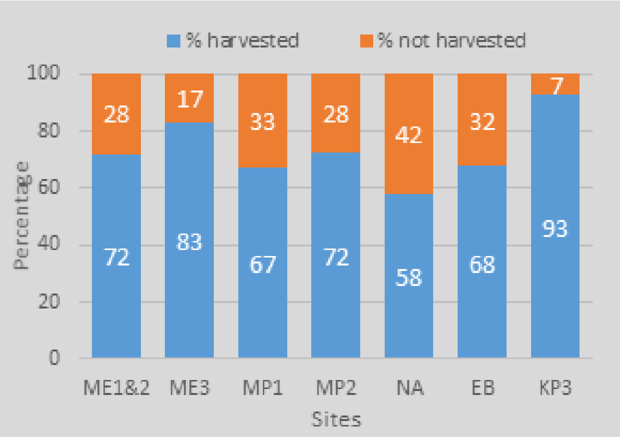

Figure 4.18: Comparison of the proportion of harvested vs unharvested plants at each harvest event.

The KP harvest proportion (93%) was deliberately high as a planned burn was scheduled immediately post-harvest. The ME sites are harvested according to plan (around 80% of the population is harvested). At the EB site – the proportion of plants harvested is only 67% (likely due to the small team size), the lack of experience of the members, and the fact that the veld was moribund with poor visibility of scattered individual plants. At all the sites, there were very few green stem plants – and no green stems were evident in the harvested material. This is to be expected at the sites where the harvested material is at least three years old (ME1 and 2, EB, KP). At MP1, MP2 and NA, it seems that the 18-month harvest interval allows for sufficient ageing of the stems to yellow/orange and brown colours, which are suitable for processing.

There is a range of plant densities across the harvested sites – with an average of 876 plants per ha, and a range from a low of 400 to a high of 1732 plants per ha (Table 4.7). Despite these differences, all sites are considered harvestable. The average plant yield per site does not vary much, with an average of 440 g across a range of 305 g to 501 g (Table 4.7).

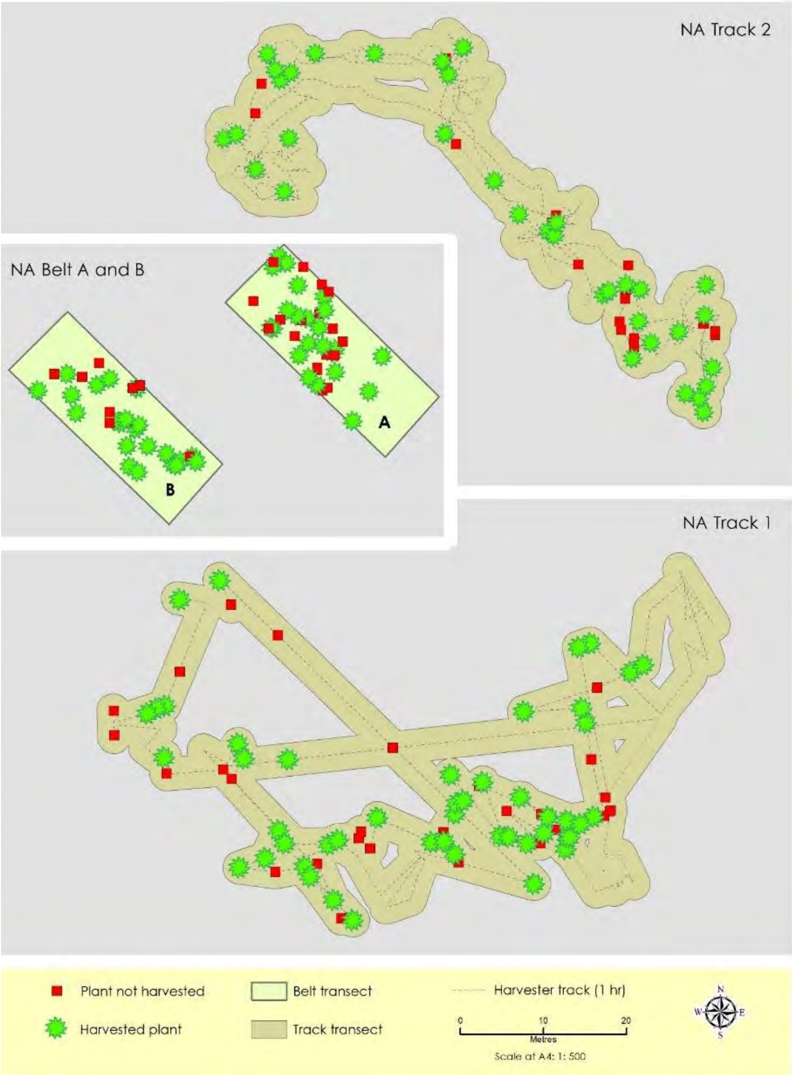

Figure 4.19: NA – an example of a harvester transect walk and population transects with harvested versus unharvested plants marked. Scale is consistent across diagrams.

4.4.3.3 Harvest and harvester territory surveys

The total (harvest) territory (Table 4.7) is the area accessed by the tracked harvesters at each site. Where the physical landscape is a single feature, or two separate features, with populations confined to those areas, the number of hectares needed by the team is lowest. At ME1 & 2, ME3 and KP3, the total territory accessed by the tracked harvesters is less than 3 ha in total (column2, Table 4.7). The area accessed by each individual harvester at these sites, (plus the NA site) is around 1 ha with shared (average) total territory (Table 4.7, Column 3) access of less than 1 ha and as low as 0.36 ha. The physical terrain at a site, plus the vegetation form (illustrated in Figure 4.20), also affects harvesting success: open grassy fynbos sites (e.g.: ME 1&2, Figure 4.20b and MP2, Figure 20c) are easy to work whereas dense, taller vegetation hampers harvesting (e.g.: EB Figure 20a and MP1, Figure 20d).

The high-density sites at ME1 & 2 and ME3 with 1731 and 1251 plants/ha, respectively (Table 4.7, Column 4), result in the highest average harvester yields of 116.70 kg and 127.20 kg and the highest yield per hour of

21.20 kg and 19.40 kg (Table 4.8). Although the lowest load (70 kg per harvester due to a short working day of only four hours) is recorded at EB – the number of kilograms per hour is high at 17.5 kg (Table 4.8, Column 7). In other words – the return per hour of effort is better than at MP1, MP2, NA and KP3.

Table 4.7: Spatial characteristics and the plant population characteristics at the harvest event sites.

Site	Total territory (ha)	Total Harvesters	Plant density/ha	Ave. plant yield (g)	Physical nature of site and effect on territories
ME1 & 2	2.52	12	1731	410	Narrow territories running parallel down a broad spur, low grassy fynbos.
ME3	2.90	11	1251	500	Extensive convex to concave slope, grassy fynbos with scattered *Leucadendron* sp.
MP1	7.28	12	750	380	Scattered patches of honeybush, lots of dead ground, dense protea veld.
MP2	8.97	12	657	400	Grassy fynbos along spurs, dead ground in between which was crossed for access.
NA	3.48	5	700	440	SW facing slope up a long kloof, plants bottom to top, scattered proteas in grassy fynbos.
EB	4.17	4	500	501	2 separate patches, with scattered clusters of *C. intermedia*. Located along a spur and in an amphitheatre; moribund, grassy fynbos, with areas of dense tall shrubs.
KP3	2.70	4	680	350	2 separate patches: along a spur (protea veld) and on adjacent slope (moribund grassy fynbos).
Ave.	4.57	9	876	440	
Max.	8.97	12	1731	501	
Min.	2.52	3	400	305	

Table 4.8: Summary of territory data from tracked harvesters plus estimates of material harvested (kg) per unit time.

Site	No. of tracked harvesters	Ave. harvest territory(ha)	Ave. harvest territory/total harvest territory (ha)	Ave. kg/ harvester	Harvest duration (hrs)	Kg/hour
ME1and2	4 (of 12)	1.13	0.63	116.7	6	19.4
ME3	9 (of 11)	0.36	0.32	127.2	6	21.2
MP1	3 (of 12)	3.35	2.43	83.0	6	13.8
MP2	4 (of 12)	2.59	2.24	91.8	6	15.3
NA	5 (of 5)	0.87	0.70	91.8	6	15.3
EB	3 (of 4)	2.03	1.39	70.0	4	17.5
KP3	3 (of 4)	1.01	0.90	75.0	6	12.5
Ave.		1.62	1.23	92.1	6	16.2
Max.		3.35	2.43	118.3	6	17.5
Min		0.87	0.63	70.0	4	12.5

Figure 4.20: State of the veld (related to fire history and vegetation community) and the physical environment affects harvester movement. a) Harvesters on a steep slope at EB, moribund vegetation hampers movement. b) and c) Grassy fynbos at ME1&2 (*Cyclopia intermedia* plants are indicated with purple tags) and MP2 where *C. intermedia* plants are easy to find. terrain makes movement easy. d) Tall protea veld at MP1 which outcompetes the *C. intermedia* causing it to grow tall with fewer stems and lower yields per plant (average 380g).

4.4.3.4 Transect walk with harvesters and harvest site mapping

The harvester tracks (Figure 4.19) and territories (Figure 4.21) are based on a GPS unit carried by the harvester over a harvest day. The harvester territory in hectares is generated using the convex hull polygon function (ArcMap 10.8) to develop an area around the limit of the track locations. This automated function gives a repeatable method but cannot account for the overlap of territories, so the average harvester territory as a part of the total territory (boundary of the area used by the group of tracked harvesters) is more meaningful (Table 4.7, column 4). Neither of these methods accounts for areas at the site where no honeybush occurs or dead ground which must be traversed to get from one population to another.

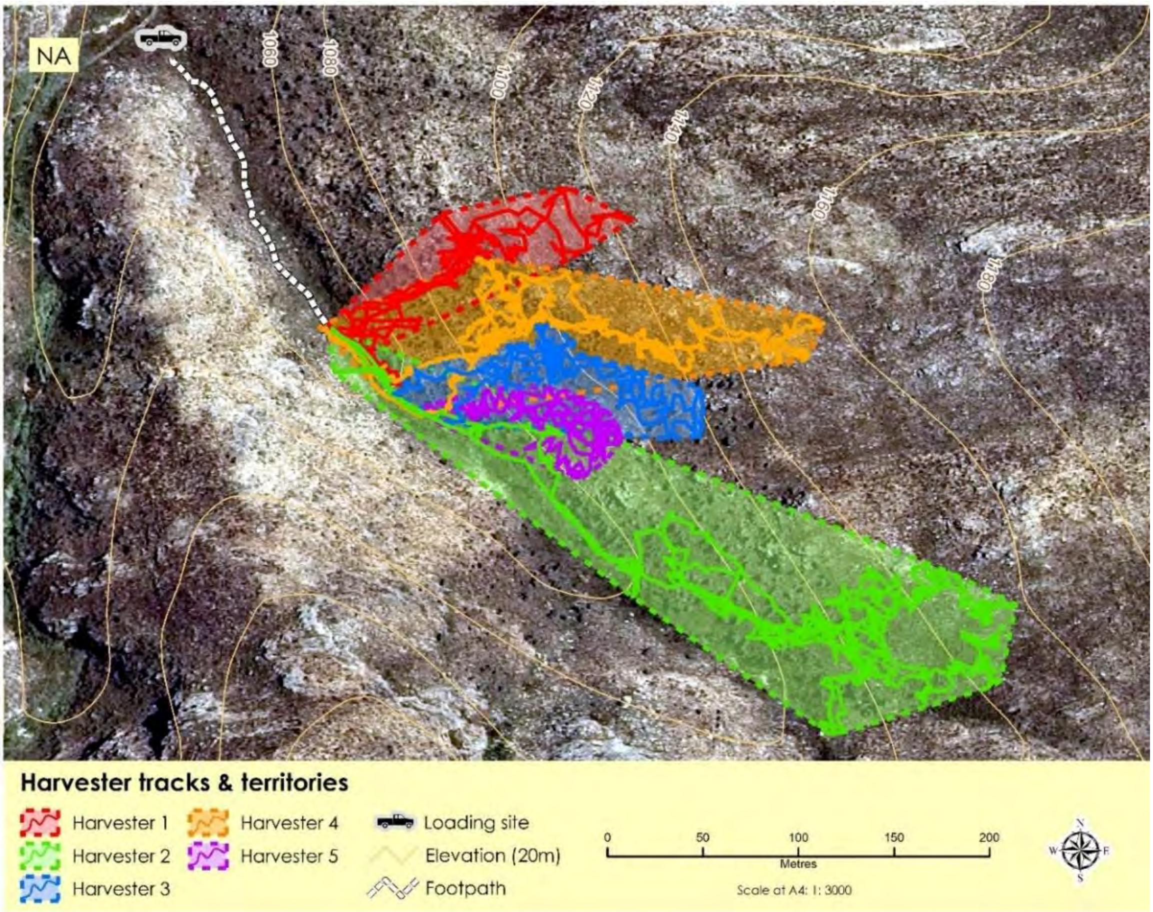

Figure 4.21: An example of harvester tracks and territories as captured for the NA site.

At most harvest sites, harvester ‘territories’ are quite well defined by the team. For the contract team, young harvesters must walk the furthest to find harvestable plants while older, more experienced harvesters get the ‘better’ territories. For example, in Figure 4.21, *Harvester 2* (green territory) is the youngest member of the team and must walk the furthest. As shown on the map, there is minimal overlap of territories for this team. For the family team at EB, where profits are shared, the team works together to share the best areas and the loads. For the farm team (ME1 & 2 and ME3), the order of the harvest day is well defined with a standard load of 1300-1400 kg to bring in and set roles of harvesters, bundlers and carriers. In terms of the harvest plan, the harvesters in the contract team have to work harder and access larger areas (3.35 ha and 2.59 ha, Table 4.8) at MP1 and MP2, respectively to get an acceptable harvest event yield as they should only be harvesting 50% of the population. They manage to keep their harvest load figures up (83 kg and 91.8 kg) at MP1 and MP2 by cutting a larger proportion (on average, 66%) of the population instead of the planned 50%.

The lower load per harvester at KP is explained by averaging the figures. The two male harvesters brought in 115 kg and 110 kg respectively, but fetching and carrying, and some harvesting (75 kg) is shared by two female family members who have an equal share in the days’ harvest load. A similar approach is followed by the EB harvest team made up of two (young) women and two (young) men, where the men harvest more by weight and do extra trips to carry the load off the site, but the total load for the day is shared. A series of photographs in Figure 4.22 illustrate the harvesting sequence, from identifying a mature plant (a) to cropping of the plant (b) through to loading (e).

Figure 4.22: a) Harvester QW beside a plant of medium size and suitable harvest age. b) A plant is cut by a harvester with a sickle (or secateurs); c) A bundler/carrier binds harvested material; d) A harvester carries a 50kg load to the transport point; e) Harvest bundles are weighed and accounted for at a piece rate.

The transect tracks (Figure 4.19) represent one hour in the harvesters' day, during which they were accompanied to discuss and record typical practices. Questions from the Louterwater workshop questionnaires were administered during the transect walks and are included in the graphed results and the thematic content analysis of Chapter Three. The main output from these walks relates to the teams' stated harvest practice (Table 4.6) in terms of the proportion of plants harvested.

4.5 Discussion

The aim of this part of the research was to establish the sustainability of harvest enterprises and associated harvester livelihoods as they relate to the use of the *C. intermedia* resource. To achieve sustainable use of a wild resource, it is necessary to understand the nature of the harvest in terms of harvest practices and traditions. Depending on the type of plant and the parts that are harvested, the social, cultural and economic setting, and traditional or formal controls of harvest, there will be varying impacts from low to high (Cunningham, 2001; Peters, 1999). It is a common feature of natural resource use that there is incomplete and/or a lack of documented information on harvest knowledge, practices, and long-term impacts of harvesting on yields (Hanazaki et al., 2018; Ingram et al., 2012; Schippmann et al., 2006). Without this kind of information, putting in place the means to use a resource sustainably is difficult (Ingram et al., 2012).

4.5.1 Sustainability check

The enterprises represented in this harvest analysis have profiles typical of the honeybush industry: a resident farm staff team, a small family contract team, and a large contract team. From a farmer or harvest manager's perspective, it is necessary to maintain a consistent yield over time to meet demand, while a harvester must be able to practice their trade and make a reasonable livelihood. In the summary diagram (Figure 4.23), there are four sustainability checks per enterprise (or per farm) related to the analyses conducted. Across the aspects considered, the KP enterprise exhibits full sustainability (green) across yield per harvest period, yield per hectare, harvester load, and conforming to a professed harvest practice. ME is sustainable across three of the four areas, with annual yield records showing a downward trend (red). The variability is explained by the farmer as a deliberate adjustment of harvesting effort in response to market demand or other farming priorities. For the UN enterprise, three farms show increased yields and three farms show decreased yields (Farm One, Four and Five), although yield decrease on Farm Four is explained in terms of loss of access to the full harvest area due to change in ownership. Harvester loads decline significantly over time on Farms Two, Four and Five across harvest periods. When only the first and last harvest periods are analysed, loads decline on all six farms. The whole UN enterprise, across six farms, scores only six checks for sustainability, and 18 checks against. On a per-farm basis, harvesting on Farms Three and Six meet two out of four sustainability checks (50%), Farms Four and Five are wholly unsustainable, and Farms One and Two are partly (25%) sustainable. The harvest practice aspect indicates whether the team practices what they profess in terms of the proportion of plants harvested: all the UN farms fail the sustainability check on this aspect.

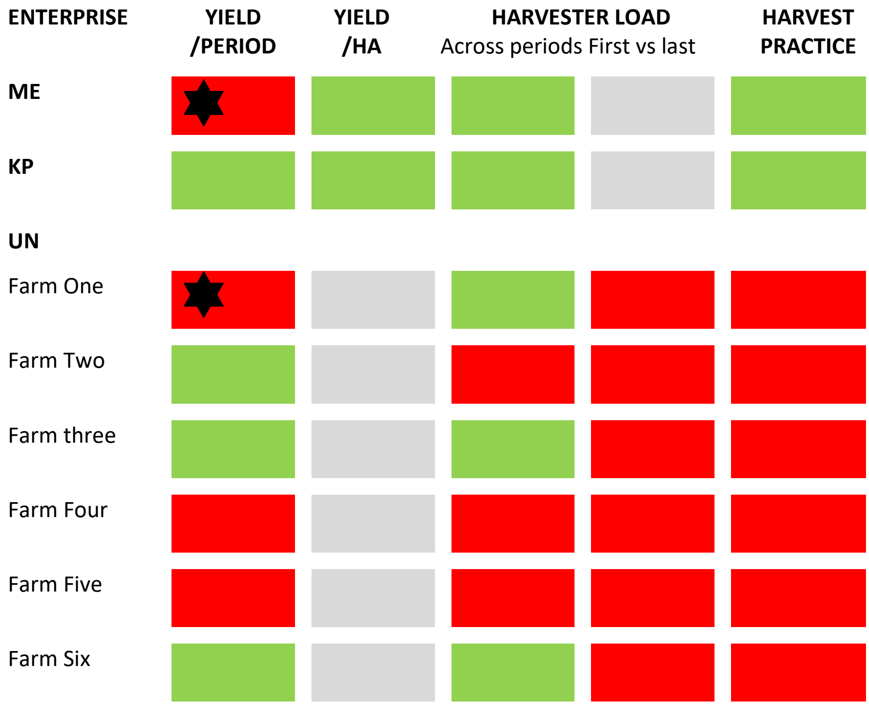

Figure 4.23: Summary of aspects of the sustainability of harvesting across all enterprises. Grey blocks indicate that an aspect is not analysed, green signifies sustainability and red indicates unsustainability. Black stars indicate an explanation given by the farmer or harvest manager.

4.5.2 State of the resource

The condition of the resource is partly influenced by fire: across the UN and ME datasets, harvest yields in post-fire periods were consistently higher than in periods with a no-fire effect. KP did not have a fire during the period of interest, and, as explained by the farmer, the lower yield in the third harvest period can be linked to an absence of fire. Both these farmers use fire conservatively to manage the veld, allowing 12-14-year intervals (considered relatively natural in this region of the fynbos – see Kraaij and van Wilgen, 2014). At ME, the variability in total annual yield is statistically significant, but is explained with reference to post-fire harvests (which are consistently higher than average), deliberate adjustment of annual offtake in response to market demand, and adjustment of effort in relation to other farming priorities. There is a range in yield per hectare across harvest periods (257 to 390 kg/ha) for all the harvest patches, but the differences are statistically insignificant. The harvest plan for both these enterprises is a four-year interval, after which about 80% of a population is harvested (confirmed through field surveys). For both farms, intervals are adapted according to prevailing weather conditions. For example, at ME in the post-2016 fire period, populations were only harvested five to six years later, given the prevailing drought conditions (data not represented here). The results for both these two enterprises show sustainable use of the resource from an environmental perspective. This knowledge and adaptive management based on LEK can prove invaluable to sustainable wild resource use (Hopping et al., 2016; Papageorgiou et al., 2020).

For the UN team (characterised by full-time, contract harvesters, doing piece-rate work, supplying a processor with high demand), descriptive statistics showed that on three of the farms assessed, total harvest yield per harvest period is declining. On these farms, the number of recorded harvest periods is five or six, and the average harvest interval is only 2. 0 to 2.5 years. These three farms, which make up 60% of the area of 1290 ha covered in this six-farm analysis, are not being harvested sustainably. As recorded by Grogan et al (2010), unsustainable use of natural resources, driven by demand for the product, leads to population decline. On the other three UN farms, which have only been harvested four times (based on the data analysed) with an average harvest interval of 2.5 to 2.75 years, harvesting is being carried out sustainably (514 ha or 40% of the area under consideration).

For the six enterprises analysed, around 61% of the area of 1966 hectares of honeybush-bearing land is managed sustainably, whereas 39% is not being harvested sustainably.

4.5.3 Best practice harvesting

In terms of the nature of the teams and their practice, the resident farm team (ME), although large (12 to 14 harvesters), is highly experienced and efficient, as seen by the high average harvester loads (c. 110 kg). The team's social structure ensures that everyone sticks to best practice, and younger team members learn from older members. Even if plants are small or green in colour at a harvest site, because a full harvest of the population is carried out at each harvest event at four-to-five-year intervals, all growth will be mature and suitable for cropping. Being involved in the whole value chain, harvesters know that mature plants produce the best tea.

The smaller family teams (represented at KP and the EB harvest) are cohesive units managed closely by a senior family member. Their harvest may not be as intensive at a site. However, despite the team's small size, the return per unit effort is high because there is plenty of material available (KP average across three harvest periods – 130 kg). The shared income leads to shared work in the field and potentially better sharing of knowledge and experience.

As confirmed by the harvest manager, the large contract team (UN) is challenging to manage in terms of best practice. For example, inexperienced team members or outsiders are problematic regarding unsustainable practices. The same point was made by harvesters at the Louterwater workshop, who see inexperienced outsiders as responsible for illegal harvesting and bad practice. In the South African aloe harvesting community, Melin et al. (2017) note that unsustainable aloe harvesting (EC) is associated with newcomers to the industry. Schmidt & Ticktin (2012), in an assessment of Golden Grass harvest (Brazil), recorded that newcomers to the industry harvest too early in the season and kill the plants. With a large team, although all harvesters know the plan to harvest 50% of the population, payment is piece rate, so there is an incentive to bring in as much as possible at a harvest event. The average proportion of plants cropped in belt surveys and transect walks was 66%, which means that at least 16% of plants are harvested too young at each harvest. Hernández-Barrios et al. (2015) have shown that too frequent harvesting of palm leaves was ecologically unsustainable, and it was economically unsound because stunted leaves (post-harvest regrowth) were undesirable to the market. Similarly, the harvest of young *C. intermedia* stems produces poor-quality tea and depletes plant vigour.

Further issues are encountered when illegal harvesters visit the site between planned harvest events, and crop the remaining plants in the population that are only 18 months old. From a management perspective, 50% cropping at 18-month intervals (as the harvest manager explained) spreads risk in that in the event of fire, only half the crop is burnt, allowing a spread of income for harvesters and the farmer. However, based on the results of this research it is clear that 50% cropping at 18-month intervals, cropping three-year-old plants – is not adhered to. The harvest interval ranges from 1.8 years to 2.75 years, with Farms One, Four and Five (identified as having unsustainable harvest yields and harvester loads) subject to higher frequency harvesting. Therefore, this practice is not considered sustainable, although it was recorded as an option in the *Wild honeybush harvesting field guide* (McGregor, 2018). Further data collection and analysis (Chapter Five results on the effect of a three-year harvest interval) have shown that plant vigour declines when intervals are too short.

4.5.4 Sustainability of harvester livelihoods

Wild harvesting is an important contributor to the livelihoods of honeybush harvesters, although it is only a part-time occupation for many. The contribution of wild-harvested products to rural livelihoods has been promoted as a way to improve livelihoods, and in South Africa, the role of wild product harvesting in many rural areas has been shown to contribute to security for many households (Peterson et al., 2012; Shackleton and Shackleton, 2004). For the ME and KP enterprises, harvesters bring in above-average loads at each harvest event, although they only work part-time. Income from part-time harvesting would be greater than the upper limits of figures given by Shackleton et al. (2011) of USD1130, as a portion of household income. The consistency in loads over time for ME and KP signify sustainable resource use from the perspective of harvester livelihoods.

For the UN enterprise, the change in harvester load across harvest periods shows some important patterns: for all six farms, the average harvester load declined from the first harvest period to the last harvest period. There is a weak correlation between harvester team size at an event, and the harvest yield at an event, indicating that increasing the number of harvesters at a site will not improve yield if the veld is not productive. With a team size of more than 10 members, the average harvester load is 74 kg, whereas, for less than 10 members, the average load is 94 kg, with around 12% of harvesters bringing in an average load upwards of 140 kg. Therefore, a sustainable team size, allowing each harvester to make a reasonable livelihood, is less than 10 members. According to Stanley et al. (2012), given the opportunity, wild product gatherers can earn above-average wages and achieve a level of economic sustainability as measured by the international absolute poverty line (USD2.15 per day in 2022, The World Bank, 2022).

A series of calculations of labourer earnings are presented in Figure 4.24 based on the Dept. of Employment & Labour (2024) farming sector minimum wage (Figure 4.24a) and various harvester income scenarios (a–d). The annual earning potential of a harvester bringing in 74 kg per harvest event is R53 280 (Figure 4.24b). At the same time, a farm labourer earns R48 540 in annual wages across 11 months (Figure 4.24a), but only R39 715 if aligned with the four-day week/nine-month working year of a harvester. (Harvester weeks are short due to the strenuous nature of the work). An average load of 74 kg for a harvester yields a better livelihood than a farm labourer on minimum wage. If the average harvester load for a team of 10 or fewer harvesters is considered (94 kg), a harvester can earn R67 680 in a nine-month year (Figure 4.24c), which is much better than a farm labourer over an 11-month year. A high-earning harvester, bringing in 140 kg at a harvest event, can earn up to R100 800 in a nine-month year (Figure 4.24d).

Considering what this means in terms of the area needed per harvester, to harvest sustainably at four- or five-year intervals: if 43.9 ha is required annually, then a harvester practising a four-year interval needs175.6 ha or 291.5 ha for a 5-year interval, respectively (Figure 4.24e). Converting this figure to actual harvester jobs –relative to the estimated current harvest area currently in use (Chapter Two), there are an estimated 57 or 46 jobs depending on the interval practised (Figure 4.24f).

These calculations are simplistic in that they do not accommodate extra employment benefits for either example, nor do they factor in fluctuations in the price of harvested material (influenced by market demand). The harvester case is based on average load, but in reality, some harvesters bring in consistently larger loads per harvest event, and can earn substantially more (the average harvester load for 12% of events is > 140 kg and up to 220kg). Some harvesters can find part-time work elsewhere (commonly fruit picking) in the months when they are not harvesting. A farm labourer earns a standard hourly wage but may have benefits like an annual bonus, access to produce from the farm, job stability, etc. In areas where wild resource harvesting is seasonal, part-time harvesting, with part-time farm labourer work, is a feature of wild resource use as accounted for in other South African case studies of Buchu harvesting (Williams & Kepe, 2008), Marula fruit harvesting (Shackleton, 2004) and Baobab fruit harvesting (Venter & Witkowski, 2013).

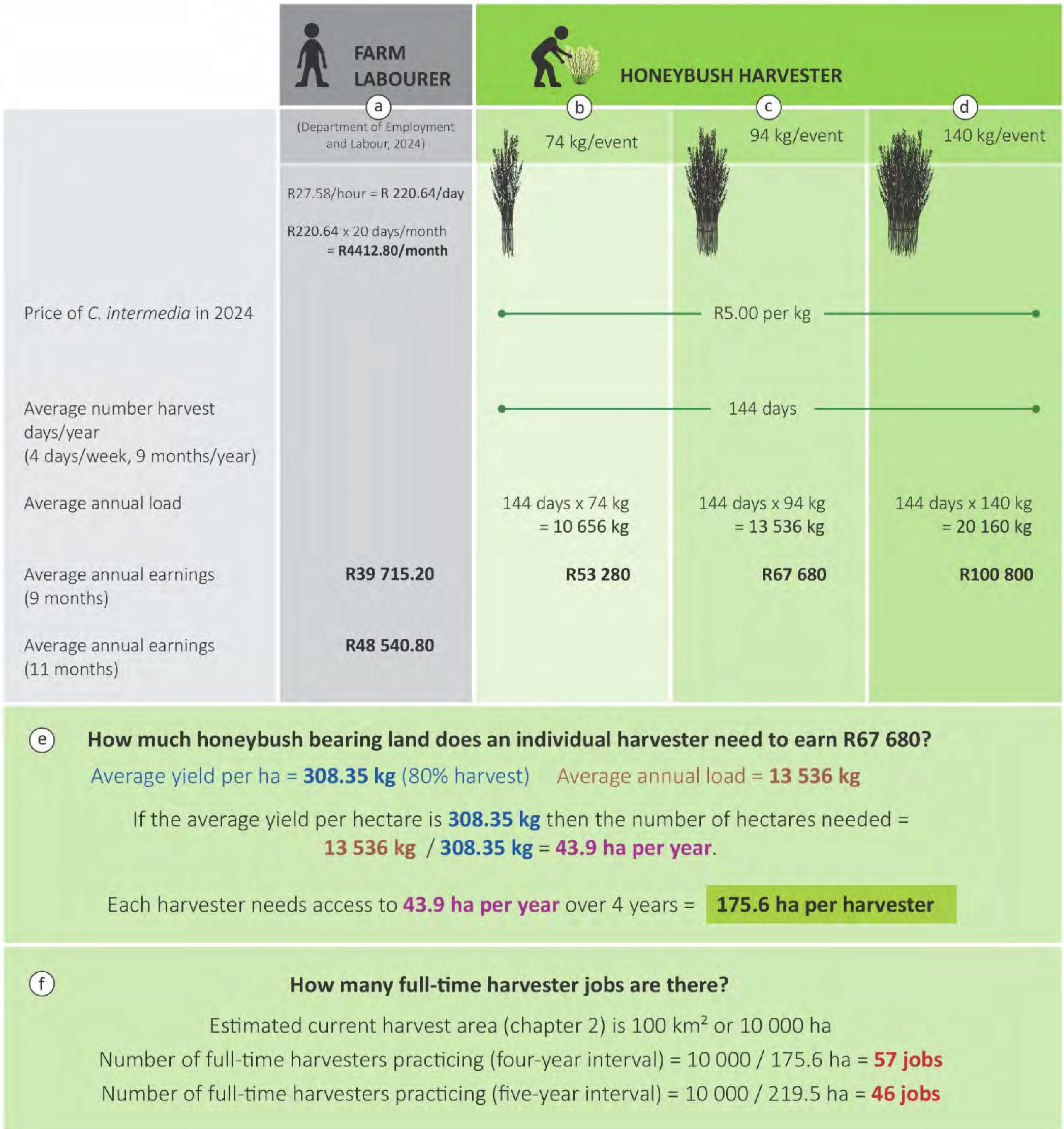

Figure 4.24: Estimates of potential livelihoods. a) Wages of a farm labourer; b) a honeybush harvester with average harvest load of 74 kg, (team of 11 plus harvesters); c) average harvest load for a team of 10 or less harvesters (94 kg); d) an above average load brought in by 12% of harvesters (140 kg). e) Estimate of land needed per harvester, using four and five year intervals and f) estimate of actual number of jobs based on the two intervals. (Values are ZAR, farm labourer earning is based on the 2024 Dept. of Employment and Labour minimum wage for the agricultural sector; value per kg of *Cyclopia intermedia* is the 2024 industry rate).

4.5.5 Wild harvesting of honeybush in context

The use of wild resources is a significant part of rural household livelihoods in South Africa (Peterson et al., 2012; Shackleton & Shackleton, 2004). Access to and use of the wild honeybush resource has similarities with, and differences to, other wild harvesting enterprises described in the review of literature for this chapter. Access to land in general - and specifically for wild resource harvesting is a feature of South African history (Puttick et al., 2011; Shackleton et al., 2001). For the most part, wild resource harvesting in South

Africa takes place on communal lands, as evidenced in the buchu (Williams & Kepe, 2008), aloe (Melin, 2017) marula (Wynberg & Laird, 2007), and baobab harvesting industries (Venter & Witkowski, 2013). Exceptions to this are fynbos flower picking (Privett et al., 2020) and honeybush harvesting, where harvesting occurs (almost exclusively) on privately owned land. Access to land (both private land and state-owned land, like conservation areas) for harvesting was noted by honeybush harvesters at the Louterwater workshop as a concern. The results of the analysis in this chapter suggest that harvesting on private land, managed by the farmer, is sustainable. Issues of various aspects of sustainability are common across all enterprises. A lack of communication in the fynbos cut-flower industry between commercial farmers (who cultivate fynbos flowers) and wildflower pickers has been noted as problematic (Privett et al., 2020) because it leads to a loss of livelihoods for wildflower pickers. Honeybush harvesters recognised the value of clear communication with landowners regarding harvesting agreements as an important feature of good practice to ensure sustained access to the resource (as reported at the Louterwater workshop). Loss of access to harvest sites for marula harvesters due to competing land use was recorded by Wynberg and Laird (2007) as a threat to marula harvesters livelihoods. While marula and baobab products have a large local market, the other products (aloe, buchu, fynbos flowers), as does honeybush, have a large export market component. There are similarities across all these industries in terms of best practice, with TEK and LEK guiding approaches to harvesting. Unsustainable practices (over-harvesting and careless cropping) are a threat to the highly localised buchu industry (Williams & Kepe, 2008), whereas for the aloe resource, which is abundant and widespread, threats to sustainability are low (Melin, 2017). The evidence from this analysis of honeybush harvesting shows that harvesting is unsustainable if it is too frequent, or poorly managed, leading to a decline in harvest yields and harvester loads. In contrast, since only the fruits are collected from baobab and marula trees, ecological sustainability is not an issue (Wynberg et al, 2003). Across all these industries, harvesting is mostly carried out by women (except for buchu), whereas honeybush harvesters are almost exclusively men due to the physical nature of the work.

Whatever form wild resource use takes, managing the use of the resource to provide a sustainable yield, where the rate of harvest should not exceed the rate of regeneration (Daly, 2005), is required to support social, economic and environmental sustainability. The ME and KP enterprise achieve this whereas the UN enterprise does not, particularly when harvest team sizes are too large. The pressure of changing from a cottage industry to a commercial one, with increasing wild harvest volumes, is problematic (Early-Capistrán et al., 2020; Grogan et al., 2010). However, the growth of trade in wild harvested products is recognised as contributing to livelihoods, particularly in South Africa (Shackleton et al., 2005) and therefore must be carried out sustainably. Achieving sustainable use in wild product trade can only happen with an understanding of best practice, sustainable yields, and ecological impacts (Shackleton et al., 2005; Williams et al., 2013).

4.6 Limitations

The analysis was based on only seven harvest events. The number of transects was limited by time, resources and harvester activity. To avoid influencing the normal harvest activity, transects may not have been placed ideally, or too few were laid out. The wetter sites in Tsitsikamma Sandstone Fynbos, where harvesting conditions are different, were not represented in a harvest survey.

Observations and explanations were sometimes limited because there was not always enough discussion about why harvesters did what they did, partly because of the researcher's need to observe and learn, and partly because of a desire not to intrude on the harvesters' territory. It was not always appropriate to interrogate harvesters about their practices, given their willingness to accommodate researchers. It seemed safer to let the data show what practices were being employed. Details may have been lost in translation from Afrikaans to English, particularly where the Afrikaans spoken by harvesters was colloquial. The format of data available for each enterprise was slightly different, so analyses were not identical across the three enterprises. In particular, accurate mapping of harvest patches (rather than per farm) and allocation of yield per harvest patch over time for the UN enterprise may have yielded greater insights into sustainability.

4.7 Summary

The chapter was focused on collecting data on three different styles of harvest enterprises (a resident farm staff team, a small family contract team and a large contract team) to assess the sustainability of harvesting enterprises and harvester livelihoods. The Sustainable Livelihoods Approach (SLA) was a source of ideas for methods for this part of the research under the category of participatory methods, central to SLA. These included expert mapping sessions with harvesters, harvest managers and farmers in mapping their harvest sites; transect walks used to observe and learn about harvest practice; focus group discussions to gather qualitative data on community perspectives with regard to the industry in general, and honeybush harvesting as a livelihood, and harvest practice. Methods were also drawn from the literature on natural resource management, which typically combines qualitative methods (such as interviews and focus group discussions) and quantitative methods (surveys of natural resource harvesting). Harvest enterprise histories (narrative and record-based) were recorded through in-depth interviews with purposively selected harvest managers, chosen based on experience, length of harvesting history and willingness to participate. Harvest records were analysed using descriptive statistics to quantitatively assess the sustainability of harvest enterprises over time as measured by yield per harvest period and the average loads collected by harvesters. Harvester activity data was recorded at harvest events using a GPS and combined with plant densities and average plant yields to calculate the territory required per harvester to harvest enough *C. intermedia* to make a reasonable livelihood.

The overarching theoretical framework for this chapter is sustainability science – characterised by its broad framing of many aspects of sustainability, including socio-cultural, economic and environmental aspects, all of which must be understood when assessing the sustainability of harvest enterprises and harvester livelihoods. Insights into natural resource use and its contribution to livelihoods (particularly in South Africa, and internationally) came from the substantial body of non-timber forest product literature.

The findings showed that a large contract harvest team, operating at three-year intervals, cropping 50% of the plants was unsustainable on three out of six farms. As team size increased above 10 harvesters, the average yield per harvester dropped from 94 kg per harvest event to 74 kg. From an environmental point of view, the harvest was not sustainable on two out of six farms, and it declined in the fourth and fifth harvest seasons. The resident farm and small family teams had better, consistently higher average harvest event yields and showed sustainable yields even after five harvest seasons. This was partly related to the nature of these teams, where the family team was closely managed by a respected senior family member (or farmer) experienced in harvesting. The resident farm team had a long history of working in the same harvest areas and was experienced in all parts of the honeybush enterprise, from veld management to quality tea production.

In terms of harvester livelihoods, the potential earnings of a honeybush harvester working four days a week, nine months of the year, bringing in a 74 kg load were estimated to be better (ZAR53 280 per year) than that of a farm labourer earning an annual income of ZAR48 540 per year (farm labourer wage of ZAR220.64/day for 11 months). To earn this income and harvest sustainability (four-year harvest interval), a harvester needs access to a minimum of 175.6 ha of *C. intermedia*-bearing veld over four years. Relative to the available current *C. intermedia* harvest area, this level of harvesting could yield 57 full-time harvester livelihoods.

4.8 References

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Chapter 5 Characterising the wild *Cyclopia intermedia* resource

Contents

List of figures

List of tables

5.1 Introduction

Much of our understanding of the *Cyclopia intermedia* plant in its wild setting is based on work by Schutte (1995). Her thesis dealt with all 23 *Cyclopia* species and forms the foundation of our knowledge about the environment in which these species grow. In terms of the effects of harvesting on *C. intermedia*, only two pieces of research are available: a Master's thesis (Barnado, 2014) that dealt with two harvested localities and one unharvested locality with three populations at each, and a published study (Lee, McGregor and Coetzee, 2023) that looked at the effect of harvesting on fecundity across 10 populations on a farm in the Bo-Kouga (Western Cape). There is currently no other formal record of the impacts of harvesting on individual plants or populations of *C. intermedia* across the distribution range. Concerns have been recorded that wild populations are declining (du Toit et al., 1998; Joubert et al., 2011; Schutte-Vlok, 1998) because of unsustainable harvesting (poorly managed with intervals that are too frequent) and illegal harvesting (unpermitted, unmanaged harvesting with random harvest intervals that are too frequent).

Without this specific information, we rely mainly on our knowledge of general fynbos ecology and similar species to frame our understanding of how to use and manage the resource (e.g. Jones, 1994). A characteristic of local ecological knowledge is that it can provide the best available locally specific knowledge around resource use (Cunningham, 2001). Still, it does not provide a broader context and understanding of patterns and practices across the full range of the species. As the industry has evolved from a local cottage industry to a commercial one (Joubert et al., 2011), it has become necessary to link the use and management of the resource to sound scientific knowledge, to protect the wild resource and to ensure the international biotrade market of sustainable use of the resource (UNCTAD, 2014; WBCSD, 2010). Sound scientific knowledge can promote the implementation (and acceptance) of biodiversity-related policies, such as biodiversity management plans, TOPS (Threatened or Protected Species) listing, and permitting regulations. In practical terms – for harvesters and farmers alike – scientific knowledge can provide information to promote sustainable use of the resource in terms of best practice harvesting, managing harvest intervals and optimal fire management.

5.1.1 Aim and objectives

This chapter improves our knowledge of the resource in its natural setting under both harvested and unharvested conditions. It aims to characterise *C. intermedia* populations across its distribution range to better understand the resource's nature and the harvesting's impact. This was achieved through the pursuit of the following objectives:

1. Characterisation of the physical habitat of *C. intermedia* populations across its range.
2. Investigation of allometric relations in *C. intermedia*, and the effects of fire and biophysical factors on plant size.
3. Assessment of the effects of harvesting, fire, and plant size on plant fecundity.

4. Evaluation of the effects of unregulated harvesting on plant vigour over time in a wild population of *C. intermedia* (Case study 1).
5. Assessment of the effects of short-interval harvesting on plant vigour in cultivated *C. intermedia* (Case study 2).

A summary of the chapter content is presented in Figure 5.1: the six objectives are each addressed through a range of methods, from GIS-based analysis to statistical analysis, with some interviews to fill gaps or verify the data. Results are presented as graphs, maps and statistics, and interpreted in the discussion in the context of improved management and sustainable resource use based on greater knowledge and understanding of the plant. A summary of the key findings of the chapter follows the discussion.

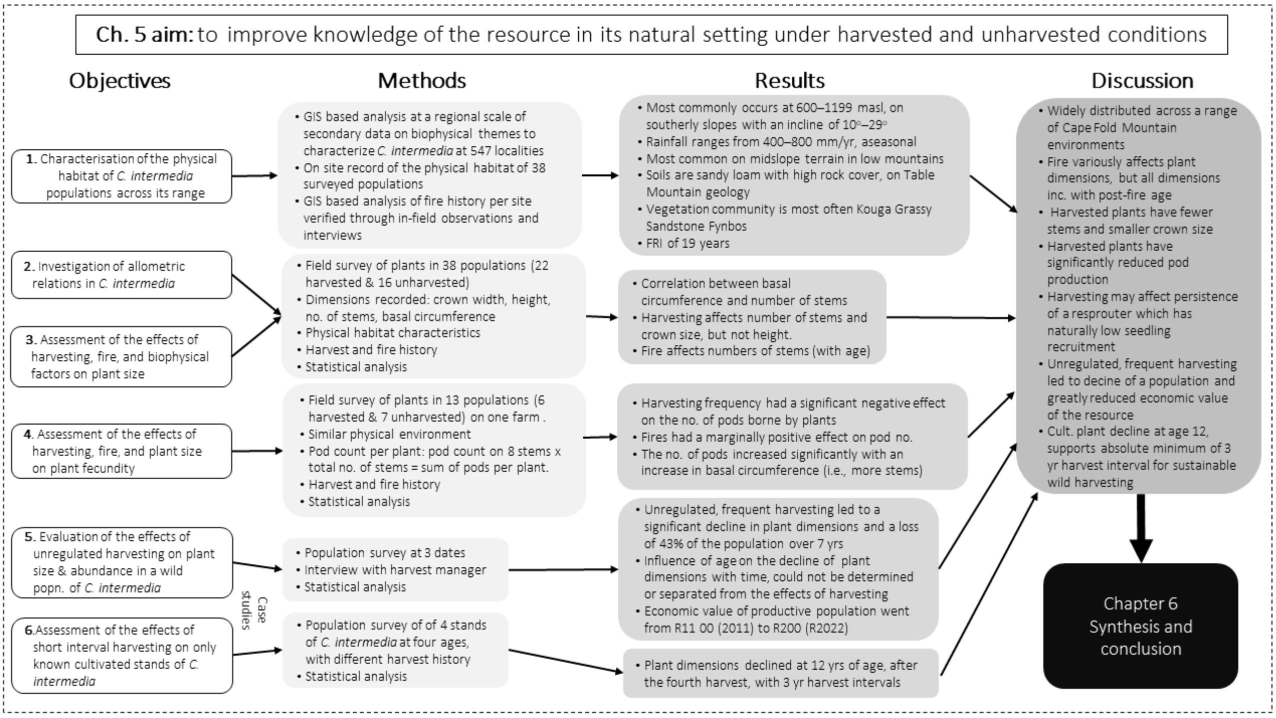


Figure 5.1: Overview of the structure and contents of Chapter Five.

5.2 Literature review

This chapter considers the biogeographical environment where *C. intermedia* exists to characterise the resource. It is an appropriate framing for the work because it is geographical – being concerned with the distribution of plants and biological processes, together with the causes and implications thereof. An emphasis on the role of humans places it firmly in the realm of geographers rather than biologists (Tivy, 2018). Furthermore, as expressed by Lomolino (2001), few disciplines can be more relevant to understanding and conserving biological diversity than biogeography. This part of the research requires an understanding of the physical environment which gives rise to fynbos communities, the nature of populations of *C. intermedia* as an element of mountain fynbos communities, and its response to harvesting.

5.2.1 The biophysical environment

Twelve regional scale units or bioregions (areas of similar physical geography, biological communities and processes) are associated with the Fynbos Biome within the Greater Cape Floristic Region (CFR). The *C. intermedia* distribution area extends across three of these bioregions: the Eastern Fynbos-Renosterveld (65.43% of the area), Western Fynbos-Renosterveld (31.24%), and Southern Fynbos (3.33%) (SANBI, 2018). In this topographically complex and diverse landscape of the Cape Fold Mountains, environmental variables contribute to explaining distributional patterns of taxa, growth forms, and habitat types. Investigating some of these variables and the environmental patterns they give rise to will contribute to characterising the *C. intermedia* range. The vegetation communities where *C. intermedia* typically occurs are confined to higher-lying mountain areas (Mucina & Rutherford, 2006). Within the *C. intermedia* range, there are 16 vegetation types (SANBI, 2018). Still, five vegetation types are dominant, making up 75% of the area: Kouga Grassy Sandstone Fynbos (27.75%), Kouga Sandstone Fynbos (23.78%), Tsitsikamma Sandstone Fynbos (12.10%), South Swartberg Sandstone Fynbos (10.52%), and North Swartberg Sandstone Fynbos (8.66%).

The physical environment of *C. intermedia* is dominated by steep south-facing slopes of the Cape Fold Mountains, stretching from Port Elizabeth in the east to Montagu in the west and as far inland as Willowmore (Manning & Goldblatt, 2012). According to Joubert et al. (2011), elevation ranges from 500 m to 1700 masl. It occurs naturally in some flat areas (in protected areas on the gentler slopes of Witdraai, Teeberg and the Eastern Kouga, and at the Joubertina Dam, set aside for water conservation). Still, it favours steep terrain that is unsuitable for intensive agriculture.

The dominant rock types in the Fynbos biome are sandstones of the Cape Supergroup associated with the Cape Fold Belt (formed around 280 mya), which underlies 47.1% of the area, together with shale (19.5%), other sedimentary rocks with clay minerals such as feldspars (10.9%) and other minor geologies (Bradshaw & Cowling, 2014). The sandstone-dominated geology gives rise to characteristically sandy, acidic, and infertile soils. However, there is a large variation between soil properties at a local scale and at the landscape level, which underlies the distribution of diverse vegetation communities in this nutrient-poor Mediterranean climate ecosystem (Richards et al., 1997).

Fynbos montane regions (where *C. intermedia* occurs) are topographically complex, giving rise to a variety of diverse habitats. Work by Campbell (1983) is particularly relevant to this study because it covers all the montane regions within the *C. intermedia* distribution range. He found that in the interior mountain ranges, steepness, aspect and slope position influence soil formation, and that high rock cover overlaying shallow soils is a feature of the land surface. Soils on steeper slopes, at higher altitude and on north-facing aspects, are less well-developed and characteristically shallow. Nutrient gradients and fluctuations are related to topography, which influences soil depth, moisture retention and chemical processes (Bergh & Compton, 2015). Fire intensity, duration and return interval further affect soil chemical properties by depleting and mobilising carbon and other nutrients (Pellegrini et al., 2021). Fire also impacts soil physical properties such as aggregate stability, organic matter content, microbial composition and hydrophobicity (Agbeshie et al., 2022). Further insights into the complexity of fynbos soil chemistry have recently been described by Bergh & Compton (2015) and Soderberg & Compton (2007), who found that seasonally variable aerosol depositions of nutrients from marine and inland aeolian sources, via berg winds and frontal systems, are a source of significant nutrient inputs to fynbos soils.

Soils where honeybush occurs are described as rocky, loamy or sandy soils (Schutte, 1997) that are well-drained, with a low pH and low phosphorous content (Joubert, 2011) and characteristically nutrient-poor. Soil analyses at three *C. intermedia* sites conducted by Barnado (2014) showed that soil moisture levels were significantly higher where *C. intermedia* was present than in adjacent sites with no *C. intermedia*. Soil texture was classified as sandy loam: all samples comprised more than 80% sand, 10-15% silt and 3-5% clay. In a more detailed analysis of soils' physical and chemical make-up, Michau (2022) compared sites on Melmont farm where honeybush is present to adjacent sites where it is absent. As expected in the heterogeneous landscape, there was variation in soil properties between sites, but there was no significant pattern in the results.

The dissected topography of the fynbos biome gives rise to complex climatic patterns, with variability across gradients from west to east, coast to interior, low to high altitude, and south to north aspects (Campbell, 1983). The west-to-east gradient shows some significant differences. In the west, summer solar radiation is high (30 MJ /m^2/day) with high seasonal temperature ranges and high-class A pan evaporation rates (1800 – 2000 mm). In the east, solar radiation is lower (25 MJ /m^2/day) with lower seasonal temperature ranges and lower class A pan evaporation rates (1300 – 1700 mm). In the west, rainfall is concentrated in the three winter months (accounting for 80% of MAP), while in the east, only 35% of rain falls in the winter. The eastern parts of the fynbos fall within an all-year-round rainfall zone as defined by Schulze (2007) – more accurately described as bimodal with reliably wet spring and autumn rainfall months (McGregor, 2017a). The *C. intermedia* range falls almost wholly within the all-year-round rainfall zone.

In a time when southern Africa is experiencing a period of observed and modelled long-term aridity (Shongwe et al., 2009), the Eastern Cape experienced a severe, although not unprecedented, drought from 2015 to 2018 (Archer et al., 2022). The drought reduced agricultural production and, through the additional impacts of the COVID pandemic, continues to affect the region. The winter rainfall region of the Western Cape recorded the worst drought since 1904 from 2015 to 2017, with a return period of greater than 300 years (Archer et al., 2019) with significant impacts on agricultural production (Otto et al., 2018; Theron et al., 2021). An analysis of weather data (SAWS, 2017) across 24 stations in the *C. intermedia* distribution range showed below-average rainfall for all stations for 2016 and 2017 (McGregor, 2017b).

In terms of climate change, potential range loss in the *C. intermedia* distribution area varies depending on the climate change scenario. Using MaxEnt species distribution modelling software to model the change in the distribution of *C. intermedia* populations, McGregor (2017b) showed a predicted range shift of 24.8% to 26.3% (loss of suitable range) based on representative carbon pathway (RCP) scenarios of RCP 4.5 (low predicted effect) and RCP 8.5 (high predicted effect) respectively.

5.2.2 Resprouter ecology

The botanical term resprouting is used in the context of a plant's response to disturbance, where it implies the potential for repeated vegetative regeneration from a source of protected buds and meristems, drawing on resources from the lignotuber (Clarke et al., 2013). *C. intermedia* may be described as a basal resprouter where basal buds, protected mainly by bark, resprout at or below ground level after moderate to high-intensity fires, drawing on lignotuber resources. In this position, the basal buds are also protected by the soil because of its low thermal conductivity (Clarke et al., 2013).

In fire-prone shrublands (like fynbos), persistence through resprouting is a key survival strategy (Bond & Midgley, 2001). As a resprouter, *C. intermedia* prioritises investment of resources to replenish its lignotuber and new shoots (Schutte et al., 1995). It produces fewer seeds than reseeder species and will, therefore, have fewer buds and flowers and sporadic recruitment from seed (Bond & Midgley, 2001; Schutte et al., 1995). The success of persistence through resprouting depends on the nature of the disturbance and its frequency, severity, and variability. Disturbances such as fire are costly in terms of the resources required to enable plant population recovery and regrowth (Enright et al., 2007). Resprouting has many advantages over seedling recruitment, including rapid growth and re-occupation of space, reduced population turnover, minimised impact of disturbance and reduced dependence on seeds for population maintenance (Bond & Midgley, 2001). Trade-offs come in terms of biomass production and reproduction, lower seed output, lower seedling recruitment, and delay in reaching sexual maturity (Bell & Ojeda, 1999; Lamont & Wiens, 2003). At some stage, resprouters must recruit to replace adult mortality, and for perennials (like *C. intermedia*), storage of seed in the soil is still important (Enright et al., 2007). A study by Makhuza (2021) found no soil-stored seeds or seedlings in three harvested and three unharvested *C. intermedia* populations of two to five years' post-fire age, highlighting poor recruitment from seed in the case of *C. intermedia*. This area of the species' ecology is poorly researched. It requires more attention, particularly regarding the sustainability of populations subject to harvesting as a disturbance, which may impact recovery, vigour and fecundity.

5.2.2.1 Plant phenology and fecundity

Phenology is the study of recurrent biological events such as leaf unfolding, bud-burst, flowering and leaf fall (Stucky et al., 2018), and may be considered a visible, external expression of changes in resource use and allocation (Pierce, 1984). The different phenophases of a species are influenced both by its genetics and surrounding environmental conditions (Fenner, 1998). Understanding species' phenology and its effect on ecosystem processes and services can contribute to managing natural resources across a wide range of natural and altered ecosystems, such as in agricultural production, wildlife management and alien invasive plant control (Denny et al., 2014). Many fynbos species show a growth peak during summer and autumn, with the onset of flowering in the spring (September). However, phenophases are delayed by two to three weeks in the eastern fynbos areas (Pierce & Cowling, 1984). For *C. intermedia*, the vigour of the reproductive cycle from the emergence of buds in autumn (May/June) through to flowering in spring (September/October) and pod production in early summer (November/December), was seen to be a potential indicator for investigating the effects of harvesting. In 2021, a pilot study by Hofmeyer (2021) showed that the abundance of buds and flowers was lower in three harvested *C. intermedia* populations than at three unharvested sites, confirming the need further to investigate the fecundity of harvested and unharvested populations. Fecundity measures the reproductive capacity of sexually mature individuals in a population (Bradshaw & McMahon, 2008). The ability to reproduce at the right time, in synchrony with environmental conditions and resource availability, is crucial for the survival and persistence of species. In plants, fecundity can be affected by many factors, including plant size (rather than age), intraspecific competition between individuals, survivorship, or growth due to exploitation of resources or interference by individuals of another species (Begon et al., 2009). Flower, fruit, and seed production are considered suitable measures of plant health, since reproduction is taxing on a plant's energy resources (Obeso, 2002; Richardson et al., 2013), and can therefore be used to measure plant vigour. In a diverse fynbos community, most resprouters can regrow rapidly after fire and reach reproductive maturity, producing flowers and fruits in the first post-fire season (Midgley & Rebelo, 2008; van Wilgen & Forsyth, 1992). This characteristic in *C. intermedia* has been reported anecdotally and confirmed through observation of populations of this species (McGregor, 2017c). Flowering is further noted as being more prolific after harvesting (Barnado, 2014) and in the second and third years after fire, declining after that (McGregor, 2017c).

5.2.3 Disturbance

Disturbance in nature is a natural phenomenon but is also a feature of human impact on ecosystems. Understanding the role and nature of disturbance regimes is significant because this knowledge can be accounted for by society through management and policy decisions (Newman, 2019). All ecosystems are subject to change, brought about by gradual successional processes through to abrupt changes brought about by disturbance. A widely used definition of disturbance is an event that is spatially and temporally relatively discrete, impacts the structure and function of an ecosystem at the community or population level, and changes the availability of resources or the physical environment (Burton et al., 2020; White & Pickett, 1985). Since disturbance regimes have been recognised as emergent behaviours of complex systems, it is not possible to "… perfectly predict future disturbance events nor control their outcomes" (Newman, 2019, p. 3).

Disturbance in the traditional sense is described by White & Pickett (1985) as a reset of the successional clock, where, although the dominant organisms are removed, the abiotic and biotic parameters of the site recover to a previous state, and potential biomass production on that site recovers to an ultimately predictable trajectory of that change. Such a situation seldom occurs in nature, partly because humans, acting as agents of disturbance, have caused significant shifts in the characteristics of disturbance events (Newman, 2019; Turner, 2010). For example, in the Fynbos, their actions have altered fire size, intensity, frequency, and seasonality (Slingsby et al., 2017). Other disturbances include land cover alteration, mowing, harvesting, burning, cultivation, logging, road building, and water diversions (Burton et al., 2020).

Recovery after a disturbance is costly in terms of plant resources that are drawn from the lignotuber reserves and surviving meristems, potentially at the cost of other phenophases/plant stages such as producing buds, flowers and seeds, or growth (Bond & Midgley, 2001). While resprouter species typically have higher levels of stored carbohydrates than non-resprouting species, and can maintain a bud bank to support rapid post-disturbance growth, frequent disturbances will deplete the carbohydrates in the underground rootstocks (Pausas & Keeley, 2014). Disturbance at the wrong time in the plant phenological cycle wastes reserves used for seed production and prevents successful completion of the cycle.

5.2.3.1 Fire as disturbance

Fynbos vegetation is fire-prone and fire-adapted, and "…managing fynbos equates to managing fires" (Kraaij et al., 2013, p. 1), particularly with regard to fire return intervals. Natural fire-return intervals for most fynbos vegetation are in the order of 10-50 years (Kraaij & van Wilgen, 2014). The season of burn varies: the western, winter-rainfall areas experience fires in the dry summer and autumn months. The eastern regions (where rainfall is bimodal) may experience fires at any time of the year, with a tendency for winter fires associated with hot, berg wind conditions (Kraaij and Van Wilgen, 2014). Due to various aspects of global change affecting ignitions and fire spread patterns, the incidence of fires has increased, and fire return intervals have become shorter, in many parts of the fynbos biome (Slingsby et al., 2017).

Changing fire regimes can have a significant impact on fynbos communities, particularly where fires burn at very short intervals (four years or less), where components of plant communities that take longer than four years to set seed, for example, obligatory reseeder proteoid species, may be eliminated entirely (Kraaij et al., 2013). Marais et al. (2014) describe numerous factors linked to resprouter success based on a comparison of post-fire regeneration of resprouters and reseeders in a mountain fynbos vegetation community. The extent of lignotuber exposure and pre-fire vigour (number of pre-fire shoots) were negatively and positively (respectively) correlated with post-fire resprouting success.

A fire frequency analysis of the *C. intermedia* distribution range based on MODIS fire imagery (NASA, n.d.) showed one or two fires per 16 years for the study area from 2001 to 2017 (McGregor, 2017b). While the data were limited by the short period of record in the context of this study, what is remarkable was the extent of fire in areas where wild honeybush is harvested. From June 2016 to July 2017, 26% (10 600 ha) of the honeybush-producing mountain lands in the Eastern and Western Cape were burnt. In terms of the use of the resource, fire is an important feature of production. It improves access for harvesting, and promotes vigorous resprouting of *C. intermedia* such that within two years of a fire, plants appear large enough to harvest (McGregor, 2017c). In a comparison of *C. intermedia* populations in adjacent four and 16-year-old patches of fynbos veld, Cohen (2016) showed that plants in the old veld grew tall and leggy, measuring double the height and half the crown size, with an average of one-eighth of the stem count of plants in the four-year-old veld.

5.2.3.2 Harvesting as a disturbance

Much published literature on the effects of harvesting on plants focuses on measures of fecundity and/or plant vigour and population persistence in response to removing certain plant parts (i.e. blooms or leaves, rather than the whole plant). Some of the examples come from the fynbos – where much of the focus is on reseeder rather than resprouter response to harvest of blooms (Maze & Bond, 1996; Treurnicht et al., 2016; Cabral et al., 2011; Mustart & Cowling, 1992; Privett *et al.,* 2014). One study considers the impacts of harvesting on *C. intermedia* fecundity and yield (Lee et al., 2023), while another study considers resprouter versus reseeder success of two *Cyclopia* species under harvested and cultivated conditions (Motsa et al., 2017). Examples of harvesting of resprouter forms of rooibos (Louw, 2006) and buchu harvesting (De Ponte Machado, 2003) are most similar to *C. intermedia* harvesting as they both deal with resprouter fynbos plant forms. Other examples come from unrelated plants (Endress et al., 2004; Lopez-Toledo et al., 2018) or distantly related plants (Witkowski et al., 1994; Lamont et al., 2020). All these examples contribute to understanding the effect of harvest on plant fecundity and/or plant vigour and population persistence and illustrate the gap in knowledge on the sustainability of wild honeybush harvesting (specifically for *C. intermedia*).

Maze and Bond (1996) reported that harvesting 50% of flowers in a Protea population impacts post-fire recruitment. In the post-fire environment, seedling recruitment happens within the first few years, with low mortality once plants reach the age of about three years (Lamont et al., 2020). Adult fecundity is measured by the size of the canopy seed bank, which can be affected by harvesting. When fecundity is low, and recruitment is essentially density-independent because of limited seed (as in the case of resprouters), harvesting can have adverse effects on fecundity. Furthermore, Treurnicht et al. (2016) showed that geography affected sensitivity to harvesting: populations near the range edges for species with large geographical ranges were more likely to be impacted by harvesting, because range limits coincided with less suitable climatic conditions for growth, reproduction and persistence.

In an assessment of post-fire fecundity as measured by cone production, seed set and seed survival for 20 species of Proteaceae (representing three resprouter forms and 17 reseeder forms), Walter et al. (2023) used modelling to understand the biotic interactions between species across 19 fynbos plant communities. They found that cone production and seed set were facilitated by neighbourhood effects immediately post-fire, but competition had an increasingly negative impact within a few years. In another modelling exercise, Cabral et al. (2011) assessed cone and seed production (i.e. fecundity) at local to regional scales to describe the persistence and abundance of three reseeder wild Proteaceae (*Protea neriifolia, Protea repens* and *Protea compacta*) under harvested conditions. The key findings were that sustainable harvesting yields varied depending on the species and the scale of investigation. At a local scale, even at low thresholds of flower head harvest (< 10%), abundance of all three species declined dramatically. At a metapopulation scale, abundance and persistence were less affected by harvesting, although even at this scale *P. neriifolia* and *P. compacta* abundance declined dramatically. *P. repens* was less sensitive, up to ≈ 45% harvest threshold, beyond which abundance and persistence declined steeply. They concluded that decreased seed availability through harvesting can affect population dynamics, such as adult abundance, if recruitment is limited by seed availability. These modelled results contrast with those of Maze & Bond (1996), who assessed sustainable harvest levels based on seed production in field trials. They found that with harvest rates of 50% of *P. repens* flower stems, adequate seed was produced for recovery of the population post-fire. In contrast, *P. neriifolia* could sustain harvest levels as high as 95% and still produce enough seed for the persistence of the population.

Field trial monitoring of four commonly harvested fynbos shrubs (all reseeder forms of Proteaceae) by Mustart & Cowling (2016) showed that repeated annual harvesting of 70% of inflorescences or cones by the stem-cutting method reduced the following season's cone production for three out of the four species under study. They also identified that the remaining cones were more vulnerable to insect predation and had lower seed sets than unharvested specimens. They deemed a harvest level of 50% of inflorescences or cones at two-year harvest intervals to be sustainable to avoid severe seed bank depletion, thereby improving the persistence and abundance of populations. Flower harvesting trials were conducted by Privett *et al.* (2014) on four fynbos species made up of two reseeders (*Erica corifolia* and *Erica imbricata)* and two resprouters – (*Brunia laevis* and *Stavia radiata*) with four levels of experimental harvest. Harvesting took place annually over a five-year period. Intensive harvest of 75 to 100% of inflorescences was largely unsustainable. In comparison, harvesting of 25% to 50% of stems per individual plant, which allowed recovery of the plants plus sufficient time for seed set and storage, was deemed to be sustainable.

In the only published study on the impacts of harvesting *C. intermedia* vigour, Lee et al., (2023) investigated the relationship between fecundity and plant yield across 10 populations of *C. intermedia* of the same post-fire age with a similar harvest history on the same farm. The analysis was based on a bud count per plant modelled as a function of overall plant health, position in the landscape, and potential yield. The results showed that large plants in the valley bottom gave the highest harvest yield and were the most fecund. At these sites, rock cover was lowest, vegetation cover was high, and soil depth was likely highest, which would explain the relationship. In a comparison of the reseeder, *Cyclopia subternata*, and resprouter, *Cyclopia genistoides*, Motsa et al. (2017) found that *C. subternata* had a higher fecundity and germination rate than *C. genistoides* in both a cultivated and natural setting. They predicted that because larger, physiologically mature plants have more stored resources to draw on for seed production and maturation of a greater proportion of seeds per ovule, the fecundity of *Cyclopia* species may increase with age. Slabbert (2016) found that for the same two species, the resprouter, *C. genistoides,* was more resistant to insect pest damage, because it naturally regenerates biomass after disturbance.

In an assessment of the sustainability of harvesting of the resprouter buchu *Agathosma betulina* De Ponte Machado (2003) found the traditional practice of three-year harvest cycles favoured several aspects of sustainable harvesting. A three to four-year interval post-fire or post-harvest allowed for a good seed set (fecundity improved with age after around three years), re-establishment of carbohydrate reserves, and, most significantly, high oil yield. In contrast, annual harvesting led to high mortality and dominance of young plants with lower oil yield. Seedling survival varied in response to fire and naturally occurring drought, with high mortality in the hot, dry summer months. Furthermore, unharvested plants resprouted more vigorously in dry periods than harvested plants, post-fire. Based on a field study combined with traditional knowledge of harvesting of wild populations of a resprouter form of rooibos (*Aspalathus linearis*), Louw (2006) assessed the impact of harvest timing and frequency on reproduction and biomass yield. According to traditional practices, plants were typically harvested at two-year intervals, although they may be subjected to annual cropping if rains were good. Rooibos plants usually flower in October, with growth occurring from September to April. The best harvest practice, in terms of yield, plant recovery and reproductive success (based on traditional knowledge and confirmed with scientific monitoring), was to harvest in summer at a moderate intensity (50-70% cropping of leaves and shoots). Although some drier sites produced the best harvest yields in winter, reproduction was negatively affected, effective sweating (in processing) was limited by cold temperatures, and this practice was therefore deemed unsustainable. Greater harvest intensity led to poor regrowth and reduced flowering and seed set.

In a 32-month trial on the effect of leaf harvesting of the palm *Chamaedorea radicalis* in Mexico, Endress et al. (2004) showed that one to four single-leaf harvest treatments in a year increased leaf production modestly. However, marketable yield declined within two years because the new leaves were significantly shorter and less desirable on the market. In a six-year trial of palm leaf harvesting at high and low intensities of *Brahea aculeata* in Mexico, Lopez-Toledo et al., (2018) found that for harvested plants – leaf production rates increased annually, while fecundity declined after the fourth harvest. Furthermore, seed germination and seedling growth rates from plants subjected to high-intensity harvesting were significantly lower than non-harvested palms. The response reflects altered resource allocation to leaf growth rather than reproduction, ultimately affecting the reproductive success of the species.

Flower harvesting of *Banksia hookeriana* (a Proteaceae plant of dry-Mediterranean scrub-heath in Western Australia) was found to impact flower and cone production, seed bank dynamics and plant architecture (Witkowski et al., 1994). In harvested populations, bloom picking of mature plants over a nine-year period reduced plant canopy area and volume. Harvested plants produced fewer blooms, and produced and stored less seed than unharvested plants, although seed fertility in both treatments was not significantly different. Resprouting response from naturally plucked stems (by cockatoos) was much more likely than from picked stems. In conclusion, Witkowski et al. (1994) note that under adverse conditions (increased fire intervals and prolonged drought effects), reduced seed store caused by flower harvest may become problematic and should be considered when resolving the conflict between conservation and commercial exploitation of populations.

5.3 Methods

5.3.1 Data collection

5.3.1.1 Biophysical habitat characterisation

Secondary spatial data sets were used to compile information on biophysical variables as a series of thematic maps (vegetation, geology, terrain division, rainfall, rainfall seasonality, elevation, aspect, slope and fire frequency) across the *C. intermedia* distribution range. The data sources for these maps and the attributes used are given in Table 5.1. Through a series of graphs, the mapped biophysical data is compared with site characteristics of the 531 *C. intermedia* localities (*C. intermedia* populations from existing records described in Chapter Two) and the 38 sites at which data were collected for analysis in this chapter. Climate graphs showing temperature and rainfall for four sites were created from the CHELSA (Climatologies at high resolution for the earth's land surface areas) bioclimatic variables (Karger et al., 2021) to provide some detail of local climate patterns across the range.

In ArcGIS Pro 3.0.3 (Esri Inc., 2022), all spatial data layers were projected to the Albers Equal Area projection with a central meridian of 25°E, standard parallels -24°S and -33°S, referenced to the WGS84 datum. A *C. intermedia* distribution polygon was used to ‘clip’ the nine thematic data layers listed in Table 5.1 to derive data only for the area of interest. (Methods used to create the *C. intermedia* distribution polygon and the 531 *C. intermedia* locality points were described in Chapter 2).

Table 5.1: Biophysical variables extracted from thematic data layers and presented as maps and graphs.

Thematic map	Source	Attributes (biophysical variable of interest) and data range in the *C. intermedia* range
Vegetation	SANBI, 2018	24 Fynbos communities, reduced to 5 types & 'Other'
Geology	DEA, 2000, ENPAT	7 geological series, reduced to 5 classes. 2 geologies = <0.25% of the area were removed from display and analysis.
Terrain division	DEA, 2000, ENPAT	5 classes based on Kruger, 1993 represented in ENPAT.
Rainfall	DWS, n.d., WR2012	Mean annual precipitation (mm), from 112–1348 mm. Classified into 8 classes (data) and 6 classes (map). *
Seasonality	Schulze, 2007	3 seasons derived from a summary of median monthly rainfall. **
Elevation	NASA, 2013, SRTM, 1 sec DEM	Elevation (m), per cell. 10 classes from 0–2413m, cells of >1800m combined into 1 class = 0.23% of area.
Aspect		Aspect (^{o}) from 0–360 ^{o}, per cell. 9 classes including 'Flat'.
Slope		Slope (^{o}) from 0–70^o, 11 classes, cells of >50^o combined in to 1 class = 0.02% of area.
Fire frequency	NASA, n.d.	Date of fire 2001–2023, fire frequency and FRI (fire return interval) for dist. range.

* The most accurate version of a data layer was used to extract values for locality points, whereas a more generalised version was used for the map for aesthetic purposes.
** Schulze, (2007) justifies the use of median rainfall as a statistically valid value in comparison to mean rainfall which may be inflated by a few extreme events.

Primary data per survey site was collected for seven other biophysical variables according to the methods described in Table 5.2, which included: terrain morphological unit, invasive alien plant (IAP) presence, evidence of disturbance and fire, description of physical vegetation form (illustrated in Figure 5.3), proportion of rock cover, soil texture and harvest status. This information was needed for Objectives Two to Four (this chapter) and for the harvest surveys (Chapter Four). The locations of 38 survey sites (Figure 5.2) were captured with a GPS unit (Garmin GPSMAP®62s) and transformed into point feature classes for use in ArcGIS Pro.

Site no.	Name	Status	Site no.	Name	Status	Site no.	Name	Status	Site no.	Name	Status
1	Topkop	H	11	Tweeling se laagte	UH	21	Louterwater pines	H	33	Teeberg	UH
2	Andrieskraal	H	12	Geelwalle	H	22	Mtn Pastures lo	H	34	Witdraai	UH
3	Oukop	H	13	Geelwalle new	H	23	Mtn Pastures hi	H	35	Bergplaas hi	UH
4	Sleeppad 1	H	14	Steilkop	H	24	Narouga	H	36	Bergplaas lo	UH
5	Sleeppad 2	UH	15	Hilltop south	UH	26	Eve Brand	H	37	Cockscomb E.	UH
6	Sleeppad 3	H	16	Hilltop north	UH	27	Koos Se Bos	H	38	Cockscomb W.	UH
7	Sandrivier 1	UH	17	Hilltop	UH	28	Ratelberg	H	40	Towerkop	UH
8	Sandrivier 3	UH	18*	Rhebok vlakte old	UH	29	Van Niekerksberg	H	41	Anysberg	UH
9	Sandrivier 4	H	19	Louterwater gully	H	30	Uitvlugt	H	**C**	Op-die-Tradouw	H
10	Tweeling se laagte	H	20	Louterwater gully	H	32 / **D**	Joubertina dam	H			

Figure 5.2: Location of survey sites. Sites 4–18 are population and fecundity surveys located on Melmont Farm. *Site 18 represents two sites, site 39 was removed from the dataset (too few records). Site D is the site for case study 1 (Declining population, site 32) at Joubertina dam. Site C is the location of case study 2 (Cultivated *Cyclopia intermedia*).

Table 5.2: Biophysical variables recorded at each of the 38 survey sites and the method used to assess the variable.

Variable	Method
Terrain morphological unit	Based on Mac Vicar et al, (1977) classes: crest, scarp, midslope, footslope, valley bottom.
IAP	Recorded as absent (0) or present (P) in the vicinity of a site.
Disturbance	Recorded as absent (0) or present (P), score of low/medium/high related to % of area affected (0–25%, 25% to 50% and > 50%). Includes: grazing by livestock, proximity to a track/road, excavation, pipeline, fence line.
Fire	Post-fire vegetation age and/or noted as recent (0–3yrs); not recent (4–10 yrs) or old – >10 yrs. Fire evidence: charred stems, protea branch/node count for post-fire age.
Rock cover	% surface rock/stones: 0–25%/25–50%/50–75%/>75%. Estimated per transect in four 1m x 1m quadrats; bedrock recorded as absent (0) or present (B).
Physical vegetation form	3 dominant genera noted. Four descriptive classes (input from harvesters and farmers as related to harvesting). Grassy fynbos; Grassy fynbos with scattered shrubs or small trees; Grassy fynbos, dense shrubs or small trees; Dense shrubs and small trees, little grass. (Illustrated in Figure 5.3).
Soil	Hand texture measured on site to derive textural classes: sand; sandy loam, sandy clay loam (Mac Vicar et al, 1977).
Status	Observation of cut stems and knowledge of the site history from harvest manager or farmer, recorded as harvested (H) or unharvested (UH).

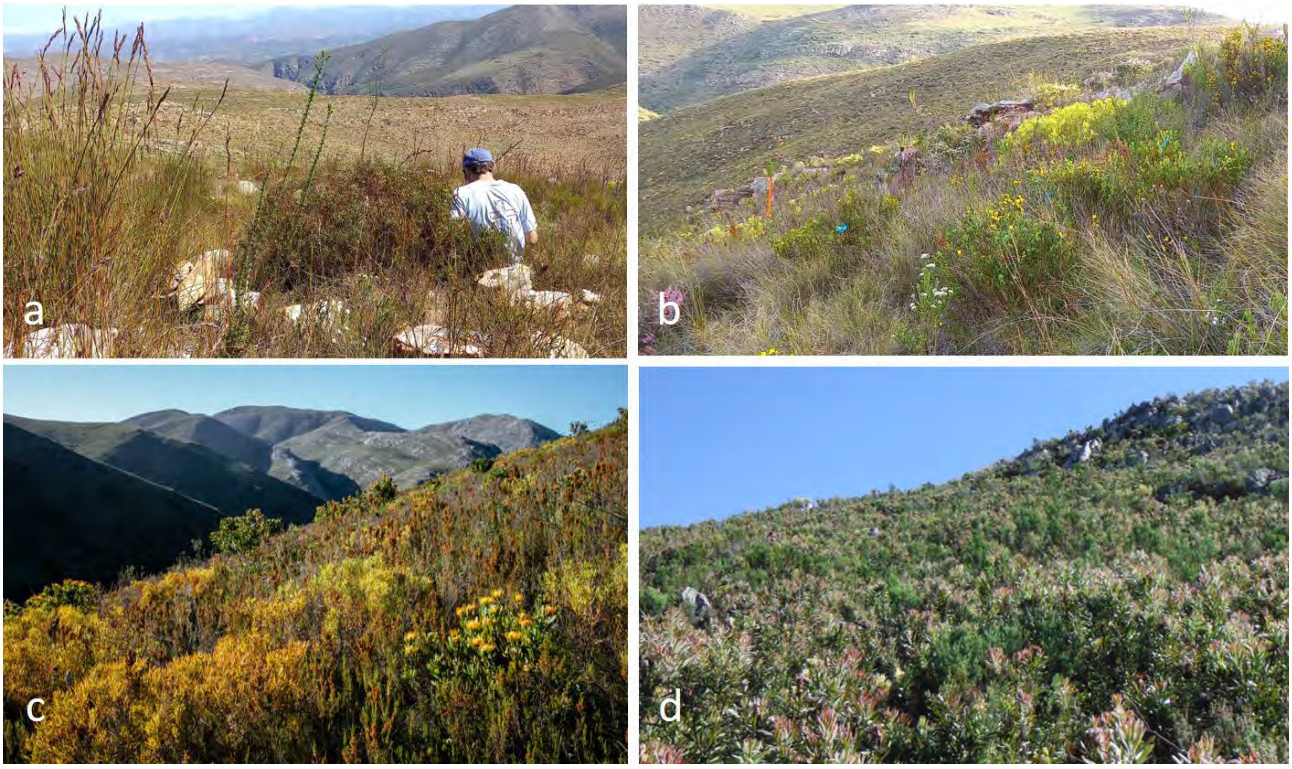


Figure 5.3: Vegetation structure at survey sites: a) Grassy fynbos (Rhebok-vlakte, Site 18); b) Grassy fynbos with scattered shrubs or small trees (Geelwalle, Site 12); c) Grassy fynbos with dense shrubs and small trees (Tweeling-se-laagte, Site 10); d) Dense shrubs and small trees, very little grass (Mtn Pastures Lo, Site 22). Based on the SANBI 2018 vegetation map, site a) is Kouga Grassy Sandstone Fynbos, while the other three sites are Kouga Sandstone Fynbos.

Information on fire history was required for input to the analysis was conducted under Objectives 2 and 3. Based on anecdotal evidence and an analysis of MODIS fire data since 2001 – the fire return interval (FRI), frequency of fires at each site and the date of the most recent fire (pre-survey) were determined. The process of accessing and preparing the data is shown as a model (Model 5.1) in Figure 5.4. Monthly fire data (*Collection 6.1 MODIS surface reflectance and active fire products*) from 2001 to the first date of the survey (October, 2015) was downloaded from the University of Maryland as compiled monthly shapefiles of polygons indicating the presence or absence of fire. The shapefiles were compiled from daily images from the *MODIS Burned Area Product* collection (NASA, n.d.) and processed to achieve standardisation across all dates (Giglio et al., 2018). Although the resolution of the source imagery is relatively low (230 m x 230 m), accuracy is adequate. In an accuracy assessment of MODIS MCD64A1 C6 products, Katagis & Gitas (2022) showed a 78% detection success for burned areas in Mediterranean ecosystems for fire extents > 100 ha. As the research progressed, monthly data were downloaded and manually checked (1) for fire presence. If fires occurred in the study area, the layer was retained. The selected monthly fire layers (2) were 'Clipped' to the *C. intermedia* distribution map (3). These layers (4) were input to a 'Union' (5) to produce a complete fire frequency layer (6; 'Union' is a process which combines the full spatial extent and all the attributes of all the input layers in a single layer). The complete fire frequency layer (6) incorporates a fire date field, which indicates the presence or absence of fire if filled. Using this value, the sum of fires in each polygon was calculated (7) to derive a fire frequency value in the 'All fires' layer for input to Model 2. A sum of the burnt area across the study period was used to derive a simple estimate of mean fire return interval (FRI) based on an equation by Forsyth & van Wilgen (2008) where FRI = *y/(b/a)*, (*b* is the sum of the burnt area of all fires recorded over *y* years and *a* is the area of the area of interest).

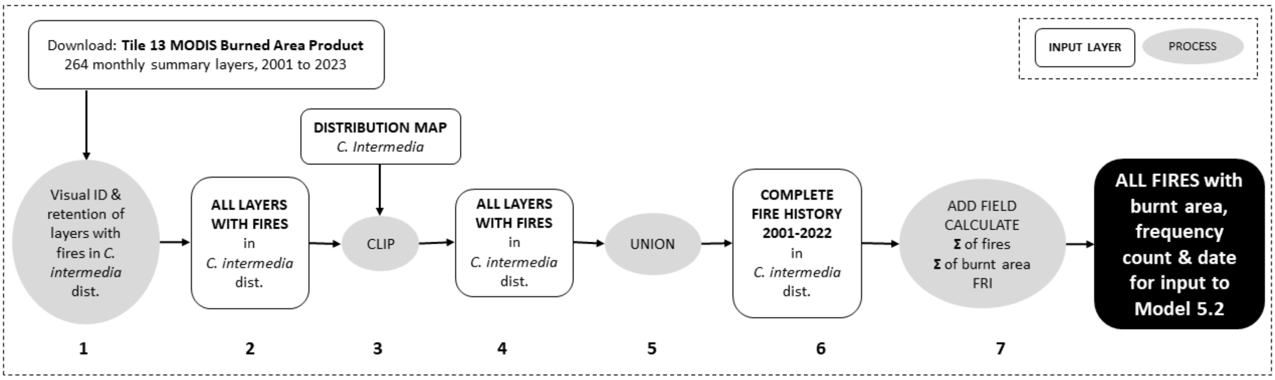


Figure 5.4: : Model 5.1 - deriving fire frequency, fire dates and FRI across the C. *Cyclopia intermedia* distribution range, 2001 to 2023.

It was necessary to verify fire occurrence in the field since small fires are sometimes missed and the low-resolution imagery does not record an accurate fire extent edge. At field sites, an estimate of the most recent fire was made based on evidence of burnt plant material and where reseeder *Protea* shrubs were present, estimates were made using the method of ageing fynbos veld by counting branch nodes where each node represents a year of growth, added to an initial establishment time assumed to be two years (Esler et al., 2014). Fire frequency and dates were also confirmed in discussion with the farmer, conservation official or harvest manager, then correlated with the results from Model 5.1. Where there were discrepancies (such as a site falling outside a nearby MODIS fire occurrence boundary), then Landsat 4-5 Thematic Mapper (TM) Level-1 (pre-2015), or Sentinel2 images (post-2015) were consulted to refine the fire boundary and verify fire occurrence. These image collections are available to browse by date and image source, via the USGS GloVis application, https://glovis.usgs.gov/app#

On Melmont farm, a more detailed fire frequency analysis involving a combination of images of suitable quality from Sentinel2 and Landsat 4-5 Thematic Mapper (TM) Level-1 were used to digitise fire scars (outlines) more accurately for 1996 to 2021. The date and extent of the fires were verified in discussion with the land owner. A report containing maps and a description of the fire frequency, as prepared for the landowner for input to organic certification requirements, is attached as Appendix 5a.

5.3.1.2 Allometry and the effects of harvesting, fire and biophysical factors on plant size

The population mapping exercise identified harvested and unharvested *C. intermedia* sites (Chapter 2). The choice of sites was aimed at getting a spread across the distribution range. Still, in reality, the selection of 38 suitable sites came down to sites where a) access was feasible and b) the landowner granted permission to access. Surveys were also linked to harvest dates so that both plant and harvest surveys could be carried out. For harvested sites, the selection was biased in favour of sites with a known and reputable harvest frequency derived from permits, with further details supplied by the landowner or the harvest manager (Chapter 3).

A population was defined by any physical feature (hill crest, major rock outcrop/spine, drainage line, change in vegetation community or a road/track) which separated areas where *C. intermedia* was present and where it was not. In total, 38 sites were surveyed, consisting of 16 unharvested and 22 harvested sites. The main survey period was from 2017 to 2019, with additional surveys in 2021. As surveys progressed, it became apparent that for practical reasons, transects would need to be smaller where plant densities were high, and that they would need to be positioned in accessible areas. Most often, three transects of 10 x 25 m were surveyed at a site. Depending on plant density, transects sometimes extended to 10 x 50 m, or occasionally, where the terrain and time allowed, as large as 10 x 100 m (Figure 5.5). Transect locations were recorded using a GPS and demarcated with a measuring tape. The location of all *C. intermedia* plants within the transect were recorded with a GPS and flagged with numbered, highly-visible fabric tags. The locality data (which gave a count of plants per transect), plus the transect boundaries, were used to generate the density of plants per site.

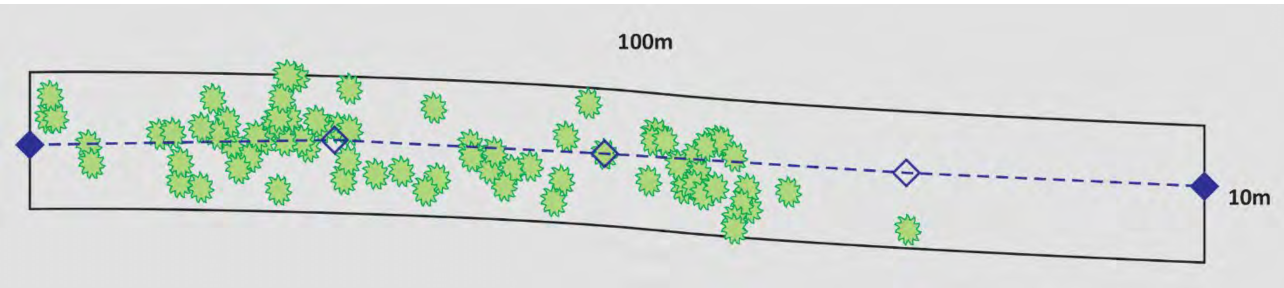


Figure 5.5: Example of a 10x100m transect laid out with pole markers at 25 m intervals and all plants within the transect marked with highly-visible tags and located with a GPS reading.

Every plant was measured (Figure 5.6a and b) with reference to: height, crown (two measurements of widest crown and perpendicular width), number of living stems, basal circumference (soft tape wrapped around the base of the living stems), colour of stems, presence of buds, flowers or pods and their abundance. Additional comments were recorded per plant-on-plant health, presence of pests or visiting insects, evidence of illegal harvest, dead plants and evidence of recent fire. Seedlings, if present in the transect, were individually recorded. For an example of a standard plant allometry data sheet – see Appendix 5b.

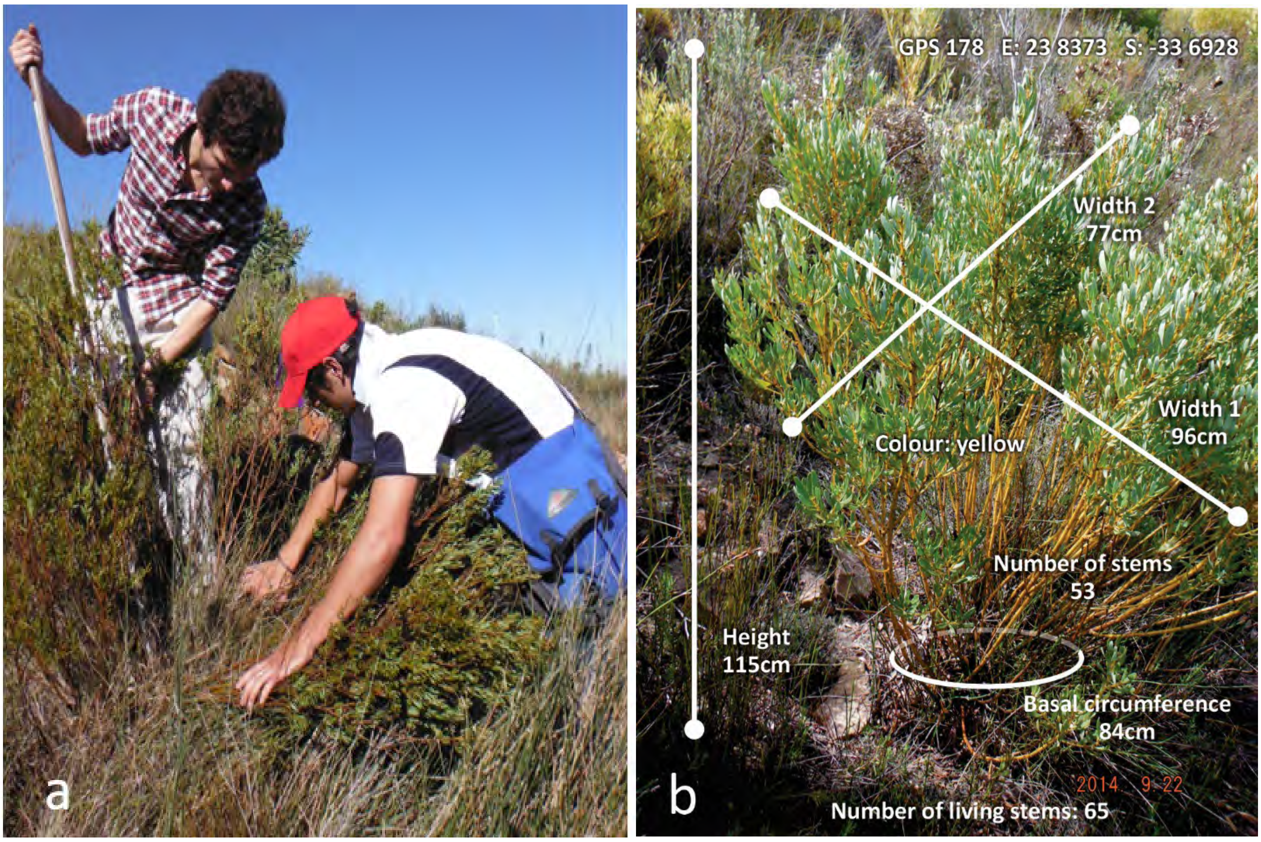


Figure 5.6: a) Field assistants taking plant allometry measurements of height measured with a 1.7m survey pole, stem count and canopy dimensions. b) Illustration of dimensions captured for each plant.

5.3.1.3 Effects of harvesting, fire and plant size on plant fecundity

To assess fecundity, 13 sites were selected on Melmont farm in the eastern Kouga, (Figure 5.7). From June to mid-December 2022, a total of 292 plants were marked and monitored across six harvested populations with a known harvest frequency, and seven unharvested populations. Characteristics of the physical environment were controlled such that all sites were at a similar elevation and aspect, with similar vegetation communities and soils. It was assumed that all sites experienced similar climate regimes. At each site, a transect of 25 x 10m was laid out and all plants in the transect were numbered and tagged (Figure 5.8a-c). The aim was to include at least 25 plants per site, but due to varying plant abundance, between 13 and 32 plants were marked per site. On the first visit at the beginning of the budding phase (June 2022), eight stems on each plant were tagged with four (two stems per wire) different coloured wires (Figure 5.8a and b). Previous surveys of plants on the same farm (n = 500 plants) yielded an average stem count of 23, making eight stems a 35% sample. Considering practicalities (time to mark, availability of different wire colours and time to count) an eight-stem sample was deemed adequate. The dimensions of each plant (height, basal circumference, average crown diameter) and the number of stems were recorded.

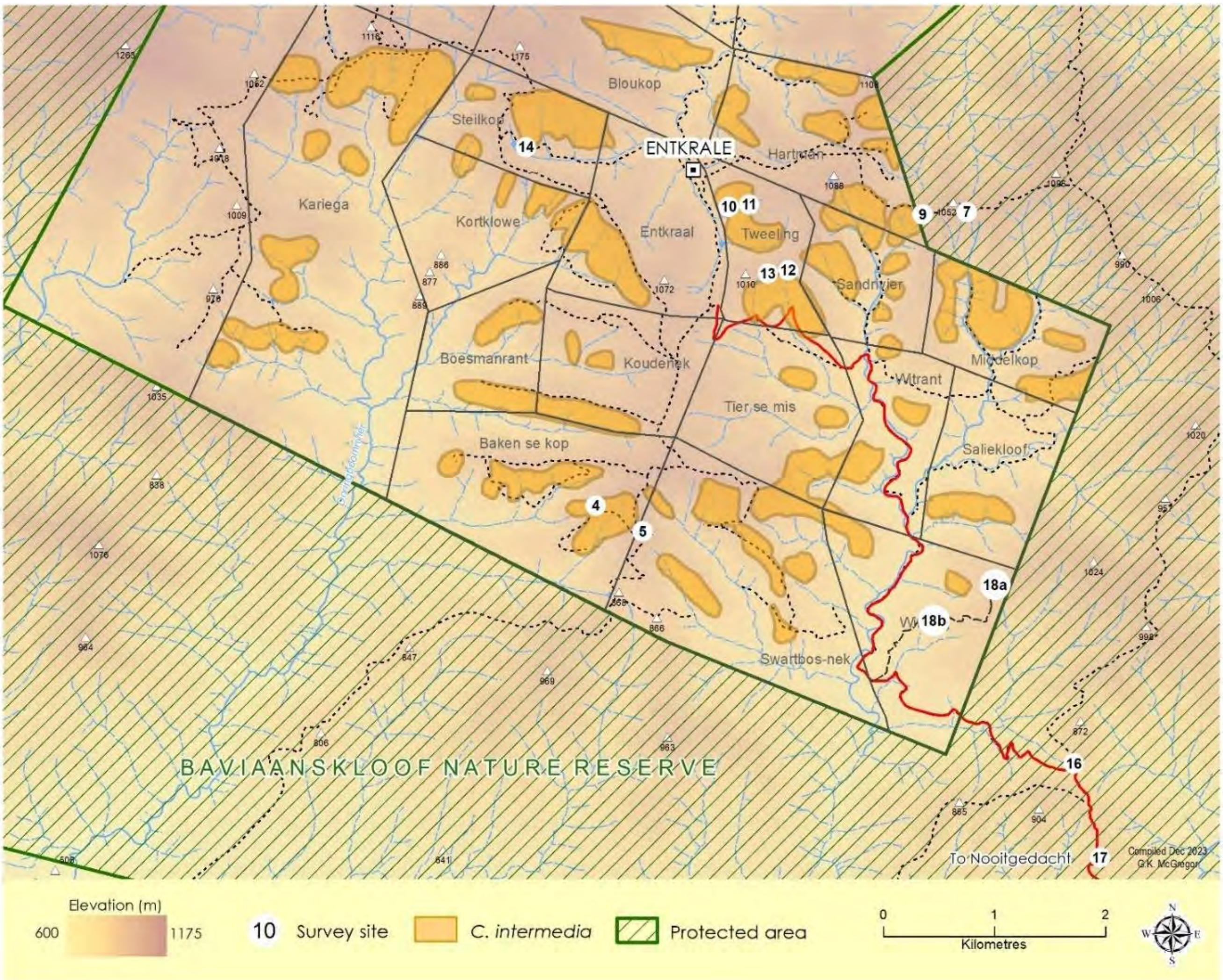


Figure 5.7: Location of fecundity survey sites on Melmont farm.

On a subsequent visit, when the plants were deemed to be in full pod (no flowers remaining), pods were counted on each of the marked stems. Repeated visits ensured that fecundity surveys would capture the most complete pod phase at a site. Pod counts started in late August at Sites 16, 17 and 18a (Figure 5.7, southerly location relative to other sites) and ended at Sites 10 and 11 (more northerly location) at the beginning of December. For the final analysis, an average number of pods per stem was calculated based on the pod count of eight stems, multiplied by the total number of stems in the population, to estimate the total number of pods per plant. If a plant had less than eight stems, then the calculation was adjusted to reflect an actual pod count (i.e. all stems and pods were accounted for).

Data on harvest history per honeybush patch from 2000 to 2021 were available from the landowner (Chapter 3). Derivation of fire frequency is described under the methods for Objective 1 in this chapter.

Figure 5.8: Marking of plants for pod monitoring. a) Close-up of a twisted coloured marking wire 10 cm long and loosely attached low down on the stems. b) Plant with two coloured wire twists each around two stems; c) Plant tagged with numbered, durable, nylon fabric tag. The plant has 12 stems, with an average of four pods per marked stem, making a total estimate of 58 pods.

5.3.1.4 Case study 1: Unregulated harvesting

The Joubertina dam site (Figure 5.2, Site 32 'D') was identified by Mr. S. van der Merwe (retired Agricultural Extension Officer and Joubertina resident, pers. comm., March 2015) as a site of unregulated harvesting. The site is unusual because it has not been transformed for agriculture despite its location on deep soils in a gently sloping valley bottom, which is a designated water catchment area. The land is easily accessed via a dirt road and lies only 8 km from the town of Joubertina. The land is owned by the Dutch Reformed Church, but managed by the Wabooms River Irrigation Board, which grants permission for formal harvesting to harvest teams who can then apply for a permit to harvest from the EC DEDEAT.

Population survey

The survey area at this site measured approximately 25 x 25 m (Figure 5.9), within which 35 plants were located with a GPS, marked with small metal tags (for longevity, placed discretely at the plant base where they would not be visible to harvesters), and surveyed in 2015. The same plants were re-surveyed in 2017 and 2022. On each of these survey occasions, measurements were taken of the plants' crown diameter, height, and a count of the number of stems. Plant mortality was also recorded on each survey occasion if numbered plants were no longer present.

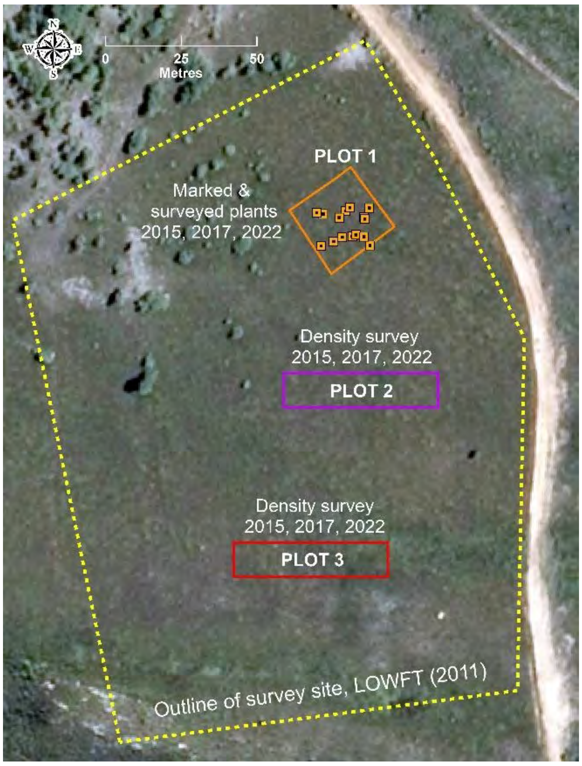


Figure 5.9: Surveys at the Joubertina dam site. All plots are within the yellow LOWFT (2011) boundary to ensure that some aspects of the 2015, 2017 and 2022 data compare with the 2011 report.

Harvest history

Information about the site was provided at a site visit (January 2017) with a harvest manager who wished to remain anonymous. This person had a permit to harvest the site and was able to provide a partial harvest history for the site.

Estimating yield and economic effects

Information from a 2011 survey of the same *C. intermedia* population and other nearby populations was available in a report (LOWFT, 2011). The mapped data and figures on plant density and yield were captured to give additional perspectives on the state of the population over time. To support this analysis, an additional two plots (Figure 5.9, Plots 2 and 3) of 10 x 50 m were laid out, 50 m and 100 m south of the first plot, within the area delineated in the LOWFT (2011) report to monitor plant density over time. Plant density counts were repeated with the population surveys. The density of plants per hectare was calculated from the sum of the counts for the three plots and converted to a density per hectare. Yield per plant was calculated based on the average number of stems per plant at the three survey dates, multiplied by an average stem weight of 0.025 kg (Chapter 3 – harvest survey data).

5.3.1.5 Case study 2: Frequent harvesting of cultivated plants

For this case study, the only known cultivated stands of *C. intermedia* were surveyed at Bo-Vlakte farm, Op-die-Tradouw (Figure 5.2 on the far western side of the map, Site C). Three stands were surveyed on different dates to represent *C. intermedia* plants of known age. The stands were within 800 m of each other, with similar environmental conditions: sandy soil; elevation of 730–750 masl; slope inclination of 3–5°; and a southerly slope aspect. All surveys were undertaken close to three years after the last harvest, just before the next harvest. Stand 1 was surveyed six years after planting, after one harvest; stand 2 was surveyed 11 years after planting, after three harvests; stand 3 was surveyed 12 years after planting after three harvests and re-surveyed 17 years after planting after five harvests. At each survey, 30 to 65 plants were measured per stand. Basal circumference, crown diameter, height, and number of stems were recorded as described in the methods for Objective 2. The harvesting regime was similar across all the surveyed stands: first harvest at three to four years after planting as seedlings, and harvested, thereafter at approximately three-year intervals (Mr. N. Janse van Rensburg, Farmer, pers.comm., August 2017).

5.3.2 Data analyses

5.3.2.1 Biophysical habitat characterisation

To present data on all the biophysical variables for the *C. intermedia* distribution range, nine thematic data layers containing attributes of biophysical variables were used as input to Model 5.2 (Figure 5.10), which was run in ArcGIS Pro. The fire frequency layer plus the eight biophysical data layers (input – 1), were 'Clipped' (vector layers) or 'Masked' (raster layer) to the study area (2) to derive a spatial extent for each layer representing only the *C. intermedia* distribution range (3). The area (km^2) per class in each biophysical layer was calculated (4) to derive the 'expected' frequency of occurrence. Attribute information from all the layers was combined with each point feature (representing 'observed' frequencies) through a 'Spatial join' (4). Fire frequency values were also 'Extract(ed)' (4) from the fire layer (raster) to the point features. The resulting attribute tables of data (5) were analysed (6) to produce a breakdown of expected vs observed frequencies per locality point and for each of the 38 survey sites.

Further analysis of the data was carried out in Microsoft Excel (Microsoft Corporation, 2016). A chi-square test of independence was run to examine the relationship between the expected frequency of each variable (elevation, slope aspect, slope inclination, vegetation, geology, terrain, mean annual precipitation, rainfall seasonality and fire frequency) and the observed *C. intermedia* localities.

Maps of seven (out of nine) of the biophysical variables across the *C. intermedia* range were compiled in ArcMap 10.8. (Esri Inc., 2019) to illustrate patterns of the broader biophysical environment. Slope aspect and slope inclination were not displayed as maps as the high resolution of these data layers obscures patterns at the scale of presentation. Biophysical information collected at the survey sites was summarised to give an overview of the preferred physical habitat of *C. intermedia* populations. The information was needed for input to Objectives Two to Four of this chapter, and for analysis of the harvest in Chapter Three.

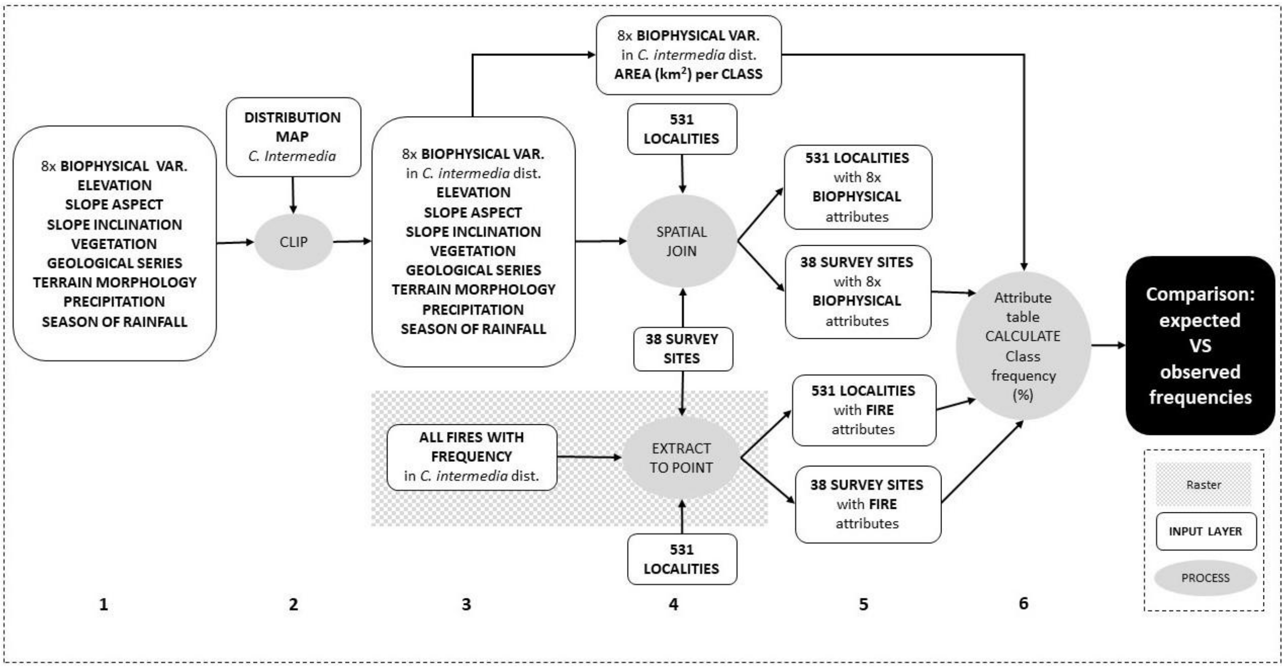


Figure 5.10: Model 5.2 – the approach used to extract all the biophysical variable information for the *Cyclopia intermedia* distribution range and for each of the 531 locality points and the 38 survey sites.

The fire frequency data were prepared as illustrated in Model 5.1 (Figure 5.4), following which the output fire layer from Model 5.1 was converted to a raster layer to simplify the analysis such that every cell retained only a fire frequency value. The 'All fires with frequency' layer was input to Model 5.2 (Figure 5.10, step 3). Using 'Extract to point' (4), the fire frequency value was joined to each of the 531 localities and the 38 survey sites (5). A calculation (6) was run in the attribute table of these layers to derive the observed fire frequency from no fire through to five fires in 22 years.

5.3.2.2 Allometry and the effects of harvesting, fire and biophysical factors on plant size

None of the measures of plant size (basal circumference, crown diameter, plant height, and number of stems) nor the measure of post-fire plant age at the time of survey (hereafter 'post-fire plant age'), conformed to normality as determined from the Shapiro-Wilk test. Non-parametric Spearman rank correlation was thus used to explore relationships between measures of plant size and plant age.

To determine the effects of harvesting, fire and biophysical factors on plant size, GLMs were employed using the *Rcmdr* package in the R Statistical Software, v4.3.1 (R Core Team, 2023). Measures of plant size, namely, basal circumference, crown diameter, plant height, and number of stems in relation to the predictor variables: i) harvesting frequency (the number of harvests since 2000); ii) fire frequency (the number of fires since 2001); iii) post-fire plant age, and the biophysical factors, iv) elevation, and v) mean annual rainfall were assessed. Slope and aspect were not included as there was little variation in these factors across survey sites (the species largely occurs on moderate to steep, and cool, southerly facing slopes; Chapter 2). To check for potential collinearity between fire frequency and post-fire plant age, and between rainfall and elevation (respectively), Spearman-rank correlation was used. All four predictors were retained as the correlation coefficients were < 0.6, which is regarded as a threshold for the inclusion of both factors into a model (Tabachnick & Fidell, 1996). All the response variables (the measures of plant size) were transformed on account of their right-skewed distributions.

5.3.2.3 Effects of harvesting, fire and plant size on plant fecundity

Generalised linear models (GLMs) were employed using the *Rcmdr* package in the R Statistical Software, v4.3.1 (R Core Team, 2023) to assess the number of pods as a measure of plant fecundity, in relation to the predictor variables: i) harvesting frequency (the number of harvests since 2000); (ii) fire frequency (the number of fires since 2000); and iii) basal circumference as the most representative measure of plant size (see allometry results). Given that adult *C. intermedia* plants flower within a year or less of a fire, plant age at the time of the survey was not included as a factor. Neither were biophysical factors included, given the limited variation in these factors across the single farm where fecundity surveys were undertaken. GLMs with Poisson distribution and the log link function were used given that the response variable constituted count data. This variable was square-root transformed after adding one (1) to deal with counts of zero.

5.3.2.4 Case study 1: Unregulated harvesting of a wild population

To assess whether the size of plants (in terms of crown diameter, height, and number of stems, respectively) subjected to unregulated harvesting changed over time (2015, 2017, 2022), Friedman analysis of variance (ANOVA) by ranks for repeated measures was employed using Statistica v.14.1.0. (TIBCO, 2023). Only the plants that survived the entire survey period (n = 20) were considered in these analyses.

Plant density figures per hectare were calculated based on the number of plants in a plot of known size in the population survey (Plot 1) and the two adjacent plant density surveys (Plots 2 and 3). By using stem count and adding a value of stem weight (0.025 kg, harvest surveys, Chapter 3), it was possible to estimate potential yield per plant and per hectare at the Joubertina Dam site for four dates expressed as a potential rand (ZAR) value.

5.3.2.5 Case study 2: Frequent harvesting of cultivated plants

To compare plant size (in terms of basal circumference, crown diameter, height, and number of stems, respectively) among cultivated stands of different plant ages with different numbers of harvests but similar harvest intervals (three years), a Kruskal Wallis H test was employed (as the data did not conform to normality) followed by Dunn’s test for multiple comparisons if significant differences ($P < 0.05$) existed using Statistica v.14.1.0. (TIBCO, 2023).

5.4 Results

5.4.1 Biophysical characteristics of the distribution range of *C. intermedia*

The bar charts in Figures 5.11 and 5.12 present the variation in biophysical variable classes in terms of the distribution range, with the blue bars representing 'expected' values as a percentage of the range, in comparison to the 'observed' frequency of localities (orange) and survey sites (grey). By comparing locality data to the survey sites, it can be seen whether the survey sites represent the typical range actually occupied by *C. intermedia*. Where all bars are at a similar level, there is no difference between observed and expected values.

Across all the variables, the results showed that there is a statistically significant difference ($P < 0.05$) between variation in environmental variables in the distribution range and what is actually observed based on locality data and survey sites. In other words, the results suggest a strong preference for, or avoidance of, certain classes of biophysical variables by *C. intermedia*. Degrees of freedom for the analysis varied from 2 to 10 at a confidence level of 0.95.

For elevation (Figure 5.11a and Figure 5.14a), despite the availability of sites in the 0–600 masl class, the frequency of *C. intermedia* records in this class is low. From 600 – 1199 masl, the frequency of *C. intermedia* localities (73.53 %) is higher than the proportion available in the distribution range (61.36%), indicating a preference for this class. The plant is found most frequently in the 800 – 999 masl class. Thereafter, the frequency of localities declines relative to the available area. With reference to the survey sites: the 600 – 1199 masl class is well represented (89% of sites).

For slope aspect (Figure 5.11b): northerly facing slopes (NW, N and NE) are least favoured – available territory in the distribution range is greater (40.57 %) than the frequency of *C. intermedia* locality records (34.5 %). Southerly facing slopes are favoured, making up 46.8 % of locality records relative to 41.0 % available in the distribution range. For west and east-facing slopes, the availability in the distribution range is mirrored by the frequency of localities and survey sites. Flat to gentle slopes (0–9^{o} classes, Figure 5.11c) are common in the distribution range of *C. intermedia* (28.6%), but not preferred. *Cyclopia intermedia* populations are most commonly found (71.5% of localities) on slope inclination classes from 10^{o} to 29^{o,} although this class makes up only 57.6% of the distribution range. As slope inclination increases from 30 to 39^{o} (11.0% of distribution range), the number of locality records declines to 8.5%. In the steepest areas (40 to >50^{o}) making up 2.7% of the distribution range, only 1.1% of localities are found.

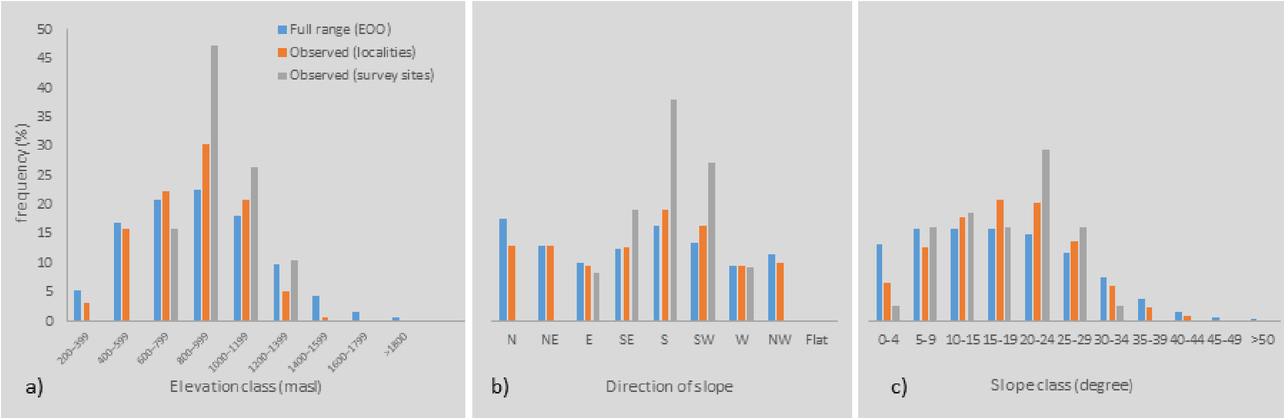


Figure 5.11: Frequency of occurrence of classes of: a) elevation, b) slope aspect and c) slope inclination within the *Cyclopia intermedia* distribution range (blue) relative to 531 observed localities (orange) and 38 survey sites (grey).

Non-fynbos vegetation types comprising 15.1% of the distribution range are not included in this analysis as *C. intermedia* only occurs in fynbos communities. There is a clear preference for Kouga Grassy Sandstone Fynbos (27.5% of the distribution range, represented at 36.4% of localities) and North Swartberg Sandstone Fynbos (8.6% of the distribution range, represented at 23.5% of localities) and a slight preference for Kouga Sandstone Fynbos (Figure 5.12a and Figure 5.14b). 'Other Fynbos communities' and Tsitsikamma Sandstone Fynbos make up 21.8% of the distribution range, but only 9.7% of localities.

More than 50% of the distribution range receives less than 500 mm of rainfall per annum (Figure 5.12d, and Figure 5.14e), supporting only 29.4% of localities. There is an abundance of localities (60.0%) in the 401 – 600 mm class, although it makes up only 33.6% of the area. The wetter areas with above 600 mm of rainfall (11.3% of the area) support 14.9% of the localities. With regard to seasonality of rainfall (Figure 5.12e and Figure 5.14f) – the extensive all-year rainfall zone (95.0% of the area) accounts for 99.0% of localities, while the very small winter and very late summer rainfall zones (5.0% of distribution range) support the remaining 0.9% of localities.

Table Mountain geology (72.42% of the distribution range, Figure 5.12b and Figure 5.14c) is clearly a preferred geology, supporting 92.0% of *C. intermedia* localities. The remaining localities (7.9%) are spread across the other four geologies (27.3% of the distribution range). The largest terrain class (Figure 5.3c and Figure 5.4d) in the distribution range is low mountains, which comprise 65.3% of the area and support 88.3% of *C. intermedia* populations, indicating a clear preference for this terrain. The remaining localities are found in high mountains (26.7%), with a very low portion (8.0%) found in the terrains classed as hills, lowlands with hills, and plains and hills.

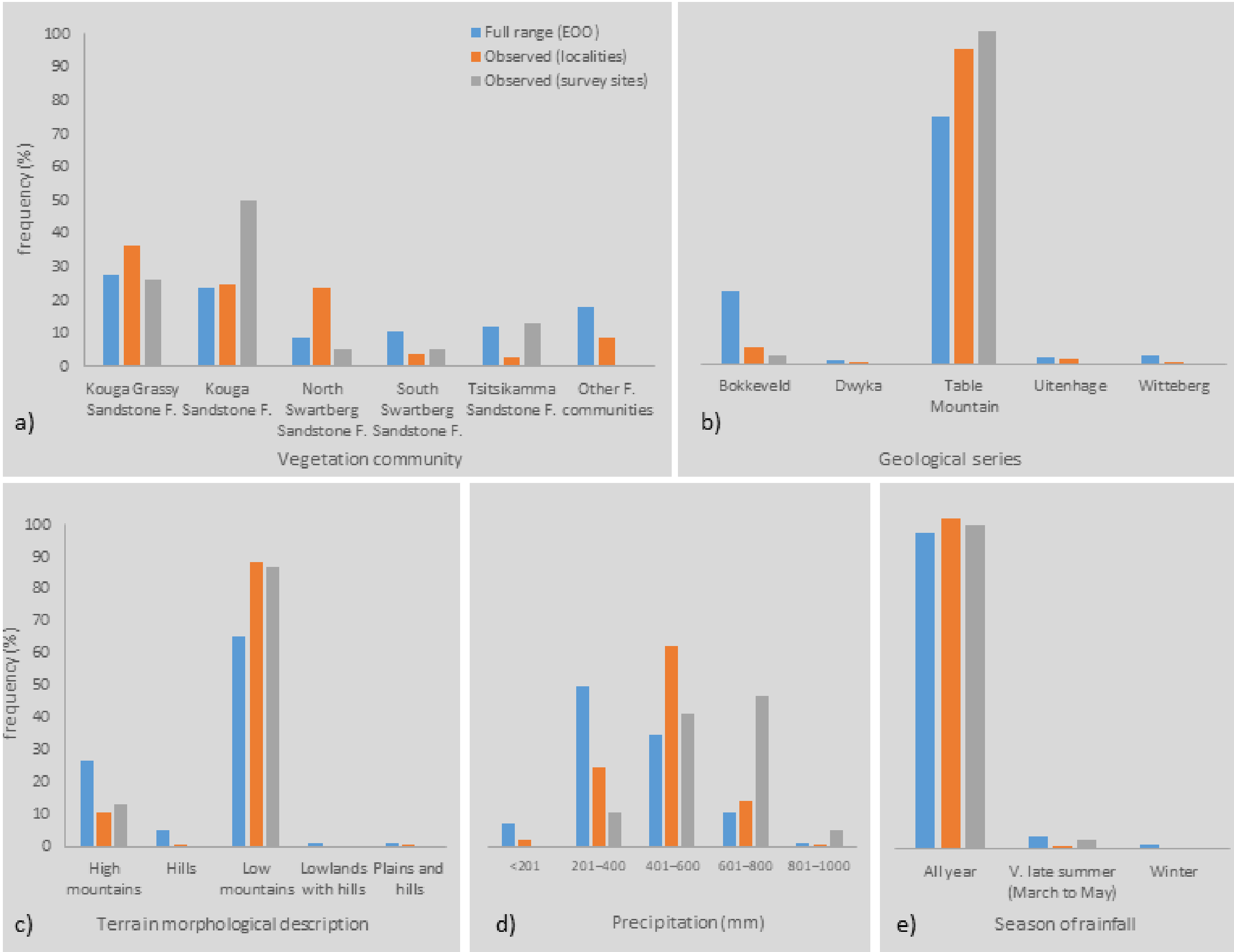


Figure 5.12: Frequency of occurrence of selected biophysical variables: a) vegetation, b) geology, c) terrain, d) precipitation and e) rainfall seasonality in the *Cyclopia intermedia* distribution range, for the 531 localities and the 38 survey sites.

The bi-modal pattern of rainfall is evident from the climate graphs of the eastern sites (Figure 5.13a to c), with the most rain falling in March (autumn) and October (spring), while the lowest rainfall is recorded in June/July, i.e. mid-winter. In the arid west, at the Anysberg site (Figure 5.13d), the pattern is more that of a winter rainfall area with the highest rainfall values from April to August and lowest values in the summer months (December and January). Modelled average rainfall values for all sites are higher than those available from other sources:

- Melmont, (Q. Nortje, Farmer, pers. com., September 2016): 550 mm. Supported by records from 2010–2020. He also notes that even in severe drought conditions, moisture is always consistently available as mist in the mountains where the honeybush grows
- Anysberg mountain stations (Brand et al., 2018): 290–230 mm
- Bo-Kouga (E. Smith, Farmer, pers. com., November 2015): 600–700 mm
- Louterwater (C. Muller, Farmer, pers. com., September 2016): 750 mm

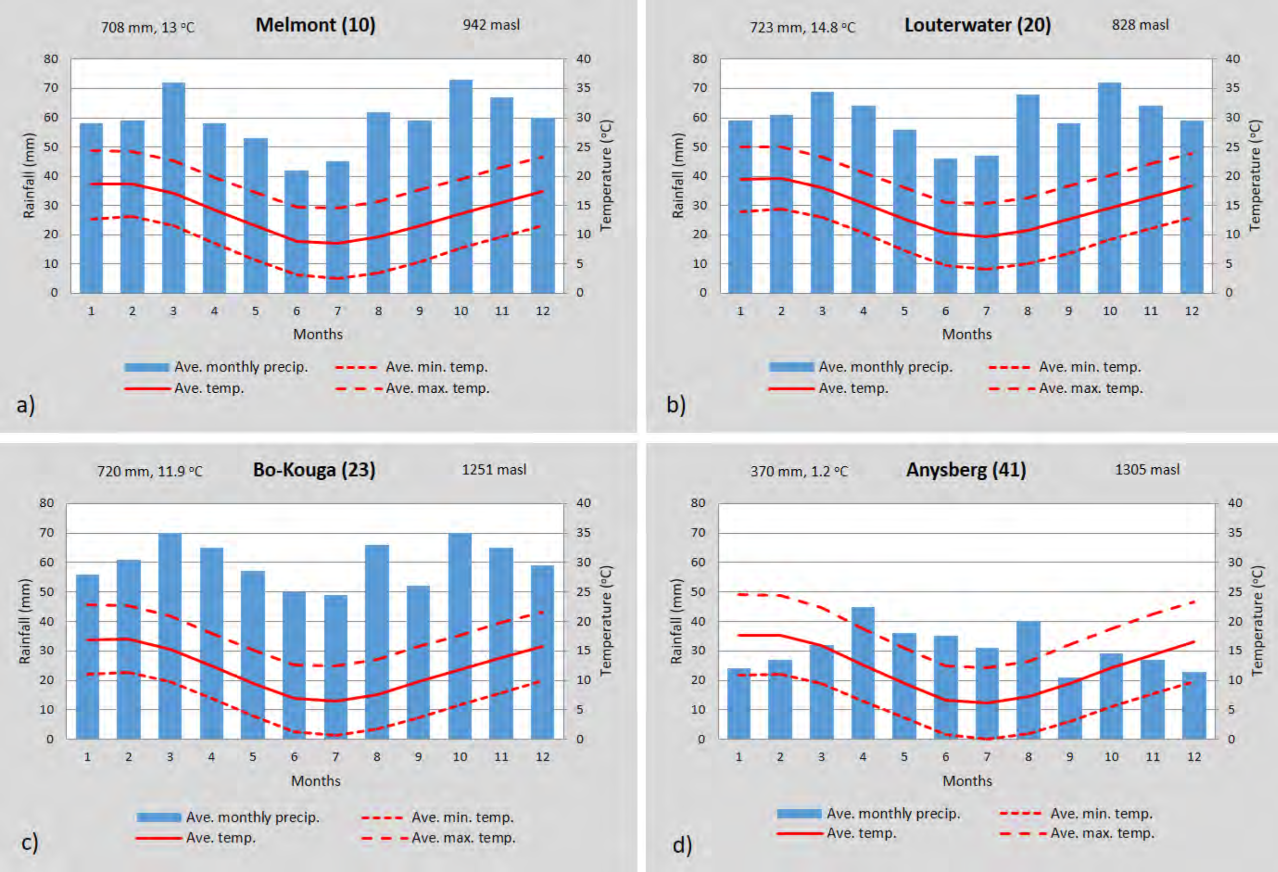
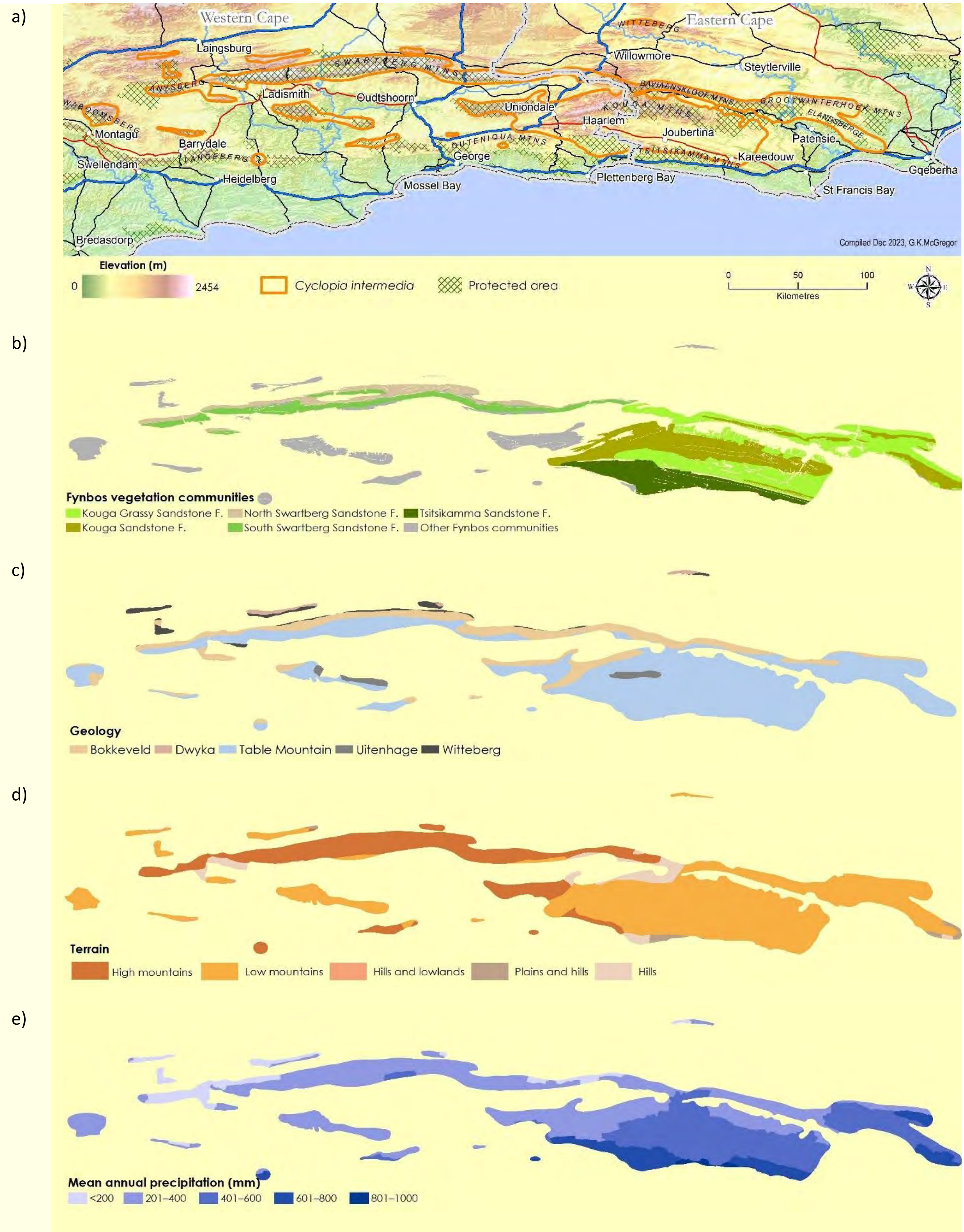


Figure 5.13: Climate graphs for four sites across the *Cyclopia intermedia* distribution range from east to west (a to d). Monthly values are based on modelled data, at a resolution of 1 km^2 (Karger et al., 2017). The station name for the graph is the general area, while the number corresponds to the actual site (Table 5.3). Mean annual precipitation and mean annual temperature values are given (top left) and site elevation (top right).

5.4.1.1 Fire frequency

The overall fire return interval (FRI) for the *C. intermedia* distribution range, based on a record of 22 years from 2001 to 2022, is 18.8 years. A more detailed analysis of fire frequency (Figure 5.14g and Figure 5.15) shows that from 2001 to 2022, 38.4% of the distribution range (≈ 4448.3 km^2) did not burn at all, 37.9% burnt once, 19.1% burnt twice (2217.8 km^2) and 3.8% of the distribution range burnt three times (443.8 km^2). Only 0.7% of the area (74.2 km^2) burnt four times, and 0.1% (16.2 km^2) burnt five times. An area of less than 1 km^2 burnt six or seven times (not represented in Figure 5.15, but represented in the five-to-seven-year frequency class on the map, Figure 5.14g). Many of the surveyed sites have burnt twice in the last 22 years (14 sites, 36.8%), while 28.0% have not burnt at all. Five sites (13.2%) burnt three times. For the locality data the pattern is slightly different: the most common fire frequency over the 22-year record was one fire at 38.6% of the sites, then two fires in 22 years at 30.6%. There was a scattering of three fires in 22 years (13.2%) in the Langkloof, Kouga, Elands Valley (far eastern extent) and the eastern Swartberg. There were no fires recorded at 16.4% of the sites in the 22-year monitoring period. A very small number of sites have burnt four or five times (0.015%). These high frequencies occur exclusively in the Elands Valley area near the far eastern end of the *C. intermedia* distribution range (dark red colours; Figure 5.14g).


a)
Western Cape
Eastern Cape
Laingsburg
Willowmore
Steytlerville
Ladismith
Oudtshoorn
Uniondale
Haarlem
Joubertina
Patensie
Montagu
Barrydale
Swellendam
Heidelberg
George
Mossel Bay
Plettenberg Bay
Kareedouw
Gqeberha
St Francis Bay
Bredasdorp
Compiled Dec 2023, G.K.McGregor
Elevation (m)
0
2454
Cyclopia intermedia
Protected area
0
50
100
Kilometres
b)
Fynbos vegetation communities
Kouga Grassy Sandstone F.
North Swartberg Sandstone F.
Tsitsikamma Sandstone F.
Kouga Sandstone F.
South Swartberg Sandstone F.
Other Fynbos communities
c)
Geology
Bokkeveld
Dwyka
Table Mountain
Uitenhage
Witteberg
d)
Terrain
High mountains
Low mountains
Hills and lowlands
Plains and hills
Hills
e)
Mean annual precipitation (mm)
<200
201–400
401–600
601–800
801–1000

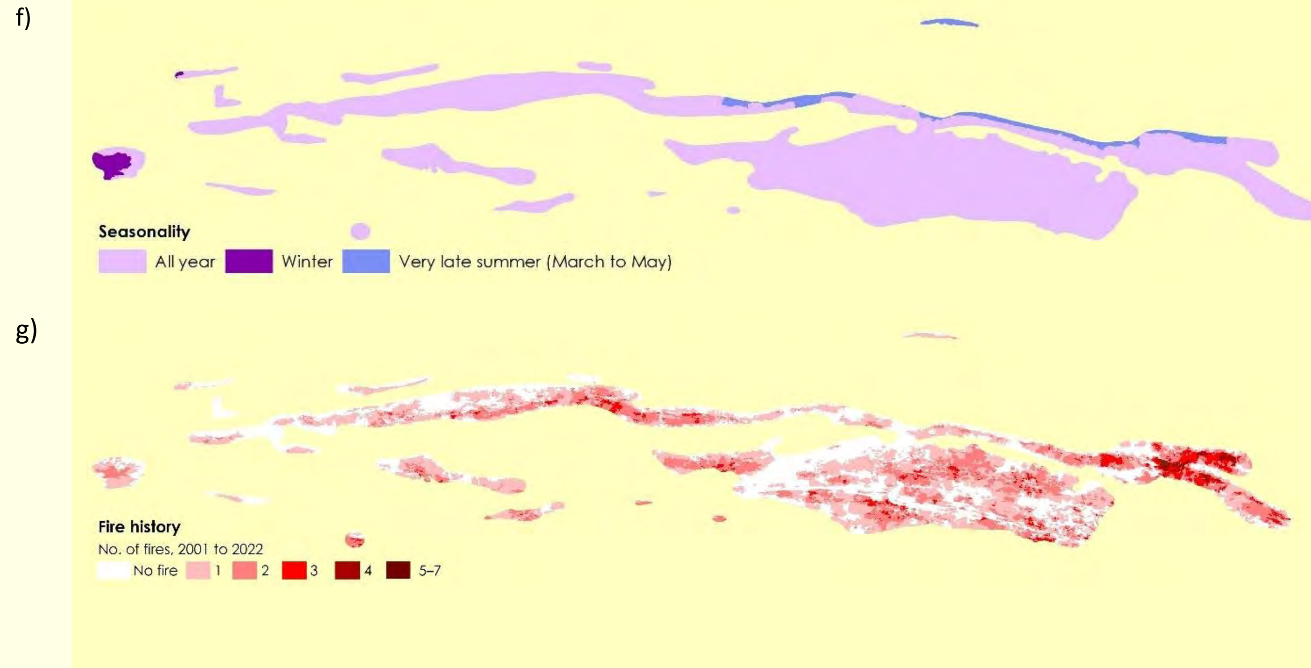


Figure 5.14: Biophysical variables within the *Cyclopia intermedia* distribution range without including slope aspect and slope inclination. The first map (Elevation) serves as an index for the other maps in terms of places and mountain ranges.

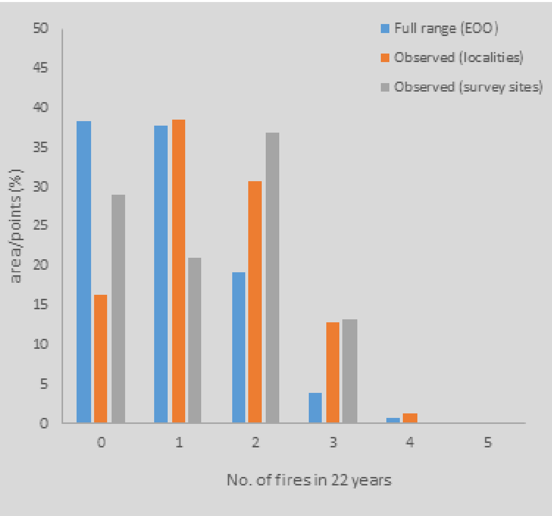


Figure 5.15: Fire frequency across the *Cyclopia intermedia* range and at the 531 localities and 38 survey sites.

5.4.1.2 Biophysical characteristics recorded at the survey sites

At a local scale, the survey site biophysical characteristics were summarised to derive a more detailed picture of typical *C. intermedia* sites (see summary table, Appendix 5c). The most common terrain unit was a midslope position (89.5% of sites), with only a few sites found on the crest (7.9%) and footslope (7.9%). Soils were dominated by sandy loams (73.7%), and at all except four sites (soil form not described), soils were described as a Mispah form (shallow Orthic A-horizon overlying weathered bedrock). IAP's were present at five sites (13.2%), located on the south-facing slopes where rainfall is high (600–800 mm zone), and soils were deep sandy loam and sandy clay loam. Four of these sites also had a low degree of rock cover (<10.0% rock fragments in the soil and no bedrock present), while the fifth site had > 50% rock cover and bedrock present. While this analysis did not systematically consider the potential effect of invasive alien plants, based on observation, IAP infestation is largely unmanaged. It is regarded as a threat to the *C. intermedia* resource.

Disturbance (other than harvest) was present at 26.3% of harvested sites, mainly in livestock grazing (particularly post-fire where nutritious resprouting shoots appear) or track/road construction. The majority (73.7%) of sites were relatively undisturbed. At two unharvested sites on privately owned land, there was evidence of livestock grazing and a track. Still, all unharvested sites in protected areas were considered to be in a natural state with no disturbance (beyond naturally occurring fires).

The dominant vegetation form at survey sites was grassy fynbos with scattered taller shrubs or small trees (47.4%). The most common vegetation community recorded was Kouga Grassy Sandstone Fynbos, making up 50.0% of sites, with 26.3% of sites in Kouga Sandstone Fynbos. The North and South Swartberg Sandstone Fynbos communities make up 10.5% of sites each, with Tsitsikamma Sandstone Fynbos making up 13.2%.

5.4.2 Allometry and the effects of harvesting, fire and biophysical factors on plant size

There were statistically significant relationships between all the respective measures of plant size, but the correlation coefficients were the highest between basal circumference and the other measures of plant size (Table 5.3; Appendix 5d – associated scatterplots). Basal circumference was thus selected as the most representative measure of plant size to assess the potential effects of plant size and other factors on plant fecundity. Although the correlations between post-fire plant age and the different measures of plant size were statistically significant ($P < 0.05$), the correlation coefficients were low (< 0.25), such that the relationships between plant age and plant size were not conclusive.

5.4.2.1 Evidence of recruitment

Seedlings were generally scarce at survey sites and were only recorded at four (10.5%) sites despite 11 sites having post-fire ages of less than three years. Seedlings constituted 12% of the population at Louterwater pines (Site 20), 24% at Louterwater gully (Site 21), 3% at Koos Se Bos (Site 27), and 15% at van Niekerksberg (Site 29). Three of the four sites were on the Tsitsikamma Mountain slopes, and one on the south-facing slopes of the Kouga Mountains. All sites had annual rainfall greater than 600 mm.

Table 5.3: Spearman's rank correlation results for the relationships among several measures of plant size and post-fire plant age of *Cyclopia intermedia*. Scatterplots of these relationships are in Appendix 5d.

Measures	rho	*P*	S	n
Basal circumference & Crown diameter	0.84	< 0.001	16563451	847
Basal circumference & Height	0.58	< 0.001	42857234	847
Basal circumference & Number of stems	0.82	< 0.001	18598125	847
Basal circumference & Post-fire plant age	0.11	0.001	89931915	847
Crown diameter & Height	0.63	< 0.001	267028294	1634
Crown diameter & Number of stems	0.60	< 0.001	290619861	1634
Crown diameter & Post-fire plant age	0.25	< 0.001	533204413	1634
Height & Number of stems	0.08	0.001	666823270	1634

Height & Post-fire age	0.06	0.012	662131604	1634
Number of stems & Post-fire plant age	0.08	0.001	650663079	1634

Harvesting frequency did not significantly affect the basal circumference (considered a proxy for lignotuber size, Prof. B. Lamont, pers. comm., October 2016) or height of plants harvested in the wild, but it negatively affected crown diameter and number of stems (Table 5.4, Figure 5.16). In other words, the crown diameter and the number of stems decreased with an increase in the number of harvests. Fire frequency variously affected different measures of plant size: basal circumference and number of stems increased, but crown diameter and plant height decreased with increasing fire frequency. All measures of plant size, except plant height, increased with post-fire plant age. Elevation only affected the basal circumference of plants, with plants at higher elevations having smaller circumferences. Mean annual rainfall positively affected plant height, but negatively affected basal circumference and number of stems.

Table 5.4: Output of linear models that assessed the effects of harvesting frequency, fire frequency, post-fire plant age, elevation, and mean annual rainfall on several measures of plant size, namely the square-root of basal circumference, crown diameter, height and number of stems, respectively, of *Cyclopia intermedia*. Related effects plots are in Figure 5.16.

Factors	√Basal circumference		√Crown diameter		√Height		√Number of stems	
	Estimate	*t value*	*Estimate*	*t value*	*Estimate*	*t value*	*Estimate*	*t value*
Number of harvests	0.066	1.4	-0.087	-3.5***	-0.017	-0.9	-0.083	-3.3***
Number of fires	0.338	2.1*	-0.551	-7.2***	-0.837	-15.1***	0.321	4.2***
Post-fire plant age	0.111	6.6***	0.067	5.2***	0.011	1.1	0.063	4.9***
Elevation	-0.002	-3.2**	0.001	1.6	0.0004	1.7ᵻ	0.0004	1.2
Annual rainfall	-0.008	-6.2***	-0.001	-1.1	0.005	8.8***	-0.004	-5.0***
Model Adjusted R^2	0.076		0.085		0.199		0.087	
Model F-statistic	15.0***		31.5***		82.3***		32.1***	
Degrees of freedom	5, 842		5, 1628		5, 1628		5, 1628	

Significance codes: ᵻP < 0.1, *P < 0.05, **P < 0.01, ***P <0.00

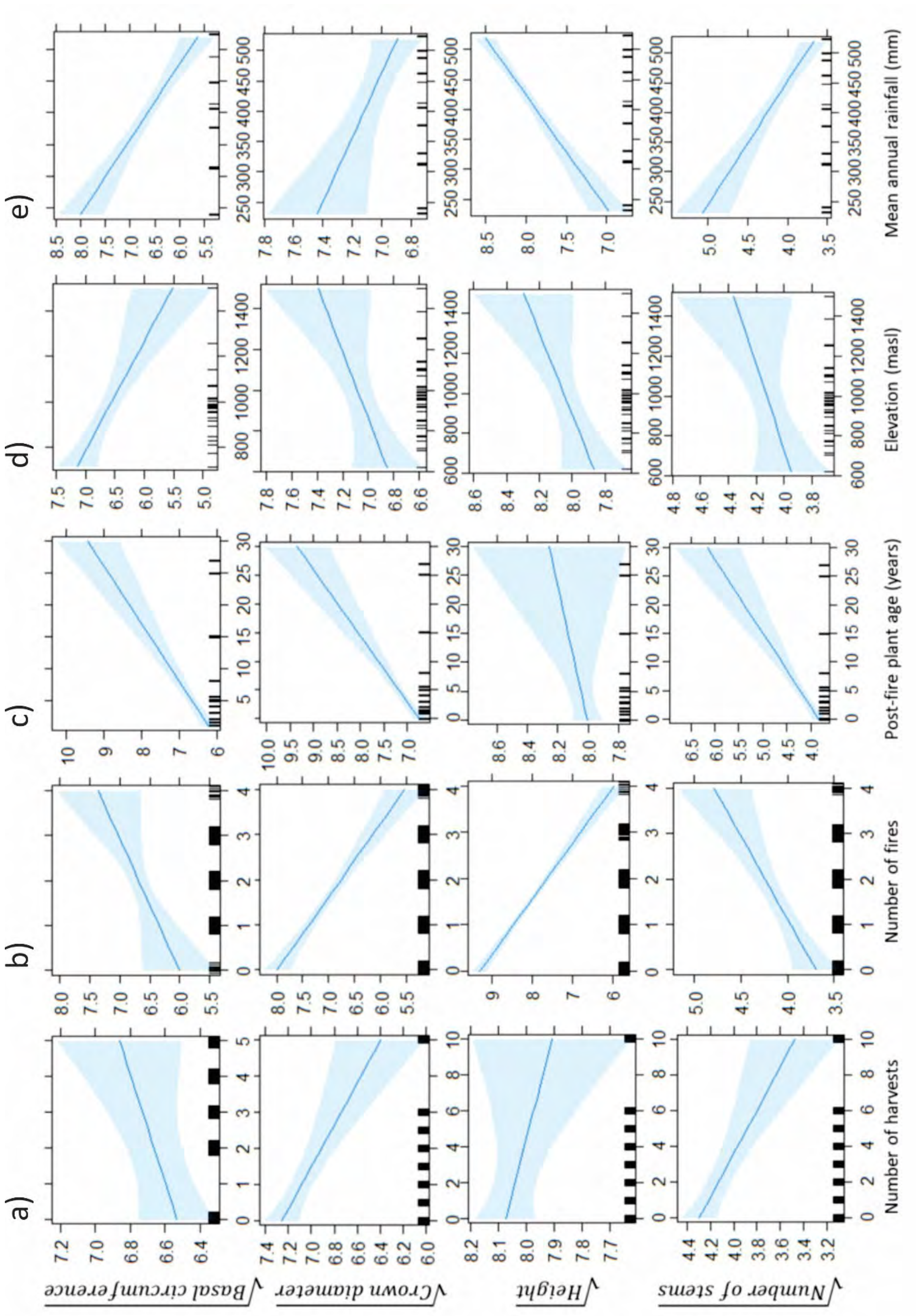


Figure 5.16: Effects of a) the number of harvests, b) number of fires, c) post-fire plant age, d) elevation, and e) mean annual rainfall on the square root of basal circumference, crown diameter, height, and number of stems, of *Cyclopia intermedia*. Shaded bands depict standard errors. Related linear model outputs are in Table 5.4.

5.4.3 *Effects of harvesting, fire and plant size on fecundity*

Harvesting frequency significantly negatively affected the number of pods borne by plants harvested in the wild: the number of pods declined with an increasing number of harvests (Table 5.5; Figure 5.17). Fires had a marginally significant positive effect on the number of pods; as the number of fires increased, the number of pods also increased. The number of pods borne by plants also increased significantly with plant size as measured by basal circumference.

Table 5.5: Output of generalised linear models that assessed the effects of harvesting frequency, fire frequency, and basal circumference as a measure of plant size on the square-root of the number of pods as a measure of plant fecundity for *Cyclopia intermedia.* Effects plots for the number of pods are in Figure 5.17.

Factors	√Number of pods	
	Estimate	*z value*
Number of harvests	-0.037	-2.5*
Number of fires	0.069	1.9ᵗ
Basal circumference	0.012	20.1***
Degrees of freedom	3, 288	

Significance codes: ᵗP < 0.1, *P < 0.05, **P < 0.01, ***P <0.001

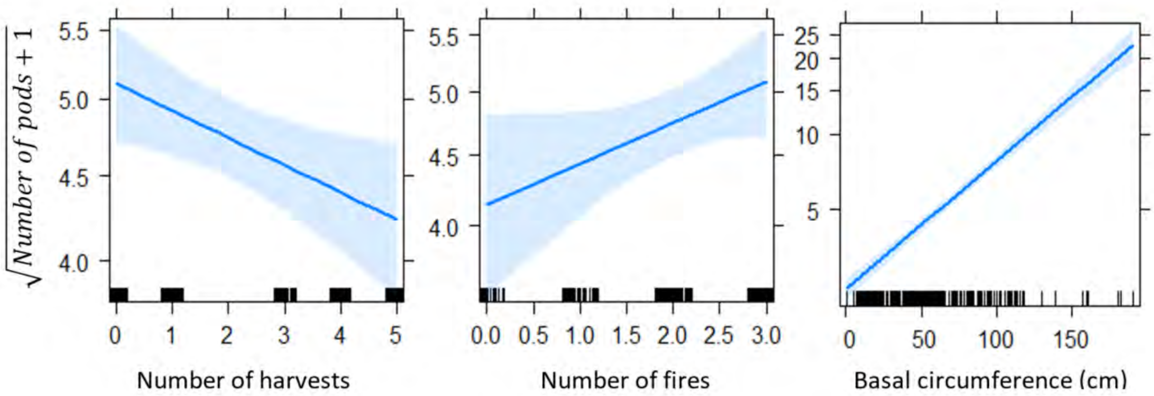


Figure 5.17: Effects of the number of harvests, number of fires, and basal circumference as a measure of plant size on the square root of the number of pods borne by *Cyclopia intermedia* plants. Shaded bands depict standard errors. Related linear model outputs are in Table 5.5.

5.4.4 Case study 1: Unregulated harvesting (Joubertina dam, Site 32)

5.4.4.1 Population survey

Five (14%) of the 35 plants in the wild subjected to unregulated harvesting died between the 2015 and 2017 surveys, while ten (33%) of the remaining 30 plants died between the 2017 and 2022 surveys. Thus, 43% of the plants subjected to unregulated harvesting died during the study period of seven years. The size of the plants (Figure 5.18) which survived throughout the study period declined significantly over time in terms of crown diameter (chi-square = 7.4, P = 0.025), height (chi-square = 21.6, P < 0.001), and number of stems (chi-square = 13.4, P = 0.001). The range of condition of some of the plants in this population is illustrated in Figure 5.19, from a) marked plant for which only the tag remains, to d) showing a plant in reasonable health.

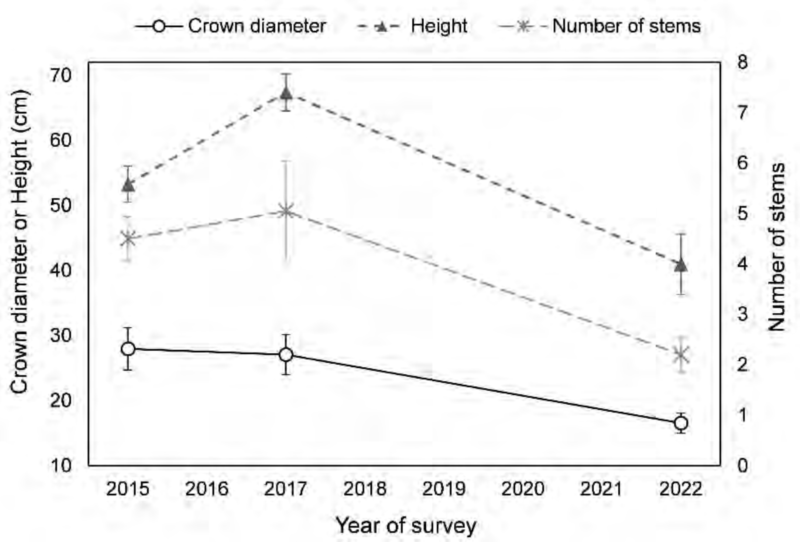


Figure 5.18: Change over time of monitoring (2015, 2017 and 2022) the size of plants in a wild population of *Cyclopia intermedia* subjected to unregulated harvesting. Means (± SE) are shown for crown diameter, height and number of stems of 20 plants that survived throughout the study period.

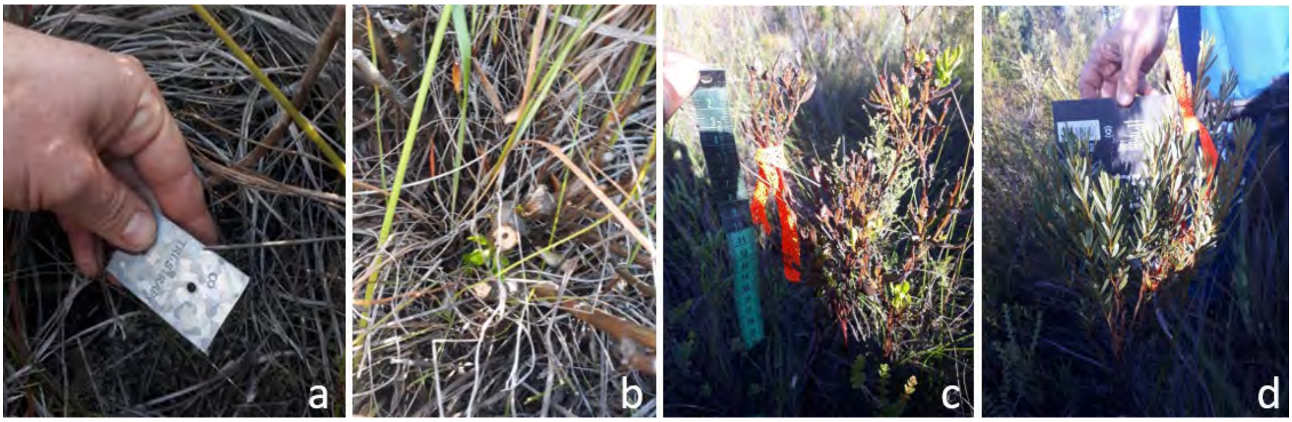


Figure 5.19: Joubertina dam (population 32) condition of plants in an area of unregulated harvesting. a) Remains of plant no. 8: a single dead stem and a tag; b) Stubs of cut stems and a single shoot; c) An ailing plant with insect damaged leaves and some new growth, about 25 cm in height; d) Plant in reasonable health with mature growth, standing about 75 cm tall.

5.4.4.2 Harvest manager interview

At the time of the second survey in this study (January, 2017), the site was deemed to be ready for harvest in three months' time. The harvest team had a permit to harvest every two years, where their practice was to crop plants of suitable size (taller than knee height), with stems of dark colour (not green), which would give tea of high quality. According to the harvest manager, yields had declined because other harvesters (seen as outsiders) harvested between their permitted harvest dates. These illegal harvesters were careless in cropping, often leaving half the stems on a plant, stunting healthy resprouting. According to the harvest manager, the plants were getting old, and no young plants were emerging. The market had been low for a few years, so this team and illegal harvesters had not harvested as much as they would typically. The harvest manager expressed the concern that if the harvest were delayed to allow plants to mature, an illegal harvester would harvest 'their' crop. He explained the problem as follows:

No-one controls this place and everyone who passes takes a bit so that soon there is none left. Each harvester thinks that if he does not take what is there – the next harvester will, so he takes what he can even though it is not the best way to do it. That is also why there are many half-harvested plants which do not grow well.

The harvest manager also harvested on nearby privately-owned land, at a site at a higher elevation where the plants were in much better condition and the harvest yield was consistently high. He estimated a yield of 1 to 1.5 kg per plant after a three-year harvest interval, based on his last harvest in 2015.

5.4.4.3 Economic value of the resource

Potential yield at the Joubertina Dam site for four dates is expressed as a potential ZAR value (Figure 5.20a, b and c). The R^2 value for all plots (> 0.9), indicates a good fit and a strong downward decline in plant density, potential yield per hectare, and potential income over time.

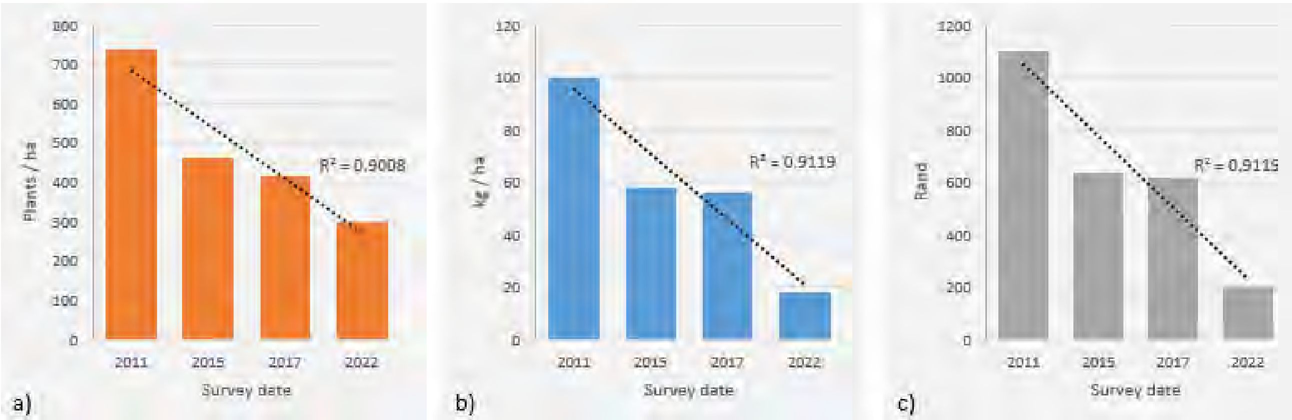


Figure 5.20: Estimating the potential economic impact of a declining *Cyclopia intermedia* population in terms of yield and potential income at the Joubertina dam site. a) Plant density per hectare; b) Potential yield per hectare in kg / ha; and c) The potential ZAR value of the yield from a hectare of *Cyclopia intermedia*, based on a price of ZAR11.00 per kilogram of wet material, paid at the processing plant in 2011.

Relevant information from the LOWFT (2011) report on the condition of the population included a comparison with populations at nearby sites on private land, which were difficult to access. Plants were rated as "strong" with much greater potential yield (≈ 1.5 kg). The report also observed that despite the recent fire (March, 2009), there were no seedlings in the population, plants had been carelessly or partly cut, and there was evidence of dead plants.

5.4.5 Case study 2: Frequent harvesting of cultivated plants

The plants in the cultivated stands with different numbers of harvests at three-year intervals differed significantly in their median size in terms of basal circumference ($H_{3, 159}$ = 50.8, P < 0.001), crown diameter ($H_{3, 159}$ = 32.3, P < 0.001), height ($H_{3, 159}$ = 36.0, P < 0.001), and number of stems ($H_{3, 159}$ = 50.0, P < 0.001; Figure 5.21). Plants increased in all the measured dimensions until the age of 12 years, by which time they were harvested three times, thereafter their size declined significantly by the age of 17 years after five harvests. Figure 5.22 shows the 12-year-old stand at the time of the first survey in 2017.

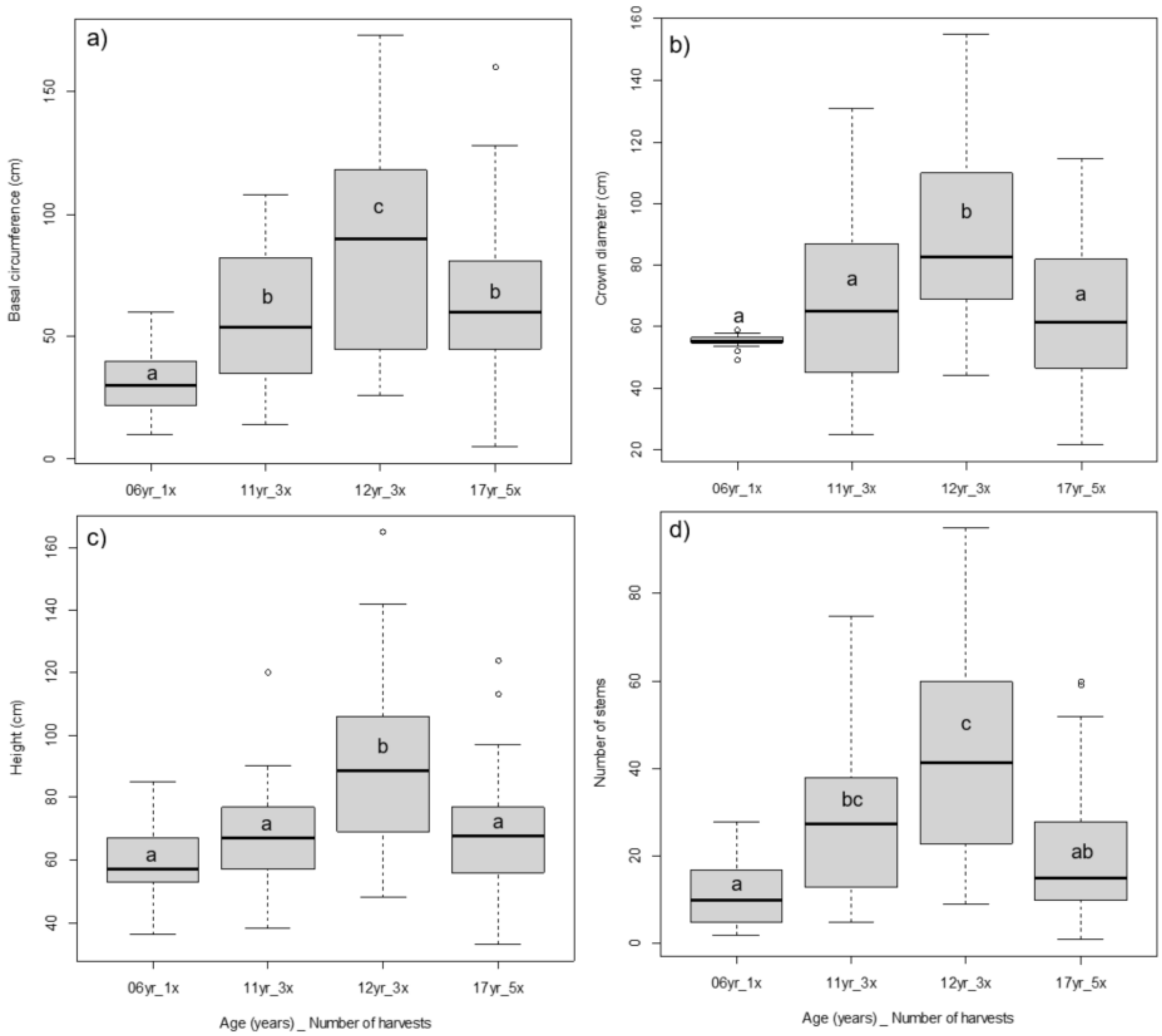


Figure 5.21: Plant size measures (a) basal circumference, (b) crown diameter, (c) plant height, and (d) number of stems compared among cultivated stands of *Cyclopia intermedia* surveyed at different post-planting ages and thus subjected to increasing periods of harvesting at 3-year intervals. Box-and-whisker plots: bars=medians, boxes=25–75 quantile ranges; whiskers=1.5 × interquartile ranges; and dots=outliers. Disparate small letters denote significant differences among groups based on Kruskal Wallis H test results and Dunn's multiple comparisons.

Figure 5.22: Cultivated *Cyclopia intermedia* at Bo-Vlakte, Op-die-Tradouw. The site is remarkable because it is the only known, producing cultivated stand of *C. intermedia.*

5.5 Discussion

This chapter served to improve our knowledge and understanding of the nature of populations of *C. intermedia* as an element of mountain fynbos communities, and the plants' response to harvesting to assess the sustainability of harvesting wild populations.

5.5.1 The biophysical environment of *C. intermedia*

Cyclopia intermedia is a widely distributed fynbos plant with a distribution extent of 11 496 km^2 in mostly mountainous terrain in the Cape Fold Mountains. An analysis of the biophysical environment of the species' distribution range and area of likely occurrence served to extend and refine what was published on the habitat requirements of *C. intermedia* by Joubert et al. (2011) and Schutte (1997). The current study showed that the species is a generalist thriving in a range of conditions, in abundant to sparse populations across a complex of rugged landscapes from 300–800 masl, on rocky soils and steep slopes with an average annual rainfall of < 300 mm to > 800 mm, with preference for particular conditions within these ranges (Figure 5.23). The wide range occupied by *C. intermedia* and its success as a resprouter that responds well to (limited) disturbance, makes it the most available and the most harvestable of the *Cyclopia* species, and, therefore potentially, the most vulnerable to exploitation (Schutte-Vlok, 1998; du Toit et al., 1998). Its location in mountain environments (steep slopes, high elevation, poor soils, difficult access) is advantageous because the land is generally not useful for other purposes. The potential threat of IAP's in the Cape Fold mountains is described as significant by Kraaij et al. (2011). Within the *C. intermedia* range, IAP's were present at 13.2% of surveyed sites but were not systematically considered in this analysis. IAP's were noted as a threat to the resource by McGregor (2017c).

A better understanding of the biophysical characteristics of the *C. intermedia* habitat may contribute to refining use and management of harvested populations for optimal yields, and catering for predicted effects of climate change through, for example, adjustment of protected area boundaries to incorporate an altered range.

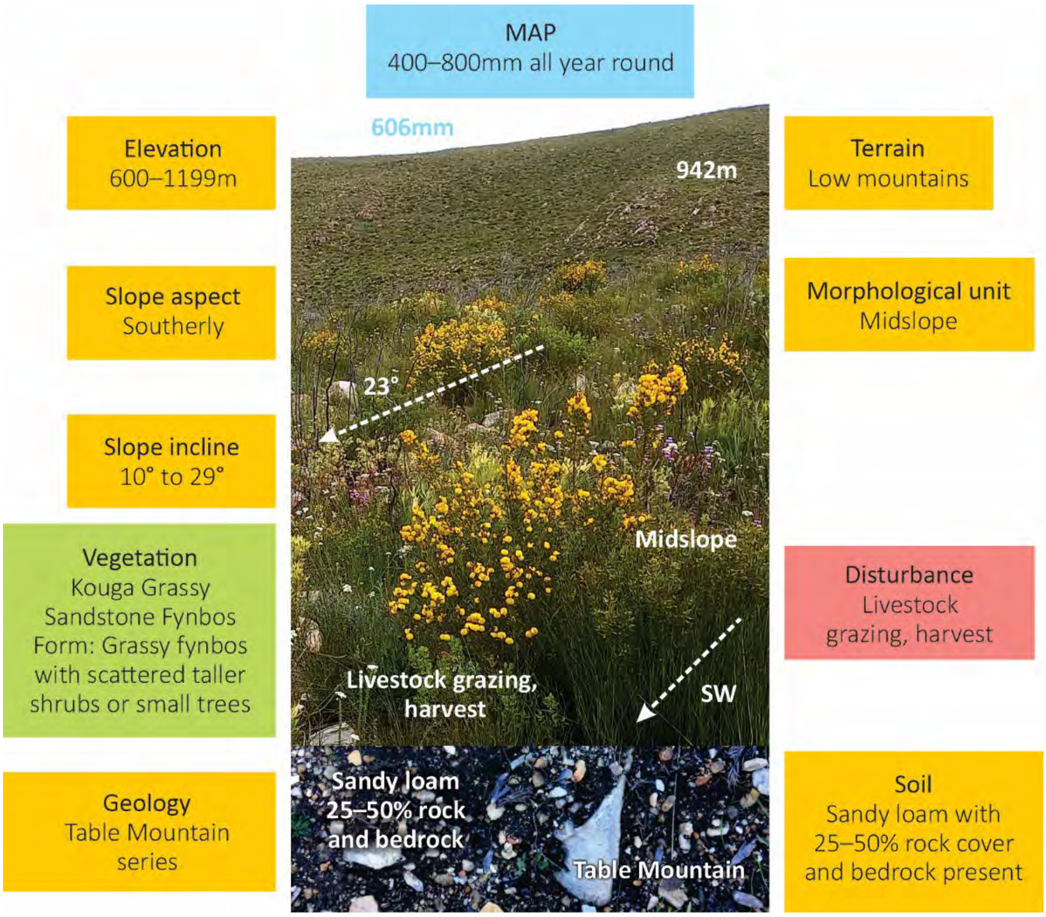


Figure 5.23: Summary of typical biophysical characteristics at the site of a *Cyclopia intermedia* population. The actual biophysical characteristics at this site (Tweeling-se-laagte, site 10) are displayed in white text.

5.5.2 Harvesting effects on plant vigour

An analysis of the allometry of plants served as input to other objectives. Basal circumference (closely correlated with numbers of stems) was identified as the most representative measure of plant size for use in assessing the potential effects of harvesting on plant vigour. The allometry of unharvested plants was generally larger in all dimensions than harvested plants, but only crown diameter and number of stems were significantly different. Based on the data used for the GLM analyses of plant allometry, descriptive statistics of the average dimensions of harvested versus unharvested plants are summarised in Figure 5.24. These research findings contradict those of Barnado (2014), who found that harvested plants had more stems than unharvested plants. However, these results are based on a much bigger sample across a variety of environments.

Figure 5.24: Summary of the differences between harvested and unharvested plants in actual figures based on descriptive statistics of the data sets.

The results of the fecundity analysis showed that pod production (and therefore seed availability for germination and seedling establishment) is impacted significantly by harvesting: the number of pods borne by plants decreases with an increasing number of harvests. Figure 5.25 summarises some descriptive statistics for measures taken in the fecundity survey, highlighting the differences between harvested and unharvested plants. The finding is supported in research by Lee et al. (2023), which demonstrated that large *C. intermedia* plants (a function of stem number and stem length) are the most fecund in bud production. The allocation of resources to growth rather than to reproduction is one of the natural trade-offs of the resprouter form (Bell & Ojeda, 1999; Lamont & Wiens, 2003), but in the instance of harvested *C. intermedia* plants, it may represent a further imbalance with reserves being drawn on regularly (every four years) for growth. Harvest trials conducted on the palm *C. radicalis* demonstrated that the allocation of resources to new leaf production after harvest led to a decline in flowering and fruiting after the fourth harvest, ultimately affecting the species' reproductive success (Lopez-Toledo et al., 2018). In a large-scale process-modelling exercise dealing with the persistence of 26 Proteaceae species in the CFR, Treurnicht et al. (2016) concluded that when fecundity is low and seed is limited (as in the case of resprouters), harvesting can have profound adverse effects on fecundity. They further noted that effects are often amplified at the edge of a species' range where biophysical conditions may be less than ideal.

Figure 5.25: Summary of the differences between harvested and unharvested plants in actual figures based on descriptive statistics of the data sets.

Two case studies were presented to further understand the effects of harvesting on plant vigour, which are useful in providing insights into aspects of sustainable use of a resource.

Case study 1: this study is instructive because it shows the effects of unregulated harvesting. The site represents a worst-case scenario of unsustainable wild honeybush harvesting: it is accessible, easy to harvest and unmanaged. A combination of data collection methods, including an interview with a harvest manager, provided a fuller picture of the state of the site. Information from the harvest manager explained the slight increase in plant height and number of stems in 2017, because the harvest before that year was in November 2014 with a harvest interval of 2.5 years for recovery. The population analysis showed that unplanned harvesting with short harvest intervals significantly affected a population, causing it to decline. Careless cropping of the plants, leaving plants partly harvested, may also have had a negative effect on resprouting vigour. As shown by Lee et al. (2023), 50% cropping of plants caused significantly reduced growth of new stems compared to the plants that were fully cut. A once productive resource with reasonable economic value was degraded within seven years to one-tenth of its value. Lopez-Toledo et al. (2018) note that a non-planned harvesting approach may negatively affect vital rates and long-term dynamics of populations.

The role of 'outsiders' with poor harvesting practices who have no permission to harvest at particular sites is a common complaint amongst harvesters who are proud of their best practices (Chapter 3). The perceived threat of outsiders without adequate knowledge of harvesting best practice is not uncommon in wild resource use. In the Marula industry, outsiders are not allowed to harvest (Wynberg et al., 2003, Chapter 3), while in the Golden Grass industry in Brazil, early season harvest by newcomers was found to cause high plant mortality, whereas experienced harvesters, harvesting at the correct time, did not cause mortality (Schmidt and Ticktin, 2012). The Joubertina dam site can be seen as an example of the widely criticised "tragedy of the commons" identified by Hardin (1968), where the desire of the individual for short-term gain overrides any knowledge of best practice and sustainable use by a larger community. Some harvesters admitted to taking what they could when the resource is available before someone else does (a feature of wild resource harvesting, noted by Malgas, 2022). The decline of a common resource is not inevitable: from the experience of community-based research projects in Maine, Indonesia, Nepal and Kenya, Ostrom (1990) showed that individuals and communities could successfully manage common resources (CPR) in a variety of areas through cooperative institutional arrangements. Malgas (2022) proposed a community-based management approach for the honeybush resource, who used Ostrom's socio-ecological framework (Ostrom, 1990) to frame the honeybush industry. The approach is a 'bottom-up' one, stressing that regulation through government intervention can only be effective if supported by individuals and communities. Support for control of the resource by the harvesting community, who have good knowledge of the use of the resource, was voiced strongly by harvesters at the Louterwouter workshop (Chapter 3). At the same time, farmers advocated for local area knowledge to be used at a local level to inform regulation and management.

Case study 2: a cultivated population survey represents a baseline dataset of plant physical dimensions at known ages, under known harvest regimes, against which wild plants can be measured and better understood. Most significantly, it highlights that with three-year harvest intervals in the cultivated population (the interval practised by some wild-harvest teams), a plant reaches its most productive stage at around 12 years, with vigour declining thereafter. The data are limited because there were no comparable wild sites nearby with a similar climate, and no control group showed how unharvested plants would perform. The effect of competition in a wild population and the density of plants were also not accounted for. Plants may decline after 12 years simply due to age. However, in wild harvested populations with conservative harvest intervals (four years), plants are estimated to reach 35 years of age (Mr Q. Nortje, Farmer, pers. comm., September 2016; Mr P. van Rensburg, Harvest manager, pers. comm., October 2016). Therefore, it was likely that plant decline at age 12 after four harvests was related to premature ageing and decline in vigour because of the frequency of the harvesting. The case study provides a guideline for a minimum harvest interval in a wild harvesting context for sustainable use.

5.5.3 Fire effects

Fire incidence in the study area is not within the normal range for the fynbos. Fire return intervals in the study area (19 years) are within the range of values given for the fynbos of 8–40 years (Van Wilgen et al., 1992) and specifically the eastern fynbos (8–26 years for the eastern Tsitsikamma, Kraaij et al., 2013). Since fire frequency positively affected the number of stems per plant, plants subjected to a greater number of fires would be expected to produce more pods. Fire frequency for the populations in the fecundity survey was never greater than three, and most often, two fires over 25 years.

The data from this analysis did not produce a clear picture of the impact of fire on *C. intermedia* populations. As expected, plant dimensions increased with post-fire age (except for height). It was anticipated that seedlings would be present at early post-fire site surveys, which comprised 29.0% of surveyed sites (11 out of 38 sites), but seedlings were only found in small numbers at four harvested sites. The lack of seedlings in resprouters is not unexpected (Bond & Midgley, 2001; Schutte et al., 1995), but at some stage, resprouters must recruit to replace natural adult mortality that is not related to disturbance history but to age (Enright et al., 2007). In a survey of the post-fire community of three montane fynbos resprouter species and five reseeder species, Marais et al. (2014) found no resprouter seedlings. Makhuza (2021) found no seedlings across surveys of harvested and unharvested *C. intermedia* populations in the Eastern Kouga Mountains. The fact that seedling counts are low in harvested populations and non-existent in unharvested ones suggests that this is a natural occurrence. Germination rates for the sites surveyed in this research may have been affected by the severe drought conditions experienced across the Eastern and Western Cape from 2015 to 2019.

5.5.4 Management of the *C. intermedia* resource

The results of this analysis bring out some information relevant to improved management and use of the resource. An analysis of plant allometry alone does not show the adverse effects of harvesting on plant vigour. However, the fecundity surveys show that harvested plants produce fewer pods, which may be linked to the production of fewer stems in harvested plants. Harvesting practice should be adjusted to promote optimal conditions for seed set: with longer harvest intervals, plants can produce more stems and ultimately more pods and, therefore, more seeds. Unregulated and short-interval harvesting are shown to have a negative effect on plant vigour: harvest intervals must be greater than three years and should allow for four to five years of recovery before the next harvest. This would also allow several seasons for seed production to build up soil seed stores. Witkowski et al. (1994) noted that, particularly under adverse conditions such as drought and frequent fire, reduced seed store caused by flower harvest may become problematic. The low incidence of seedlings is potentially of concern in harvested populations, particularly when considered together with the results of the fecundity surveys. Without adjustment of harvest practice and proactive management for optimal seed production, harvesting may impact the long-term persistence of populations. Other management options include augmentation with seed from nearby unharvested populations, leaving large plants unharvested in each population, relaxing harvest intervals periodically, allowing the maximum number of seasons for seed set between harvests, and adjustment of harvest timing to allow for completion of the full reproductive cycle.

Fire management by landowners may not replicate the natural regime as they typically choose to burn during cool, safe weather conditions to reduce the risk of fires getting out of control (Q. Nortje, Farmer, pers. com., September 2016). In fynbos, the season and type of fire are important, particularly in seedling recruitment and healthy resprouting, both of which are linked to pre-fire plant vigour (Marais et al., 2014). Natural fynbos fires are typically very hot and are required for Cyclopia and other leguminous plants to induce scarring of the seed testa to enable seed germination. Hot fires during high fire danger conditions are thus essential for successful recruitment from seeds. Hence, planned burns should allow for this natural pattern and should be considered when managing the veld for sustainable harvesting.

The results suggest that other management options must be considered for harvested populations that would allow for optimal seed production and recruitment. For example: harvesting practice that adjusts intervals to allow the maximum number of seasons for seed set, adjustment of harvest timing to allow for completion of the reproductive cycle, no harvesting of large plants with large bud numbers.

5.5.5 Limitations

The effects of a prolonged drought were spread across the whole *C. intermedia* distribution area, when most of the surveys took place. The 2021 surveys took place in a year of more normal rainfall, and it is not possible to separate the cumulative effects of the preceding years of drought from, for example, pod production.

Estimates of the number of harvests and classification of populations as harvested or unharvested were based on the best available records, whereas in reality, some sites considered unharvested may have been harvested illegally or been harvested before declaration as a reserve (e.g.: sites at Teeberg and Bergplaas). Populations may have been harvested more often than was recorded but at lower intensities, since demands were much lower.

Seedling data was only described and not analysed because of the small amount of data. Understanding the regeneration of populations through seedling recruitment is important in the context of sustainability of resource use and represents a gap in our knowledge. Anecdotal evidence suggests a life span of 35 years for plants in a harvested population. Still, because the honeybush industry is relatively young (20 years of commercial production) it may be that many populations are only just beginning to show signs of stress.

Since site access depended on harvest team arrangements, it was not always possible to lay out surveys ahead of the harvest team. Therefore, plots were laid out rapidly and were not always optimally or carefully placed.

The case studies were initially opportunistic surveys, which became relevant and evolved into useful datasets. Lack of proper planning for control sites and other comparable sites to accompany harvester surveys resulted in limited achievement of more detailed insights. In the case of the Joubertina Dam site (unregulated harvest), other data sources were used to improve the site's data.

5.6 Summary

Chapter Five was focused on understanding the nature of the *C. intermedia* resource and assessing the effect of harvesting on plant populations. The starting point was a desktop analysis using GIS to characterise the biophysical preferences of the species, confirming that it is generalist, occurring where rainfall is 300–1000 mm, mostly on moderate to steep, southerly facing slopes, on sandy and sandy loam soils, at elevations from 300–1800m. Through field surveys at 38 sites, the allometry of individual plants in harvested (22) and unharvested states (16) was measured. At 13 of these sites (six harvested, seven unharvested) a survey of pod production per plant was conducted to measure the effect of harvesting on plant fecundity. Fire and harvest history data were collected at each site using a qualitative approach through structured interviews with farmers and harvest managers. The anecdotal evidence was quantified for inclusion in the statistical analysis.

The methods for this chapter were primarily quantitative. The plant allometry data and biophysical variable data per site were analysed statistically using generalised linear models to investigate the effect of the biophysical environment, fire and harvest on plant vigour. The results revealed that neither fire nor harvest significantly affected plant vigour, although harvested plants were slightly smaller in all dimensions. With regard to fecundity – only 27% of harvested plants bore pods while 63% of unharvested plants bore pods, and the unharvested plants bore more pods. Appropriate methods were taken from ecological and NTFP studies and informed by literature on the use of NTFPs and natural resource use in general, focusing on studies of fynbos ecology and resprouter ecology.

A case study of a *C. intermedia* population subjected to unregulated harvesting served to illustrate the effect of unknown, short harvest intervals on a population. The number of plants in the surveyed population declined by 43%, and the surviving plants declined dramatically in all measured dimensions over a seven-year monitoring period, with a corresponding decline in the harvestable value of the resource from around ZAR 1100 in 2011 to ZAR 200 in 2022. A second case study of four cultivated populations of *C. intermedia* of different ages served as a control experiment (known plant ages, three-year harvest intervals and known harvest history of one to five times). Plants were found to decline in all dimensions after year 12 after four harvests.

The chapter's findings highlight the need to consider longer harvest intervals in response to local conditions, with some consideration of the effect of harvesting on seed production and the long-term persistence of *C. intermedia* populations.

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Chapter 6 Synthesis and conclusion

Contents

6.1 Introduction

The need for a better understanding of the impact of harvesting on any wild-harvested resource is widely acknowledged, as many traditional enterprises have made the transition from cottage industries to commercial enterprises (Chamberlain et al., 2019; Joubert et al., 2011). If a resource has been exploited by a community over a long period, it may be that its extraction is sustainable, but the pressure of commercial-scale extraction is unlikely to be so (Aswani et al., 2018; Early-Capistrán et al., 2020). In assessing the sustainability of resource use, observations of population structure were a common approach, together with modelling (Gaoue et al., 2016; Schmidt et al., 2011; Treurnicht et al., 2016). Long-term studies of sustainable harvesting are difficult to conduct in complex social-ecological systems (Soldati & De Albuquerque, 2011; Ticktin & Shackleton, 2011). In the case of honeybush (*Cyclopia* spp.), the research focus has been on the development of the cultivation of several species, the composition and biochemistry of the plant, as well as studies dealing with potential health benefits and the technological and quality aspects of herbal tea and extract production and. Few studies have been conducted that contribute to understanding the sustainability of wild harvesting, which, up until 2017, supplied 85% of the annual crop. Therein lay the motivation for this research.

6.2 Summary of findings

This investigation into aspects of sustainability of the wild honeybush industry has filled a gap in our understanding of the use of this wild resource – by improving our knowledge of the social, economic and environmental aspects of harvesting wild *C. intermedia*. The findings were achieved through the pursuit of five main objectives, using a range of mixed methods, including GIS-based analysis, statistical analysis, interviews, and thematic content analysis. The main findings per objective/chapter are summarised below.

1. Chapter One presented a review of literature – placing the work in an international and national context. This was achieved by synthesising published and unpublished work (mostly from the last 30 years) on the honeybush industry to give a complete perspective of our current state of knowledge on the topic. The positioning of the research as a piece of work that is both applied and engaged was important, because it supported the researcher's undertaking to conduct relevant and useful research to the industry and its stakeholders. The chapter established a broad perspective of the research – and emphasised that the research represents a geographical view, rather than a focussed botanical perspective. This view allowed for the incorporation of the many elements of the industry (including all stakeholders). It used a conceptual framing of the industry in a physical mountain landscape, mirroring the environment in which the honeybush industry is set.
2. Chapter Two dealt with mapping the resource. The creation of a detailed spatial data set for *C. intermedia* at the distribution range and farm scale was motivated by the understanding that inventory is recognised as the first step in any natural resource management approach (Schippmann, 1997). A

distribution map of *C. intermedia* was created through desktop mapping using secondary datasets, map input from experts and existing locality data to give a range estimate of 11 496km^2. Based on habitat preferences and modelling approaches, a refined estimate of where *C. intermedia* is likely to occur was estimated to be 2 220 km^2. The areas of commercial harvest mapped by farmers and harvesters were used to create a *C. intermedia* harvest zone of 1448 km^2. Not all harvest sites were mapped, but they were estimated based on known sites of harvest from sustainable management plans; the area in use was estimated to be approximately 100 km^2. A significant estimate derived from these mapping tasks was that a substantial proportion of the distribution range falls within protected areas comprising 5 654 km^2 (49%), which increases to 61% at the likely level of occurrence.

3. Chapter Three documented existing knowledge about the plant and best practice harvesting from traditional and local ecological knowledge holders, who were the best available source of information at the outset of this research. Most of the data was collected in a workshop attended by representatives of all stakeholder groups. Participants contributed their knowledge and experience through focus group discussions, and questionnaire surveys to a formal body of knowledge around best practice harvesting. The data, collected in this way, supplemented with one-on-one interviews with individual stakeholders, and combined with the best available scientific knowledge at the time, formed the basis of the best practice guidelines for wild *C. intermedia* harvesting. Some of the critical elements which were included in the guidelines were: plants should be cut close to the ground, stem thickness should be as slim as a pinkie finger or less (max. 1.5 cm diameter), stem length should be longer than 50 cm, plant age (i.e., harvest interval) should be 2–3 years, flowering plants can be harvested, the best tool for harvesting is a clean, sharp sickle. The need to recognise the value of experienced, knowledgeable harvesters to the industry was raised, as was the importance of trust and respect between harvesters and farmers. Processors who require high-quality harvested material (i.e., mature plant material, which is clean and free of foreign matter) to produce premium-grade tea were recognised as key role players in the value chain who might compel harvest teams to practice sustainable harvesting.
4. Chapter Four dealt with the characterisation of wild harvesting enterprises (identified through the workshop) in terms of the economic sustainability of the enterprises and associated livelihoods. Harvest enterprises representing three different styles (resident farm staff, small family team and large contract team) provided a record of their approaches to harvesting and harvest history records spanning 20, 13 and 12 years, respectively. Harvest event surveys with each of the three enterprises followed the work compiled on best-practice harvesting to understand and establish what actually happened at harvest events. At these surveys, the large contract team was found to be over-harvesting, cropping on average 65% of a population instead of the claimed practice of 50% cropping at 18-month intervals. Harvest history analysis showed a decline in harvest yields and harvester loads on three out of six farms harvested by the contract team. The small family team working on a four-year harvest interval, managed

to bring in high average per harvester yields, and where they harvested, the harvest history analysis showed sustained yield over time. The resident farm team, practising 4–5 year intervals, adjusted according to local environmental conditions, had the highest average harvester yields, and yield per hectare was sustained over the 20-year period of record. Based on the data collected, it was calculated that a harvester would need access to 175.6 ha of honeybush veld over a four-year period, or, 291.5 ha over a five-year period to earn an annual income (2024 values) of ZAR53 280 (74 kg harvest load) to ZAR67 680 (94 kg harvest load) which would be better than a farm labourer on minimum wage (Dept. of Employment & Labour, 2024).

5. Chapter five focussed on characterising wild *C. intermedia* populations and their preferred physical environment under harvested and unharvested conditions to establish baseline knowledge of the species and its response to use. Knowledge of the physical habitat requirements of *C. intermedia* was initially based on a desktop analysis of 547 localities across the distribution range. *Cyclopia* intermedia is a generalist, occurring at elevations of 350 to 1900 masl; on slopes of 5 to 35 degrees, with aspects ranging from southerly to northerly, but not including true west or true east sectors. Rainfall across the sites ranged from 250 mm in the Anysberg, to 1000mm on the northern slopes of the Tsitsikamma Mountains.

   Based on the desktop analysis, typical sites for field surveys of 38 populations (16 unharvested and 22 harvested with known harvest history) were identified. Using transects, populations and individual plants were mapped and measured in terms of their dimensions. Statistical analysis was used to ascertain differences between harvested and unharvested populations. Plants in unharvested populations were slightly larger, but only the number of stems and crown width were significantly greater than harvested plants. The time since the last disturbance or post-fire age did not seem to make a difference to plant vigour, and even in recently burnt populations, there was a noticeable absence of seedlings (zero count) or young plants (four or five stems). The only populations found to have seedlings were on the better-watered slopes of the northern side of the Tsitsikamma Mountains, where annual rainfall is ≈ 750 mm. Further insights into the effects of harvesting were gained through surveys of fecundity in seven harvested and six unharvested populations on one large farm. An analysis of pod counts showed that the reproductive cycle was affected by harvesting, and there was a significant reduction in pod production in harvested plants.

   To understand the effects of frequent harvesting, a survey of a wild population subjected to unregulated harvest and a study of cultivated stands of *C. intermedia* of different ages and harvest history were carried out. The population subjected to unregulated harvest declined in population number by 43% over a period of seven years, with a corresponding decline in the potential harvest value from ZAR1 100 per ha to ZAR200 per ha, over 11 years. At the cultivated site with three-year interval harvesting, the analysis revealed that plants declined in all dimensions (height, crown size, number of stems) at around 12 years of age, after four harvests, leading to a 50% decline in the fifth harvest.

6.3 Theoretical value of the research

The review of literature presented in Chapter One represents a collection of material framed in the context of a conceptual (spatially related) model of the wild honeybush landscape. It is novel in that the honeybush industry, and wild harvesting in particular, has not been documented holistically. The chapter reviews unpublished sources containing valuable records of honeybush-related activities. A paucity of literature that is relevant to understanding sustainable harvesting was identified. There is a body of literature on wild resource use, both internationally and locally, from which lessons around assessment of aspects of the sustainability of wild resources may be learned. The literature showed that sustainable use of wild resources is possible, but it is species-specific (Gaoue et al., 2016) and closely linked to the socio-cultural and economic context (Ticktin & Shackleton, 2011). Studies also show that a combination of scientific assessment and local ecological knowledge yielded good results, which were most likely to be taken up by resource users (Papageorgiou et al., 2020). The findings of this research prove that local stakeholders' involvement in research can contribute to the development of harvesting guidelines, a better understanding of issues around resource use, and the adoption of best practice (as evidenced by reports from the EC permit officer and processors).

A mapping exercise produced a current and detailed map of the distribution of *C. intermedia.* It went beyond existing maps to delineate isolated patches in outlying mountain environments based on field surveys and expert input. It represented detailed data of harvest areas mapped at the farm scale. The approach demonstrated the value of expert mapping combined with systematic approaches (GIS-based MCS and SDM) to create a comprehensive and accurate product, as Cowling et al. (2003) recognised. The method is repeatable for any resource mapping exercise. Data captured from local experts added an important dimension of detail to the dataset, which allowed a reasonable estimate of the utilised wild resource (not previously calculated with any reasonable level of accuracy). Establishing the size of the resource is an essential step in a resource assessment of wild-harvested species. The delineation of the extent of the resource in protected areas provides essential (and accurate) data on the protection level of a species for input to any biodiversity-related planning. For example, the NDF process requires an estimate of the protection level of the species range. The readily available extent of occupancy (EOO) as presented on the SANBI Red List (Mhlongo et al., 2022) is too large (28 585 km^2) and inaccurate to be useful for calculating the proportion of the *C. intermedia* range in protected areas, even for national scale planning. Given the potential impacts of climate change (estimated at a 40% range reduction, *C. intermedia* RA, in press), this kind of data may be necessary for future planning, for example, for protected area expansion. The data collected in this research represents a current view of the resource, but also records changes over time in terms of sustainable and non-sustainable use of the resource, and serves to identify aspects relevant to detecting the effects of harvesting (like fecundity and harvest history), which should be taken into account when monitoring plans are developed.

The collection of best practice harvesting knowledge represents a current (and only) set of formally recorded information on methods and techniques of wild harvesting of *C. intermedia*, and as such, is an important record of traditional knowledge that is gradually diminishing (Crouch et al., 2008). In recording this knowledge, it was possible to identify gaps or misunderstandings that could be filled or corrected using the best available scientific knowledge. In 2017, for example, the most commonly cited harvest interval was 2–3 years, more frequent fires were considered to be a good thing for the veld and honeybush production, there was some confusion around what was seedling and what was a resprouting plant, (in areas previously considered too overgrown to harvest), and, harvesting in protected areas was not seen to be problematic. TEK and LEK are recognised as essential, but should always be considered alongside scientific research, for developing effective and meaningful action worldwide in dealing with environmental issues (Ramnath, 2014). Where resource use changes from subsistence level to commercial scale, as is the case with the wild honeybush industry, management and sustainable resource use must be supported by scientific data collection and analysis to make the best decisions. At the time of the development of the guideline for wild harvesting in 2017–2018, guidelines of this kind based on LEK and TEK, together with the best available scientific knowledge, were uncommon across national and international collections. The change from a commonly cited 2–3 year harvest interval to a 3–4 year interval was achieved during the research, such that the current commonly accepted harvest interval is 3–4 years. (Based on the findings of Chapter Five – there is strong motivation to expand this to a 4–5-year interval).

The collection of harvest history data of *C. intermedia* to establish the economic sustainability of harvesting enterprises represented what was described by Vance et al., (2001) as a data-poor scenario, where TEK/LEK was the only kind of knowledge available on the historic use of the resource. The data compiled on harvest enterprises represents a unique collection of harvest yield history, offering data-based insights into the economic sustainability of harvesting. The finding that harvest yields and harvester loads declined across three out of eight farms surveyed where short-interval harvesting and over-harvesting were practised, confirmed concerns expressed by Joubert et al., (2011) and Schutte-Vlok, (1998) regarding the sustainability of wild harvesting of the resource. These kinds of findings align with comparable research conducted on buchu (*Agathosma betulina*) harvesting by De Ponte Machado, (2003), which showed that 3–4 year interval harvesting produced better oil yields, greater fecundity and longevity of plants in comparison to annual harvesting.

The finding that a harvester in a well-managed team of the right size (< 10 harvesters) can make a fair livelihood in contrast to the minimum wage for farm workers justifies using smaller teams. This aligns with findings by Stanley et al., (2012), who found that on a global scale, wild resource harvesters are known to make better livelihoods than their counterparts who earn minimum wages. Given the estimated 46 to 57 jobs for harvesters based on a current harvest area of 100 km^2, the figures highlight the need for access to cultivation to grow the industry in terms of livelihoods for rural people.

The data collected to assess plant vigour in harvested vs unharvested populations is important: it did not show significant differences. Some insights that came out in the analysis include the fact that there was a lack of seedlings and young plants. Resprouter ecologists, Bell & Ojeda, (1999) and Lamont & Wiens, (2003) note the lack of seed or seedlings in resprouter populations as a trade-off of resprouter ecology. If taken in the context of lower fecundity in harvested populations (as the results showed), it may be cause for concern. Reduced fecundity in harvested plants in other wild resource contexts (Fynbos flower harvesting) has been identified by Mustart & Cowling, (1992) and Privett et al., (2014), who found reduced production of inflorescences in the season following harvest. Both the survey of unregulated and short-interval harvesting are novel: data of this kind does not exist for *C. intermedia*. Translation into a production figure gives a strong economic incentive to maintain a healthy population. The data on the response of cultivated plants to regular three-year interval harvesting is significant since it indicates that three years is the absolute minimum interval which should be practised for maintaining plant vigour and population persistence. It provides a valuable benchmark for consideration of harvest intervals for sustainable wild harvesting.

6.4 Applied value of the research

6.4.1 Value to the industry

One of the main contributions to the industry from this research was the production of the wild harvesting guidelines. They were developed in response to a call from a range of stakeholders in the industry and were well received in terms of providing good information and practical guidelines for honeybush resource management. The guidelines included a toolkit for farm management plans and a harvest record form for harvesters. While it is difficult to measure the effectiveness and value of the document, feedback from the permitting officer for the Eastern Cape indicated that applications for harvesting permits had improved with the inclusion of better maps and better estimates of yield. The NGO Living Lands has implemented the guidelines on 12 farms, a further six farms are known (anecdotal) to use the guidelines in their resource management. It was established that the three processors who receive wild-harvested material promote using the guidelines by harvest teams (for certification purposes, this is valuable to processors). Based on the above knowledge, it is possible that around 50% of the area used for commercial wild honeybush harvesting is managed sustainably, according to the principles laid out in the guidelines. The actual value of the document to harvesters was not determined.

The mapping exercise established the size of the resource and its value in terms of production and livelihoods. It indicated that the wild industry is potentially at its limit in terms of a sustainable supply of material and livelihoods. These results underscore the need to expand cultivation (which is desirable from a processor's perspective), which has become the focus of the industry. It also points to the need to set a premium price for wild-harvested, organic *C. intermedia* to promote it as a high-value crop, worth using sustainably.

Overall, improved knowledge and understanding of the honeybush resource for management purposes may allow farmers, landowners and harvesters to implement practices that ensure the sustainable use of the resource. These might include: an increased time interval between harvests, augmentation of wild populations to ensure the persistence of harvested populations, and an appreciation of the need to adjust harvest regimes according to knowledge of the area in terms of fire events and prevailing weather. A further consideration in management should be the harvest team type. Data now show benefits for both the environment (sustained yield) and harvester livelihoods of the value of well-managed teams and experienced harvesters in smaller numbers, allowing harvesters a realistic opportunity to earn a fair livelihood. It was also learnt that harvesters involved in the full value chain from veld management through to processing have a greater understanding and appreciation of the value of mature harvest material, which produces quality tea to satisfy the market.

6.4.2 Value in terms of policy and regulations

Through this research, the researcher gave substantial input in the form of derived facts and figures to various honeybush-related projects at a national scale, which informed the development of policy and regulations. These included: the development of a biodiversity management plan (BMP) for *C. intermedia* and *C. subternata* published in 2022 (DFFE, 2022); revision of the status of *C. intermedia* on the SANBI Red List in 2023; the development of a resource assessment (RA) of *C. intermedia* in 2023–2024 (DFFE, 2023); and development of an NDF (DFFE, 2023). On behalf of SAHTA, the results of this research were used directly for: motivating the removal of *C. intermedia* from the current TOPS listing by the DFFE in 2023 (not yet published in final form); drafting a response to the poorly conceived Indigenous Knowledge Act regulations (DSI, 2022), published in 2023; and in drafting a response to the revised Bio-Economy Strategy (DFFE, 2024). Without the information produced during this research, these motivations would have lacked a strong, evidence-based foundation.

The guidelines have proved useful to the permitting officer for the Eastern Cape. With the data available in the field guide (McGregor, 2018), he was better equipped to assess permit applications, having a range of potential values of plant yields and densities for farms across the harvesting zone. Knowing the location of harvest areas has also alerted the officer to possible illegal harvest in protected areas where permits are granted for harvesting on adjacent privately owned land.

6.5 Limitations and future research

6.5.1 Limitations

The lack of detailed data for the Western Cape and missing data for some of the Eastern Cape farms where harvesting takes place is a limitation of the research because it reduces the accuracy of estimating the size of the utilised resource. The value of mapped data captured for this research has proved beneficial in assessing the size (spatial extent), utilised resource extent and associated livelihood value for harvesters. A paucity of data on some areas provides a good motivation for developing a permit system or self-regulation by industry stakeholders, for all honeybush harvesting and processing. This would ensure the traceability of harvested material from its origin to final product output. Likewise, the availability of harvest history data was limited to harvest enterprises with records who were willing to share them. The data that was collected was useful, but a larger set of records with further detail of yields for each harvest area on all farms would have allowed for a more rigorous comparison of the harvest team types and their harvest practice in relation to changing yields.

While a significant effort was made to include as many possible stakeholders in the workshop and in all aspects of the research dealing with the collection of TEK and LEK, some stakeholders who may have wished to participate, did not. For example, methods of harvest practised by harvesters in the Plettenberg Bay area, on the wet, southern Tsisikamma slopes, are slightly different, as are the methods of harvesters in the Elands Valley harvesting areas. This information was not formally recorded. There was limited representation of young, inexperienced harvesters, who might have benefitted from being involved in the process.

A resource inventory of a plant distributed across 11 496 km^2 of mountainous terrain in the notoriously heterogeneous landscape of the Fynbos is a big undertaking in terms of the ground that must be covered. Known gaps in the data coverage include the south-facing slopes of the Tsitsikamma, the Kammanassie mountains (all in protected areas, therefore no harvesting takes place) and the Elands Valley (harvested).

The commercial honeybush industry is young – commercial-scale harvesting and processing only began in the late 1990's. Many of the surveyed populations had only been harvested 3–5 times. Given that a plant can live for about 35 years it may be that the kind of effects which might cause populations to decline (such as reduced fecundity), have not yet manifested in the populations surveyed.

Other threats to the species' persistence were not considered. Alien invasive plants (IAPs) were recorded at several survey sites and are common in parts of the distribution range, but their actual effect on *C. intermedia* populations was not determined. Impacts such as climate change and associated changing fire regimes were also not considered.

6.5.2 Future research

There is a need to monitor the use of the honeybush resource from production through to processing and primary sales. Given the small number of harvest teams and the fact that only three processors (situated in the Eastern Cape Langkloof) handle wild-harvested material, it would be possible to establish a high level of traceability of harvested material. Traceability would ensure compliance with international biotrade standards and contribute to premium rates for organic, sustainably harvested *C. intermedia*. Since processors are obliged to keep accurate records for certification purposes, the development of a system of traceability could be founded on improving what is already in place.

Further research should include identifying gaps that need to be filled for monitoring purposes. Long-term monitoring of harvested and unharvested populations considering fecundity and seedling recruitment would give insights into the impacts of harvesting on population persistence. This research only considered the effect of harvesting, other stressors in the system – such as invasive alien plants (IAPs), climate change, changing fire regimes and land transformation were not accounted for. Several stressors may be present at any one time at low intensity, without causing any evident impact on an ecosystem, but "stressor ensembles" (Simmons et al., 2021) in particular combinations can produce unpredictable responses. The effect of some stressors can be monitored using desktop methods (e.g., GIS, remote sensing, spatial modelling). Still, their actual impact on populations would need to be measured (e.g., how does the form, abundance, and yield of *C. intermedia* plants change when competing with IAP's?).

To reduce the effects of harvesting on plant vigour, it may help to improve the timing of harvests (currently determined by demand, suitable weather conditions, and availability of harvesters) using knowledge of the phenology of *Cyclopia* spp., which has been established for cultivated *Cyclopia* spp. While some teams harvest for visibility when plants are in flower, it should be possible to develop an optimal harvest timing to put the least strain on the plant. This could be informed by the kind of horticultural work carried out by Karsen et al., (2022), who investigated the best time to harvest for cultivated species.

6.6 Is the harvesting of wild *C.intermedia* sustainable?

From an ecological perspective, the effects of harvesting on populations surveyed for this research were not found to be detrimental to the vigour of *C. intermedia* plants. However, fecundity of plants in harvested populations was found to be lower than that of unharvested populations, and this may have longer-term implications for the persistence of harvested populations. In economic terms (for the farmer, harvest manager and harvesters), declining yields on farms harvested by a large contract team, working to a 50% cropping at 18-month intervals (i.e., harvest of three-year-old plants) is unsustainable. The finding that cultivated *C. intermedia* plants decline after 12 years based on three-year harvest intervals, confirms the need to do away with short-interval harvesting, if harvesting is to be sustainable. In economic terms, this may reduce income for the farmer and the harvester, but in ecological terms, the populations will likely persist. The damage done to a population under unregulated, frequent cropping, which led to a decline of the population and a reduction in economic value by 80%, clearly indicates that unregulated harvesting is unsustainable. From a social and economic perspective, the size and type of harvester team affect the potential for harvesters to earn a fair livelihood: harvesters in smaller teams have greater earning opportunities.

The conclusions drawn in this research are based on data collected and analysed using a mixed methods approach, which tells a richer story than one with a singular modus. While the value of using TEK and LEK was realised in this research, without scientific data collection and analysis methods, it would not have been possible to produce answers supported by data, to the questions raised in this thesis.

The harvesting of wild *C. intermedia* still makes a significant contribution to the industry annually. More importantly, *C. intermedia* is the "Gold standard" for honeybush, which fetches a higher price at all levels of the value chain. The C. intermedia wild resource will always yield a high-value, organic product if used sustainably. It will provide livelihoods – particularly for traditional harvesters and local ecological knowledge holders with a lifetime of knowledge and experience linked to using the plant. Additionally, good management practices linked to the sustainable use of the resource can positively impact habitat conservation in the surrounding areas. There is potential for market growth with the promotion of geographic indicator status, use in the alcoholic beverages industry, use as a nicotine carrier in the tobacco industry, and potential pharmaceutical and nutraceutical uses.

6.7 References

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Appendix 2a: Protected Areas where *C. intermedia* occurs (DFFE, 2023)

World Heritage Site	Date of declaration
CFR Protected Areas: Baviaanskloof	2009/01/30
CFR Protected Areas: Swartberg Complex	2009/01/30
National Park	
Garden Route National Park	1964/12/04
Mountain Catchment Area	
Anysberg Mountain Catchment Area	1978/09/29
Groot Swartberg Mountain Catchment Area	1978/09/29
Klein Swartberg Mountain Catchment Area	1978/09/29
Kammanassie Mountain Catchment Area	1978/09/29
Swartberg-Oos Mountain Catchment Area	1978/09/29
Rooiberg Mountain Catchment Area	1978/09/29
Langeberg-Wes Mountain Catchment Area	1979/11/02
Langeberg-East Mountain Catchment Area	1981/10/09
Forest Wilderness Area	
Doringrivier Wilderness Area	1988/05/20
Nature Reserve	
Loerie Nature Reserve	1976/01/26
Whiskey Creek Nature Reserve	1984/12/07
Attakwaskloof Nature Reserve	1986/07/25
Kleinberg Private Nature Reserve	1987/07/03
Van Stadens River Wild Flower Reserve	1963/04/19
Blouberg Protea Nature Reserve	1989/06/02
Anysberg Provincial Nature Reserve	1990/08/17
Kouga Private Nature Reserve	1992/03/20
Tenax Private Nature Reserve	1992/07/24
Gamkapoort Nature Reserve	1992/10/09
Sepree Rivier Private Nature Reserve	1993/03/05
Gamka Mountain Provincial Nature Reserve	1994/05/06
Gamkaskloof Provincial Nature Reserve	1994/05/06
Sustersdal_Private_Nature_Reserve.pdf	1996/01/12
The Fort Local Nature Reserve	1996/04/19
Taayskloof Private Nature Reserve	1998/12/04
Die Poort Private Nature Reserve	2001/07/06
Swartberg Private Nature Reserve	2002/08/08
Groenefontein Provincial Nature Reserve	2008/08/01
Wolwekop Nature Reserve	2009/05/08
Blue Hill Nature Reserve	2013/09/20
Rooiolifantskloof Nature Reserve	2014/01/10
Baviaanskloof Hartland Nature Reserve	2014/03/17
Kromme Riviers Hoogte Nature Reserve	2014/03/17
Sedarkloof Nature Reserve	2015/05/08
Baviaanskloof Nature Reserve	2016/03/04
Skilderkrantz Nature Reserve	2016/03/04
Wildealsvlei Nature Reserve	2019/03/29
Formosa Nature Reserve	

Appendix 3a: List of stakeholders interviewed to gather information about the harvest.

Code	Role	Format of engagement	Harvest area
JH1	Harvest manager	Interview in field	Langkloof
JH2	Harvest manager	Interview in field	Langkloof
PVR	Harvester/manager	Interview @ home	Joubertina, middle Langkloof
SF	Harvester/manager	Interview @ home	Tsitsikamma
CS	Harvester/manager	Interview in field and @ home	Bo Kouga, Uniondale area
IK	Harvester/manager	Workshop and interview in field	Tsitsikamma
JL	Harvester/manager	Workshop	Bo Kouga, Haarlem
DD	Harvester/manager	Workshop	Bo Kouga, Haarlem
QW	Harvester	Workshop and interview in field	Eastern Kouga
GS	Harvester	Workshop and interview in field	Eastern Kouga
BD	Harvester	Workshop and interview in field	Louterwater
HJ	Harvester	Interview in field	Eastern Kouga
AT	Harvester	Interview in field	Eastern Kouga
PL	Harvester	Interview in field	Eastern Kouga
MC	Harvester	Workshop	Joubertina
SL	Harvester	Workshop	Joubertina
GB	Harvester	Interview in field	Bo Kouga, Uniondale area
KB	Harvester	Interview in field	Bo Kouga, Uniondale area
BH	Harvester	Interview in field	Bo Kouga, Uniondale area
FH	Harvester	Interview in field	Joubertina
JK	Harvester	Interview in field	Joubertina
TK	Farmer	Interview in field and @ home	Joubertina
QN	Farmer	Interview in field and @ home	Eastern Kouga
ES	Farmer	Interview @ home	Baviaanskloof
NF	Farmer	Interview @ home	Onder-Kouga
EG	Farmer	Workshop	Onder-Kouga
CM	Farmer	Interview @ home	Middle Langkloof
PN	Farmer	Interview @ home	Joubertina
CH	Farmer	Interview @ home	Upper Krom
GF	Farmer	Interview @ home	Onder-Kouga
BD	Farmer	Interview @ home	Bo-Kouga
DH	Farmer	Interview @ home	Bo-Kouga
KD	Farmer	Interview @ home	Uniondale area
QN	Processor	Workshop, interview in field and @ home	Eastern Kouga
MV	Processor	Interview @ factory	WC
VJ	Processor	Interview @ factory	WC
GF	Processor	Workshop, interview @ factory	Joubertina
MB	Processor	Workshop	Langkloof
HA	Processor	Workshop, interview @ home	Humansdorp

Appendix 3b: Harvester worksheet

Western Cape Government	EADP 696: DEVELOPMENT OF GUIDELINES FOR THE SUSTAINABLE HARVESTING OF WILD HONEYBUSH A project initiated by the Department of Environmental Affairs and Development Planning

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DEVELOPMENT OF GUIDELINES FOR THE SUSTAINABLE HARVESTING OF WILD HONEYBUSH

HARVESTER WORKSHEET

The purpose of these worksheets is to record the range of knowledge from individual role players in the wild honeybush harvesting industry. We will then have small group discussions around each of the topics on this worksheet in order to gain a better understanding of everyone's knowledge. The information will be treated confidentially and will be presented anonymously in the report.

1. Background information

a) Your name

b) What is your role in the honeybush industry? (may be more than 1 role). Put a X in the box which best describes what you do.

Harvest manager (organises team, permit, transport, logistics, does not necessarily harvest, often a retired, older harvester)	**Harvest leader** (actively harvest, trains the team, experienced)	**Harvester** (one of the team members)	**Other?**

c) What species do you harvest? To indicate what species your team harvests, check the boxes below and indicate the approximate proportion of the annual harvest weight per species, per year as a percentage.

Bergtee / *C. intermedia*	Vleitee / *C. subternata*	Genadendal tee / *C. maculata*	*C. Plicata*
%	%	%	%

d) Are you currently harvesting? If so, would we be able to make an arrangement go out on a harvest on your farm during the period 7-24 Feb? Indicate by checking a box below.

Yes	No	Possible date:

2. Your team

To describe the make-up of your team, fill in the information in the boxes below .

No. of team members	No. Male: No. of Female:	Age range of team members:	Type of harvest team	
			Independent contract harvest team	Employed on a farm, harvesting is part of your job

WORKSHEET: HARVESTER 1/6

3. Harvesting experience a) Where or how did you learn to cut honeybush?	
b) How long have you been harvesting ? (no of years)	

c) Is this a full time occupation?	Yes	No	If 'no, what is your other occupation?

d) How many days per week do you harvest?		e) How many weeks per year do you harvest?	

f) Where do you harvest? Can you name the farms or landowners and the nearest towns.

g) Do you keep the same harvest sites from year to year?	Yes	No	Explain your answer.

What is your harvest interval ie: how often do you visit the same site?	Every year	Every 1- 2 years	After 3 years	After 4 years

4. The harvest process Fill in the information in the boxes below to help you describe a typical harvest day from leaving home in the morning to the end of the day when you off load the harvest.

a) Travel distance in km To furthest site: To closest site: On average:	b) Walking distance: after you arrive at the site in your bakkie, long does it typically take to walk to the actual harvest site? Describe the range of values.
c) On average, how many hours do you harvest for?	d) How heavy is the average load that you carry?
e) How many loads do you carry in a day?	f) On average, what is your total harvest load per day?

5. Plant and harvesting knowledge (NOTE: species specific)

In terms of your knowledge of the harvesting of honeybush, address the queries in each of the boxes, for *bergtee* and if relevant, for *vleitee*. If the question is irrelevant, cross it out.

A. Bergtee/*C. Intermedia*

a) Harvestable plant age	b) Size of plant: Height/stem length	c) No of stems	d) Colour of stems	e) Diameter of stems

Are there reasons for the figures/ choices given above? If so, explain briefly.

a

b

c

d

e

f) Do you harvest when in flower? Why/Why not?

g) Do you cut the whole plant or part of the plant and why?

B. Vleitee/*C. subternata*

a) Harvestable plant age	b) Size of plant: Height/stem length	c) No of stems?	d) Colour of stems	e) Diameter of stems

Are there reasons for the figures/ choices given above? If so, explain briefly.

a

b

c d e
f) Do you harvest when in flower? Why/Why not?
g) Do you cut the whole plant or part of the plant and why?

h) Put a cross in the box below to indicate which tool you prefer to use		
Secateurs	Sickle	Why do you choose this tool?
i) Are there any other factors to consider when deciding whether to harvest a plant or not? Please list them		

6. Harvesting of seed a) Do you harvest seed?	No	Yes
If yes, name the species and describe your method.		
b) What do you do with the seed? Check the relevant box.	Own use for seedlings	For sale
7. Experience of being a harvester a) What are the things you like the most about being a honeybush harvester?		

b) What are some of the problems you face being a harvester? List and describe some of them.
8. Problems and threats to/in the wild honeybush harvesting industry c) Based on your knowledge and experience, what are some of the threats and issue that you see in the wild harvesting honeybush industry?

9. Monitoring, permitting and legislation a) Do you think that a permitting system for wild honeybush harvesting is a good thing?	Yes	No
Explain your answer.		
b) Having an agreement with a landowner to harvest on their land is important, suggest what you think are the most important aspects to cover in an agreement.		

10. Linking experience to guidelines

a) Based on your knowledge and experience, list aspects of the wild honeybush industry which you think should be included in the guidelines for the sustainable harvesting of wild honeybush.

b) Explain or expand on some of these ideas.

11. The way forward

a) Who should be in charge of monitoring and managing the sustainable harvesting of honeybush and why?

b) Do you, at least in principle support the implementation of guidelines aimed at ensuring the sustainability of the wild harvested honeybush industry?	Yes	No	Maybe

12. New contacts and comments

a) Do you know of anyone whom we should contact with regards to the development of these guidelines who may not have been included thus far? Please supply their name/organisation/contact details.

b) If you have any additional information you would like to contribute, feel free to do so....

WORKSHEET: HARVESTER 6/6

Appendix 3c: Landowner/landuser/farmer worksheet

Western Cape Government EADP 696: DEVELOPMENT OF GUIDELINES FOR THE SUSTAINABLE HARVESTING OF WILD HONEYBUSH A project initiated by the Department of Environmental Affairs and Development Planning **Project Manager:** Albert Arthur Ackhurst, Head of Component, Biodiversity Tel: 021 483 8364 E-mail: Albert.Ackhurst@westerncape.gov.za	**Service Provider** Caroline Gelderblom Consulting **Project Leader** Gillian McGregor, Dept. of Geography,Rhodes University, Grahamstown Email: g.k.mcgregor@ru.ac.za; Tel: 083 399 3888

DEVELOPMENT OF GUIDELINES FOR THE SUSTAINABLE HARVESTING OF WILD HONEYBUSH

LANDOWNER/LANDUSER/FARMER WORKSHEET

The purpose of these worksheets is to record the range of knowledge from individual role players in the wild honeybush harvesting industry. We will then have small group discussions around each of the topics on this worksheet in order to gain a better understanding of everyone's knowledge. The information will be treated confidentially and will be presented anonymously in the report.

1. Background information

a) Your name

b) The name of your farm and the locality.

c) Size of the farm in hectares.

d) Check the description which best describes your wild honeybush harvesting operation:

Resident harvest team on farm	Harvest team contracted to harvest	Have honeybush on farm but do not harvest	Other?

e) What is the approximate area of wild honeybush that is accessible to harvest on your farm?	Area in ha

f) To indicate what species you harvest, check the boxes below and indicate the approximate % harvest weight per species, per year as a percentage.

Bergtee /*C. intermedia* %	Vleitee / *C. subternata* %	Genadendal tee / *C. maculata* %	*C. Plicata* %

f) Are you currently harvesting? If so, would we be able to make an arrangement go out on a harvest on your farm during the period 7-24 Feb? Indicate by checking a box below.

Yes	No	Possible date:

LANDOWNER/LANDUSER/FARMER WORKSHEET 1/7

2. Honeybush harvest history on your land Describe the history of the use of wild honeybush use on your land:			
a) No of years of harvesting (time period)	b) Approx. total average yield per year	c) What % of your farm turnover per year comes from honeybush?	
d) Have you noticed changes in the yield of honeybush from areas on your land, over time? If so, describe those changes and give a reason why this might be so.			
e) If the value of wild honeybush increased, would you or could you, increase your annual harvest ?		Yes	No
f) If 'yes,' do you believe you can do this safely without impacting the sustainability of the wild honeybush? Explain your reasoning.			
3. The harvest a) How often do you visit the same harvest site? (harvest interval) b) Do you stick to a particular time of year for harvesting? If so, why? c) Do you choose particular weather conditions for harvest days? If so, why? d) Approximately how long is your harvest period per year? (Total no of days)			

e) What is the harvest team size?

f) Do you ever go out and check the teams at work?

g) Do you check the actual harvest load? If yes, what do you check for?

h) Do you use fire to manage your honeybush lands? If you do, briefly describe how your fire management approach.

i) Do you have a formal plan for managing your wild honeybush harvesting? If yes, briefly outline the aspects you consider in your plan.

4. Plant and harvesting knowledge (NOTE: species specific)
In terms of your knowledge of the harvesting of honeybush, address the queries in each of the boxes, for *bergtee* and if relevant, for *vleitee*. If the question is irrelevant, cross it out.

A. Bergtee/*C. Intermedia*

a) Harvestable plant age	b) Size of plant: Height/stem length	c) No of stems?	d) Colour of stems	e) Diameter of stems

f) Do you harvest when in flower? Why/Why not?

g) Do you cut the whole plant or part of the plant and why?

B. Vleitee/*C. subternata*				
a) Harvestable plant age	b) Size of plant: Height/stem length	c) No of stems?	d) Colour of stems	e) Diameter of stems

f) Do you harvest when in flower? Why/Why not?
g) Do you cut the whole plant or part of the plant and why?

h) What tool do your teams use and why?	
Secateurs	Sickle

i) Do you actively teach the harvesters these things? Fill in your answer in the boxes below.		
Yes, briefly explain your approach.	No	I expect the contracted team to have this knowledge

j) Are there any other factors to consider when deciding whether to harvest a plant or not?
5. Harvest infrastructure a) How do you transport the harvest? b) Do you put in roads/tracks specially for honeybush? c) Do you use slides? d) What is the average harvest weight of wild honeybush harvested per day?

e) Which factory do you supply? f) Does the factory collect from you?		
6. Harvesting of seed a) Do you harvest seed on your farm?	No	Yes
If yes, name the species and describe your method.		
b) What do you do with the seed? Check the relevant box.	Own use for seedlings	For sale
7. Problems and threats to/in the wild honeybush harvesting industry a) List and explain some of the threats and issue that you have knowledge of, or have had to deal with.		
b) What do you think is the single largest threat to the wild honeybush industry?		
8. Monitoring, permitting and legislation The EC has a permitting system for the harvesting of an approximate annual declared tonnage of *bergtee* and/or *vleitee*, cultivated or wild harvested, for harvesters and farmers/landowners. In the WC, a permit is required to pick or transport any fynbos flora, but the plant species is not specified nor is the quantity. a) Do you think that the permitting system in the EC is worthwhile? Comment on positive and negative aspects. b) Can you suggest how this approach should be improved or better co-ordinated?		

LANDOWNER/LANDUSER/FARMER WORKSHEET 5/7

d) Who should monitor and enforce this permitting?

e) If the granting of a permit to harvest wild honeybush is dependent on the landowner supplying a management plan, outline what you think would feasible for a landowner to produce (without the services of a specialist).

10. Linking experience to guidelines

a) Based on your knowledge and experience, list aspects of the wild honeybush industry which you think should be included in the guidelines for the sustainable harvesting of wild honeybush.

b) Explain or expand on some of these ideas.

11. The way forward a) Who should be in charge of monitoring and managing the sustainable harvesting of honeybush and why?			
b) Do you, at least in principle support the implementation of guidelines aimed at ensuring the sustainability of the wild harvested honeybush industry?	Yes	No	Maybe
If you answered 'maybe,' please explain.			
12. New contacts and comments a) Do you know of anyone whom we should contact with regards to the development of these guidelines who may not have been included thus far? Please supply their name/organisation/contact details. b) If you have any additional information you would like to contribute, feel free to do so….			

LANDOWNER/LANDUSER/FARMER WORKSHEET 7/7

Appendix 3d: Processor worksheet

Western Cape Government
EADP 696: DEVELOPMENT OF GUIDELINES FOR THE SUSTAINABLE HARVESTING OF WILD HONEYBUSH
A project initiated by the Department of Environmental Affairs and Development Planning
Project Manager: Albert Arthur Ackhurst, Head of Component, Biodiversity
Tel: 021 483 8364 E-mail: Albert.Ackhurst@westerncape.gov.za

Service Provider Caroline Gelderblom Consulting
Project Leader Gillian McGregor, Dept. of Geography,Rhodes University, Grahamstown
Email: g.k.mcgregor@ru.ac.za; Tel: 083 399 3888

DEVELOPMENT OF GUIDELINES FOR THE SUSTAINABLE HARVESTING OF WILD HONEYBUSH

WORKSHEET: PROCESSOR

The purpose of these worksheets is to record the range of knowledge from all those individual role players in the wild honeybush harvesting industry. We will then have small group discussions around each of the topics on this worksheet in order to gain a better understanding of everyone's knowledge. The information will be treated confidentially and will be presented anonymously in the report.

1. Background information

a) Your name.

b) The name of your factory and the locality.

2. Production

a) How many tons of honeybush do you process per year and how has your processing volume changed over the period that the processing plant has been in operation? Use the boxes below to indicate changes in processing volume over time at your processing plant. Edit the dates if necessary.

Start (or around 2000)		2005	2010	2016
Wild (% or tons)				
Cultivated (% or tons)				

b) To what do you attribute these changes? Briefly explain the main reasons.

c) Do you need wild tea, even if in time the cultivated sector produces enough volume? Explain why you need wild honeybush.

d) What species of wild honeybush do you process? Check the boxes below and indicate the approximate % intake weight per species, per year as a percentage (give values for 2016)			
Bergtee /*C. intermedia* %	Vleitee / *C. subternata* %	Genadendal tee / *C. maculata* %	*C. plicata* %
3. Processing standards In order for processing to be efficient, what do you require in terms of 'standards' that the incoming crop must meet? Use the boxes below to record what you require of the wild crop.			
State of the plants			
a) Age of plant	b) Diameter of stems	c) Flowers present/absent	d) Colour of stems
e) Are there any other factors relating to the plant that are important to consider?			
f) How do you ensure that these standards are met at your processing plant?			
4. The nature of wild crop supply What are some of the issues associated with dealing with a wild crop? Use the headings below, and briefly comment on them. a) Reliability of supply b) Quality of harvested material			

WORKSHEET: PROCESSOR 2/4

b) Health and safety standards

d) Permitting

e) Any other issues?

5. Monitoring, permitting and legislation

a) Given the small number of honeybush processing plants through which all honeybush must pass, the processing stage is the obvious place to implement monitoring, permitting and legislation related to the harvesting of wild honeybush. Are you prepared to be involved in this type of operation, in principle, and provided it is not too onerous?

Yes	No	Maybe

If you answered 'maybe' what conditions would need to be in place for you to agree?

6. Linking experience to guidelines

b) Given your experience in and knowledge of the industry, do you have some ideas about some (simple) management procedures that could be included in the guideline that might be monitored by the processor when the harvest load is delivered, that would contribute to the sustainability of the wild honeybush harvesting? Please share your ideas.

7. The way forward

a) Do you, at least in principle support the implementation of guidelines aimed at ensuring the sustainability of the wild harvested honeybush industry?

Yes	No	Maybe

If you answered 'maybe' what conditions would need to be in place for you to agree?

b) Who should be in charge of monitoring and managing the sustainable harvesting of honeybush and why?

8. New contacts and comments

a) Do you know of anyone whom we should contact with regards to the development of these guidelines who may not have been included thus far? Please supply their name/organisation/contact details.

b) If you have any additional information you would like to contribute, feel free to do so....

Western Cape Government

EADP 696: DEVELOPMENT OF GUIDELINES FOR THE SUSTAINABLE HARVESTING OF WILD HONEYBUSH
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WORKSHEET: PROCESSOR

The purpose of these worksheets is to record the range of knowledge from all those individual role players in the wild honeybush harvesting industry. We will then have small group discussions around each of the topics on this worksheet in order to gain a better understanding of everyone's knowledge. The information will be treated confidentially and will be presented anonymously in the report.

1. Background information

a) Your name.

b) The name of your factory and the locality.

2. Production

a) How many tons of honeybush do you process per year and how has your processing volume changed over the period that the processing plant has been in operation? Use the boxes below to indicate changes in processing volume over time at your processing plant. Edit the dates if necessary.

	Start (or around 2000)	2005	2010	2016
Wild (% or tons)				
Cultivated (% or tons)				

b) To what do you attribute these changes? Briefly explain the main reasons.

c) Do you need wild tea, even if in time the cultivated sector produces enough volume? Explain why you need wild honeybush.

d) What species of wild honeybush do you process? Check the boxes below and indicate the approximate % intake weight per species, per year as a percentage (give values for 2016)			
Bergtee /*C. intermedia* %	Vleitee / *C. subternata* %	Genadendal tee / *C. maculata* %	*C. plicata* %
3. Processing standards In order for processing to be efficient, what do you require in terms of 'standards' that the incoming crop must meet? Use the boxes below to record what you require of the wild crop.			
State of the plants			
a) Age of plant	b) Diameter of stems	c) Flowers present/absent	d) Colour of stems
e) Are there any other factors relating to the plant that are important to consider?			
f) How do you ensure that these standards are met at your processing plant?			
4. The nature of wild crop supply What are some of the issues associated with dealing with a wild crop? Use the headings below, and briefly comment on them. a) Reliability of supply b) Quality of harvested material			

WORKSHEET: PROCESSOR 2/4

b) Health and safety standards

d) Permitting

e) Any other issues?

5. Monitoring, permitting and legislation

a) Given the small number of honeybush processing plants through which all honeybush must pass, the processing stage is the obvious place to implement monitoring, permitting and legislation related to the harvesting of wild honeybush. Are you prepared to be involved in this type of operation, in principle, and provided it is not too onerous?

Yes	No	Maybe

If you answered 'maybe' what conditions would need to be in place for you to agree?

6. Linking experience to guidelines

b) Given your experience in and knowledge of the industry, do you have some ideas about some (simple) management procedures that could be included in the guideline that might be monitored by the processor when the harvest load is delivered, that would contribute to the sustainability of the wild honeybush harvesting? Please share your ideas.

WORKSHEET: PROCESSOR 3/4

7. The way forward

a) Do you, at least in principle support the implementation of guidelines aimed at ensuring the sustainability of the wild harvested honeybush industry?

Yes	No	Maybe

If you answered 'maybe' what conditions would need to be in place for you to agree?

b) Who should be in charge of monitoring and managing the sustainable harvesting of honeybush and why?

8. New contacts and comments

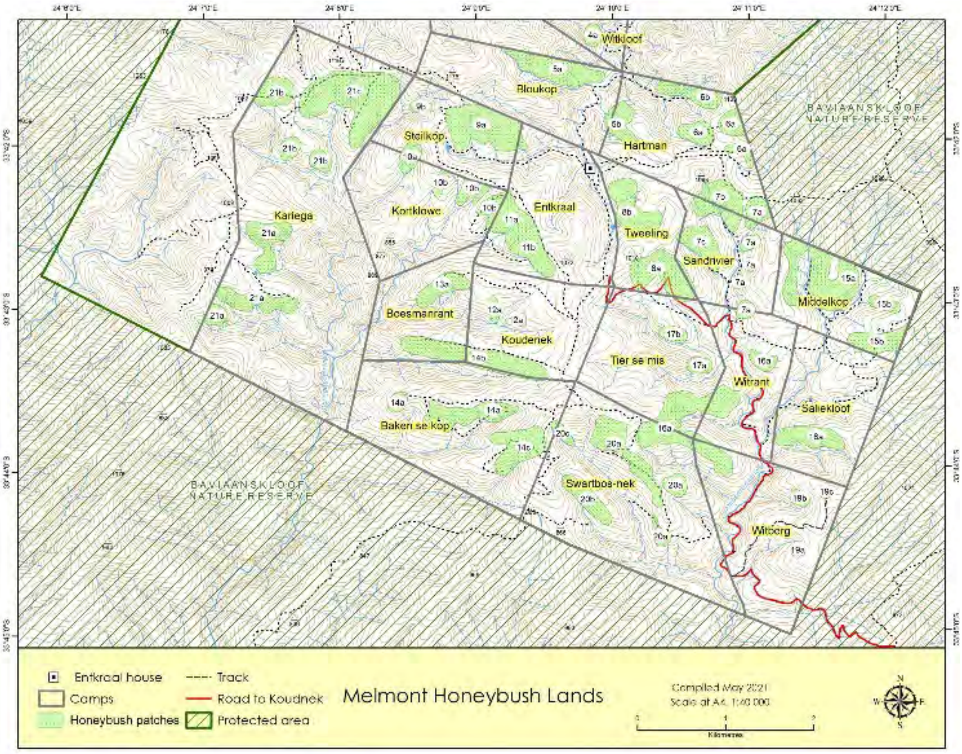
a) Do you know of anyone whom we should contact with regards to the development of these guidelines who may not have been included thus far? Please supply their name/organisation/contact details.

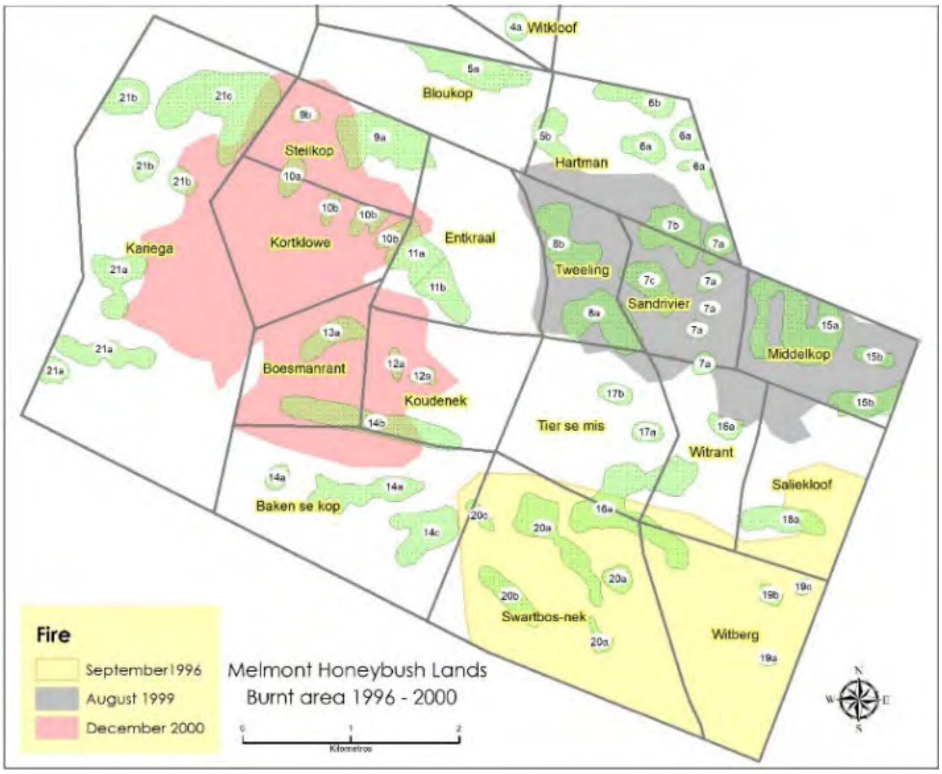
b) If you have any additional information you would like to contribute, feel free to do so....

Appendix 5a: Melmont fires - 1996 to 2021

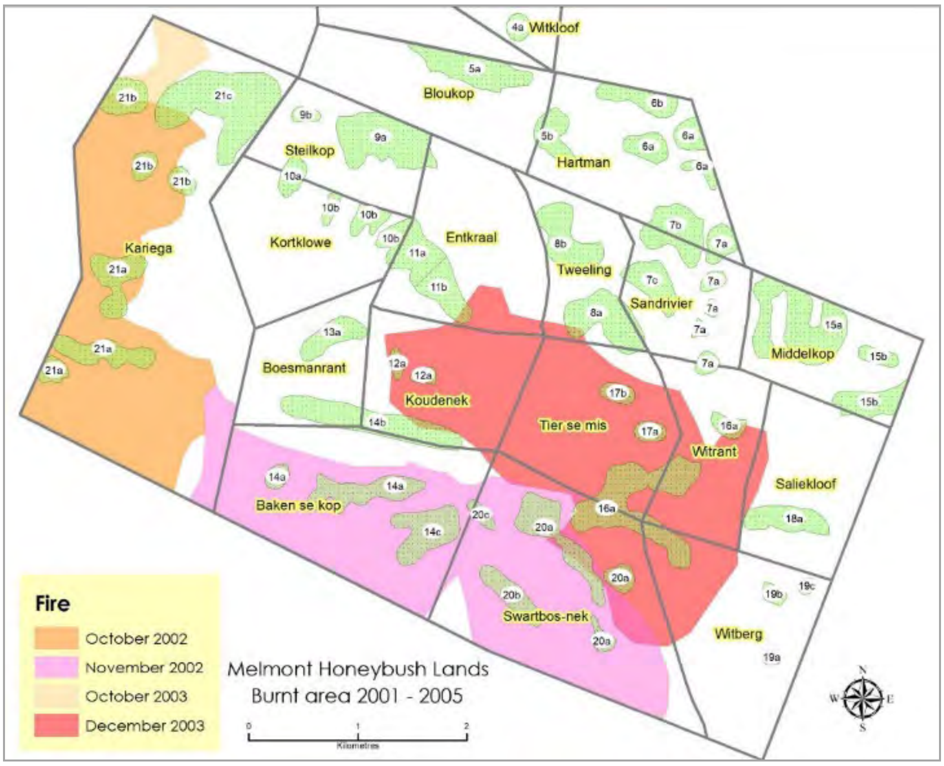
Notes and maps, prepared on request for E. Nortje for input to organic certification documentation.

May 2021, G.K. McGregor, Rhodes University, Makhanda.

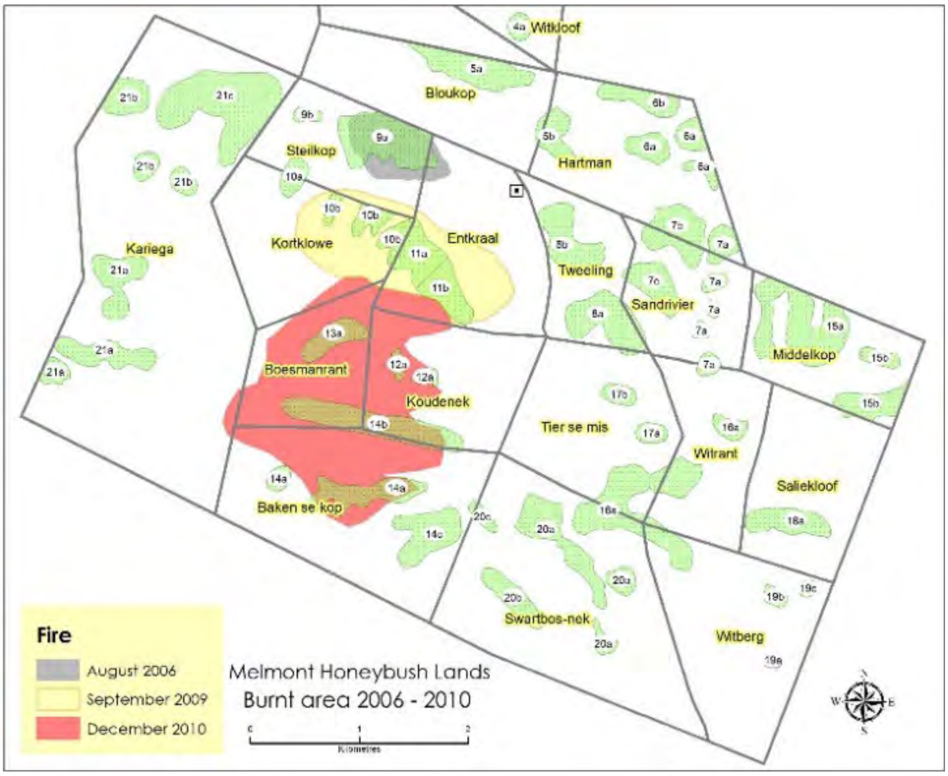


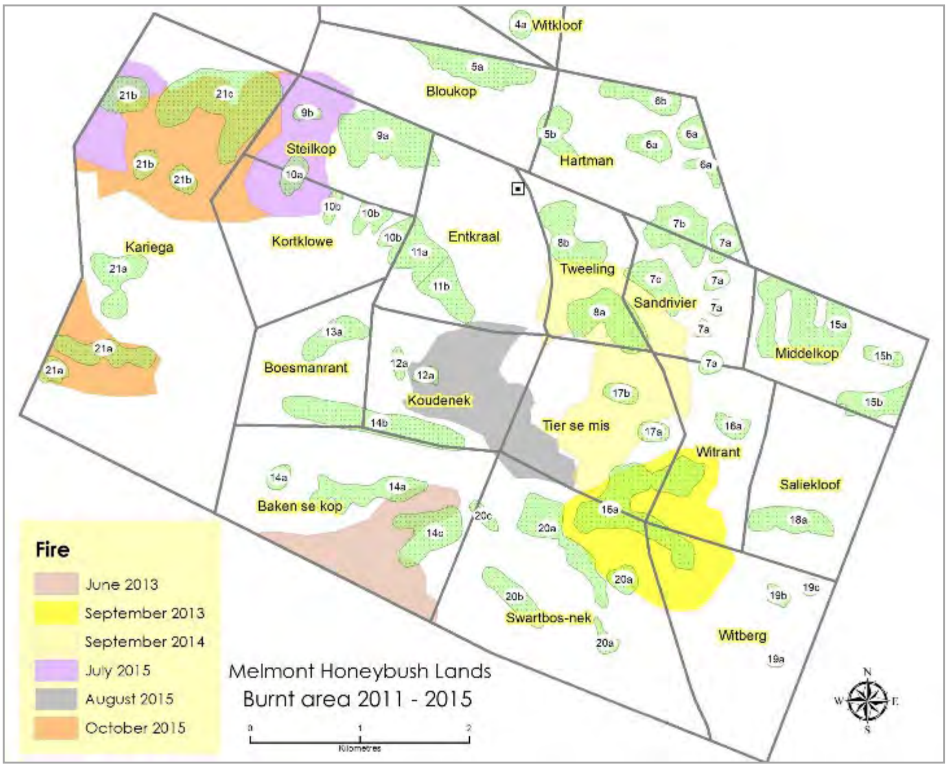


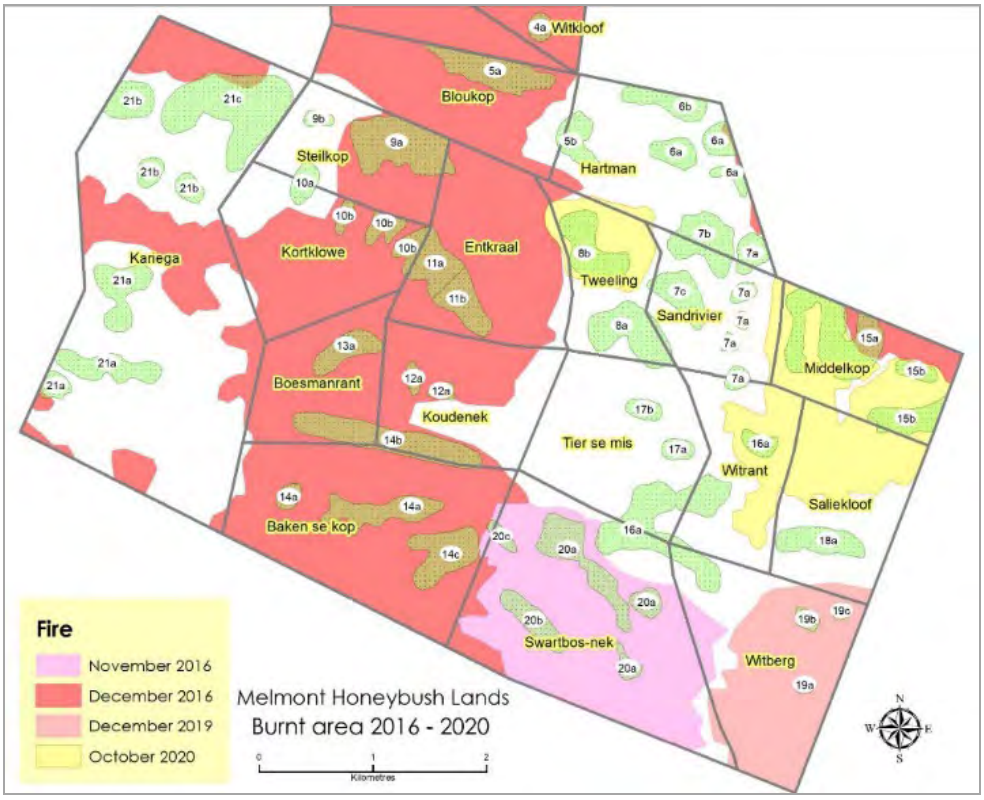
Fire
September1996
August 1999
December 2000
Melmont Honeybush Lands
Burnt area 1996 - 2000
Witkloof
Bloukop
Hartman
Steilkop
Kortklowe
Entkraal
Kariega
Tweeling
Sandrivier
Middelkop
Boesmanrant
Koudenek
Tier se mis
Witrant
Saliekloof
Baken se kop
Swartbos-nek
Witberg



Fire
October 2002
November 2002
October 2003
December 2003
Melmont Honeybush Lands
Burnt area 2001 - 2005
Witkloof
Bloukop
Hartman
Steilkop
Kortklowe
Entkraal
Kariega
Tweeling
Sandrivier
Middelkop
Boesmanrant
Koudenek
Tier se mis
Witrant
Saliekloof
Baken se kop
Swartbos-nek
Witberg


Witkloof
Bloukop
Steilkop
Hartman
Kortklowe
Entkraal
Kariega
Tweeling
Sandrivier
Middelkop
Boesmanrant
Koudenek
Tier se mis
Witrant
Saliekloof
Baken se kop
Swartbos-nek
Witberg
Fire
August 2006
September 2009
December 2010
Melmont Honeybush Lands
Burnt area 2006 - 2010
0
1
2
N
W
E
S


Witkloof
Bloukop
Steilkop
Hartman
Kortklowe
Entkraal
Kariega
Tweeling
Sandrivier
Middelkop
Boesmanrant
Koudenek
Tier se mis
Witrant
Saliekloof
Baken se kop
Swartbos-nek
Witberg
Fire
June 2013
September 2013
September 2014
July 2015
August 2015
October 2015
Melmont Honeybush Lands
Burnt area 2011 - 2015
0
1
2
N
W
E
S



Data creation

Honeybush patches

Honeybush patches were created by 'expert' mapping by Q. Nortje on a base map prepared at 1: 20 000. The mapsheets were geo-referenced and heads-up digitised as polygons in ArcMap10.6. Area 'codes' were updated in April 2021 by Q. Nortje and S. Nortje. Area codes and patch delineation align with the farm harvesting plan where harvest yield and processed yield are collated per harvest area.

Fire history

Identification of burn area and date of burn on Melmont farm was based on preliminary mapping using MODIS fire data 2001 to 2020 (accounts for about 80% of fires). This was followed by more focussed, detailed mapping of burn scars from various images from different platforms at the relevant dates. All imagery was downloaded via the USGS GloVis application, https://glovis.usgs.gov/app# as follows:

- For the period 1996 to 2012 Landsat 4-5 Thematic Mapper (TM) Level-1;
- For the period March 2013 to March 2015 Landsat 8;
- From March 2015 to December 2020 – Sentinel2.

There is a period in 2011 -2013 where imagery is unavailable or very poor due to Landst7ETM failure and fires in this period may not be well represented. Fire extents and occurrence were checked with the farmer. Only fires that affect honeybush areas were recorded – some smaller fires do occur that are not represented.

The date of a fire is taken as the date of the first image with a clearly visible burnt area. Sometimes it may be a month or two before a suitable image can be identified (due to cloud cover, sensor malfunction *etc*). If another fire occurs in that period – it may appear to be part of the first fire and will get classified as such.

Where fires burn within the boundaries of the Melmont farm – the **Total burnt area (ha)** is given as well as the **Area of honeybush burnt (ha)**. (*Melmont_fire_year_ha_comments.xls*). If a fire burns beyond the farm boundary – only the burnt area within the farm is given. Fires which do not affect the honeybush patches are not recorded.

Harvest practices
The total area of honeybush in use on Melmont is 668,7ha.

The period of detailed harvest history is 2000 to 2020 (Excel spreadsheet). Harvesting took place before with demand picking up in the mid to late 90's. In 1995 Melmont sent their first large export consignment to Japan (8 tons). They currently have organic certification for 25 tons, which means a harvest of about 45,5 tons of wet material per year, given a moisture loss in processing of 45%.

The harvest takes place every one to two weeks, weather permitting. The honeybush truck can take a 1300kg load and the harvest team of 11 to 13 harvesters can bring in a load of this size in a day under reasonable working conditions. Based on these figures - they need about 30-35 harvest days per year to bring in their annual 45-ton harvest. They harvest in response to demand – so in some years the tonnage is much lower. All harvest sites are accessible by vehicle along tracks put in for that purpose, so the harvesters can concentrate on harvesting rather than carrying. The factory can process a 1300kg load per week (cutting, fermenting, drying) but there is room for expansion of this volume.

Standard practice is to harvest every 4 years. This is adjusted according to the farmer's assessment of the state of the tea. Post-fire the tea sprouts abundantly and may appear ready for harvest after a shorter interval, but must be given time to mature to produce good-quality tea. In the event of drought – a farmer may choose to extend the harvest interval to give the plants more time to recover.

Harvested honeybush patches
In terms of harvest – patch details include the farm name (four farms), the camp (18 camps) and the area (36 areas). Each 'area' (honeybush patch) has a name and a code eg: Sandrivier camp (Camp 6). Bak se rant (Patch a) is '6a.' Some patches are made up of more than one polygon eg: Kortklowe camp, Dikrug patch 10b is actually 3 polygons, but is treated as one harvest area in the harvest records.

Harvested patches and fire history
Maps show honeybush patches overlaid on the full fire extent and the part burnt per patch per fire event in five-year batches.

In the spreadsheet: if more than 50% of a patch is burnt in a fire event it is noted as burnt. If less than 50% of the area burns, the burn is not recorded. However, the total burnt area in hectares for that fire event – includes all pieces. Also - if the burn area is less than half a hectare of a patch that patch is not recorded as burnt. The reason for this relates to accuracy levels: heads-up digitising of the burn scar is highly generalised, sketching of the patches was done at about 1: 20 000. Therefore, accounting for fractions of burnt patches is over-accurate and falsely so.

On the map sometimes the patch is small and may be obscured by the label eg: August 2015 – only one part of 12a (Klein Rooiwyn, Koudnek) was burnt and is obscured by the patch label.

There are 20 fire events in the 25-year period 1996 to 2020. Of the 19 fires: 5 occur in December, 2 in November, 4 in October and September, 3 in August and 1 each in June and July. The fire history starts in 1996 – as the fire history in years prior to the first harvest records (2000) impact on the yields in the first few years of record. In the fire comments table – a note is made if the fire is a wildfire (based on size and extent beyond the boundaries of the Melmont camps and time of year). It is seen as a controlled fire if it's a smaller area, contained on Melmont and at a time of year when burning by permit is allowed. The farmer has a conservative burning approach – and plans to burn areas every 12-14 years. A honeybush patch which does not burn becomes tall and scraggly, is difficult to access and is not worth harvesting once the veld is about 12 years old.

***C.intermedia* – harvesting, fire and drought**

This is a well-managed honeybush farm, where sustainable harvesting has been practiced. Therefore, yields from a harvest area should not decline over time despite repeated harvest if/because harvest intervals are kept at about 4 years.

Picking up this 'pattern' of sustainable use in the harvest data will be upset by fire and drought as the harvest interval may be adjusted in response to fire or drought. In terms of what we understand about honeybush ecology – a *C. intermedia* recovers vigorously post-fire and gives larger than normal yields in the first post-fire harvest. A post-fire harvest interval may be shorter (3 years?) because the plants grow vigorously and reach a harvestable size/yield in a shorter time.

Under drought conditions – yield may be reduced by less plant growth (despite sticking to a regular interval) and potentially lighter, drier plant biomass. An experienced farmer will likely adjust accordingly – and delay harvesting, to increase the harvest interval, give the plant a chance to recover for longer and thereby keep the yield consistent.

Overall - a combination of fire (either too many or too infrequent) and drought may well impact negatively on production and health of the population.

Notes: Nov 2016 fire should be October. Area 4 – is nominal – as are areas 19 a and c (Witberg). Do not rely on yield figures for these areas. 'Bad records' are: 19a, 19c and 4a. These 'patches' were made up to fit the yield datasheet and were not sketched by the farmer – so they could be bigger/smaller than shown.

Data source notes

(TM) Level-1 Data Products, 30-meter multispectral data from Landsat 4 and 5. (July 1982 to May 2012) 16 day repeat cycle.

Landsat 7 Enhanced Thematic Mapper Plus (ETM+) Level-1 Data Products, July 1999 to present. May 2003 – Scan line corrector error. Enhanced Thematic Mapper Plus (ETM+) 15- to 30-meter multispectral data from Landsat 7. (1999 to present)

The European Space Agency's Multispectral Instrument on the Sentinel-2 satellite provides global (from 83 degrees north 56 degrees south latitude) 10-meter resolution, multispectral images every 10 days (2015-present). Since June 2015. Also options to save: Burn_Area_Index_(BAI); Burned_Area_Detection; Normalized_Burn_Ratio_(NBR) which all allow for easier identification of burns.

Landsat 7 ETM+ C1 Level-1LE07_L1TP_172083_20091108_20161219_01_T1

Melmont Fire history – Excel data sheet

Area	Farm	Camp	Patch No.	Patch (ha)	Fire1	Fire2	Fire3	Fire4	Fire5
Vaalbank se rant	Koudeneks-rante	Witkloof	4a	4.28	2016/12/16				
Bloukop	Koudeneks-rante	Bloukop	5a	23.98	2016/12/16				
Kranskraal	Koudeneks-rante	Bloukop	5b	12.03					
Wit baken se rant	Koudeneks-rante	Hartman	6a	19.25					
Hartman se rant	Koudeneks-rante	Hartman	6b	12.31					
Bak se rant	Koudenek	Sandrivier	7a	18.14	1999/08/26				
Swartbos	Koudenek	Sandrivier	7b	21.66	1999/08/26				
Skurwekop	Koudenek	Sandrivier	7c	14.16	1999/08/26	2014/09/04			
Geelwalle	Koudenek	Tweeling	8a	25.60	1999/08/26	2014/09/04			
Tweeling se laagte	Koudenek	Tweeling	8b	21.06	1999/08/26	2014/09/04	2020/10/01		
Steilkop	Koudenek	Steilkop	9a	35.06	2006/08/11	2016/12/16			
Groenhoek	Koudenek	Steilkop	9b	3.00	2000/12/01	2015/07/13			
Van Zyl se hoek	Koudenek	Kortklowe	10a	6.61	2000/12/01	2015/07/13			
Dikrug	Koudenek	Kortklowe	10b	16.63	2000/12/01	2009/09/01	2015/10/13	2016/12/16	
Agter Jakkalsnek	Koudenek	Entkraal	11a	14.98	2009/09/01	2016/12/16			
Tint se kloof	Koudenek	Entkraal	11b	14.56	2009/09/01	2015/08/13	2016/12/16		
Klein Rooiwyn	Koudenek	Koudenek	12a	5.79	2000/12/01	2003/12/01	2010/12/01	2015/08/13	2016/12/16
Rooiwyn se kloof	Koudenek	Boesmanrant	13a	12.29	2000/12/01	2010/12/01	2016/12/16		
Donkiebaan	Koudenek	Baken se kop	14a	24.61	2002/11/25	2010/12/01	2016/12/16		
Kousa se kloof	Koudenek	Baken se kop	14b	34.86	2000/12/01	2003/12/01	2010/12/01	2016/12/16	
Sleeppad se rant	Koudenek	Baken se kop	14c	21.06	2002/11/25	2013/06/04	2016/12/16		
Middelkop	Makateeskloof	Middelkop	15a	40.24	1999/08/26	2016/12/16	2020/10/01		
Drom se rug	Makateeskloof	Middelkop	15b	18.04	1999/08/26	2020/10/01			
Witrant	Makateeskloof	Witrant	16a	54.59	1996/09/02	1999/08/26	2003/12/01	2013/09/08	2020/10/01
Besemgoedkloof	Makateeskloof	Tier se mis	17a	4.52	2003/12/01	2014/09/04			
Kei	Makateeskloof	Tier se mis	17b	4.80	2003/12/01	2014/09/04			
Saliekloof	Makateeskloof	Saliekloof	18a	15.48	1996/09/02				
Spekboomrant	Makateeskloof	Witberg	19a	1.48	1996/09/02	2019/12/26			
Grootkrans	Makateeskloof	Witberg	19b	3.20	1996/09/02	2019/12/26			
Kalbasfontein	Makateeskloof	Witberg	19c	1.48	1996/09/02	2019/12/26			
Bos se rant	Makateeskloof	Swartbos-nek	20a	32.62	1996/09/02	2002/11/25	2003/12/01	2013/09/08	2016/11/01
Krismis se rant	Makateeskloof	Swartbos-nek	20b	12.09	1996/09/02	2002/11/25	2016/11/01		
Blouhoek	Makateeskloof	Swartbos-nek	20c	3.31	1996/09/02	2002/11/25	2016/11/01		
Dieprivierlaagte	Kariega	Kariega	21a	38.45	2002/10/30	2015/10/13			
Gladbanke	Kariega	Kariega	21b	21.23	2002/10/30	2003/10/01	2015/07/13	2016/12/16	
Kommandokloof se nek	Kariega	Kariega	21c	54.62	2015/10/13	2016/12/16			

Appendix 5b: Plant allometry data sheet

SITE: DATE: RECORDER: LAST FIRE: farmer, GIS, on site age

GPS NO's: ALITUDE: ASPECT: SLOPE: HARVEST STATUS: & last harvest

VEGETATION: Phys. form & 3 dominant genera SOIL TYPE: hand texture ROCKINESS %:

SITE DESCRIPTION & COMMENTS: Aliens, browsing, tracks/roads/paths

TERRAIN: ALIEN VEG: DISTURBANCE:

Plant No.	GPS pt.	Height cm	Crown 1 cm	Crown 2 cm	No. stems	Stem colour	Basal circ. cm	Bud/Flo/Pod	Seedl.	Comment (health, insects, dead plant etc)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										

Appendix 5c: *Summary* of results for 38 survey sites – biophysical characteristics as measured on site.

Terrain morphological unit (based on Mac Vicar, et al, 1977	Sites	% frequency
Crest	1; 17; 29	7.89
Scarp	28	2.63
Midslope	2; 3; 4-9; 10-13; 15; 16; 18; 19; 20; 23; 26; 27; 30; 33; 34; 35; 36; 37; 38; 40; 41	78.96
Footslope	14; 21; 22	7.89
Valley bottom	32	2.63

Alien vegetation	Sites	% frequency
Present	19; 20; 30; 32	10.53
Absent	All other sites	89.47

Disturbance (includes: grazing by livestock, disturbance by animals, close proximity to a track / road / excavation / pipeline / fenceline *etc.*).	Sites	% frequency
Present	1; 3; 5; 6; 10; 14; 15; 17; 18; 32	26.32
Absent	4; 7; 8; 9; 11; 12; 13; 16; 24; 26; 27; 28; 30; 33; 34; 35; 36; 37; 38; 40; 41	73.68

Rock cover (surface rock/stones, estimated per transect in four 1mx1m quadrats)	Sites	% frequency
Low: 0 – 25 %	2; 19; 20; 21; 32	13.16
Moderate: 25-50 %	1; 3; 4; 5; 6; 10; 11; 15; 17; 18; 22; 23; 24; 26; 34; 36; 37; 38	50.00
High: 50 - 75%	7; 8; 9; 12; 13; 16; 27; 28; 29; 30	26.31

Physical vegetation form (description of veld, non-specific)	Sites	% frequency
Grassy fynbos	12; 13; 14; 17; 29; 32; 34; 38; 41	23.68
Grassy fynbos with scattered taller shrubs or small trees	1; 4; 6; 7; 8; 9; 18; 21; 23; 24; 26; 27; 28; 33; 35; 36; 37; 40	47.37
Grassy fynbos with dense taller shrubs or small trees	2; 3; 10; 11; 15; 16; 19; 20; 30	23.68
Dense shrubs and small trees	5; 22	5.26

Soil (hand texture based on Mac Vicar et al, 1977)	Sites	% frequency
Sandy	1; 2; 3; 17; 33; 34; 38; 41	21.05
Sandy clay loam	14; 32	5.26
Sandy loam	4 – 13; 15; 16; 18; 19 – 30; 35; 36; 37; 40	73.69

Appendix 5d: Scatterplots of the relationships between various plant size measures and post-fire plant age